Iowa Motor Vehicle Fuel Reduction Program

Final Report

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The Iowa Motor Vehicle Fuel Reduction Program was a cooperative effort by the the U. S. Department of Energy, the Iowa Department of Natural Resources, the Iowa Department of Transportation, and Iowa State University Extension.

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EXECUTIVE SUMMARY

This report documents the results of a three million dollar traffic signal improvement demonstration program, known as the Iowa Motor Vehicle Fuel Reduction Program (the program). The program was funded with the use of oil overcharge funds and administered by the Iowa Departments of Natural Resources and Transportation.

The objective of the program was to provide restitution to overcharged motorists by improving the efficiency of traffic signals. More efficient traffic signals reduce fuel consumption, delay, travel time, and automobile pollution while improving traffic safety. The program demonstrated the effectiveness of improving traffic signals and resulted in a 14.20-to-1 benefit-to-cost ratio.

The design of the demonstration program called for traffic control hardware and timing plan improvements in cities spread throughout Iowa. Also, the improvements were to be evenly distributed to cities of all sizes; small cities (less than 10,000 in population), medium cities (10,000 to 50,000 in population), and large cities (over 50,000 in population). There were nineteen cities selected to serve as demonstration projects.

The technology used in the improvements was dependent on the needs of the community. Four cities upgraded isolated intersections to fully actuated, four cities coordinated arterials with time-based-coordinators, ten cities controlled arterials with closed-loop systems, one city upgraded the control of a downtown network system, and one large city made a variety of improvements using combined techniques.

Estimates are made of the benefits of upgrading the remaining signals in the state. A conservative estimate of the potential benefits are that Iowans could potentially receive an additional $1.9 million per year in benefits in small cities, $8.1 per year in medium cities, and $3.2 per year in large cities.

The report also investigates staffing levels in Iowa cities of traffic signal technicians, electricians and traffic engineers. Relationships are found between the number of traffic signals within a community and the size of the staff.

The report concludes by making four recommendations. In summary, the recommendations are:

1. The 1989 Iowa General Assembly passed a new law requiring the coordination of traffic signals in towns with three or more traffic signals. Before rules are adopted for enforcement of required coordination, a survey should be

taken to determine the condition of traffic control equipment in Iowa cities and the capabilities of their technical staffs.

2. There are several unmet needs for training and technology transfer to the personnel that maintain and operate traffic signals in Iowa cities. Efforts should continue to upgrade the traffic control knowledge and skills of municipal employees.

3. The simultaneous installation of nineteen traffic signal improvements provides a rare opportunity to study the traffic safety benefits of improved traffic signal control. In roughly five years, the accident patterns and frequencies of the upgraded locations should be studied to determine the safety impacts of the improvements.

4. Most Iowa cities do not have a written traffic signal maintenance policy. Of those cities that use contractors to maintain traffic signals, none were found to have written contracts. The lack of written procedures and informal contracts is felt to represent an area of almost unlimited legal liability. Guidelines should be generated to aid in the development of traffic signal maintenance policies and standards, and to aid in the development of formal maintenance service contracts.

ACKNOWLEDGEMENTS

The Iowa Motor Vehicle Fuel Reduction Program was funded with oil overcharge funds. The Iowa Department of Natural Resources is responsible for the administration of oil overcharge funds in Iowa. Through a cooperative agreement, the Iowa Department of Transportation, Office of Local Systems was placed in-charge of the administration of this particular Oil Overcharge program. Mr. Roger Anderberg, Urban Systems Engineer, of the Iowa Department of Transportation served as program administrator.

Iowa's Rural Transportation Technology Transfer Program (the Local Transportation Information Center) conducted the technology transfer element of the Iowa Motor Vehicle Fuel Reduction Program. Mr. Anderberg's assistance and help in the drafting of this report and other technology transfer tasks is gratefully acknowledged.

Tom Maze served as the program manager of the technology transfer element. Dr. Maze is an associate professor of Civil Engineering. During the course of the Program Dr. Maze was partially supported by the Department of Civil and Construction Engineering and the College of Engineering at Iowa State University. The Department of Civil and Construction Engineering also provided office space for project personnel. The cooperation of the Department of Civil and Construction Engineering and the College of Engineering is gratefully acknowledged.

The Local Transportation Information Center is administered through Business and Engineering Extension Service (B&EE). B&EE provided administrative services for the technology transfer element.

Others that worked on the technology transfer element include Mr. Neal Hawkins and Mr. Mohammad Elahi, both are civil engineering graduate students and served as research assistants. Ms. Jan Graham administered the technology transfer element and Ms. Teddi Barron provided editorial services for the drafting of the final report. Ms. Verda Alleman and Ms. Kay Forsythe provided clerical assistance throughout the program.

There were nineteen cities that participated in the program and each willingly provided the necessary assistance to document the program.

Of special help to the technology transfer element were Mr. James Dickinson of Johnson, Brickell, Mulcahy, and Associates, Mr. Don Swan of the City of Des Moines, Mr. Shyamal Basu of Iowa Department of Transportation, Mr. Paul Glover of General Traffic

Control, Mr. Bob Budd of Brown Traffic Products, and Mr. James Connor, a distributor for Winko-matic and Multisonics equipment.

The training programs offered through the technology transfer element were directed by planning comments. The planning committee for workshops designed for traffic engineers and traffic signal technicians were planned by Mr. Gary Fox of the City of Des Moines, Mr. James Brachtel of the City of Iowa City, Mr. Duane Wittstock of the City of West Des Moines, and Mr. Roger Anderberg of the Iowa Department of Transportation. Planning assistance for the elected and appointed officials' training programs was provided by Mr. Steve Schainker of the City of Ames, Mr. Paul Wiegand of the City of Ames, Mr. Carl Metzger of the City of Ankeny, Mr. Robert Layton of the City of Urbandale, Ms. Ann Cambell member of the Ames city council, and Ms. Judie Hoffman of the Ames City Council.

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CHAPTER I
THE USE OF ENERGY OVERCHARGE FUNDS IN SIGNALIZATION PROGRAMS NATIONALLY AND IN IOWA

Traffic signal equipment and signal-timing improvements have been popular applications of oil overcharge funds in many states. To provide restitution to those overcharged by petroleum companies, California, Florida, Illinois, Maryland, Michigan, Missouri, New York, North Carolina, Pennsylvania, and Virginia funded traffic signal improvements with oil overcharge funds. When signal timings, signals, and signal systems are designed to work more efficiently, motorists save fuel, stops, delay and travel time. This is a direct and equitable method of compensating motorists originally overcharged by oil companies.

Each state chose a slightly different path for using oil overcharge funds to make signal improvements. In some programs, traffic signals were simply retimed to permit more efficient traffic operation. Other programs included the purchase of modern traffic signal equipment. And some focused on training professionals in individual communities to retime their own signals.

The Iowa program was fairly unique, however. Although it involved most elements of the other states' programs, the Iowa program went one step further. Activities were carried out to publicize the program to the general public and to public decision makers. The awareness campaign was a distinctive feature of the Iowa program.

The $3 million Iowa Motor Vehicle Fuel Reduction program implemented new traffic signal equipment and traffic signal-timing plans in 19 Iowa cities (each city's program is discussed in Chapter Four). The cities were evenly distributed in size (small, medium and large population communities) and evenly distributed geographically across Iowa. The signal improvements ranged from multi-intersection signal systems to individual, isolated intersection signals. The application of varied technologies to cities evenly distributed with respect to population and location was another unique feature of the Iowa program.

In addition to the signal equipment and signal-timing improvements, the Iowa program included three components. They were:

1. A traffic engineering consultant assisted with the selection of individual projects and, by conducting before and after studies, with the economic evaluation of each installation.

2. A publicity campaign was initiated to improve the public's awareness of its receipt of restitution and possible energy savings through the signal improvements. The "Iowa Signals Go" campaign included a press conference, press packets sent to media, a table-top display, booklet, radio and TV public service announcements, a 10-minute promotional videotape, newsletter articles, and discussions of the project on radio and TV programs throughout the state. Programs in other states have not attempted to provide wide dissemination of information to the general public.

3. A technology transfer program was conducted for technical staff and for local and state decision makers. The training program included courses for traffic engineers on traffic signal timing; training for traffic signal technicians on maintenance and operation of signals; and seminars for local officials on rudimentary intersection-control strategies. A unique feature of the Iowa program was the division of programs into three levels that targeted three distinct

groups. Training programs in other states provided instruction only for traffic engineers.

Also developed as part of the technology transfer program were a 20-minute training videotape, a slide presentation, a table-top display, several technical articles, presentations at professional meetings, and this technical report which documents the entire program.

As a result of the Iowa Motor Vehicle Fuel Reduction program, Iowa drivers will save roughly 280,000 gallons of fuel each year. A total of 299 intersections were improved within 19 Iowa cities. Some of the cities' projects involved several signals in a system; while one project improved only one intersection in a city. The benefit-cost ratios for the individual projects ranged from 0-to-1 to 55.58-to-1. Nine project cities resulted in benefit-cost ratios better than 10-to-1; six of these were above 20-to-1.

Excluding the costs of the traffic engineering consultant (who aided in the selection of the projects and conducted the before and after studies), and the costs of the technology transfer and the publicity components, the program had an overall benefit-to-cost ratio of 14.20 to 1.

In addition, an estimate was made of the potential benefits derived from making similar improvements to traffic signals throughout Iowa. Because of the limited availability of data on the current condition and operation of traffic signals in the state, all values used to derive an estimate were founded on limited factual information and couched in engineering judgement.

The estimates varied by level of technology and city size. The estimates ranged from a savings of $1.9 to $8.1 million annually.

I.A. Project Funding Source

In 1973 and 1974 the United States was under an oil embargo by the Organization of Petroleum Exporting Countries. In an attempt to protect oil consumers from price gouging by domestic oil producers during the absence of competition from Arab countries, Congress adopted the Emergency Petroleum Allocation Act of 1973. The act included regulation covering the sale of petroleum products in the period between August 1973 and January 1981. The act gave the Department of Energy the authority to control oil companies' allocation and pricing of petroleum products refined from crude oil.

Starting in the late 1970s, the Department of Energy discovered that numerous violations of the price controls had taken place and began to bring suit against the violators. Each case was later settled inside or outside of the courtroom and settlements were collected from the oil companies. When individuals could prove they had received direct economic damage from an oil company, an individual settlement was reached. When there was no direct proof of damage, it was assumed that high prices had been passed directly to the petroleum-consuming public and the Department of Energy placed the funds into a Petroleum Violation Escrow Account until a repayment plan was developed.

The original plan for disbursement of the funds was developed by Congress under the "Warner Amendment" (Section 155 of Public Law 97-377). Congress identified five areas where individual states could use the funds. The areas included: (1) fuel assistance payments; (2) weatherization programs for low-income homes; (3) conservation grants to schools and hospitals; (4) state energy conservation programs; and (5) Energy extension services. The funds were distributed to states in proportion to historical patterns of petroleum usage in each state.

The signalization project in Iowa used funds derived from the Exxon Corporation case. In the Exxon case, the Department of Energy charged that from 1975 to 1981 Exxon had overpriced crude oil produced from the Hawkins production field in Texas. In March 1983, the courts determined that Exxon had overpriced petroleum products. The U.S. District Court of the District of Columbia ordered the Exxon Corporation to pay approximately $2.1 billion in principal and interest. On March 6, 1986, the funds were distributed to states.

I.B. Iowa Fund Distribution and Program Objectives

In July of 1986, the Iowa General Assembly authorized $3 million of Iowa's portion of the Exxon funds to the Motor Vehicle Fuel Reduction Program as part of Iowa's State Energy Conservation Program. By October of 1986, the Iowa Department of Transportation developed a proposal for the disbursement of Motor Vehicle Fuel Reduction Program funds to Iowa cities.

The Iowa Department of Transportation proposed to provide restitution to Iowa consumers of motor fuels through projects that implemented energy-efficient traffic control. It was also proposed that the projects would serve as demonstrations of methods to reduce vehicle stops, delay, fuel consumption, and travel times, through the modernization of traffic control signal equipment.

REFERENCES

1. Arnold, E.D. "State Signal Timing Optimization Programs." ITE Journal, February 1989, pp. 33-35.

2. Euler, G.W., and Wilbur, A. "Oil Overcharge Program Provides Funding for Signal Timing Improvements." ITE Journal, October 1986, pp. 19-21.

3. United States General Accounting Office. "Energy Management: States' Use and DOE Oversite of Exxon and Stripper Well Overcharge Funds." Report GAO/RCED-88-152, Washington, D.C., 1988.

CHAPTER II
IOWA SIGNALIZATION PROGRAM

It was originally proposed that there should be demonstration sites in twenty Iowa communities. It was proposed that the sites be distributed evenly between small cities (less than 10,000 in population), medium cities (between 10,000 and 50,000 in population), and large cities (more than 50,000 in population). It also was proposed that the projects be geographically distributed across the state. It was believed that an even geographical distribution would enable demonstration sites to be located near a maximum number of non-demonstration cities. It was hoped that non-demonstration cities would recognize the energy efficiency of modern signalization through the examples provided by neighboring communities.

II.A . Selection Process for Individual Projects

In February 1987, the Iowa Department of Transportation requested that Iowa cities submit proposals to request funds for energy-saving signal improvements. Forty-nine proposals were received from 33 different cities. The combined requests totaled $5 million. In March the Iowa Department of Transportation screened the projects to identify a group of candidate sites that were distributed evenly in population size and geographical location. In cases where both of two competing projects met the distribution criteria, the project likely to have the most potential for energy savings was selected. The Iowa Department of Transportation identified 21 qualified sites and negotiated with the selected cities to increase the local participation in funding. The negotiations that were conducted and completed in March 1987 resulted in a total package of about $3 million of traffic signal improvements. Of that total, about $2.5 million originated from the Exxon overcharge funds and the remainder came from local sources.

The 21 projects included three projects in each of the six Iowa Department of Transportation districts, with each district having one project in each of the three population-size categories. Three projects were selected "at-large" (Decorah, Des Moines, and West Des Moines). All project sites are shown in Figure 2-1.

In April, two projects, Knoxville and Harlan, were deleted from the list of projects because their sites failed to meet the Manual of Uniform Traffic Control Devices warrants for traffic signals. Installation of equipment for the 19 projects started in June 1987.

REFERENCES

1. Maze, T.H., and Hawkins, N.R. "Iowa Motor Vehicle Fuel Reduction Program." MOVITE Journal, March 1989, pp. 10-13.

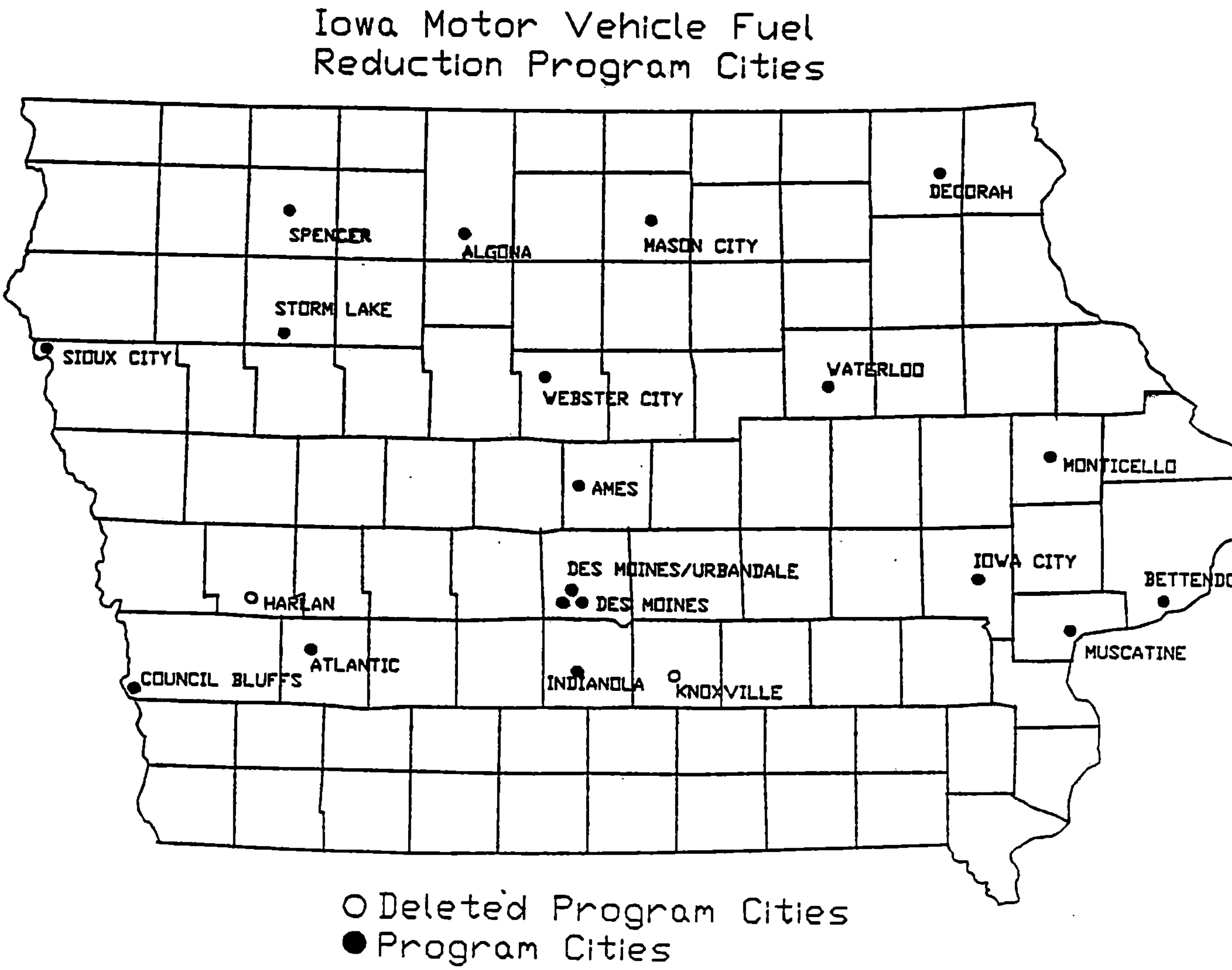

Figure 2-1, Demonstration Site Locations

CHAPTER III
TRAFFIC SIGNAL TIMING AND TECHNOLOGY[1]

This chapter deals with traffic signal technology currently available. Traffic signal timing options are often dependent on the equipment used. For this reason, the two are covered together in this chapter.

There is a wide variety of traffic signal control equipment. Traditional traffic controllers use electric motors, relays, and switches. Modern equipment uses microprocessors and solid-state control. The flexibility provided by modern microprocessor controllers has resulted in diverse equipment options and capabilities.

III.A Physical Configuration of Traffic Signals

Traffic signals that operate independently of other signals are isolated signals. Conversely, signals that are in close proximity to one another often work as a system. The configuration of signals that work within a system is dependent on the local street pattern and traffic volumes. When traffic patterns are primarily along an arterial street, signals are coordinated along the arterial. When major traffic patterns flow in more than one direction along a street grid, signal systems may be coordinated to work in a network. Networks are usually applied in large central business districts. There are few applications for network systems in Iowa.

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1. Definitions included in this chapter are taken from references 1, 2, 3, 4, and 5.

Isolated intersection control and traffic signal systems control (arterial systems and network systems) are covered separately in the following sections.

III.B Isolated Intersection Timing Elements

An isolated intersection is defined as any signalized intersection in which the flow of traffic is controlled without any consideration for adjacent intersections. The primary objective of an isolated intersection is to assign right-of-way. For each leg of an intersection, the orderly flow of traffic reduces the amount of delay, stops, and accidents experienced by motorists.

Traffic signal timing plans are primarily a function of traffic volumes. When initially designed, they are usually efficient for current traffic conditions. However, timing plans become inefficient when traffic patterns are changed as a result of development or other factors which can effect traffic patterns. Out-of-date traffic signal timings can greatly increase delay and fuel consumption. To provide for efficient traffic flow, signal-timing plans at isolated intersections should be kept up to date with current traffic conditions.

The basic features of an isolated intersection's timing plan are:

PHASE - A part of the traffic signal time cycle allocated to any one or a combination of traffic movements receiving right-of-way simultaneously. A phase simply reduces conflicts between movements.

CYCLE LENGTH - The time required for one complete sequence of signal indications. A cycle is simply a series of successive phases allocating movements through all approaches to the intersection and then returning to the original phase.

Clearly, the number of phases included in a cycle is directly related to cycle length. The more phases that are permitted, the longer the cycle length must be to accommodate the phases. On the other hand, the longer the cycle length, the longer motorists are delayed while waiting for a green light. To reach an efficient traffic signal-timing plan, a trade-off must be reached between the number of phases permitted and the cycle length.

Two additional terms which are important to the efficient assignment of right-of-way are:

LOST TIME - At the beginning of each phase, traffic flow is delayed and time is lost while cars must get up to speed through the intersection. As the light turns yellow, more time is lost to allow cars to slow down and stop before the light turns red. When the start-up and stopping time is removed, green time available for movements is lost.

TRAFFIC FLUCTUATIONS - For maximum efficiency, traffic signals must also have the flexibility to change with the time of day. All cities experience changes in traffic flow from the morning--when most traffic is inbound--to the afternoon, when the flow is outbound. These situations must be taken into account to develop a range of timing schemes.

Generally, when heavy traffic volumes are being served by an intersection, it is efficient to have long phases and, as a result, long cycle lengths. Long phases allow traffic to move through the intersection in one continuous stream during a long green light. Shorter phases may cause the traffic to suffer through start-up and stops without passing the entire stream of waiting motorists through the intersection. This increases lost time. Unfortunately, longer phases and longer cycle lengths cause longer delays to cross traffic.

III.C Intersection Controllers and Control Techniques

The operation of traffic signals is performed by local controllers. Currently, two basic types of controllers are produced and widely used: **electromechanical and solid-state.** In the past, some controllers used analog technology instead of digital technology. Although some analog controllers are still in use, most are being replaced because of their high maintenance costs and their sensitivity to weather conditions. Digital microprocessor technology has proven to be greatly superior in performance to analog equipment. Most electromechanical controllers are being replaced by solid-state equipment, although many are still in operation.

ELECTROMECHANICAL CONTROLLERS - Electromechanical controllers are one of the first types of controller used and they continue to be used widely. These units consist of a synchronous motor which drives up to three timing dials. Normally each timing dial stores a different phasing scheme and cycle length. On their surfaces, the dials contain slots in which timing keys are placed. As the dial rotates, the keys strike switches which operate a mechanical camshaft. Electrical contacts on the camshaft coordinate all signal indications at the intersection.

SOLID-STATE CONTROLLERS- There are 3 basic types of solid-state controllers: **pre-timed, NEMA, and Type 170.** Solid-state controllers perform the same functions as electromechanical controllers, but they use microprocessors instead of dials, camshafts, and switches. The advanced memory of the microprocessor can store many different phasing and timing plans. These timing plans are typed in on a keyboard.

Because they lack moving parts and gears, solid-state controllers usually out-perform the electromechanical devices.

This also makes the solid-state controller much less susceptible to weather-induced malfunctions and generally reduces preventive maintenance requirements. Because the solid-state controllers are becoming so widely used, it is important to understand the differences between the three basic and common types.

PRE-TIMED - Like electromechanical controllers, these perform the same function of allocating signal timings. They are the only solid state-controllers with moving parts. These may have up to four cam shafts and may accept actuations from pedestrian buttons or actuations from vehicle detectors. Actuations do not affect timings but are used to select different sequences. Cycle lengths and phase durations are of a fixed length.

NEMA - NEMA controllers are based on hardware, software, and operational standards set forth by the National Electrical Manufacture's Association (NEMA) to create a degree of interchangeability between various models of controllers. NEMA controllers are actuated traffic signal controllers. Cycle and phase lengths in actuated controllers can vary according to the demands of current traffic.

TYPE 170 - Developed by the states of New York and California, these feature a general purpose microprocessor that can be programmed for a variety of operations. These are generic controllers with standardized hardware, and no initial programming. The user must program the controller to perform the functions necessary at the particular intersection.

The newest type of signal controller out is known as **NEMA plus**. A byproduct of the computer revolution, these controllers have many features which were not available on the regular NEMA controllers.

NEMA Plus - These units far exceed the minimum NEMA standards in configuration and operation capabilities. Communications, diagnostics, data storage capabilities, and menu-driven interactive panels are but a few of the new features.

The type of signal controller needed for a given situation is directly related to the type of intersection control desired.

III.D Isolated Intersection Control Techniques

It is important to understand how a controller assigns right-of-way at the intersection. Controllers operate under two basic modes: **pre-timed** and **actuated.** The real difference between the two is whether or not there are detectors placed in the pavement at the intersection approaches. Detectors are capable of sensing the presence of a vehicle on one or more of the approaches.

PRE-TIMED - Pretimed control assigns the right-of-way at an intersection according to a predetermined schedule. The sequence of phases and the length of the time interval for each signal indication in the cycle is fixed, based on historic traffic patterns. No recognition is given to the current traffic demand on the intersection approaches. This type of control is well suited to intersections with predictable traffic patterns, or with frequent occurrences of congested conditions.

ACTUATED CONTROL - Actuated control operates with variable vehicular and pedestrian timings and phase intervals which depend on the presence of automobiles and/or traffic volumes, and calls from pedestrians. Traffic volumes and/or the presence of automobiles are recorded using vehicle detectors on one or more of the approaches. The three basic types of actuated control are semi-actuated, fully actuated and volume-density.

SEMI-ACTUATED - This type of control places the vehicle detectors on the side-street approaches only. This allows the major flow to operate continuously until actuated by calls from the minor approach.

FULLY ACTUATED - In this mode of operation, detectors are placed upon all approaches of the intersection. All cycle and phase lengths are determined by actuation. This type of operation is best suited for intersections of two major streets which have fluctuating traffic volumes throughout the day.

VOLUME-DENSITY - This type of control places additional detectors on high speed approaches and operates on a continuously variable cycle length. It is best suited for the intersection of two major streets which have relatively high speeds.

DETECTORS - All actuated signals require detectors to sense the presence of vehicles. The most common type of detector is the inductive loop. This consists of wire loops placed in a slot cut into the pavement. The slots can be cut in a variety of shapes ranging from a rectangle to a square or diamond. The ends of the loops are connected to an electronic amplifier which is usually located in the controller cabinet. Through these loops runs a tuned circuit. When a vehicle approaches a loop it unbalances the circuit which is sensed by the amplifier. That information is then sent to the controller for processing and decision-making.

Detectors can be used to detect individual vehicles at the intersection. And when spaced out on the pavement, they also can indicate traffic volumes so the controller can modify phasing and cycle lengths.

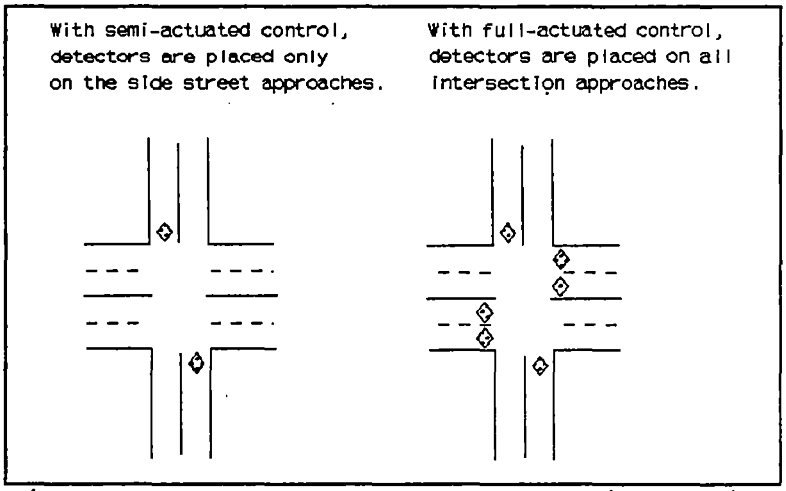

Figure 3-1, Isolated Intersections With Semi and Fully Actuated Control

Figure 3-1 shows a typical layout of intersections being controlled by a semi-actuated and a fully actuated signal. The semi-actuated signal has detectors only on the minor street. The fully actuated signal has detectors on all approaches including turning bays, if present, and pedestrian buttons for actuation if necessary.

As isolated intersection control progresses from pre-timed to fully actuated, the equipment controlling the intersection becomes more sophisticated. As equipment and ancillary devices (i.e., detectors, detector amplifiers, mast arms, and signal heads) become more sophisticated, they become more expensive and require more rigorous maintenance procedures. However, in many cases the added expense has counteracting benefits through reductions in delay, stops and fuel consumption.

III.E Coordinated Arterial Timing Elements

A coordinated arterial is defined as any signalized street for which signal timings are designed to allow traffic to travel at a predetermined speed without being stopped. The term **progression** is used to define the ability of traffic to progress along a signalized arterial without being delayed by a red light. The primary objective of a coordinated arterial is to minimize the number of stops that cars must make at intersections along a busy street. Generally, smooth flow along an arterial is facilitated by coordinating the time when green phases begin at intersections along the arterial. Progression is either achieved by coordinating signals through commands issued to each controller from a master controller, or by accurate time clocks within each local controller.

Two important terms related to coordinated arterials are:

Offset - This is the difference in time between the beginning of green at one intersection and a reference point. Usually the intersection at the beginning of the arterial system serves as the reference point. Offsets are determined by using the speed and known distance between each intersection.

Platoon - Vehicles that are traveling together in a group from one intersection to the next are called a platoon. Vehicles moving in a tight platoon can be served efficiently by a series of coordinated signals. However, as the distance between signalized intersections increases, the platoon tends to disperse. This increases the number of stops and the amount of fuel consumed, and can encourage speeding. To avoid these problems, the distance between coordinated signals should not exceed approximately one-half mile.

In general, there are no reasons for not coordinating signals along an arterial. Simple, pre-timed coordination can even be achieved with independent, electromechanical controllers. However, compared to isolated-signal operation, determining the timing plans and maintaining coordination of signals is more complicated and requires constant surveillance of the system to insure coordination.

One of the disadvantages of coordination is that cross traffic will usually experience longer delays. This is because the specific timing of green phases along the main street must be observed regardless of the demand on the cross street. Therefore, cross street traffic must wait until the green phase along the major street is completed. The green phase on the cross street is terminated when the time for the green phase on the main street is reached.

One of the associated benefits of coordination is that it reinforces motorists to drive along the arterial at the design speed. Fast traffic will be stopped at lights until the time is reached for the progressive movement. Slow traffic will miss the green phase in the direction of the progression. Through repetition, motorists will adjust their speeds while traveling along the coordinated arterial.

III.F Coordinated Arterial Control Techniques

By using information obtained from detector loops, controllers can most efficiently allocate time within the cycle for smooth traffic flow at an individual intersection. However, to coordinate signals at adjacent intersections, controllers must be physically connected or synchronized by means of very accurate clocks. Several signals may be grouped together to form a system. A system may consist of the signals on an arterial or those in a network of streets.

Normally, the purpose of grouping the signals together is to obtain coordination among them. In theory, coordination allows platoons of vehicles to travel through the system without having to stop at every intersection. The four principal ways that arterial systems can be "linked" together are through **time-based coordination, interconnected master, closed-loop distributed system**, or by **network centralized control.**

TIME-BASED COORDINATION. Time-based coordination (TBC) control utilizes no physical interconnection between intersections. The TBC is stored in the controller cabinet with the controller. A TBC device is a stand-alone unit that locally supervises a controller by the transmission of commands and pulses. This is done in much the same way as if the pulses were to come via a communications medium from a system master unit. The TBC notifies the local controller when it is time to begin the green phase for the progressive movement along the coordinated arterial.

Time-based coordinators are electronic, real-time clocks that provide the synchronous pulses necessary for the controllers to be in sync with each other. In the event of a power failure, each TBC is equipped with a rechargeable battery to sustain full-operating capability (except for output to the controller).

TBCs can be used in conjunction with timing plans which change with the time of day. They can also be used in conjunction with traffic detectors on minor streets (semi-actuated). When intersections are semi-actuated, the progressive movement is given priority. The minor street is given green only when a car is present on the minor approach and it does not interfere with the progressive flow on the major street. Additionally, the controller can abandon the time relationship with other signals and work independently in response to calls from actuation.

TBC technology has some practical advantages. Its primary advantage compared to interconnected signals is that TBC technology does not require the laying of hardwire. In locations with driveways, parking lots, buried cable, streets, and other structures along the right-of-way, laying interconnecting lines can become very expensive. The cost of laying wires also increases when there are long distances between signals or lengthy systems of interconnected signals.

Compared to interconnected systems, a minor drawback of TBCs is that it may be more complicated to conduct routine checks on individual controllers to see if they are maintaining the preselected time relationships. In hardwire systems, the coordination is maintained with a physical connection that ensures the time relation is maintained. The accuracy of TBC systems can only be checked through observation. This becomes complicated when the system includes semi-actuated intersections.

Using their internal mechanical clocks, electromechanical systems can provide similar coordination between intersections. However, such clocks are less reliable than electronic clocks and they lose the time relationship between intersections when the power supply fails.

INTERCONNECTED MASTER. Interconnected master systems work in much the same fashion as TBC controlled systems. However, hardwires connect the coordinated signals to a master clock. The master tells each intersection's controller when to start the green phase at their location on the arterial by sending the local controllers an electronic command for synchronization, called a sync pulse.

Offsets can be changed at the master without having to change timing plans at each controller. Because coordination times are controlled by the master, there is less chance for a controller to get out of sync. Some interconnected master systems are capable of utilizing volume and occupancy data obtained from sampling detectors to implement the timing plan best suited for the current traffic. Implementing timing plans based on current conditions is called traffic responsive.

Interconnected master systems can manage solid-state local controllers or simple systems can manage electromechanical local controllers. Although the interconnected master systems can coordinate a whole thoroughfare or network of arterials with one master controller, their hardwire connection has some disadvantages. The most serious disadvantage is caused by downed or malfunctioning lines. This results in all the interconnected controllers failing at once.

The cost of installing an interconnected master system varies with the length of hardwire needed to connect intersections and with the number and sophistication of the controllers used. Interconnected master systems can be particularly cost effective when coordinating a dense network of controllers. However, it may be expensive to lay hardwire to interconnect all of the local controllers.

CLOSED-LOOP, DISTRIBUTED SYSTEM. Figure 3-2 depicts the operation of a closed-loop, distributed system. The system includes local controllers at each intersection. These are supervised by a master controller. The master control is connected (usually through telephone lines) to an office monitor (usually a microcomputer).

The master is a special-purpose microprocessor that can change the local controller's timing plans to match current traffic conditions. A centrally located, desktop microcomputer is used to monitor one or more masters. The central computer also can issue new timing plans to the masters, communicating through either dedicated or dial-up telephone lines.

The system is "distributed" because signal-system functions are executed throughout the components of the system. Each level--intersection controller, master, and central monitor--performs a function within the system.

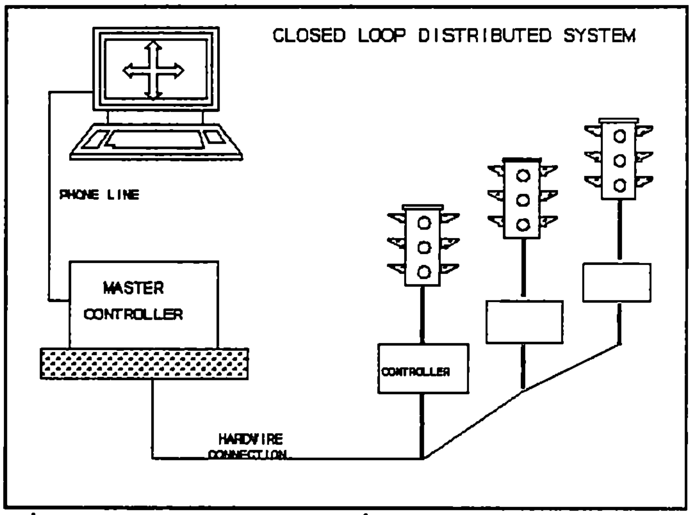

Figure 3-2, Typical Arrangement of a Closed Loop, Distributed System

"Closed-loop" simply means that all functions of the system are controlled and adjusted by the system. For example, choosing from several predetermined timing plans, the system can select the one that is most effective for the given conditions (traffic responsive). A closed-loop system has traffic-responsive capabilities and other self-contained intelligent functions. It provides two-way communication between local controllers and the master, and between the masters and the central monitor.

Closed-loop, distributed systems allow traffic-control professionals to make timing modifications from the central computer. The central computer gathers data from system traffic detectors and computes reports on traffic. These reports may be used by the traffic-control professional to adjust traffic signal timing plans and to measure the performance of the system. The system can automatically use the traffic-flow data in the traffic-responsive mode to select the most appropriate predetermined timing plan.

A closed-loop, distributed system's ability to select automatically the most efficient timing plan is just one of the benefits to motorists. The operating agency has the benefit of being able to monitor the system from the central office. For example, the computer can easily identify and document technical malfunctions and some of their causes. Technicians then know what equipment and spare parts to bring to the malfunctioning signal. During off-duty hours, traffic-control professionals can monitor the system's functions through dial-up communications and a portable computer.

CENTRALIZED (NETWORK) CONTROL. In this type of system a central computer directly controls the operation of the system intersections every one or two seconds. As part of Urban Traffic Control System (UTCS), a research and development project in the early seventies, the Federal Highway Administration developed one of the first software programs to manage traffic systems with a computer. Several enhanced versions of the UTCS software have been developed.

III. G. Communications Between Intersections

For efficient transfer of information, modern signal systems must have reliable communications between individual components. In the case of electromechanical controllers, interconnections are relatively simple. However, in a computerized system the amount and use of the information dictates that the communication system perform to a higher degree of reliability. The type and grade of communication cable is often one of the most expensive elements of improving a signal system. A variety of options is available to achieve reliable communication between intersections. Three possible alternatives are **multi-conductor or coaxial wire cable, fiber optics**, or **air path modes.**

MULTI-CONDUCTOR/COAXIAL - Multi-conductor, twisted-pair cable and coaxial cable are commonly used. These provide minimal interference and a wide bandwidth which permits the large amounts of data to be carried. This is the type of cable found in cable television systems. Use of cable already in-place can provide an effective use of transmission resources. However, there is a drawback. The traffic-control agency may lose direct control over that part of the system.

FIBER OPTICS - This technology is so effective that its use is expected to be widespread in the future. Fiber optics have a number of advantages including freedom from interference, increased safety (since lightning is not attracted to the cable), and a greatly increased capacity to carry data. The major disadvantage of fiber optics is its cost.

AIR PATH - Air path modes, such as radio, are beginning to be used at more locations. Some TBC systems can receive their pulse from the Atomic Clock in Colorado which retains their accuracy. Microwave and laser communications have also been proposed but are still in the experimental stages.

III.H Choice Of Appropriate Technology

The most desirable technology to be employed at each location is largely a function of traffic volumes and of the configuration of the local street network. For example, TBCs may be most appropriate to coordinate arterials in communities with relatively short sections of signalized arterials. However, more sophisticated control is more appropriate in dense networks or along heavily traveled arterials which have a number of signal controlled intersections.

Another condition that dictates the choice of a technology is the condition of existing equipment. For example, if signals are already interconnected, the cost of upgrading to a closed-loop, distributed system may be economical because existing cable or conduit can be reused. Also, consideration must be given to the qualifications of traffic-control professionals who will be overseeing the system. All complex control systems require skilled professional staff. In addition, the resources likely to be available for maintenance of the equipment must be evaluated. The more complicated systems will require better trained maintenance staff and more expensive parts and diagnostic equipment.

REFERENCES

1. Federal Highway Administration. Traffic Control Systems Handbook. Institute of Transportation Engineers, Washington, D.C., 1985.

2. Giblin, J.M., Kraft, W.H., Rudden, J., and Sands, R. Institute of Transportation Engineers Traffic Signal Installation and Maintenance Manual. Englewood Cliffs, New Jersey: Prentice Hall, 1989.

3. Institute of Transportation Engineers Technical Council Committee 4M-1. "Traffic Signal System Definitions." An Institute of Transportation Engineers Recommended Practice, Washington, D.C., 1978.

4. Kell, J.H., and Fullerton, I.J. Institute of Transportation Engineers Manual of Traffic Signal Design. Englewood, Cliffs, New Jersey: Prentice Hall, 1982.

5. Wright, P.H., and Ashford, N.J. Transportation Engineering Planning and Design, Third Edition, New York: John Wiley and Sons, 1989.

CHAPTER IV
PROJECT CITY DESCRIPTIONS

This chapter describes the traffic signal improvements made in each project city. Later, an overall evaluation is provided for each project. Each description includes: (1) a discussion of the site and a map of the location; (2) a detailed list of funding sources and equipment costs; (3) a description of design services for the installation; (4) technical services available through the city to support the maintenance and operation of the signal; (5) the equipment procurement procedure; and (6) the economic evaluation of the installation and comments on the site.

The nineteen projects are described in order of their population category. Small cities (less than 10,000 in population) are discussed first, followed by medium cities (between 10,000 and 50,000 in population), and large cities (more than 50,000 in population). The descriptions conclude with discussions of the three cities selected at-large.

IV.A Algona, IDOT District 2, Population 6,289

Description. The Algona project consisted of the conversion of an existing, isolated, pre-timed traffic signal to fully actuated. The signal is located at the intersection of South Phillips Street (U.S. 169) and McGregor Street. Pedestrian push-button actuation was added for the north- and south-bound pedestrians (see the map in Figure 4-1).

At this location, four-lane U.S. 169, South Phillips Street, intersects with McGregor Street, which is a two-lane City of

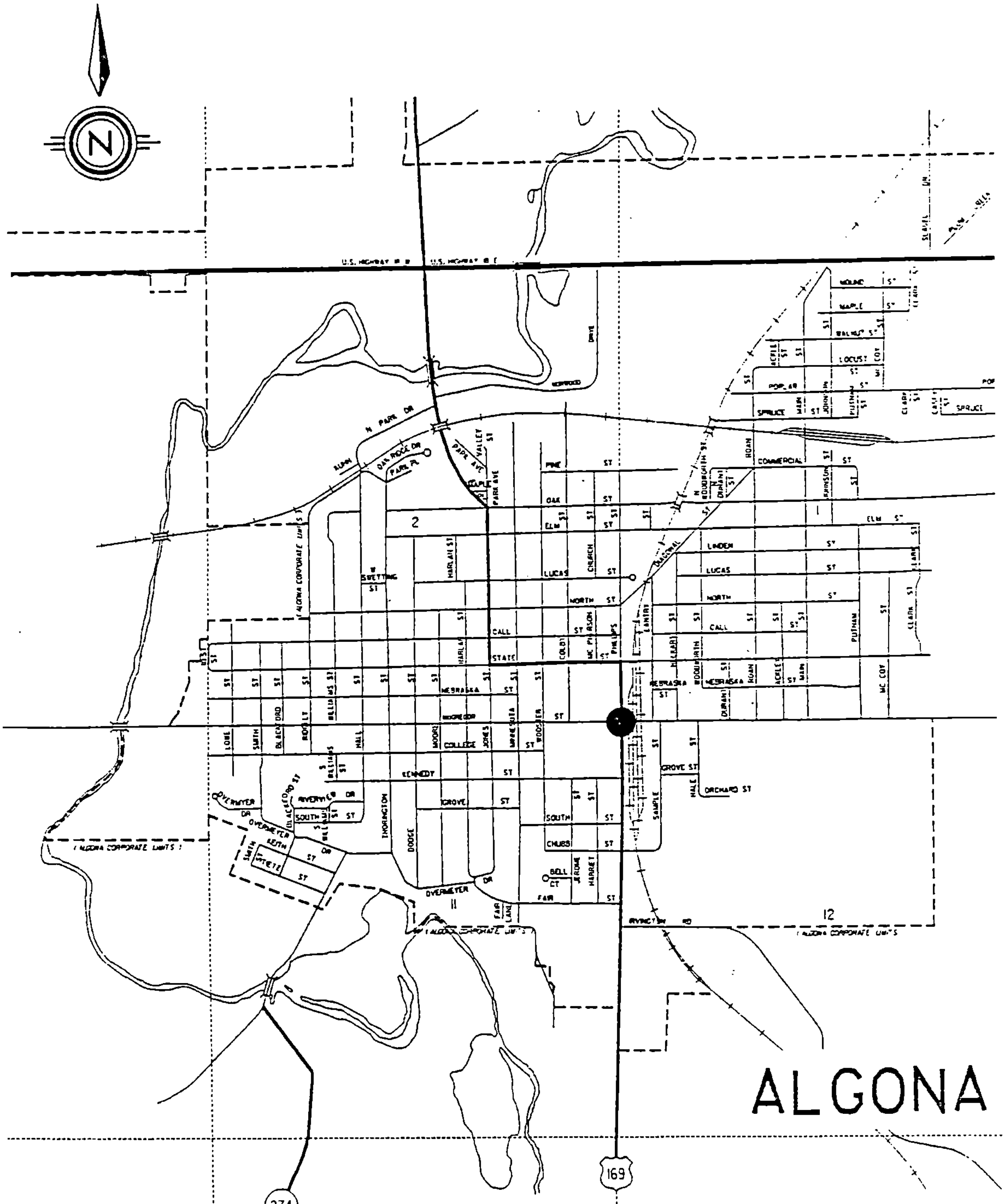

Figure 4-1: Map of ALGONA Project

Algona arterial street. The average daily traffic volume along U.S. 169 is approximately 6,000 vehicles.

The intersection is surrounded by a convenience store with gas pumps on the northwest corner, commercial businesses on the northeast and southeast corners, and a house on the southwest corner. A large grain elevator and ammonia plant are located approximately two blocks south of the intersection. The Algona high-school is approximately four blocks southeast of the intersection. An elementary school is located on block southwest of the intersection. The intersection serves as a school crossing for elementary and high-school students.

Site selection and project justification were based upon the intersection's proximity to the two schools, the grain elevator and ammonia plant, and the businesses along U.S. 169; and the fact that the previous electromechanical controller had been plagued with maintenance problems. The City of Algona wanted to improve traffic control at the intersection from pre-timed to fully actuated in order to relieve traffic congestion and coordinate pedestrian-walk indications with conflicting traffic flows.

The installation consisted of: one new Traffic Controls Technologies NEMA type, traffic-actuated controller in a new controller cabinet; four new "Walk-Don't Walk" pedestrian signals, four new pedestrian push-buttons; and twelve new traffic-detection loops and the associated wiring necessary to convert the pre-timed intersection. Although the new controller has the capability of dimming and pre-emption, it was determined that these options were not necessary at this time.

FUNDING SOURCES:

Federal Grant	$ 11,997.16	
City Match	2,117.15	(15%)
Project Cost	$ 14,114.31	

EQUIPMENT:

Traffic Signal Controller Assembly (including: timer, conflict monitor, and 4 detector amplifiers, load switches, flasher, etc. inside pole mounted cabinet, type"G")	$ 5,830
4 Pedestrian Signals (Crouse Hinds)	$ 1,048
5 Pedestrian Push Buttons and Signs	$ 255
Loop detector wire, lead-in cable; Loop sealant, 5 pull box rings and covers	$ 1,900
Equipment Cost	$ 9,033

Design Services. General Traffic Controls (a Spencer-based equipment vendor) supplied the Traffic Controls Technologies equipment. New signal timing plans were developed by a joint effort between General Traffic Controls and the City of Algona. The construction plans were handled by the City of Algona. The intersection of McGregor and U.S. 169 was originally designed, and the installation supervised, by the present Public Works Director.

Technical Support Services. Traffic signal operation is handled through the City of Algona Public Works Department and by the city electrician. The city's traffic experience is in the area of electromechanical control. Algona does have an unwritten maintenance agreement with General Traffic Controls. The agreement provides for annual inspection, emergency signal service, and technical advice.

Procurement Procedure. The City of Algona purchased the equipment and services through performance-based, competitive bidding. The predominant performance criteria were the availability and serviceability of spare parts.

Project Evaluation. A before-and-after comparison of the traffic conditions at the intersection yields the following results:

PROJECT COST	$ 14,144	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 1,682	
DELAY	379	
FUEL CONSUMPTION	651	(651 gallons)
TOTAL	$ 2,712	

BENEFIT TO COST RATIO = 1.75

Conclusions. The Algona project is considered successful due to the positive economic analysis. Vehicle and pedestrian accident reductions, maintenance savings, and reduced potential legal liability are a few of the additional un-quantified improvements. This project demonstrates the efficiency of a city of small-population size converting an isolated traffic signal from pre-timed to fully actuated control. The improvements were accomplished by installing loop detectors, a new signal controller, improved traffic signal timing plans, and pedestrian control. With adequate maintenance, annual project benefits should continue into the future.

IV.B Atlantic, IDOT District 4, Population 7,789

Description. The City of Atlantic improved their signal system by installation of a closed-loop, distributed system to supervise signals at seven intersections along 7th Street (U.S. 6) (see the map in Figure 4-2).

Seventh street is a four-lane arterial with hilly terrain located near the downtown area. None of the signalized intersections are of equal distance apart. Average daily traffic volumes along Seventh Street are approximately 6,000 vehicles. The surrounding land use consists of strip commercial development. Pre-project traffic control consisted of an assortment of electromechanical controllers. The signals were previously connected by a seven conductor cable in the following manner: Poplar Street to Walnut Street, and Olive Street to Hospital drive. The Whitney Street intersection was controlled by an isolated signal.

Project improvements linked the intersections into two groups. Due to the long distance (2288') between the Olive-Whitney intersection and Poplar-Walnut intersection, a decision was made to split the two systems. The Poplar-Walnut system is operated by a master controller located at the Walnut intersection, the Olive-Whitney system is controlled by a master located at the Olive Street intersection. Both masters communicate with and are monitored from the central-office computer.

Project actions involved the installation of three pre-timed

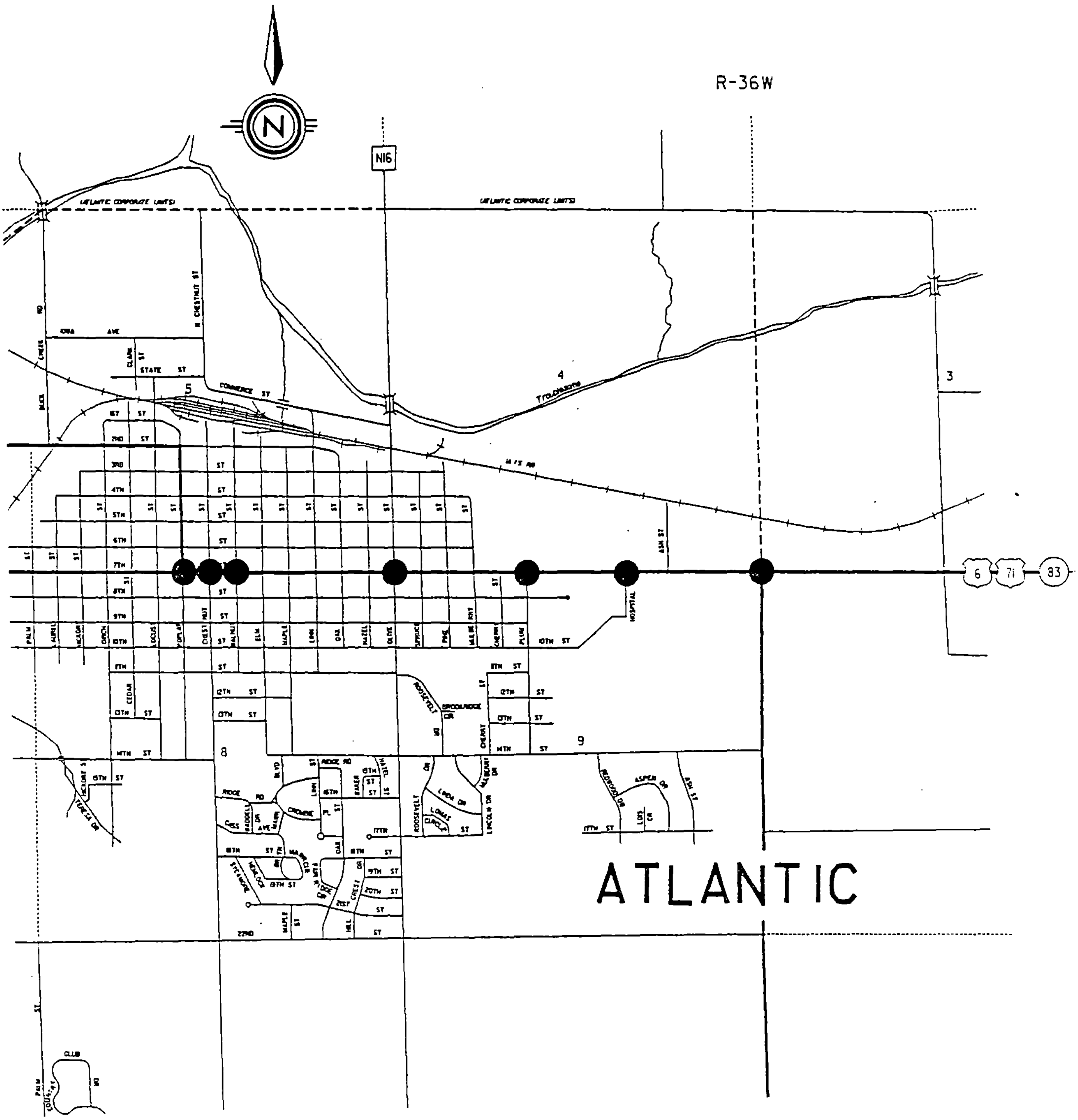

Figure 4-2: Map of ATLANTIC Project

Traffic Controls Technologies (TCT) controllers along with new cabinets and two master controllers. The Olive to Hospital Drive intersections received two new cabinets, three controllers with actuation, and a system master. The Poplar to Walnut intersections received pre-timed controllers, three new cabinets, and a system master. System communication were established by installing conduit from Hospital Drive to Whitney Street, Hospital Drive to Olive Street, Olive Street to 6th to 7th, and East of Walnut.

<u>FUNDING SOURCES:</u>

Federal Grant	$ 110,390.42	
City Match	7,388.00	(6%)
Project Cost	$ 117,778.42	

<u>EQUIPMENT:</u>

Central Office Monitor and Conduit Furnish and Install	$ 24,056.00
2 Master controllers 3 Pretimed controllers 4 Actuated controllers 5 Controller cabinets Sampling detectors (15), conduit, cable, wiring and communications system System timed and field tested	$ 86,334.42
Equipment Cost	$110,390.42

<u>Design Services</u>. General Traffic Controls (a Spencer-based equipment vendor) provided design services for the project. They also supplied the Traffic Control Technologies equipment, developed signal timings, and installed the equipment. Part of the City's agreement with General Traffic Controls was that they would provide technical training. General Traffic Controls held two workshops which were videotaped for future reference.

Technical Support Services. The signal system is managed by the City of Atlantic Public Works Department. Atlantic does have an unwritten maintenance agreement with General Traffic Control which provides for annual inspection, emergency signal service, and technical advice.

Procurement Procedure. The City of Atlantic purchased the equipment and services through performance-based, competitive bidding. The predominant performance criteria were serviceability and reliability.

Project Evaluation. A before-and-after comparison of the traffic conditions along 7th Street yields the following results:

PROJECT COST	$ 117,778.42	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 17,305	
DELAY	2,460	
FUEL CONSUMPTION	9,685	(9,685 gallons)
TRAVEL TIME	54,466	
TOTAL	$ 83,916	

BENEFIT TO COST RATIO = 6.49

Conclusions. The Atlantic project is considered successful due to the positive economic analysis. Vehicle and pedestrian accident reductions, maintenance savings, reduced pollution, and reduced potential legal liability are a few of the additional un-quantified improvements. This project demonstrated that it is efficient for a small-population city to convert a previously coordinated arterial to computerized closed-loop, distributed control. With adequate maintenance and periodic updating of signal timing plans, annual project benefits should continue into the future.

IV.C Monticello, IDOT District 6, Population 3,641

Description. Monticello modified the existing traffic signal control at two intersections. These were Highway 38 and East First Street, and Highway 151 and East First Street (see the map in Figure 4-3).

Both Highways 38 and 151 are two-lanes that carry average daily traffic volumes of approximately 2,000 and 4,000 vehicles respectively. East First Street is a two-lane arterial that runs through the central business district. Surrounding land use consists of commercial development. Through- and left-turn bays exist on all but the westbound leg of the Highway 151 intersection. The Highway 38 intersection has single-lane approaches.

Pre-project traffic control consisted of vintage 1950-model pre-timed controllers with no traffic actuation. Also developed was a U-STEP project to modify the geometry of the intersections. The project is based upon a 1979 Transportation Engineering Assistance Program study that identified the needed improvements.

Project work involved the provision of traffic-actuated control by placing new Winkomatic controllers at both intersections. At the Highway 151 intersection, a five-section signal head was added for the northbound movement to accommodate leading left-turn movements. At the Highway 38 intersection, a mast-arm signal mount was installed.

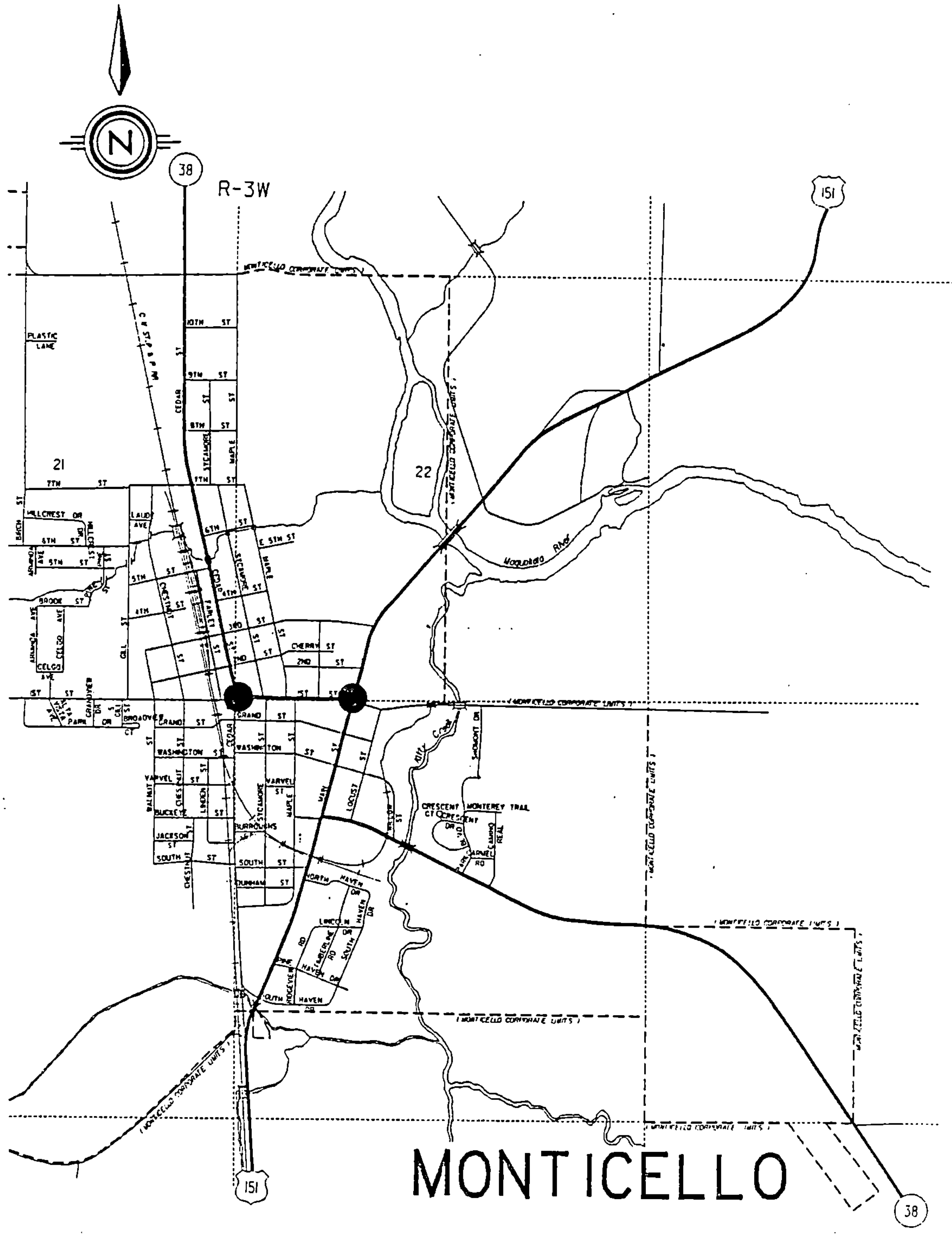

Figure 4-3: Map of MONTICELLO Project

FUNDING SOURCES:

Federal Grant	$ 78,489.51	
City Match	9,191.10	(10%)
Project Cost	87,680.61	

EQUIPMENT:

An equipment list was not provided by the city of Monticello.

Design Services. A consulting engineering firm designed the traffic signals, timing plans, and provided contract administration services for Monticello. Services were also provided by an electrical contractor firm.

Technical Support Services. Monticello signals are under the operational control of the street department. No written maintenance policy currently exists; however, a formal chain-of-command is established for emergency operations.

Procurement Procedure. The controllers, signal hardware, and installation services were purchased through performance-based, competitive bidding. The predominant performance criteria were service and the availability of spare parts.

Project Evaluation. A before-and-after comparison of the traffic conditions at the intersection yields the following results:

PROJECT COSTS	$ 90,000
ANNUAL SAVINGS	
VEHICLE STOPS	$ 0
DELAY	0
FUEL CONSUMPTION	0
TOTAL	$ 0

BENEFIT TO COST RATIO = 0

Conclusions. Although no annual savings were quantified, the Monticello project is considered marginally beneficial. The outdated controllers were a maintenance problem and increased the potential for legal liability and the potential for vehicle and pedestrian accidents.

IV.D Storm Lake, IDOT District 3, Population 8,814

Description. Storm Lake improved traffic flow with a variety of technologies at seven intersections. Time-base coordinated control, new signal controllers, and mast arms were installed at four intersections along Flindt Drive (U.S.71/I.A.7). Full- actuation control was installed at one isolated intersection on Milwaukee (I.A.7), (see the map in Figure 4-4).

Flindt drive is a four-lane, divided facility with average daily traffic volumes of approximately 3,500 vehicles. Surrounding land use varies from commercial to residential and includes school zoning.

Three new controllers were installed at the intersections of Flindt Drive and Park, Russell, and Northwestern. The controller type was specified to retain consistency with the existing equipment. Conflict monitors were installed at each intersection. Eight Pole/Mast Arms were installed at the Park, Russell, Seneca, and Oneida intersections. Four time-base controllers were installed at the Flindt Drive and Lakeshore, East 5th, Seneca, and Oneida intersections. Additional equipment installed included loop detectors, vehicular and pedestrian

Figure 4-4: Map of STORM LAKE Project

signal indicators, communications cable, and conduit. No dimming of the signals at night will be used.

FUNDING SOURCES:

Federal Grant	$ 102,504.00	
City Match	15,366.00	(13%)
Project Total	117,870.00	

EQUIPMENT:

Furnish and Install
3 Controllers, 3 Conflict monitors,
4 Time base modules, 8 Pole/mast arms,
25 Signal heads, 4 Street lights,
20 Pull boxes, Related conduit, cable,
conductors,loop detectors, signal head mounts, etc.

Equipment Cost $ 103,104.00

Design Services. Timing plans for the intersections were developed by the consulting firm of Kyehl & Payer Ltd. consulting firm. General Traffic Controls, the supplier of the Traffic Controls Technology equipment, determined the signal hardware to be installed for the Flindt Drive arterial and the isolated intersection.

Technical Support Services. The traffic signal system is under the operational control of the city's Infrastructure Superintendent. The city does have significant signal experience with time-base coordination technology. No written preventive or routine maintenance policy exists; however, a chain of command has been established for emergency signal operations.

Procurement Procedure. The equipment and services were purchased through performance-based, competitive bidding. A few of the performance criteria were serviceability, performance, and spare-parts availability.

Project Evaluation. A before-and-after comparison of the traffic conditions along Flindt Drive arrived at the following results:

PROJECT COST	$ 117,870.00	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 14,577	
DELAY	580	
FUEL CONSUMPTION	1,294	(1,294 gallons)
TRAVEL TIME	6,636	
TOTAL	$ 23,087	

BENEFIT TO COST RATIO = 1.78

Conclusions. The benefits of the Storm Lake project clearly exceeded the costs. However, the benefits of the improvements were not as great as those of other projects that adopted TBC technology (Webster City and Indianola) because the existing electromechanical controllers were coordinated. The new equipment is more flexible and more reliable. However, the traffic-flow performance was only marginally improved because the signal timing plans for both old and new systems should provide for progressive movements. With adequate maintenance and periodic updating of signal timing plans, annual project benefits should continue into the future.

IV.E Webster City, IDOT District 1, Population 8,572

Description. Webster City converted five isolated pre-timed signalized intersections on Second Street, (formerly U.S.20/I.A.17), to a time-based coordinated system. The improved intersections were U.S. 20 and Superior, Seneca, Wilson, Des

Moines, and Prospect Streets (see the map in Figure 4-5).

Second Street is a two-lane arterial street with an average daily traffic volume of 3,500 vehicles. The five intersections improved are along Second Street and within the central business district. Previous traffic control at the intersections consisted of uncoordinated electromechanical controllers.

In 1981, the consulting firm of Johnson, Brickell, Mulcahy, and Associates, Inc. performed a study of the existing traffic signals in Webster City. The study was performed under the Transportation Engineering Assistance Program (TEAP). However, due to limited funds, no action was taken towards implementing the suggested traffic signal improvements.

Project work consisted of installing new Traffic Control Technologies (TCT) controllers with time-base coordination into retrofitted or new controller boxes. Also "Walk-Don't Walk" pedestrian indications were added to the Seneca, Wilson, and Des Moines intersections. No preemption exists for the arterial, and the dimming feature will not be used.

FUNDING SOURCES:

Federal Grant	$ 34,469.87	
City Match	6,350.65	(16%)
Project Total	40,820.52	

EQUIPMENT:

Furnish and Install
Controllers (5), Conflict monitors (5),
Load switches (25), Flashers (5),
12" Green signal heads (10), Trenching,
Conduit, Concrete removal and replacement

Equipment Cost $34,469.87

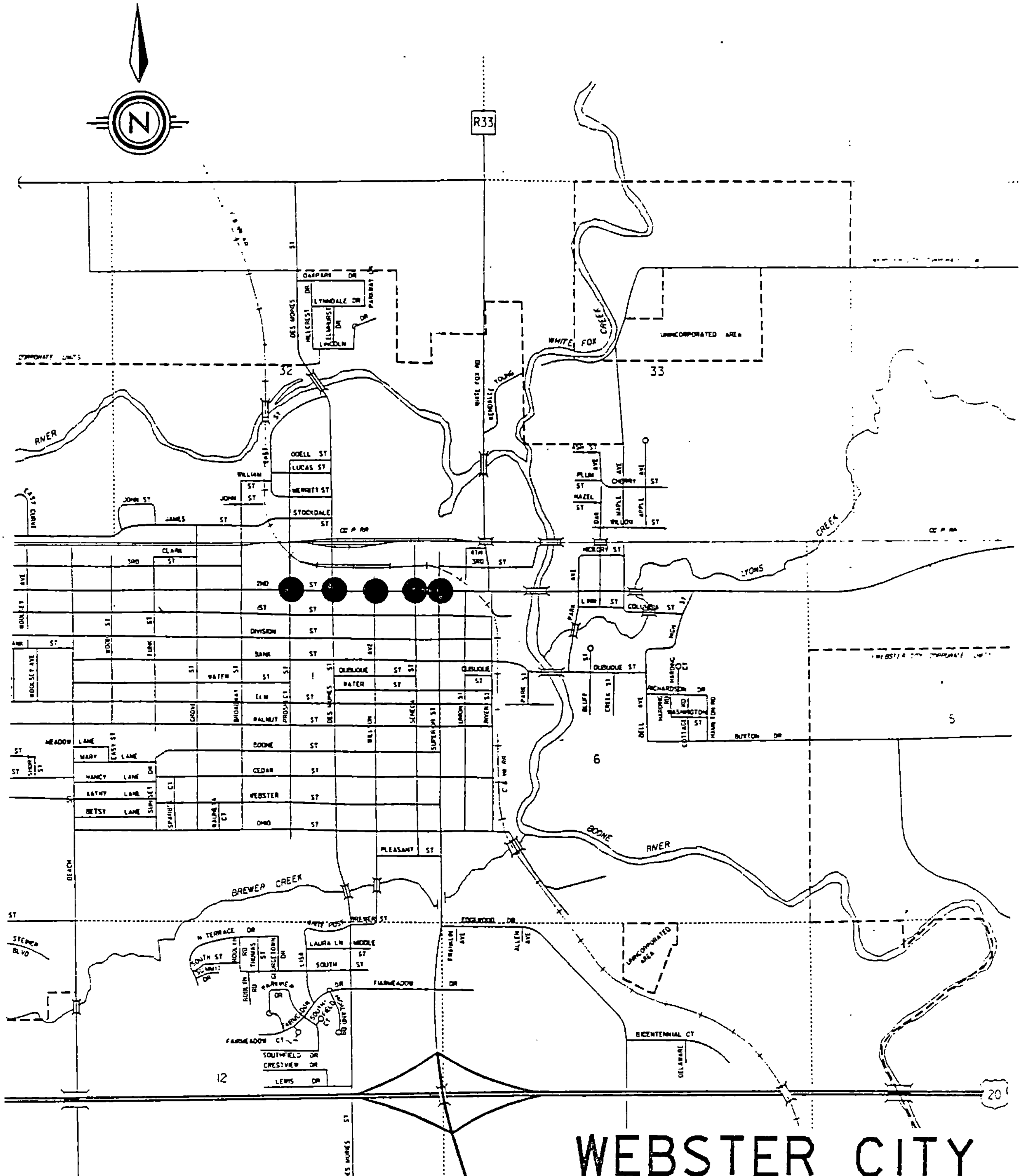

Figure 4-5: Map of WEBSTER CITY Project

Design Services. General Traffic Controls designed the traffic signal system that replaced the existing isolated electromechanical equipment. Signal timing plans were developed by Johnson, Brickell, Mulcahy, and Associates, Inc. A construction contractor was hired to install the purchased signal hardware.

Technical Support Services. The signal system is under the operational control of the Department of Public Works. Webster City does not have a written maintenance policy but does check signal hardware once per year. The city does have an on-call relationship with General Traffic Controls for emergency operations and troubleshooting.

Procurement Procedure. The equipment and services were purchased by low bidding. A few of the contract criteria were performance, serviceability, and spare-parts availability.

Project Evaluation. A before-and-after comparison of the traffic conditions along Second Street found the following results:

PROJECT COST	$ 40,820.52	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 63,079	
DELAY	1,760	
FUEL CONSUMPTION	5,711	(5,711 gallons)
TRAVEL TIME	35,748	
TOTAL	$ 106,298	

BENEFIT TO COST RATIO = 23.72

Conclusions. The Webster City project is overwhelmingly successful. The dramatic improvement in traffic-flow performance is a result of coordinating a previously uncoordinated arterial. This project demonstrated the efficiency of a small city converting a previously uncoordinated arterial to computerized time-based coordinated control. With adequate maintenance and periodic updating of signal timing plans, annual project benefits should continue into the future.

IV.F Ames, IDOT District 1, Population 45,775

Description. Ames installed a microcomputer-supervised, closed-loop, distributed system that modernized a total of 26 traffic signals within five of the City's six signal systems. The improved signals were at 18 intersections along Lincoln Way , three intersections along Grand Avenue, and five intersections along Duff Avenue (see the map in Figure 4-6).

Lincoln Way is a four-lane, major arterial carrying an average daily traffic volume of approximately 12,500 vehicles. Lincoln Way is bordered predominantly by strip-commercial development except where it runs the length of Iowa State University's campus. Channelization and left-turn lanes exist at most intersections. Previous traffic control consisted of integrated-circuit digital electronic controllers on semi-actuated timing plans. Progression was included.

Grand Avenue is a four-lane, major arterial with residential development between intersections and some commercial businesses near the intersections. Average daily traffic volume along Grand

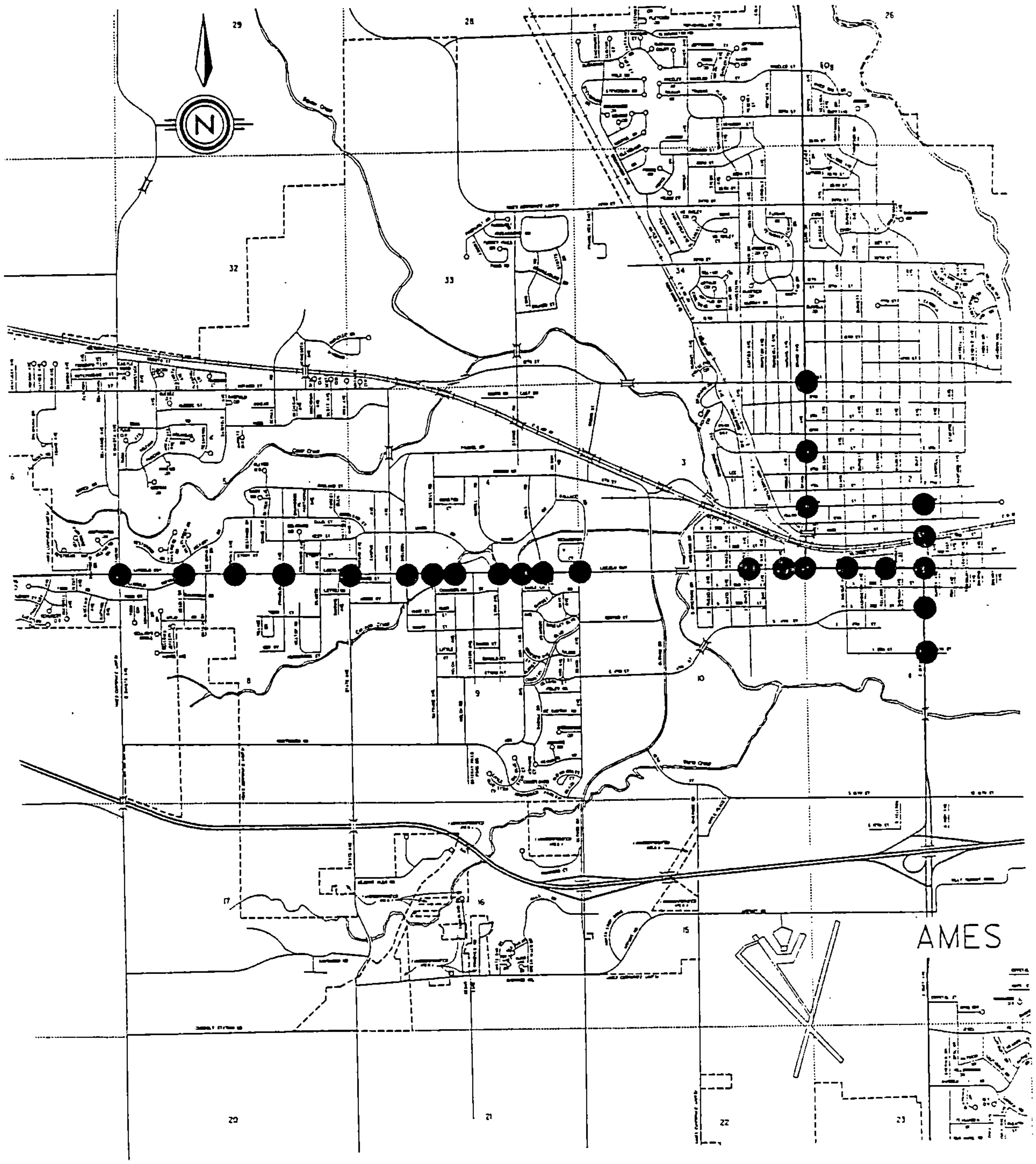

Figure 4-6: Map of AMES Project

Avenue is approximately 15,000 vehicles. Previous traffic control was the same as that on Lincoln Way.

Duff Avenue is also a four-lane, major arterial surrounded on both sides by commercial-strip development. Duff Avenue carries average daily traffic of approximately 20,000 vehicles. Site selection and project justification were based primarily upon the high traffic volumes along these arterials and the high pedestrian volumes along those sections of Lincoln Way adjacent to Iowa State University's campus.

Project improvements included:

1. Installing new Eagle Signal, NEMA type, controllers and cabinets at 25 of the 26 intersections and installing one new master controller.

2. Laying new communications cable to connect the individual intersection controllers to the master controller.

3. Locating a microcomputer system monitor at the city's public works department to supervise the system through a leased telephone line to the master controller.

The Eagle Signal system gives the ability of providing up to four types of pre-emption per intersection. Because 100 percent of the signals in Ames previously had pre-emption, maintaining pre-emption capability was an important element in the system's design. With the new system, each intersection has the ability to pre-empt normal signal operation and provide the right-of-way to specially equipped emergency vehicles. Additionally, railroad pre-emption was provided at each intersection in the neighborhood of a railroad crossing. For example, at Main and Duff there is four-way, emergency vehicle and railroad pre-emption.

FUNDING SOURCES:

Federal Grant	$ 99,171.35	
City Match	61,203.26	(38%)
Project Total	$ 160,374.61	

EQUIPMENT:

Cabinets and Controllers (25)	$ 62,830
Master Controller(1)	18,000
Computer,Printer,Monitor(1)	11,640
Communications(cable/conduit)	6,701
Installation by City	13,500
Equipment (City Share)	30,000
Equipment Cost	$ 142,671

Design Services. Intersection timing plans were developed by Dr. R.L. Carstens, a local traffic consultant. The signal equipment was purchased from Brown Traffic Inc., suppliers of Eagle Signal systems. Brown Traffic Inc. has supplied technical and educational support during the system's implementation.

Technical Support Services. The City of Ames' signal systems are under the operational control of the City Traffic Engineer. The city does have a technical staff specifically for signals. The city also has an unwritten maintenance policy for preventive and emergency signal operations.

Procurement Procedure. The equipment and services were purchased through competitive bid. Low price was the primary contractor selection criteria.

Project Evaluation. A before-and-after comparison was conducted for all three segments of the system (Duff, Lincoln Way, and Grand). The aggregate evaluation results are listed below:

<u>PROJECT COST</u>	$	160,374
<u>ANNUAL SAVINGS</u>		
VEHICLE STOPS	$	59,965
DELAY		19,272
FUEL CONSUMPTION		27,830 (27,830 gallons)
TRAVEL TIME		<u>170,407</u>
TOTAL	$	277,474

BENEFIT TO COST RATIO = 15.76

Conclusions. The traffic signal improvements in Ames were highly effective. The primary factor that lead to the project's highly positive benefit-to-cost ratio was the coordination of the city's major arterials. Compared to the old signal system, the benefits of the closed-loop, distributed system are likely to increase when the system becomes fully traffic responsive and is able to adjust timings for current traffic conditions.

IV.G Bettendorf, IDOT District 6, Population 27,381

Description. The City of Bettendorf improved traffic operations at 10 intersections throughout the city (see the map in Figure 4-7). All signal improvements involved upgrading the actuation capability of the controllers at each intersection. The additional detector loops and amplifiers improved the existing NEMA traffic controllers' ability to reduce delay.

Four of the improved intersections were along State Drive which is a four-lane arterial with commercial development along its right-of-way. Modifications to these intersections reduced delay for left- and right-turning motorists on the side streets.

Two of the improved intersections were along Grant Street

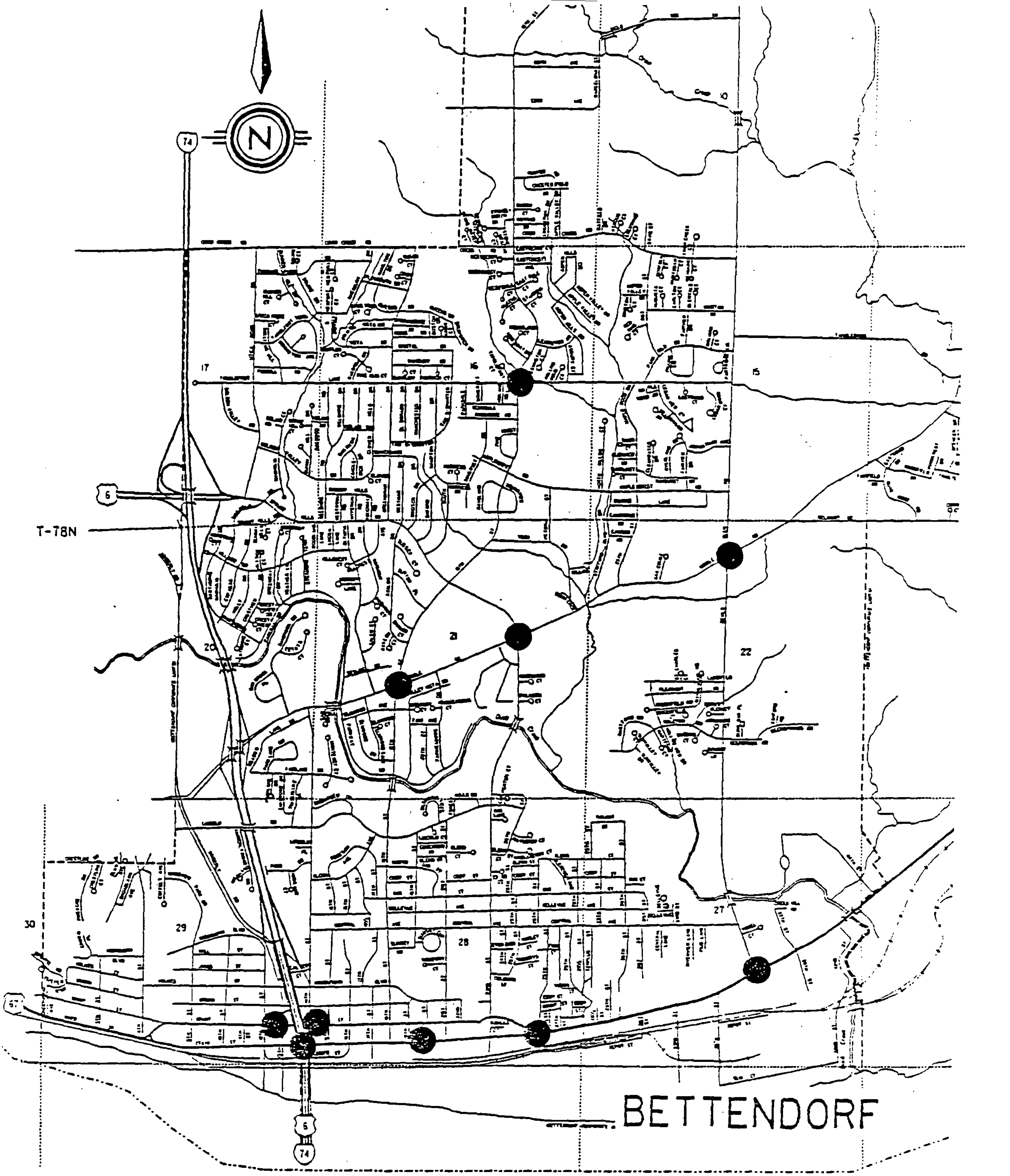

Figure 4-7 Map of BETTENDORF Project

which is a four-lane arterial surrounded by commercial development and parallelling State Street. Modifications reduced delays experienced by northbound left-turning and southbound right-turning motorists.

The third arterial improved was Middle Road, a two-lane arterial. Land use consists of businesses surrounding the intersections and residential along the arterial. Modifications focused upon adding detectors for southbound traffic flow at 18th Street; adding detectors for northbound right turns at 23rd Street; and adding detectors for northbound and southbound movements on Devils Glen Road.

To provide for better operation of advance left-turn arrows, three existing pre-timed signals were converted to semi-traffic actuated. To provide better green-time extensions for through traffic, an existing semi-traffic actuated signal was converted to fully actuated. Pre-emption and dimming were determined unnecessary. Most of the existing controllers were manufactured by Eagle Signal.

FUNDING SOURCES:

Federal Grant	$ 37,766.59	
City Match	5,604.68	(13%)
Project Total	$ 43,371.27	

EQUIPMENT:

Furnish and Install	
Loop detector amplifiers (12)	$ 1,740.00
Loop detector amplifiers w/delay (9),(f/inst.)	1,602.00
Loop wire (8,806.1 LF), conduit, splice kit,	34,424.59
Equipment Cost	$37,766.59

Design Services. No new signal timing plans were developed. Some minor timing changes were necessary and handled in-house. No training was necessary.

Technical Support Services. Signals are under the operational control of the traffic engineer. No written maintenance policy exists; however, annual maintenance is performed by the traffic engineering staff.

Procurement Procedure. The equipment was purchased through competitive bid based upon a written specification. Selection was based on the low-cost proposal.

Project Evaluation. Before-and-after evaluations were conducted at each of the improved intersections through delay studies. The evaluation resulted in the following findings:

PROJECT COST	$ 128,270
ANNUAL SAVINGS	
VEHICLE STOPS	$ 0
DELAY	0
FUEL CONSUMPTION	0
TOTAL	$ 0

BENEFIT TO COST RATIO = 0

Conclusions. The traffic signal improvements made in Bettendorf were not those that would be expected to create the greatest improvement in overall traffic flow. The actuation improvements made in Bettendorf were not necessarily intended to reduce overall delay but rather to decrease maximum delays. In addition, the benefits most likely to be significant are safety benefits through the addition of actuation on turning movements. Safety benefits were not calculated in the economic analysis.

IV.H Indianola, IDOT District 5, Population 10,843

Description. Indianola replaced the old electromechanical controllers with NEMA controllers at five intersections along Jefferson Way (U.S. 65/69, See the map in Figure 4-8). Each controller was equipped with a time-base coordinator to allow progression along the arterial.

Jefferson Way is a four-lane arterial with commercial development along its right-of-way. Average daily traffic volumes are approximately 15,000 vehicles. Previous traffic control was provided by pre-timed controllers with no arterial progression.

The project was based upon a 1985 Transportation Engineering Assistance Program (TEAP) study conducted by the consulting firm of Johnson, Brickell, Mulcahy, and Associates Inc. All signal improvement decisions were based upon the recommendations of this study.

Project work consisted of:

1. replacing the existing pre-timed electromechanical controllers at Euclid, Ashland, Salem, and East Second streets with new 820 Multisonics controllers and time-base coordination modules;

2. upgrading the existing two-phase signal operation at East Second Street to four-phase (with southbound and eastbound leading green phases);

3. replacing two signal heads at East Second with five-section signal heads;

4. adding two detectors, adding two pedestrian push-buttons, and removing two traffic signs; and

5. connecting the light at the intersection of Ashland and Jefferson Way to a pre-emption actuation device which is housed in the Fire Station on Ashland.

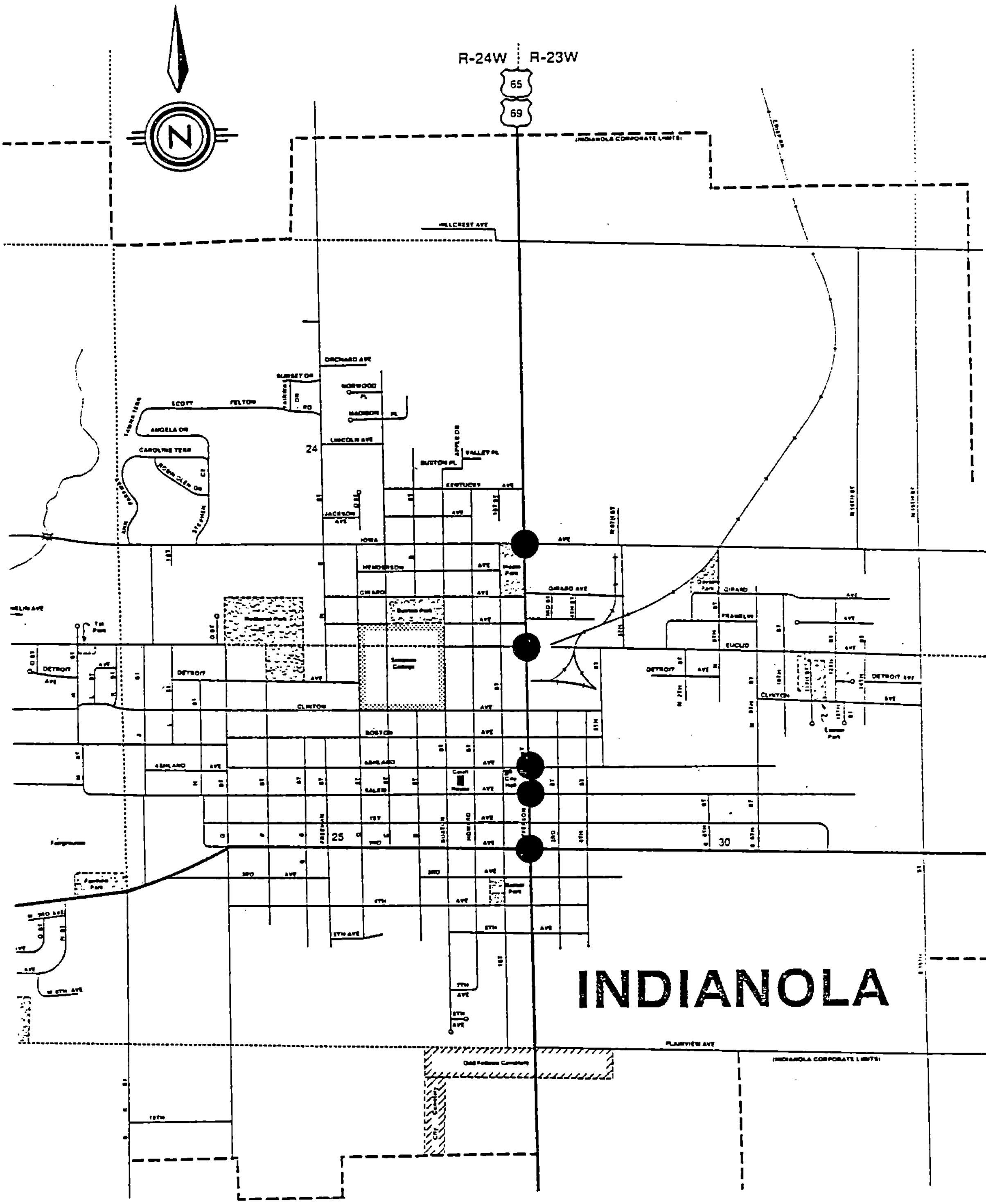

Figure 4-8: Map of INDIANOLA Project

FUNDING SOURCES:

Federal Grant	$ 51,398.00	
City Funds	$ 7,288.25	(12%)
Project Total	$ 58,686.25	

EQUIPMENT:

Furnish and Install
Controllers (4), Cabinets (4),
Conflict monitors (4), Detector amplifiers (26),
Signal heads (2 ea), and other misc. equip.

Equipment Cost $ 51,398.00

Design Services. The Dickinson Company designed the signal system, developed timing plans, and furnished and installed the required equipment. No training was necessary.

Technical Support Service. The signal system is under the operational support of the city manager. Indianola does have an unwritten maintenance agreement with the city of Des Moines covering non-routine maintenance and emergency operation.

Procurement Procedure. Indianola purchased the equipment and services through competitive bidding in which the lowest priced and conforming bid was selected. The contract included requirements for spare-parts availability and serviceability.

Project Evaluation. A before-and-after comparison of the traffic conditions along Jefferson Way provided the following results:

PROJECT COST	$ 58,686	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 90,806	
DELAY	5,691	
FUEL CONSUMPTION	17,543	(17,543 gallons)
TRAVEL TIME	97,755	
TOTAL	$211,795	

BENEFIT TO COST RATIO = 32.87

Conclusions. The Indianola project provided an exceptionally high ratio of benefit to cost because of the condition of the old signals along Jefferson Way. The old signals were completely uncoordinated.

The TBC system installed in Indianola is a low-cost method to provide coordination. Because there is no technical staff in Indianola, it is likely that a more complicated system with more advanced traffic signal technology would have been inappropriate. Given the lack of technical staff, the greatest obstacle in maintaining the benefits offered by the new system will be the city's inability to update signal timings and respond to maintenance needs of the new advanced technology.

VI.I Mason City, District 2, Population 30,144

Description. Mason City improved traffic flow at seven intersections along U.S. 18 by installation of a computer-supervised closed-loop, distributed system. The intersections of U.S. 18 and S. Eisenhower, S. Taft, S. Grover, Winnebago Way, S. Garfield, S. Pierce, and Beaumont Drive all received new controllers (see the map in Figure 4-9).

U.S. 18 is a four-lane arterial that carries an average

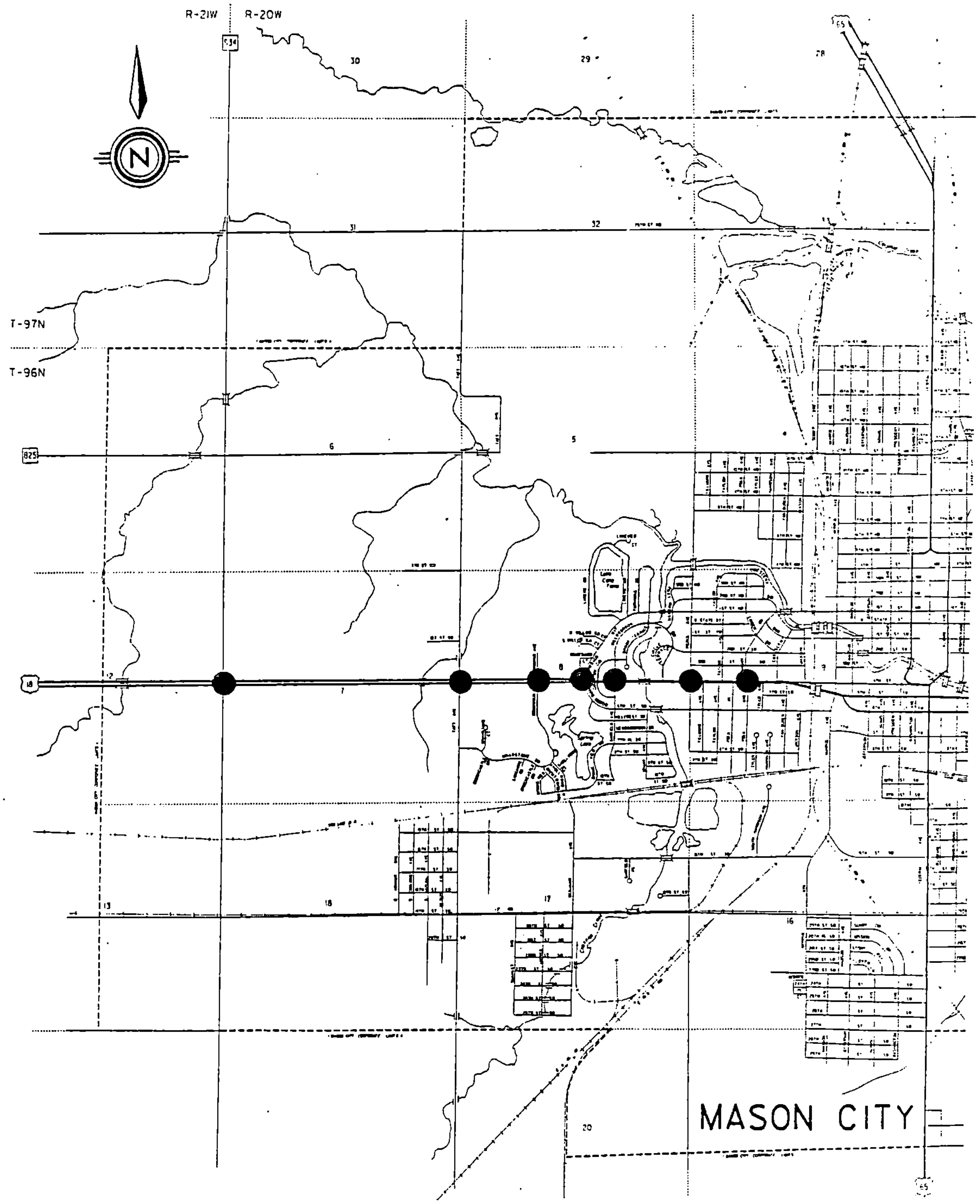

Figure 4-9: Map of MASON CITY Project

daily traffic volume of approximately 10,000 vehicles. Commercial development surrounds the arterial.

Before the new system was installed, traffic control along U.S. 18 consisted of individual, isolated intersections with semi-actuated operation. Due to the excessive distances between the intersections, the project required the installation of 12,419 feet of communications cable to link the controller units to the system master. Communications between the system master and the central-office monitor, located in the traffic office at city hall, is established by phone modem.

A Transportation Engineering Assistance Program (TEAP) study was performed in 1986 by the consulting firm of Johnson, Brickell, Mulcahy, and Associates, Inc. The study focused on improving the traffic flow along U.S. 18, from Taft Avenue to Garfield Avenue. The signal system installation was based on the recommendation in the TEAP study.

The system installed along the arterial is a Traffic Controls Technology closed-loop system. The master controller, local controllers, and computer purchased are the major components of the system. The system will not be operating with dimming or pre-emption.

The City of Mason City owns a significant amount of testing equipment such as detector testers, a suitcase conflict-monitor tester (which was purchased as part of the current traffic signal improvement program), and a suitcase controller-tester. Also, one of the traffic engineering staff members had developed a light board that helps test controllers prior to installation.

FUNDING SOURCES:

Federal Grant	$	79,730.51
City Match		4,271.26 (5%)
Project Total	$	84,001.77

EQUIPMENT:

Furnish and Install
Computer, printer, monitor (1),
NEMA controllers (7), Master controller (1),
Cabinets (4), and other miscellaneous equip.

Equipment Cost $ 55,033.81

Design Services. Timing plans were developed by General Traffic Controls. General Traffic Controls was also the supplier of the Traffic Controls Technology (TCT) control equipment. Training was provided, as needed, by General Traffic Controls.

Technical Support Services. The signal system is operated by the City of Mason City's Traffic Engineering Department. The department has experience with traffic signals ranging from pre-timed to fully actuated with time-base coordination. An unwritten emergency maintenance agreement does exist with General Traffic Controls concerning complex or non-routine maintenance of TCT equipment.

Procurement Procedure. Standardization with existing equipment was an important consideration in the equipment selected. It was felt that standardization would facilitate familiarity with the equipment and compatibility with future system expansions. The equipment vendor was selected based on the low-price bid. However, the equipment specification contained rather strict compatibility requirements and service availability demands.

Project Evaluation. A before-and-after analysis of traffic conditions for the seven intersections along U.S. 18 provided the following results:

PROJECT COST	$ 84,001	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 133,318	
DELAY	3,984	
FUEL CONSUMPTION	13,175	(13,175 gallons)
TRAVEL TIME	72,043	
TOTAL	$ 222,520	

BENEFIT TO COST RATIO = 24.13

Conclusions. The Mason City project is an excellent example of how the modest expense of upgrading existing equipment can provide significant returns. Furthermore, the close-loop, distributed system has the capacity to expand in the future. With adequate maintenance and periodic retiming of the signal system, annual project benefits should continue into the future.

IV.J Muscatine, District 5, Population 23,465

The first part of Muscatine's project was to conduct a traffic study of a 30-block area in the central business district (CBD). Later the project attempted to implement the suggested improvements. The planned improvements consisted of placing solid-state, Type 170 controllers at 18 selected intersections and interconnect the controllers into a closed-loop, distributed system. The 30-block CBD area is bounded by Pine Street, Eighth

Street, Mulberry Avenue, and Mississippi Drive (see the map in Figure 4-10).

The study evaluated traffic operations and determined recommended improvements implementation plans for traffic signals, signal interconnection, and one-way streets. The study also considered how traffic would be effected by changes in land-use activity in the downtown area; the rerouting of U.S. 61 and Iowa 22 out of the CBD; the impact of improved traffic technology; and the elimination of non-warranted traffic signals.

Previous signal control in the CBD consisted of a pre-timed master controller connected by cable to electromechanical local controllers. The existing system master and local controllers were manufactured by Eagle Signal.

In 1980 Muscatine participated in Iowa's Transportation Engineering Assistance Program (TEAP) study. The study identified and addressed the deficiencies within the CBD's traffic signal system. The new study was required due to the following traffic changes that occurred after the completion of the TEAP study:

1. Transition of the Central Business District. Since the late 1970s, the CBD had increased traffic, trade, and importance. A CBD steering committee was formed to ensure orderly transitions in land use for the CBD area. A full-time position of "Main Street Coordinator" was created to coordinate downtown revitalization efforts.

2. Effects of Highway Route Changes on CBD. Traffic volumes have declined due to the December 1984 opening of Highway 61 Bypass which circumvented the CBD. Subsequent to the Highway 61 Bypass opening, Highway 22 along Cedar Street into the CBD was rerouted to coincide with a portion of the Highway 61 Bypass. This action made it unnecessary for

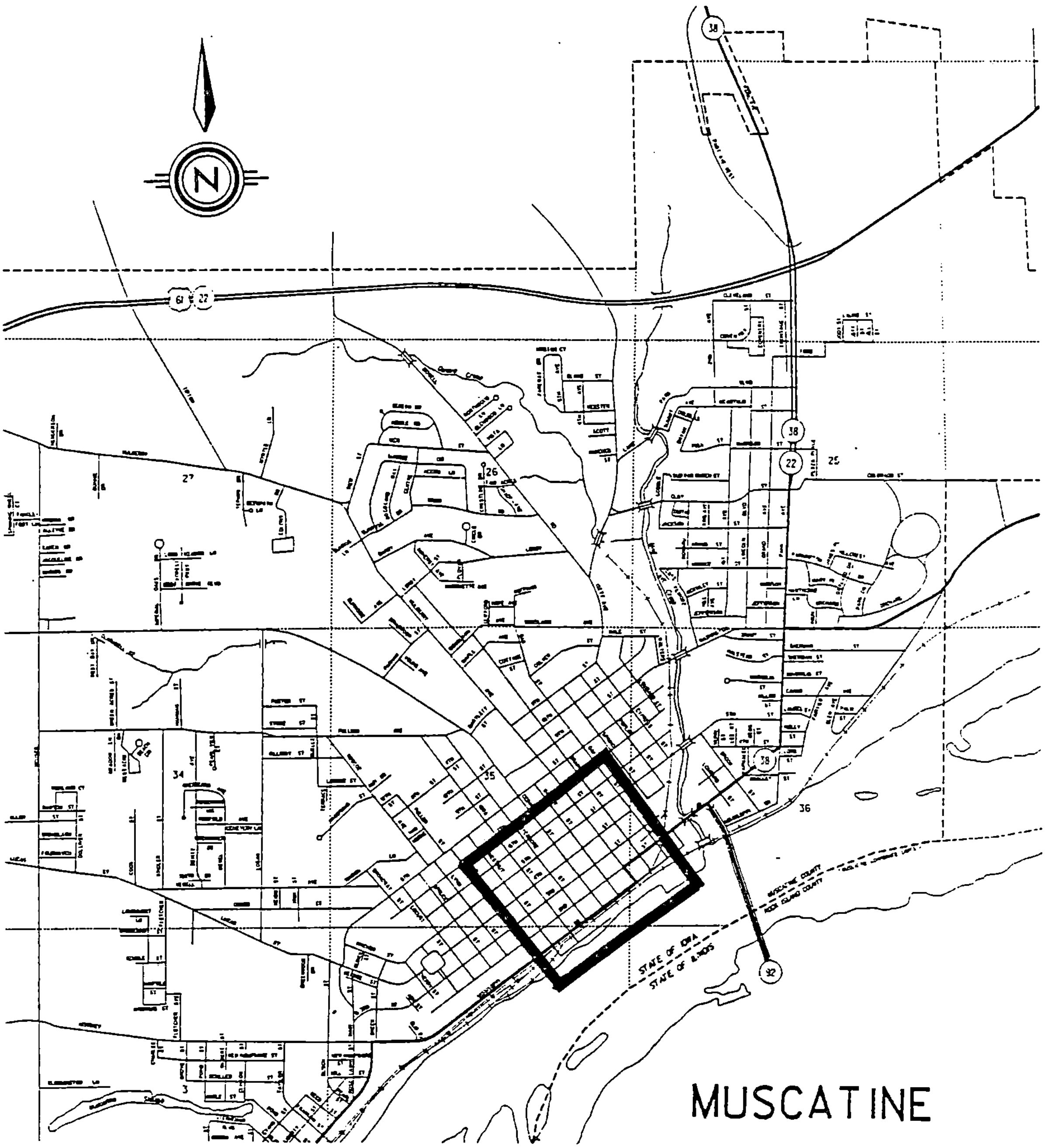

Figure 4-10: Map of MUSCATINE Project

vehicles to go through downtown to proceed east or west of the city.

3. Technological Changes - Impact on CBD. Prior to this project there were 26 signalized intersections in the downtown area. The hardware was 30-years-old and in need of replacement. Part of this project evaluated the feasibility of removing the traffic signals along Highway 92 (Mississippi Drive) from the synchronized core CBD system. Furthermore, it was anticipated that the elimination of a minimum of three to five traffic signals in the core CBD area would be conducive to more efficient traffic flow. The remaining 21 to 23 signalized intersections were improved through the installation of a new master and local controllers.

Project work involved the addition of Safetrans Type 170 controllers at all of the improved intersections. Pre-emption was included at one intersection near the fire station.

The Muscatine project initially called for the signal system to operate as a closed-loop system. However, due to a shortage of funds, the system did not achieve closed-loop operation.

Currently the 170 controllers are operating under a unique mode. The pre-emption feature is used with dummy calls to provide time-based coordination along the arterials. When funds are available to add detectors, the intersection controllers will be switched to actuated operation. This avoids the expense of providing a hardwire interconnection between the intersections. No dimming will be used for the system.

FUNDING SOURCES:

Federal Grant	$ 245,000.00	
City Match	82,110.49	(25%)
Project Total	$ 327,110.49	

EQUIPMENT:

An equipment list was not provided by the City of Muscatine.

Design Services. Stanley Consultants was the general contractor for the project. However, National Engineering Technologies Company (NET), a sub-contractor, performed the study of the existing traffic volumes and patterns, determined signal warrants, and designed traffic signal modifications. The consultants also furnished and installed the signal equipment's modifications and additions, and removed signal installations which were not warranted. The City of Muscatine paid NET an additional $ 5,000 for training city personnel.

Technical Support Services. Muscatine Power and Water is a municipally owned public utility company and has direct responsibility for the purchasing, installation, and maintenance of all traffic control devices within the city. All phases of the project, evaluation, and installation of changes in the traffic control system were coordinated by Muscatine Power and Water. No written maintenance program exist for the signals; however, a chain of command does exist for emergency signal operations.

Procurement Procedure. The system was purchased through competitive bidding. Low price was the primary selection criterion.

Project Evaluation. A before-and-after study of the traffic flow performance was conducted for the effected area. The evaluation reflects the failure to achieve closed-loop operation.

PROJECT COST	$327,110
ANNUAL SAVINGS	
VEHICLE STOPS	$ 37,641
DELAY	0
FUEL CONSUMPTION	0
TRAVEL TIME	0
TOTAL	$ 37,641

BENEFIT TO COST RATIO = 0.0

Conclusions. The Muscatine project did not provide the expected benefits. In all likelihood, the failure of the project to provide significant benefits is attributable to the inability of achieving closed-loop operation with the funds available.

IV.K Spencer, District 3, Population 11,726

Description. Spencer installed a closed-loop, distributed system of microcomputer-supervised signals at eight intersections on Grand Avenue (U.S. 18/71) between Fourth Street S.W. and Eighth Street (see the map in Figure 4-11).

Grand Avenue is a four-lane arterial that carries average daily traffic volumes of approximately 8,000 vehicles. The arterial runs through the Central Business District.

Previous signal control consisted of a semi-actuated controller at Fourth Street, seven pre-timed controllers from First Street to Seventh Street, and a full-actuated controller at Eighth Street. All of the controllers were Crouse-Hinds NEMA type controllers.

The two actuated signals used both loop and magnetic detectors. None of these detectors were suitable as sampling detectors for the closed-loop system. The signals from First to

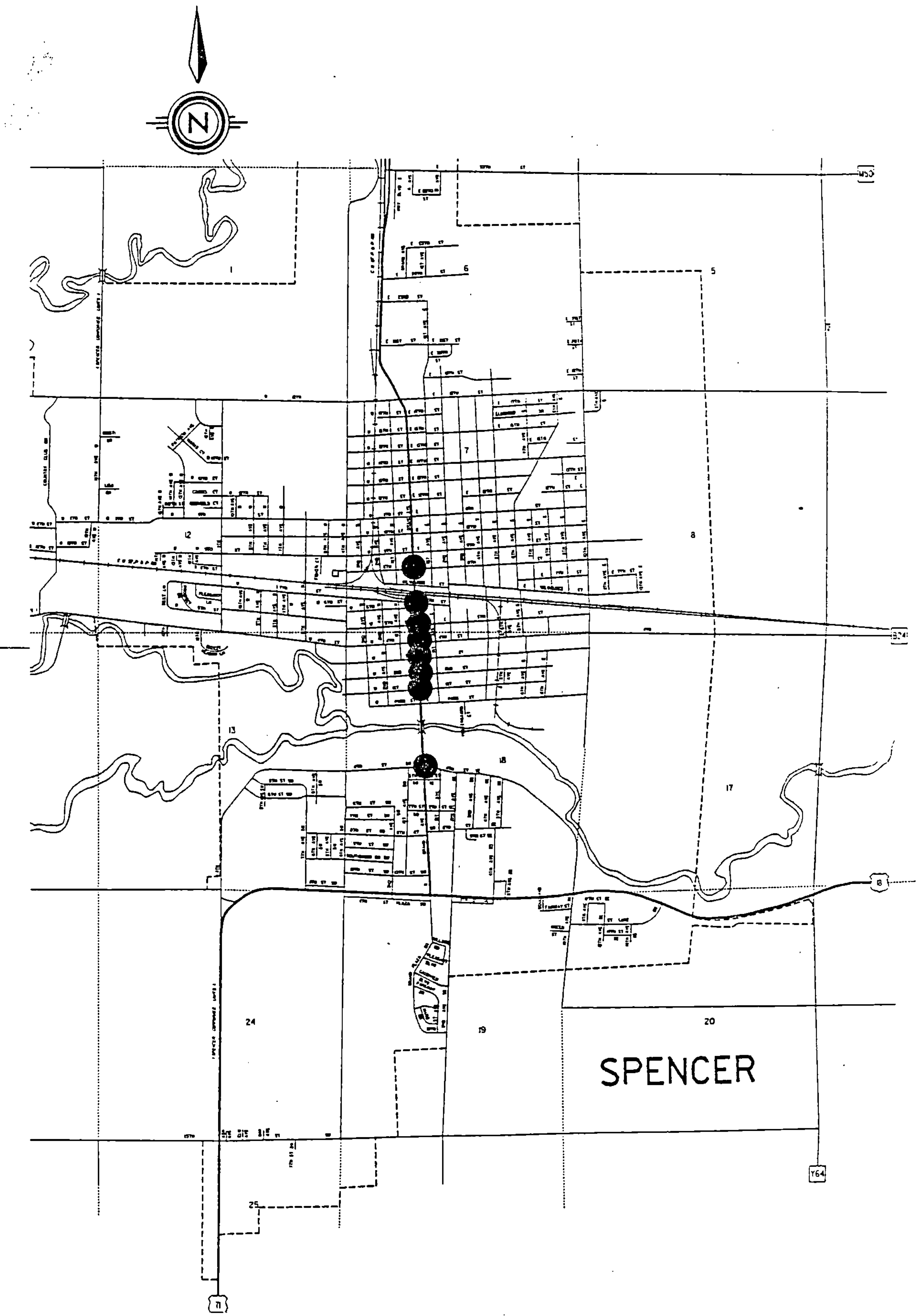

Figure 4-11: Map of SPENCER Project

Seventh Street were interconnected by a seven-conductor cable leading to a master controller located at Fourth Street. An emergency pre-emption system turned these six signals green for four minutes upon command issued from the fire station to each signal via the interconnect cable.

Although improved signal monitoring and system efficiency were two of the desired results of this project, the primary aspect of the system that interested the City of Spencer was the pre-emption capability. The new system's pre-emption capabilities far exceed those of the previous controllers.

The new signal equipment consisted of an on-street master controller, eight local controllers, sampling detectors, interconnect cable, and a Central Office Monitor(COM).

A new, master controller was installed in the existing cabinet at the Eighth Street intersection. Traffic sampling detectors were installed along the arterial to allow for continuous monitoring of traffic conditions. New controllers to upgrade control were placed at each intersection. The new controllers have the ability to operate at a reduced voltage (dimming feature). This dimming feature is not used at this time.

The controller installed at the Fourth Street intersection was a two-phase, fully actuated NEMA unit and required a new controller cabinet and wiring. All other controllers were solid-state, pre-timed units (First to Seventh Streets).

Included in the project was a new warning signal at the entrance to the fire station. The fire station is located on the east side of Grand Avenue between First Street and Park Street.

FUNDING SOURCES:

Federal Grant	$ 94,517.00	
City Match	9,891.98	(10%)
Project Total	$ 104,408.98	

EQUIPMENT:

Furnish and Install
Computer, Printer, Monitor, Modem,
Master controller (1), Controllers (8),
Conflict monitors (2), Detector amplifiers (5),

Equipment Cost $ 94,517.00

Design Services. Due to the nature and complexity of a closed-loop system, technical support was required from General Traffic Controls, the supplier and design consultant. Timing plan parameters will be fine tuned to the City's satisfaction during the first year of operation by the supplier/consultant.

Special events that generate above-normal traffic during the first year of operation shall receive additional attention to completely assure proper system performance. During these events, the suppliers/consultants engineer shall be present to make any necessary adjustments to achieve optimum system performance. The cost of these services was provided in the overall project costs. Training was provided for all personnel designated with the responsibility of operating and maintaining the system.

Technical Support Services. The signals are under the control of the Public Works Department. An unwritten maintenance agreement does exist with General Traffic Controls covering non-routine and emergency maintenance.

Procurement Procedure. The equipment and services were purchased thorough competitive, performance-based bidding. The primary performance criteria included serviceability and special features such as pre-emption.

Project Evaluation. A before-and-after comparison of the traffic conditions at the eight intersections along U.S. 18 yields the following results:

PROJECT COST	$104,409	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 33,408	
DELAY	2,918	
FUEL CONSUMPTION	7,148	(7,148 gallons)
TRAVEL TIME	41,091	
TOTAL	$ 84,565	

BENEFIT TO COST RATIO = 7.38

Conclusions. The Spencer project illustrates that cities with populations of less than 10,000 can benefit from state-of-the-art technology. Because the City has close ties with the hardware vendor (General Traffic Controls), the system is likely to be fine tuned regularly to achieve the most efficient operation. Therefore, the benefits of the system are likely to continue through the future.

IV.L Council Bluffs, District 4, Population 56,449

Description. Council Bluffs installed a traffic signal system that is closed-loop, distributed and computer controlled. It covers 14 signalized intersections and improved traffic flow along three major arterials. The improved arterials are Kanesville Boulevard, from Frank Street to Eighth and Broadway, East Broadway, from Seventh to North Avenue, and West Broadway, from Sixteenth to Thirty-fifth Street including Sixteenth Street at Avenue B and Avenue G (see the map in Figure 4-12).

Kanesville Boulevard is a two-lane arterial with both lanes dedicated to one-way (westbound) movement. This arterial was previously under pre-timed signal control. East Broadway is a one-way (eastbound) arterial previously under full- and semi-actuated control. West Broadway is a two-lane, one-way arterial flowing into East Broadway. All of the arterials are surrounded by commercial development and run through the central business district. Prior to this project, a mid-block pedestrian crossing was established on East Broadway between Park and First Street. Average daily traffic volumes for these arterials is approximately 30,000 vehicles.

Previous traffic control hardware consisted of an assortment of Eagle Signal controllers that provided progression. The intersections did not provide pedestrian-actuated control.

Project changes were performed without significant modifications made to the signal installations. All of the poles, signal heads, detectors, and other hardware remained in place. The project improvements consisted of adding new Eagle Signal controllers at the intersections, a new Eagle Signal master controller, and system detectors that allow for traffic responsive operation. A phone modem placed at the master

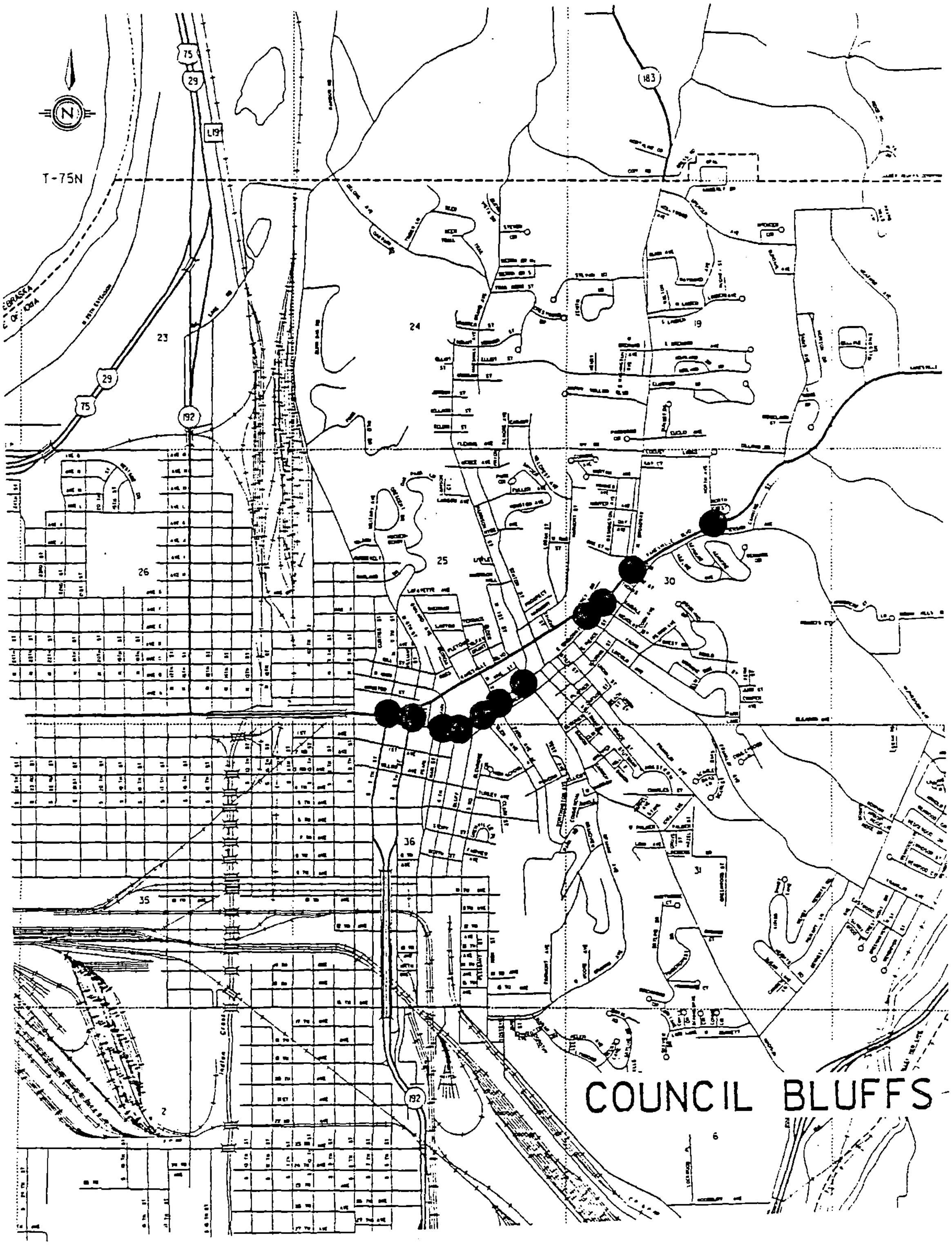

Figure 4-12: Map of COUNCIL BLUFFS Project

controller allows communication with the system's central-office monitor located at City Hall.

A unique situation exists at three of the intersections because one controller operates two separate intersections. One controller can operate both intersections because of the close proximity and geometry at the Seventh and Kanesville-Broadway, Sixth and Kanesville-Broadway, and Frank Street and Kanesville-Broadway intersections. Although all of the new controllers allow for dimming and pre-emption, these options were not implemented.

FUNDING SOURCES:

Federal Grant	$ 114,800.00	
City Match	13,470.85	(10%)
Project Total	$ 128,270.85	

EQUIPMENT:

Furnish and Install:
Master controller (1), Controllers (11),
Cabinets (9), Ped pushbuttons (72),
Computer, Printer, Modem,
Detector amplifier (34), Conf. monitor (7),
Load switches (49), etc.

Equipment Cost	$ 128,270.85

Design Services. All of the Eagle Signal equipment was furnished by Brown Traffic Products. They were also responsible for developing the new timing plans, installing all equipment, detectors, cable, etc. A consultant/sub-contractor installed the detector loops, conduit, cable, and other equipment. Brown Traffic provided training to Council Bluffs technical staff.

Technical Support Services. The Council Bluffs signals are under the operational control of the traffic engineering office. Council Bluffs currently has two traffic signal technicians. Council Bluffs' annual preventive maintenance program checks most signal hardware. An unwritten maintenance policy exists for emergency operations.

Procurement Procedure. The system was procured by competitive bidding for both the hardware and the installation. The primary criterion for selection of the contractor was price.

Project Evaluation. A before-and-after study was conducted to determine the improvements to the traffic flow that resulted from the new system. The study found the following benefits and costs.

PROJECT COST	$ 128,270	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 25,447	
DELAY	2,389	
FUEL CONSUMPTION	10,100	(10,100 gallons)
TRAVEL TIME	57,998	
TOTAL	$ 95,899	

BENEFIT TO COST RATIO = 6.81

Conclusions. The Council Bluffs' results provide an example of the advantages of upgrading an existing system to a closed-loop, distributed system. Although the previous system was coordinated, by providing more efficient control, the new system provides benefits which greatly exceed the cost.

IV.M Iowa City, District 6, Population 50,508

Description. Iowa City improved traffic flow in a two-phase project. The first phase examined the feasibility of interconnecting eight signalized intersections on U.S. 6 between U.S. 218/I.A.1 and the eastern city limits (see the map in Figure 4-13). Phase two established a microcomputer-supervised closed-loop, distributed system that connects and coordinates the intersections.

U.S. 6 is a four-lane, divided highway with commercial development along its right-of-way. Average daily traffic volumes along the arterial are approximately 22,500 vehicles. Previous traffic control along U.S. 6 consisted of individual isolated intersections with semi-actuated operation. Because considerable distances separate the intersections along the arterial interconnection was considered expensive.

The feasibility study, or Phase 1, measured and analyzed current traffic conditions. These data were used to determine the potential impact of interconnecting the signalized intersections. The interconnection was found to be feasible, and Phase 2 was initiated.

In Phase 2, the consulting firm of Johnson, Brickell, Mulcahy, and Associates, Inc. prepared the specifications for the interconnection equipment and the new NEMA controllers. Iowa City's Traffic and Transportation Department installed the interconnect wiring and new controllers.

Eagle Signal controllers were installed at the intersections of U.S. 6 and Fairmeadows, First Avenue, Sycamore, Broadway, Keokuk, Boyrunn, Gilbert, and Iowa 965. A unique situation

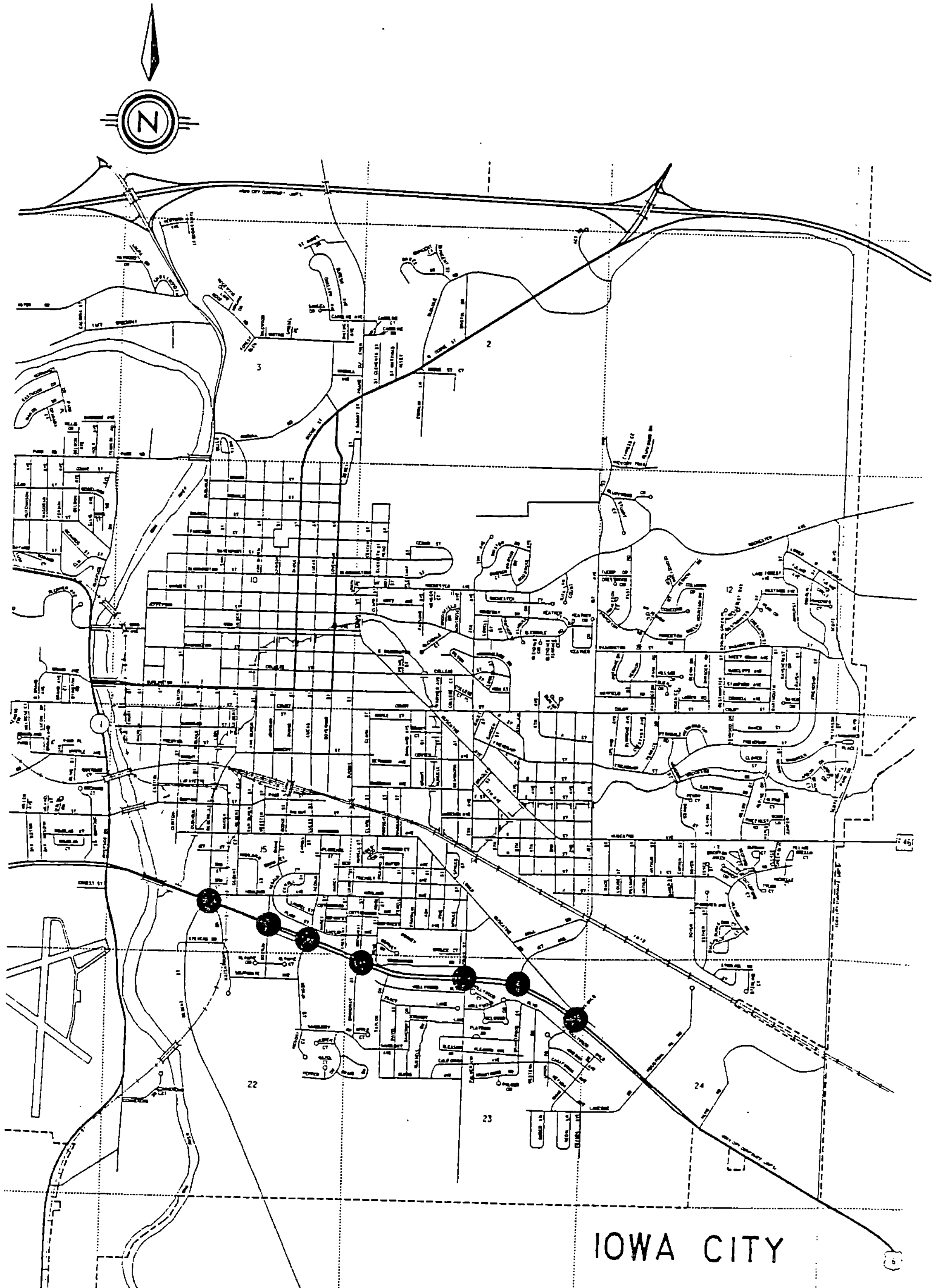

Figure 4-13: Map of IOWA CITY Project

exists due to the traffic engineering facility's close proximity to the Iowa 965 intersection. Because hardwire communication was established between the intersection and the facility, the system master could be housed at the traffic engineering office. A spare local controller was also purchased for ready availability in case of emergency operation. The computer monitor also was housed at the traffic engineering facility.

FUNDING SOURCES:

Federal Grant	$ 88,027.66
City Match	31,526.66
Project Total	$ 119,554.32

EQUIPMENT:

Furnish and Install
Computer, Printer, Monitor,
Controllers (9), Master controller (1),
Cabinets (8), Conflict monitors (8), etc.

Equipment Cost $ 55,526.04

Design Services. Design services were performed by the consulting firm of Johnson, Brickell, Mulcahy, and Associates, Inc. The consultant performed the feasibility study and designed the signal system. The designing of the signal system involved generation of timing plans and interconnect plans, and determination of signal system needs. Technical training was provided by Brown Traffic for the city staff.

Technical Support Services. The signal system will be under operational control of the Iowa City Traffic Engineering Department. Iowa City has several qualified technicians along with a full-time traffic engineer. Iowa City does have a written routine maintenance policy and an unwritten emergency maintenance policy.

Procurement Procedures. Iowa City purchased the equipment and services through performance-based competitive bidding. A few of the important performance criteria were training, serviceability, and spare-parts availability.

Project Evaluation. A before-and-after comparison of the traffic flow performance along U.S. 6 through each of the eight intersections identified a significant improvement. The improvements in traffic flow performance are listed below:

PROJECT COST	$ 119,554.32	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 144,024	
DELAY	14,668	
FUEL CONSUMPTION	42,382	(42,382 gallons)
TRAVEL TIME	246,633	
TOTAL	$ 447,706	

BENEFIT TO COST RATIO = 34.11

Conclusions. The Iowa City project received the greatest benefit to cost ratio of any arterial system implemented in the entire Iowa Motor Vehicle Fuel Reduction program. The project clearly demonstrates the benefits of providing coordinated signals on high volume arterial streets. While greatly reducing travel times by reducing stops and delays, such systems also control excessive speeds by stopping vehicles traveling faster than the progressive platoon.

IV.N Sioux City, District 3, Population 82,003

Description. Sioux City modernized their existing, 1981 vintage mini-computer-controlled traffic signal system. The system controls and monitors 79 signalized intersections. The modernization involved retrofitting the existing system to provide for microcomputer-supervised closed-loop, distributed operation. Hardware and software additions as well as controller modifications were used to retrofit the existing system.

The project was divided into three phases. In Phase 1, JHK and Associates analyzed the current traffic control system and made recommendations for improvement. In Phase 2, the consultant provided the engineering services required to develop design documents for the approved modernization work. Under Phase 3, the actual implementation took place. The consultant was retained to provide integration and change-over services to the City and assist with training staff and with monitoring the equipment procurement and oversight of the installation contracts.

Prior to the project, Sioux City's central-computerized traffic control system utilized the Urban Traffic Control System-Extended First Generation control software. This had been developed by the Federal Highway Administration in the late 1970s and implemented for the City of Sioux City by JHK and Associates in 1981. The system controlled and monitored the operation of 77 signalized intersections within the city. Approximately 85 percent of the signalized locations (most of which were located within the central business district) operated with fixed-time, electromechanical-type, local controller equipment. The remaining traffic controllers, primarily along arterial roadways, were of solid-state design and generally conformed to NEMA standards. Both types of controllers were interfaced to the central computer system through a Communications Interface and Control Unit (CICU). A CICU was installed in each controller cabinet. Communications interconnect was provided by a combination of city-owned cable and leased telephone circuits.

The project work consisted of retrofitting each CICU with a more sophisticated operations unit, and developing new computer hardware and software for the system. Each local controller was retrofitted to operate as an on-street master. A VAX mini-computer replaced the older central computer system. Pre-emption is not used on the system.

FUNDING SOURCES:

Federal Grant	$ 224,780.00	
City Funds	$ 38,246.15	(15%)
Project Total	$ 263,026.15	

EQUIPMENT:

High Resolution Color Monitor	$ 2,250.00
Graphic Display Processor	3,240.00
Graphic Tablet and Puck	492.00
Computer circuitry, cards, modems, etc.	50,766.00
Equipment Cost	$56,748.47

Design Services. Consultant design services provided by JHK and Associates were required to study alternatives for enhancing system reliability, simplifying operational requirements, adapting distributive control techniques, and reducing maintenance needs. The consultant designed the selected enhancement and assisted with acquisition and installation of the required hardware and software. Training was provided for the Sioux City traffic engineering staff by JHK and Associates.

Technical Support Services. The signal system is under the operational control of the city's traffic engineer. No written maintenance policy exists for the Sioux City; however, there are annual inspections of the traffic signal equipment.

Procurement Procedure. The Sioux City procurement was unique. Because of the uniqueness of the equipment used, the equipment was procured under a sole-source arrangement. Thus, JHK and Associates were the sole contractor for conversion.

EVALUATION OF RESULTS:

PROJECT COST	$ 263,026	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 866,299	
DELAY	10,052	
FUEL CONSUMPTION	13,027	(13,027 gallons)
TRAVEL TIME	57,036	
TOTAL	$ 946,414	

BENEFIT TO COST RATIO = 55.58

Conclusion. The Sioux City project evaluation took into account the reduced maintenance of the computer and other equipment. In the benefit-cost analysis the present worth of the reduction in maintenance cost was included in the analysis as a negative cost.

The Sioux City project most clearly points out the benefits of modern, microprocessor technology. The timing plans and the method system control were not changed. The benefits are entirely attributable to modern and reliable equipment.

IV.O Urbandale/Des Moines, District 1, Populations 19,443/191,003

The Urbandale/Des Moines project was a joint effort of the two cities. The project involved installation of a microcomputer-supervised, closed-loop, distributed control system of eight signalized intersections on Merle Hay Road (U.S. 6/I.A 401) from Hickman Road to I-35/80, and two intersections on Douglas Avenue at 59th Street and 62nd Street (see the map in Figure 4-14). The system is to be controlled by an existing computer (IBM AT) located in the offices of the City of Des Moines' Department of Traffic and Transportation.

Merle Hay Road is a four-lane, divided facility carrying an average daily traffic volume of approximately 20,000 vehicles. Surrounding land use consists of commercial development. Douglas Avenue is a four-lane arterial with similar traffic demands.

Previous traffic control for the Merle Hay arterial consisted of all isolated intersections with outdated Type 170 controllers. The isolated intersections did not provide for progression along Merle Hay Road. The City of Des Moines recently installed new Type 170 controllers for the two intersections along Douglas Avenue.

Project work involved the installation of new Type 170 Safetrans controllers and interconnect cable along Merle Hay Road

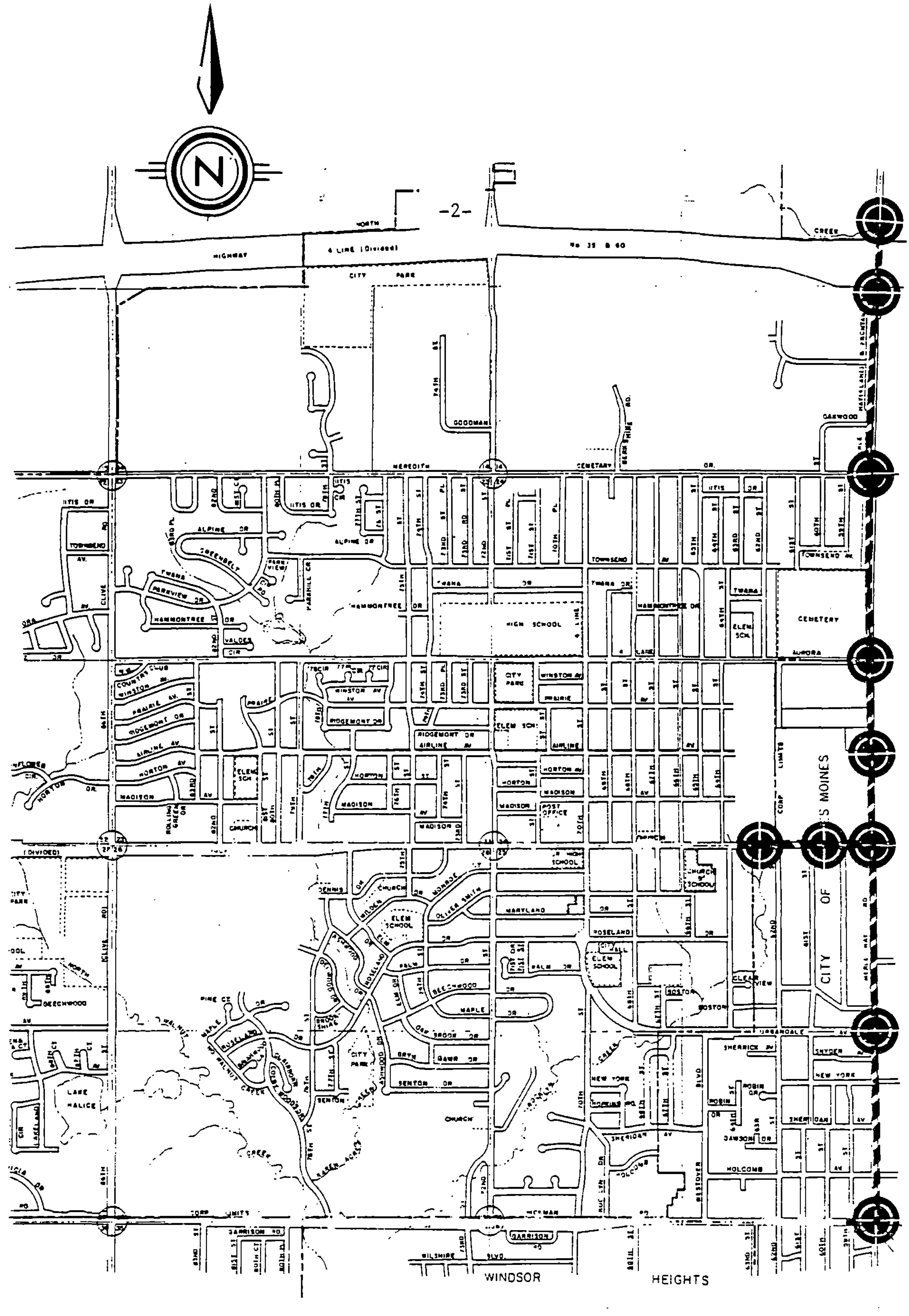

Figure 4-14: Map of URBANDALE/DES MOINES Project

for all intersections except the one at I-35/80. The 170 controller at this intersection required a slight modification. The Douglas Avenue intersections required only hardwire interconnect. In addition, a new system master controller and system detectors were installed.

FUNDING SOURCES:

Federal Grant	$ 306,993.94	
City Funds	$ 32,625.00	(10%)
Project Total	$ 339,618.94	

EQUIPMENT:

Furnished and Install
Controllers (7), Master controller (1), Cabinets (8), Signal heads (3), Signal pole, and other equipment

Equipment Cost $286,220.80

Design Services. The consulting firm of Johnson, Brickell, Mulcahy and Associates, Inc. designed the signal timing plans and determined the hardware requirements. A contractor was required to install the signal control equipment. The cities furnished $10,615 of in-kind services for traffic data collection, construction inspection, and contract administration.

Technical Support Services. The cities of Urbandale and Des Moines will have operational control of the signal system. The City of Des Moines' engineers and technicians have significant experience with Type 170 controllers and with signal maintenance.

Procurement Procedures. The equipment and services were purchased through performance-based competitive bidding. Two of the primary performance criteria considered were serviceability and availability of spare parts.

Project Evaluation. A before-and-after study was conducted to determine the traffic flow performance changes that resulted from the signalization improvement. The study resulted in significant improvements as shown below.

PROJECT COST	$ 339,618	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 351,627	
DELAY	28,104	
FUEL CONSUMPTION	77,068	(77,068 gallons)
TRAVEL TIME	445,828	
TOTAL	$ 902,627	

BENEFIT TO COST RATIO = 24.21

Conclusions. The Urbandale and Des Moines project results demonstrate the success of replacing older solid-state controllers with updated equipment. Furthermore, because of the high traffic volumes along Merle Hay Road, the benefits are multiplied by many motorists. The significance of the potential benefits of efficient traffic control in urban areas, with heavy traffic volumes, provides a compelling argument for maintaining and operating state-of-the-art traffic control equipment with efficient timing plans.

IV. P WATERLOO, DISTRICT 2, POPULATION 75,985

Description. Waterloo installed of a portion (Subsystem K) of a planned microcomputer-supervised, closed-loop, distributed controlled system. Subsystem K is comprised of 11 signalized intersections along University Avenue (U.S. 218, see the map in Figure 4-15).

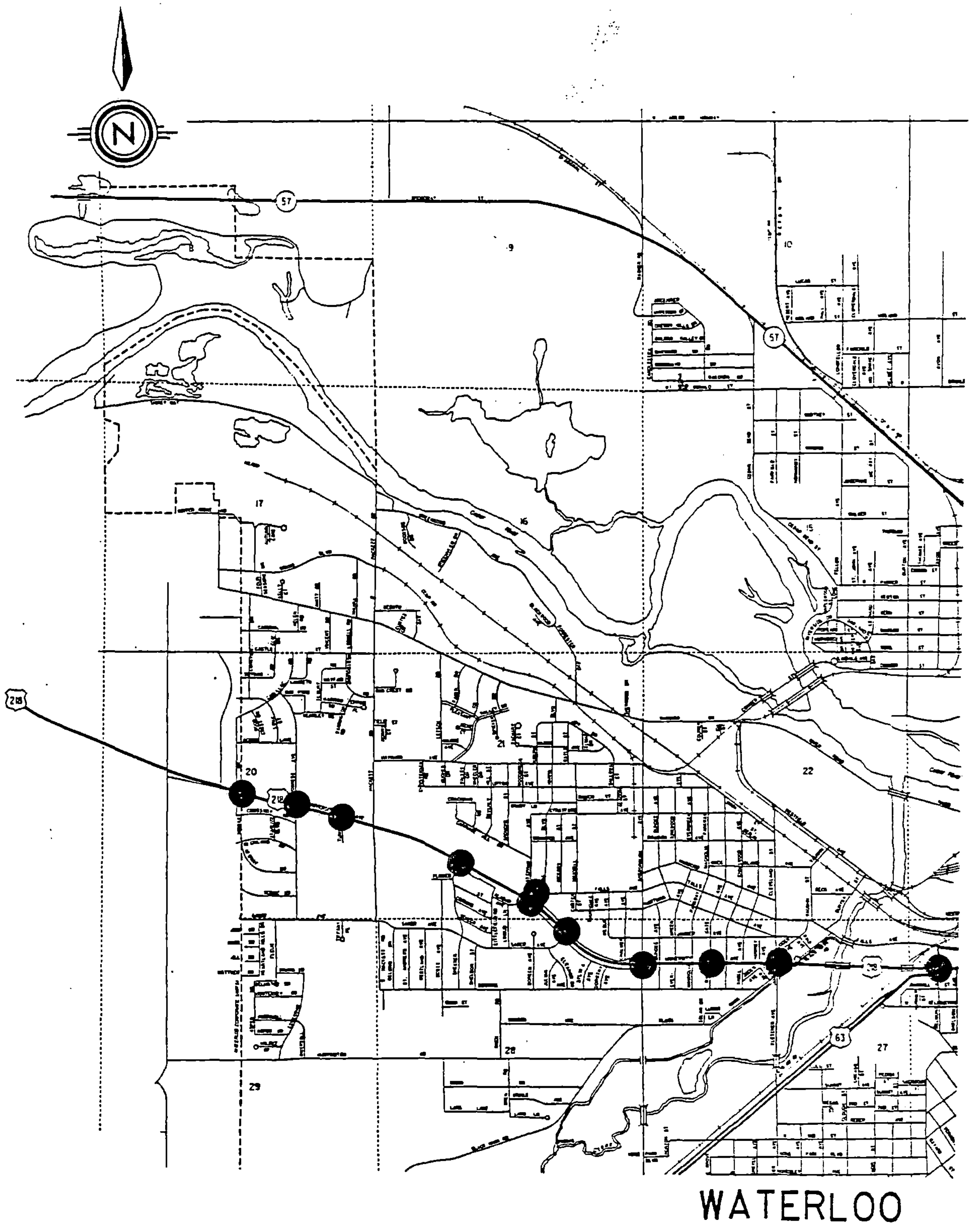

Figure 4-15: Map of WATERLOO Project

University Avenue is a major six-lane, divided arterial with left-turn bays at each intersection. The arterial carries an average daily traffic volume of approximately 22,000 vehicles. Previous traffic control consisted of time-based coordinated intersections. Commercial development surrounds the arterial and two high schools are located in the area.

The Subsystem K project was recommended by the Metropolitan Area Traffic Operations and Signal Study (MATOSS), which was conducted for the City of Waterloo by Barton-Aschman (a national transportation engineering consultant).

Project work involved the installation of three new cabinets, eleven new Eagle controllers, one master controller, and 29 two-channel loop detectors.

A unique situation exists in Waterloo. There now exists two separate types of closed-loop, distributed signal control systems in different traffic signal subsystems. At any computer terminal city personnel can access either a Traffic Controls Technology or an Eagle Signals closed-loop, distributed system. At the University and Ainsborough intersection there is an oversized cabinet which houses a TCT master controller, an Eagle master controller, and an EAGLE local controller.

Due to its proximity to the fire station, the Ainsborough intersection is the only one within Subsystem K that has pre-emption. The dimming feature is to be implemented for the subsystem.

FUNDING SOURCES:

Federal Grant	$ 134,433.77	
City Match	5,309.00	(4%)
Project Total	$ 139,742.77	

EQUIPMENT:

Computer, Printer, Monitor, Mouse, External drive, Controllers (11), Master controller (1), Conflict monitors (3), Amplifiers (25), Modem (1), Installation, Misc. cables, Wiring, Construction engineering services, Computer software, Operations training

Equipment Cost $134,433.77

Design Services. The signals and timing plans were designed by the City of Waterloo. Brown Traffic Controls, an Eagle system distributor, provided the signal equipment. Training workshops were provided by Brown Traffic also. The firm of Brice, Petrides, and Donahue performed the construction inspection and implementation activities.

Technical Support Services. Waterloo's signal systems are under the operational control of the Waterloo Traffic Engineering Department. This department has significant training with closed-loop, distributed systems in the existing subsystems. Waterloo has six signal technicians who have considerable experience with electromechanical and solid-state controllers and related signal system hardware. One technician is always on call. The technicians have a portable computer that can monitor the system in the shop or field.

Procurement Procedure. The equipment was purchased through performance-based competitive bidding. A key performance criterion was the past performance of the equipment bidder.

Project Evaluation. A before-and-after evaluation of traffic flow performance measured very little improvement. One possible reason for the slight improvement was that the pre-existing system was coordinated. Thus there was only minimal opportunity for improvement. The findings of the before-and-after study are listed below:

PROJECT COST	$	139,742.77
ANNUAL SAVINGS		
VEHICLE STOPS	$	12,258
DELAY		891
FUEL CONSUMPTION		0
TRAVEL TIME		0
TOTAL	$	13,149

BENEFIT TO COST RATIO = 0

Conclusions. Although the Waterloo project did not result in a positive benefit-cost ratio, clearly the City of Waterloo will benefit from attributes that were not taken into account in the analysis. For example, the staff can more easily monitor and maintain the signals through the system's monitor. And the timing plans are more likely to be updated regularly because of the labor savings of using the system monitor. However, the Waterloo project does illustrate that if the timing plans of the existing system are efficient, new equipment with more sophisticated control will not necessarily cause the traffic flow performance to improve.

IV.0 Decorah, District 2, At Large, Population 8,068

Decorah improved traffic flow by installing a computer-supervised closed-loop, distributed traffic control system. The new system replaced seven existing pre-timed electromechanical controllers along Water Street within the central business district (see the map in Figure 4-16).

Water Street is a two-lane arterial with commercial development along its right-of-way. Average daily traffic volumes are approximately 4,000 vehicles. Water Street's previous traffic control was coordinated by electromechanical controllers on fixed-time cycles. Time-based coordination was provided but difficult to maintain due to the inaccurate timing mechanisms in the outdated controllers.

The seven new, solid-state Multisonics controllers are connected to a master controller installed at city hall. New, larger signal heads replaced the existing obsolete heads at the intersections. The controllers enable the intersections to provide uniform traffic flow with less delay. Pre-emption was provided at all intersections. No dimming will be implemented for the system.

A new computer monitor installed at the Decorah City Hall serves as a monitoring station for the system. The new system greatly expanded Decorah's pre-emption capabilities.

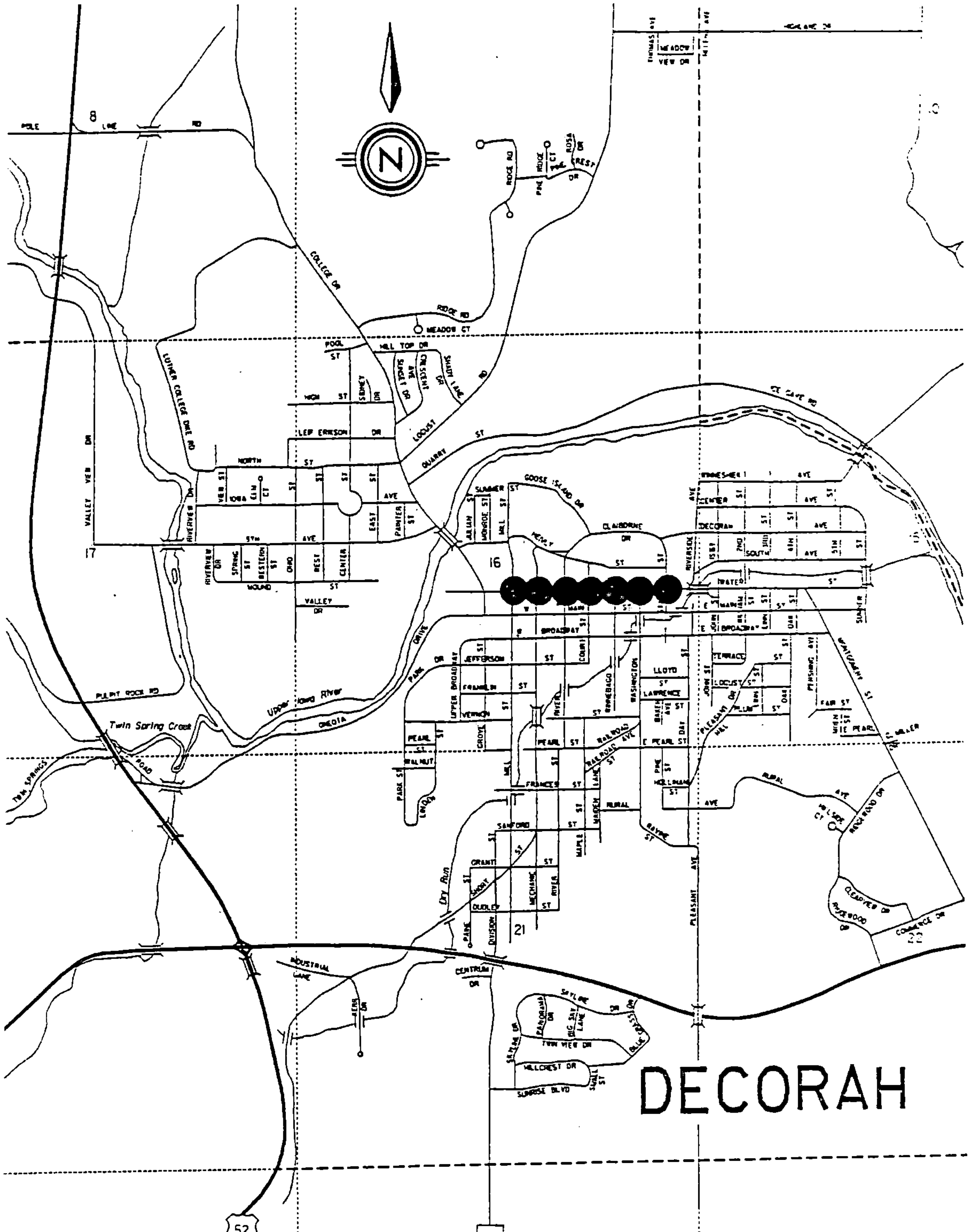

Figure 4-16: Map of DECORAH Project

FUNDING SOURCES:

Federal Grant	$ 101,975.60	
City Match	18,497.21	(15%)
Project Total	$ 120,472.81	

EQUIPMENT:

Computer, Monitor, Printer, Modem, Conflict Monitors (7), Cabinets (7), Controllers (7), Master controller (1),	$ 73,025
Traffic signal heads 28 @ $250	$ 7,000
Interconnection cable 2,200 lf.@ $1/ft.	$ 2,200
Cable to controller 650 linear feet	$ 5,000
Equipment Cost	$ 87,225

Design Services. The consulting firm of Johnson, Brickell, Mulcahy, and Associates, Inc. was hired to perform the engineering services. Timing plans were developed as were other system requirements. These included furnishing and installing the system office monitor, signals, and communications equipment.

Technical Support Services. Administration of the traffic signals in Decorah is primarily handled by the police department. Some computer training for the city personnel was provided by the consultant. System updates and technical operation of the signal system is to be handled through the "city engineer", a local consulting firm. No written maintenance policy exists for the signals. Corrective maintenance is usually performed upon emergency response by the city engineer or a representative of Multisonics.

Procurement Procedure. The system was procured using performance-based competitive bidding. Primary performance criteria were serviceability and reliability.

Project Evaluation. A before-and-after study of the traffic flow performance along Water Street was conducted. Because of the extensive pre-emption capability built into the system, a primary benefit of the new system is likely to be improved safety. However, safety benefits are not taken into account in the study. The results of the study are listed below.

PROJECT COST	$ 120,472	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 45,130	
DELAY	2,490	
FUEL CONSUMPTION	5,782	(5,782 gallons)
TRAVEL TIME	33,880	
TOTAL	$ 87,282	

BENEFIT TO COST RATIO = 6.60

Conclusions. The Decorah project's benefit-cost analysis resulted in a lower ratio than would likely be found in a larger urban area. This is partially because of the low traffic volumes in Decorah. However, the project results show the importance of efficient traffic control even in smaller urban areas.

IV.R Des Moines, District 1, At Large, Population 191,003

Description. Des Moines updated signal timings to meet current traffic demands and converted a number of intersections to fully actuated control. A total of 69 signalized intersections were modernized and retimed to meet current traffic demands. A majority of the signals were located along major arterial streets which carry heavy traffic loads often in excess of 20,000 vehicles daily (see the map in Figure 4-17).

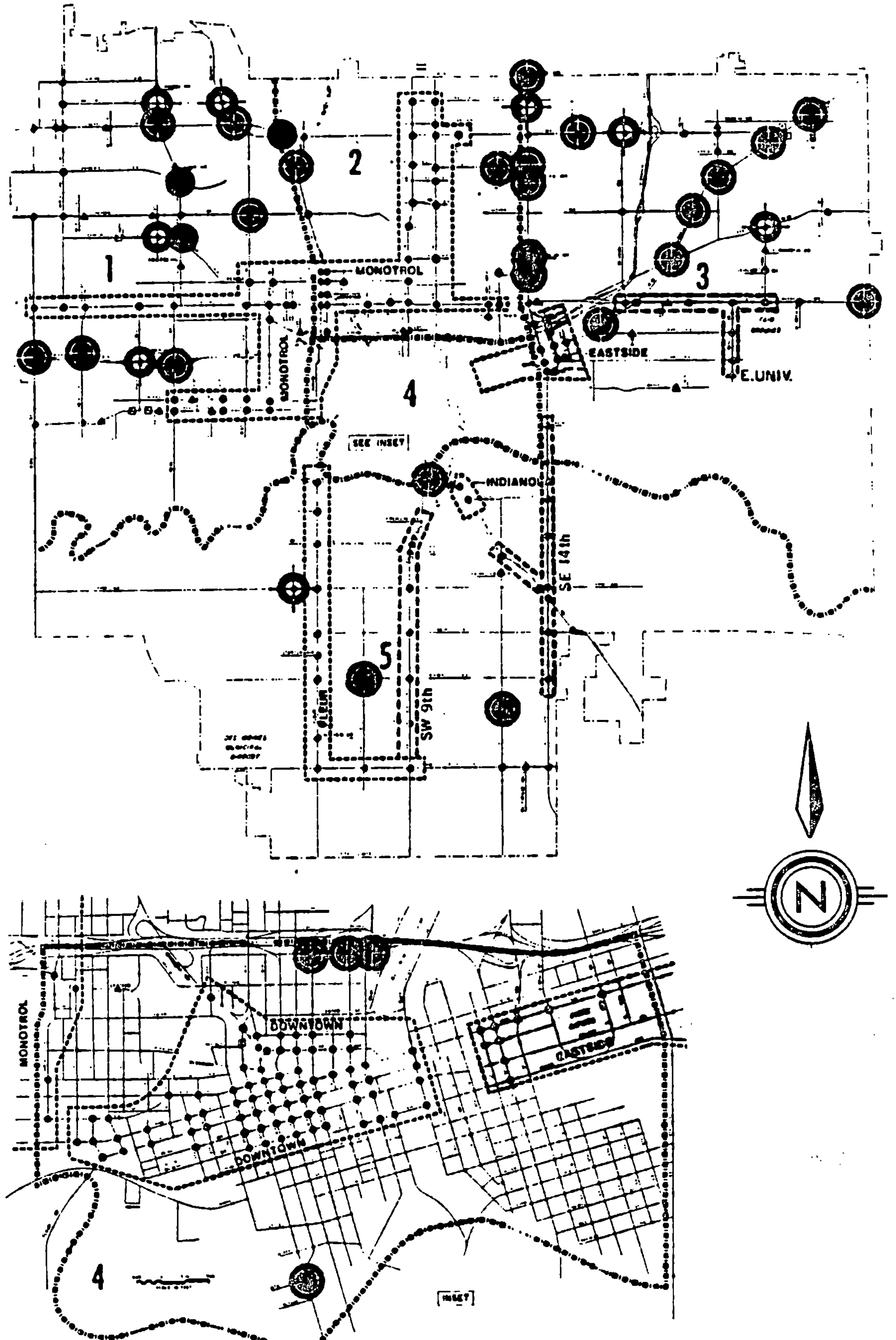

Figure 4-17: Map of DES MOINES Project

New traffic signal timings were developed for 30 signalized intersections located within three of the city's existing traffic signal systems. New traffic signal timings were developed for 28 fully actuated, isolated intersections at various locations throughout the city. Eight semi-actuated and three pre-timed signalized intersections were converted to fully actuated operation and retimed.

The 30 intersections retimed were within three different traffic signal systems. The first system consisted of 20 intersections under pre-timed operation. Eleven signals were along East 14th Street and East 15th Street (US 65/69), and nine signals were along Grand Avenue, East 6th Street and East 5th Street. Prior to the project, the system had a mixture of solid-state and electromechanical three-dial controllers, with 60-second cycles for each dial. A total of six signals were retro-fitted during 1987 with new Type 170 controllers.

The other two existing systems were located along Southeast 14th Street and along East University Street. The hardware for these two systems consisted of new Type 170 controllers which were part of an on-street closed-loop, distributed signal system. The Southeast 14th Street system included three additional intersections which were being added to the existing system along Southeast 14th Street. The East University system included a total of seven intersections along East University and East 30th Street.

The City developed construction plans and specifications to convert the eight semi-actuated and three pre-timed signals to fully actuated.

FUNDING SOURCES:

Federal Grant	$ 178,201.50	
City Funds	$ 21,150.00	(11%)
Project Total	$ 199,351.50	

EQUIPMENT:

Furnish and Install
Type 170 Controllers (3), Cabinets (3),
Conflict monitors (3), Loop detector amps (22),
Flashers (6), Cable, Conduit, etc.

Equipment Cost $ 140,080

Design Services. The consulting firm of Johnson, Brickell, Mulcahy, and Associates, Inc., developed all of the timing plan changes. At each location, the consultant conducted turning-movement counts and other studies such as intersection spacings, traffic speeds, and overall traffic patterns. For the pre-timed systems, a minimum of three timing plans were developed. A minimum of nine timing plans were developed for the intersections within the signal systems.

A contractor was selected to furnish and install the Type 170 controllers and related signal hardware needed to modify the operation of the 11 intersections to fully actuated. The contractor installed all equipment, including detector loops, handholes, conduit, controllers, pedestrian push-buttons, and field wiring.

Technical Support Services. The traffic signal systems mentioned are under the operational control of the Des Moines

Traffic and Transportation Department. The department has significant experience in the maintenance of Type 170 and NEMA controllers, signal system timing, and communications. The City of Des Moines does have a maintenance policy and procedure that was developed in 1982 as part of a comprehensive traffic signal inventory study.

Procurement Procedure. The contractor which furnished and installed the Type 170 controllers and related signal hardware was selected through competitive bidding. Price was the primary criterion for selection. The Type 170 controllers were named in the specification by the City of Des Moines because of system compatibility, technician/engineer familiarity, and ease of expansion of Type 170 controller-based systems.

Project Evaluation. Because the Des Moines project involved a number of intersections and both isolated and system control, the evaluation of the improvements involved measurement along arterials and isolated-intersection delay studies. The most effective (least cost and greatest return) improvement was the retiming of an existing closed-loop, distributed system. The retiming of the system involved only minimal field data collection (due to the system's data collection capabilities) and resulted in significant traffic flow performance gains. The aggregate results are listed below.

PROJECT COST	$128,270	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 73,010	
DELAY	9,352	
FUEL CONSUMPTION	17,940	(17,940 gallons)
TRAVEL TIME	144,050	
TOTAL	$244,357	

BENEFIT TO COST RATIO = 11.16

Conclusions. The Des Moines project included a comprehensive mixture of traffic signal improvements. Because the project included several types of improvements, the Des Moines results are felt to be representative of the likely benefits of a thorough improvement program in a large city. In other words, it is reasonable to expect the if all signal control at isolated intersections and within systems was upgraded within a large city, the benefit-cost ratio is likely to be in the neighborhood of 11-to-1.

IV.S West Des Moines, District 1, At Large, Population 23,456

West Des Moines established a microcomputer-supervised, closed-loop, distributed traffic signal system for seven intersections located along 35th Street north and south of I-235. The system included the traffic signals at the I-235 interchange ramps. The system extends from Ashworth Road on the south to University Avenue on the north (see the map in Figure 4-18).

The 35th Street corridor is a four-lane facility that carries an average daily traffic volume of approximately 22,000 vehicles. Prior to the project, five of the traffic controllers along the arterial were semi-actuated and had no detector loops

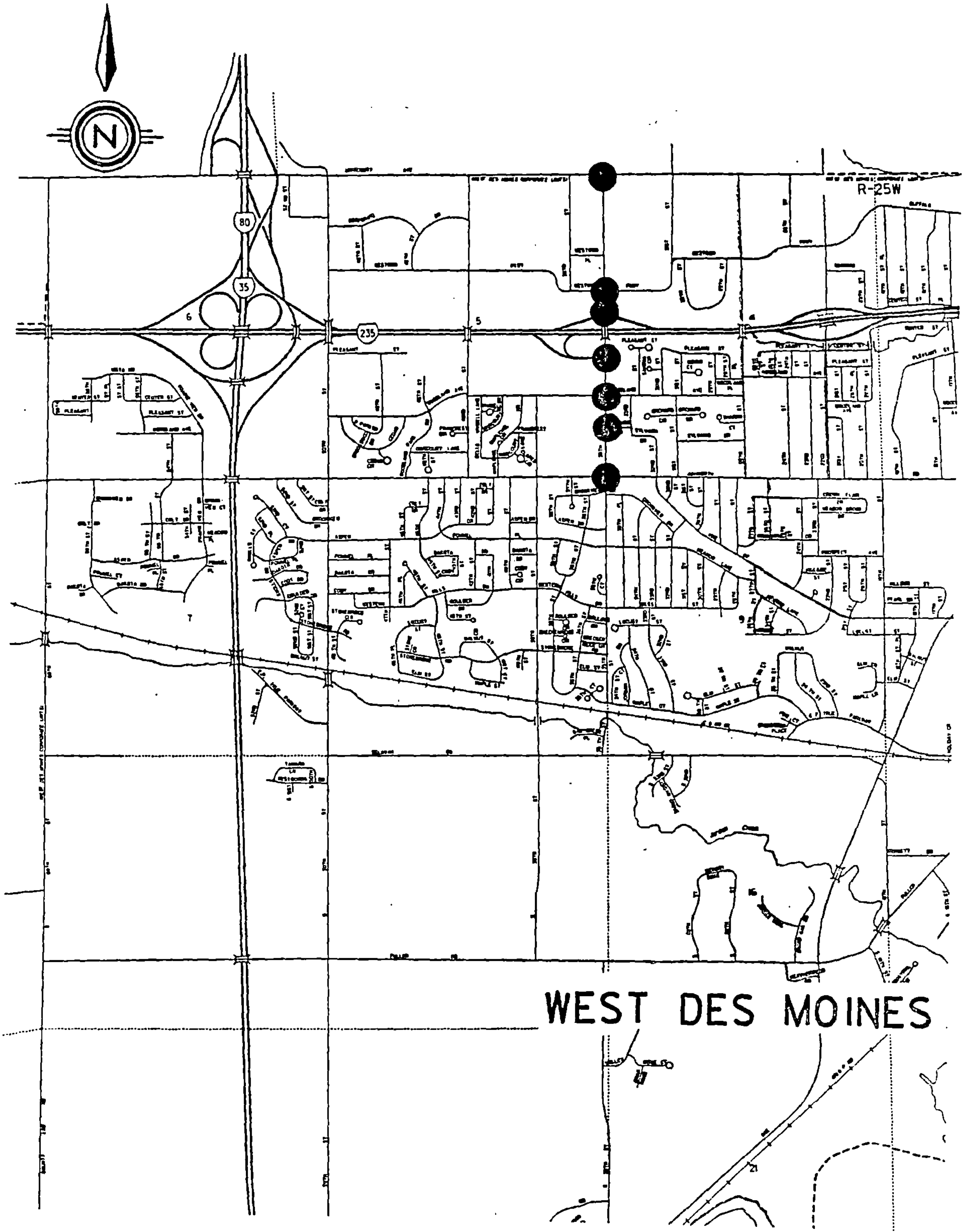

Figure 4-18: Map of WEST DES MOINES Project

on 35th Street. The controllers operated on a time-of-day basis. The system provided separate timing plans for the morning, afternoon, and off-peak traffic periods. Land use along the arterial consist of commercial-strip development.

The concerns for improving traffic control were based upon the high increase in traffic volumes, changes in land use, and future roadway extensions. The Des Moines Area Traffic Planning Committee recently completed a traffic study that predicted traffic volumes along the arterial would increase due to the planned West Des Moines office complex. In addition, West Des Moines has enjoyed an extremely rapid rate of growth in recent years. The growth has occurred specifically in the area of commercial development bounded by University Avenue on the north, 22nd Street on the east, Ashworth Road on the south, and 60th Street on the west. Another increase in traffic volumes will occur when the 100th Street connection is completed northward through Clive and Urbandale. This will result in a continuous arterial link from University Avenue to Douglas Avenue. The rising traffic volumes and intersection congestion have also increased the number of traffic accidents along the arterial.

The 1986 Accident Summary report for the Des Moines Area Traffic Planning Committee lists a segment of this corridor as having the sixth highest accident rate within the metropolitan area.

The 35th Street project consisted of expanding the number of intersections that were previously part of the system to include

University Avenue and Ashworth Road. A corridor study for 35th Street was completed in December of 1981. A 1985 Transportation Engineering Assistance Program (TEAP) study indicated a need for controller and detection loop improvements at the Ashworth Road intersection.

Implementation of the closed-loop, distributed traffic system consisted of placing new, Eagle local controllers at seven intersections; placing an on-street master controller along the arterial; and installing a computer and the necessary software at the city's public works facility. Other work included the addition of loop detectors to provide full traffic actuation on 35th Street and on some of the cross-street approaches. Dimming will not be used on the project. Pre-emption for fire trucks was provided.

FUNDING SOURCES:

Federal Grant	$ 190,159.96	
City Funds	$ 19,296.76	(9%)
Project Total	$ 209,456.72	

EQUIPMENT:

Furnish and Install
Computer, Monitor, Printer, Modem, Data cartridges, MARC software, Controllers (7), Master controller (1), Cabinets (7), Detector amplifiers (51), 3-section signal heads (13), Pedestrian heads, Ped. poles (2)

Equipment Cost $ 190,159.96

Design Services. Johnson, Brickell, Mulcahy, and Associates, Inc. developed the traffic signal system timings and designed the system. The Eagle signal equipment was purchased from Brown Traffic. Training was provided for city staff by Brown Traffic.

Technical Support Services. The signal system will be under the operational control of the city's traffic engineer. The West Des Moines staff have experience with the Eagle control system. The City of West Des Moines does not have a written maintenance plan. Corrective maintenance is generally performed on an emergency basis.

Procurement Procedure. The equipment and services were purchased through performance-based bidding. A few of the performance criteria were compatibility, serviceability, and spare-parts availability.

Project Evaluation. Before-and-after evaluations of traffic flow performance were conducted for the West Des Moines project. As expected, the traffic flow performance was measurably improved along congested West Des Moines arterials. The results of the study are shown below:

PROJECT COST	$209,456	
ANNUAL SAVINGS		
VEHICLE STOPS	$ 80,157	
DELAY	9,714	
FUEL CONSUMPTION	29,244	(29,244 gallons)
TRAVEL TIME	150,360	
TOTAL	$269,475	

BENEFIT TO COST RATIO = 11.72

Conclusions. With the rapid growth in West Des Moines, the flexibility of closed-loop, distributed control will prove to be quite useful. For example, the system can help the city's traffic engineer monitor traffic volumes and the efficiency of timing plans as traffic volumes grow. Also, the system can be expanded to control additional signals when the need arises.

IV.T OVERALL EVALUATION

Listed in table 4-1 is a summary of the results of each project and the entire program's overall benefit-to-cost ratio. The overall program had a benefit-to-cost ratio of 14.20-to-1. Clearly, the project had dramatic positive impacts on traffic flow. Not included in the evaluation are the likely benefits of improved safety and reduced pollution.

A review of the project shows that those involving signal systems along arterials with the heaviest traffic volumes had the largest benefit-to-cost ratios (with the exception of the Waterloo project). This is because substantial improvements can be made to the traffic flow along an arterial through coordination and, with heavy traffic volumes, these benefits are multiplied by larger numbers of motorists.

The projects with the smallest economic payoff were those that involved the upgrading of pretimed signals or the upgrade of semi-actuated signals to fully actuated. The reason for the smaller benefit-to-cost ratios is perhaps due to the time periods that the before-and-after measurements were performed (peak periods). During peak periods when volumes are high, actuated

Table 4-1, Summary of Economic Evaluation

City	Initial Cost	Annual Savings	B/C	Annual Savings: Stops	Annual Savings: Hours	Annual Savings: Gallons Fuel[1]
Isolated Intersection Upgrades to Fully Actuated						
Algona	$14,144	$2,712	1.75	116,000	1,300	650
Monticello	$90,000	$0	0.00	0	0	0
Bettendorf	$43,371	$0	0.00	0	0	0
Arterial Systems Coordinated With Time Based Coordinators						
Storm Lake	$117,870	$23,087	1.78	1,005,300	3,800	1,300
Webster City	$40,821	$106,298	23.72	4,350,300	16,300	5,800
Indianola	$58,686	$211,795	32.87	6,262,500	47,300	17,600
Muscatine	$327,110	$0	0.00	2,595,900	0	0
Arterial Coordinated With Closed Loop, Distributed Systems						
Atlantic	$117,778	$83,916	6.49	1,193,400	24,100	9,700
Ames	$160,375	$277,474	15.76	4,135,000	112,700	28,000
Mason City	$84,002	$222,520	24.13	9,194,400	34,300	13,300
Spencer	$104,409	$84,601	7.38	2,304,000	21,700	7,200
Council Bluffs	$128,270	$95,900	6.81	1,755,000	25,000	10,100
Iowa City	$119,554	$447,706	34.11	9,932,700	120,500	42,400
Urbandale/DSM	$339,618	$902,600	24.21	24,250,200	222,900	77,000
Waterloo	$139,743	$0	0.00	8,454,000	0	0
Decorah	$120,473	$87,282	6.60	3,112,500	18,100	5,700
West Des Moines	$209,456	$269,400	11.71	5,528,100	75,900	29,200
Computer Controlled Network System						
Sioux City[2]	$155,093	$946,400	55.58	59,745,000	49,000	14,000
Variety of Improvements						
Des Moines	$199,351	$244,351	11.16	5,035,100	72,900	17,900
Total	$2,570,124	$4,006,042	14.20	148,969,400	845,800	279,850

Annual Cost	$282,174
Benefit to Cost Ratio	14.20

1. Fuel savings includes the fuel saved as a result of stopping. In the project descriptions, fuel savings as a result of decrease stops are included in the vehicle stop savings.

2. The Sioux City initial costs include negative costs which are equal to the present worth of the computer cost savings that are accrued over the 15 year life. Also the traffic flow improvement that were

signals extend their timings on each phase to the maximum allowed. When each phase is at its maximum time length, the signal operates in a manner similar to pretimed control. Thus, new actuated signals may not provide appreciable benefits during period of high traffic volumes.

Another characteristic of actuated control which minimizes its measurable benefits relates to the purpose of fully actuated control. The purpose of full actuation is to minimize the length of delays at isolated intersections. By upgrading to fully actuated, the number of motorists stopped or delayed may not necessarily be improved. Stops may even increase. However, stops will tend to be of shorter duration.

CHAPTER V
POTENTIAL FOR ADDITIONAL SIGNAL IMPROVEMENTS

The 19 demonstration sites clearly identified the positive impacts of improved signal timing and modern traffic signal technology. These results can be used to estimate the potential benefits of improvements made to additional signal-controlled intersections in Iowa. This chapter will assess the potential benefits.

Naturally, an accurate assessment of the potential benefits of additional traffic signal improvements can not be made without a thorough investigation of existing conditions. The potential efficiency gains are dependent on the current technology used by Iowa communities, the current traffic conditions, the appropriateness and efficiency of current traffic signal timings, and the level of signal maintenance and maintenance expertise provided by the municipality. To define these conditions would require significant resources and probably would not be warranted. However, it is clear that improvements are generally needed.

To understand the magnitude of needed signalization improvements and, at the same time, employ a reasonable level of resources, a representative sample of Iowa cities has been surveyed. Findings from the sample have been extrapolated to the entire set of Iowa cities. All estimates of potential benefits are expressed in terms of a range of values (low, medium, and high forecasts of benefits) to realistically represent the uncertainty of the estimates.

V.A Study Design

No current information identifies the number, technology, or type of traffic signals in Iowa communities. Thus, a survey was required to determine this information.

The survey was accomplished in two steps. The first step was to identify which cities in the sample operated signals. This was accomplished through the use of a self addressed, stamped questionnaire mailed to the sample. (A copy of the questionnaire is included in Appendix A.) The questionnaire asked the number of signals operated by the city and, if the city had signalized intersections, who could serve as a telephone contact. Follow-up telephone contacts were made to those cities that did not respond to the original questionnaire. Approximately 75 percent of the cities sampled responded to the initial questionnaire.

The next step was to contact by telephone each city that operates signals. The purpose of the telephone contact was to determine the signal technology; identify the traffic signal technician, electrician and traffic engineering staffing levels; and to determine policies regarding traffic signal retiming, preventive maintenance and emergency maintenance. An interview form listing questions was developed to provide consistency from one interview to the next. (A copy of the interview form is included in Appendix B.)

Sample Design. The survey design categorized Iowa cities into three population sizes: small cities with populations of less than 10,000, medium cities with populations ranging from 10,000 to 50,000, and large cities with populations of 50,000 or more. Using the 1980 census, the populations and names of Iowa's 952 cities were entered into a data base and sorted by population. Ninety percent of Iowa's cities (923 cities) fell into the small category. There were 21 medium cities and eight large cities.

The actual sampling design is shown in Table 5-1. In the left column, cities are categorized by population size. Because of the extremely large number of small cities, the small-city category (cities less than 10,000 in population) was divided into three ranges (0 - 2,999).

Table 5-1, Survey Sample

Population Range	Total Number Of Iowa Cities	Number of Program Cities	Sample Size	Percentage Of Total Sampled
0 - 2,999	846	0	50	6%
3,000 - 5,999	46	1	22	50%
6,000 - 9,999	31	6	12	50%
10,000 - 49,999	21	7	14	100%
> 50,000	8	5	3	100%
Total	**952**	**19**	**101**	

The third column lists the number of cities in each city-size category that received improvements as part of the Iowa Motor Vehicle Fuel Reduction Program. Because of their involvement in the program, there was no need to sample these cities.

Using judgement, a sample deemed sufficient included 50 cities in the very small category (less than 3,000), half of the remaining small cities (between 3,000 and 10,000), and all the medium and large cities. The column on the far right lists the proportion of the total number of cities sampled in each category.

Table 5-2 further breaks down the small cities into sub-ranges for each population interval of 1,000 (i.e., 0 - 999, 1000 - 1,999, 2,000 - 2,999, etc.). Within each range, and

Table 5-2, Stratification of Small City Sample

Population Sub-Range 0 - 2999	Number of Iowa Cities	Number of Cities To Be Sampled	Percentage of Total In Sample
0 - 999	666	39	6%
1000 - 1999	134	8	6%
2000 - 2999	46	5	7%
		Total 50	
3000 - 5999			
3000 - 3999	22	10	45%
4000 - 4999	16	7	44%
5000 - 5999	8	5	63%
		Total 22	
6000 - 9999			
6000 - 6999	11	4	36%
7000 - 7999	8	3	38%
8000 - 8999	10	4	40%
9000 - 9999	2	7	50%
		Total 12	

particularly within the 0 to 2,999 range, the cities are not uniformly distributed among each sub-range. For example, in the 0 to 2,999 range, there are 666 cities (79 percent) that have populations of less than 1,000. The number of cities actually sampled in each population sub-range is listed in the right column of Table 5-2.

Within each category and sub-range, the cities were randomly selected. The cities contacted are listed in Table 5-3.

V.B Survey Results and Analysis The first step in analyzing the results of the survey was to determine the number of signals in each community sampled and the signal technology (electro-mechanical or solid state) employed. It was anticipated that the questionnaire results could be extrapolated to estimate the number of signals in all Iowa cities. Table 5-4 shows a summary of the number of signals and the intersection control technology found in the sample cities. A total of 97 cities were included in the sample. Four cities were unable to answer questions during the interview and were deleted from the sample.

Table 5-4, Number and Type of Intersection Signal Control

Population Range	Number of Cities Sampled	Number of Electromechanical Controllers	Number of Solid-State Controllers	Total Controllers
0 - 999	39	0	0	0
1000 - 1999	8	0	0	0
2000 - 2999	3	1	5	6
3000 - 3999	9	9	7	16
4000 - 4999	6	8	7	15
5000 - 5999	3	6	5	11
6000 - 6999	4	10	21	31
7000 - 7999	3	7	13	20
8000 - 8999	4	24	6	30
9000 - 9999	1	6	2	8
10000 - 49999	14	129	135	264
> 50000	3	118	327	445
Total	**97**	**318**	**528**	**846**

Table 5-3, Cities Surveyed

0 - 999					
Durango	41	Exline	217	Plymouth	463
Clayton	68	Kamrar	225	Little Rock	490
Buck Grove	84	Portsmouth	240	Earling	520
Shannon City	93	Harpers Ferry	258	New Market	554
Thornburg	103	Rowley	275	Clermont	602
Plano	111	Woden	287	Coggon	639
Bassett	128	Garden Grove	297	Early	670
Fraser	139	Greeley	313	Moravia	706
Unionville	150	Granville	336	Gilberville	740
Larrabee	169	Columbus City	367	Maxwell	783
Nodaway	185	Miles	389	Schaller	832
Shambaugh	197	Tiffin	398	Sutherland	897
Woodburn	207	Latimer	441	Gladbrook	970
1,000 - 1,999					
Lone Tree	1014	New Sharon	1225	Stuart	1650
Fredericksbg	1075	Epworth	1380	Monroe	1875
Armstrong	1153	Brooklyn	1509		
2,000 - 2,999					
Leon	2094	Sergeant Bluff	2416	Grundy Center	2880
3,000 - 3,999					
Clarion	3060	Pleasant Hill	3493	Carlisle	3073
Osage	3718	Jonston	3156	Dyersville	3825
Onawa	3283	New Hampton	3940	W. Burlington	3371
Waukon	3983				
4,000 - 4,999					
Forest City	4270	De Witt	4512	Orange City	4588
Hampton	4630	Huboldt	4794	Jefferson	4854
Manchester	4942				
5,000 - 5,999					
Sheldon	5003	Glenwood	5280	Nevada	5912
Chariton	5116	Windsor Hts.	5474		
6,000 - 9,999					
Independence	6392	Mount Pleasant	7322	Lemars	8276
Centerville	6558	Clear Lake	7548	Creston	8429
Washington	6777	Coralville	7687	Charles City	8778
Clive	6952	Grinnell	8868	Carroll	9705
10,000 - 50,000					
Oskaloosa	10989	Marion	19474	Boone	12602
Marshaltown	26938	Fort Madison	13520	Ottumwa	27381
Keokuk	13536	Fort Dodge	29423	Newton	15292
Burlington	29529	Ankeny	16565	Clinton	32828
Urbandale	19443	Cedar Falls	36322		
Greater than 50,000					
Dubuque	62374	Davenport	103264	Cedar Rapids	110243

Using the survey results, statistical analysis was conducted to determine if there was a statistically significant relationship between the number of signalized intersections in a community and its population. A very strong statistical relationship, in fact, was found between population and total number of signals (both electromechanical and solid-state). However, the true causal relationship is not between population and signals. The number of traffic signals within a community is related to traffic volumes and traffic congestion. However, traffic volumes and traffic congestion are highly related to population.

One Iowa city that violates the consistant relationship between traffic signals and population is the City of Clive. Because Clive is a suburb of Des Moines, urban congestion overlaps into Clive. Also, major arterials run through Clive. Although Clive has a population of only 6,952, the city operates 14 signalized intersections. This is roughly double the number of signals in the average community in the 6,000 to 6,999 population interval.

In Figure 5-1, the total number of intersections in a city versus population is plotted. Although there is a clear relationship between the two variables, the slope of the relation is not monotonic throughout the population range. To determine if the slope of the relationship is significantly different at different levels of population, relationships are estimated for cities in each of the individual population categories (small,

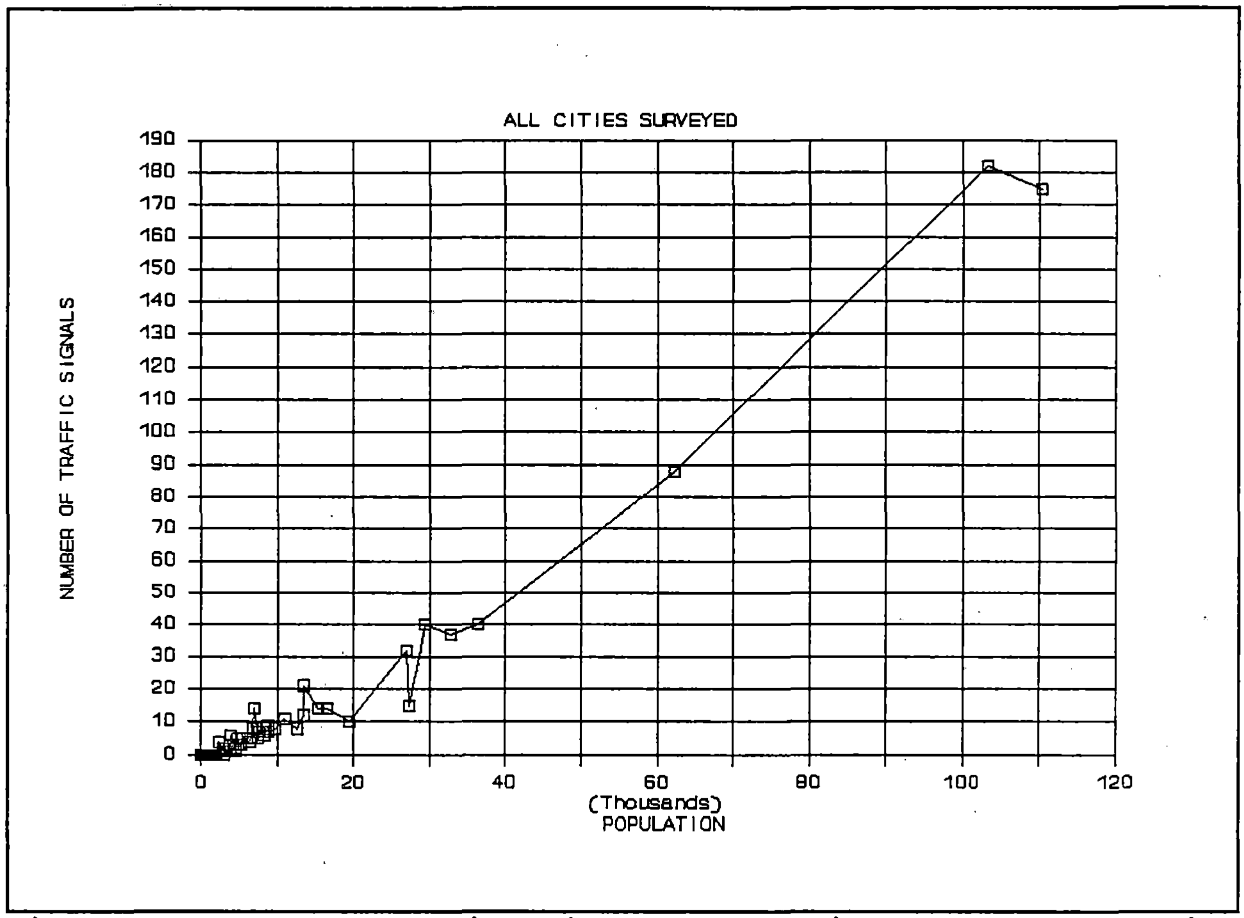

Figure 5-1, Number of Signalized Intersections Versus Population For All Cities Sampled

medium, and large) and for the combined group. The differences in the relationships are investigated to determine the need to disaggregate the data by population category.

Overall Analysis. The overall analysis includes all of the cities in the survey. The regression equation for the entire sample is shown below and the high coefficient of determination and t-statistic of the slope parameter demonstrate a very strong relationship between population and the number of signals in a community. The estimation results are in equation 5-1. The equation excludes the data derived for the City of Clive and cities without signals.

$$Y = -5.7 + 1.5 \underset{(3.64)}{(X)} \quad \text{R-Squared} = 0.97 \qquad (5\text{-}1)$$ [1]

Where: X = The population of the city in thousands
Y = The number of signals in the city

Small City Analysis. The analysis of small cities includes data derived from 50 cities with populations under 10,000 (with the exception of the City of Clive). Individual relationships were estimated for cities in the population sub-ranges 0 - 2,999, 3000 - 5,999, and 6,000 to 10,000. However, the individual equations estimated did not account for even 50 percent of the variance in traffic signals per city and therefore the relationships for each of the individual sub-ranges were dropped.

The overall relationship for all the small cities did provide highly statistically significant estimates. The regression equation is shown in equation 5-2. A plot of the data is included in Figure 5-2. Figure 5-2 shows the relationship (equation) estimated for only the small cities and the relationship for all the cities (the overall equation) in the sample.

$$Y = -0.6 + 1.5 \underset{(20.61)}{(X)} \quad \text{R-Squared} = 0.84 \qquad (5\text{-}2)$$ [2]

Where: X = The population of the city in thousands
Y = The number of signals in the city

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1. The numbers below the slope parameters are student's t-statistics.

2. The numbers below the slope parameters are student's t-statistics.

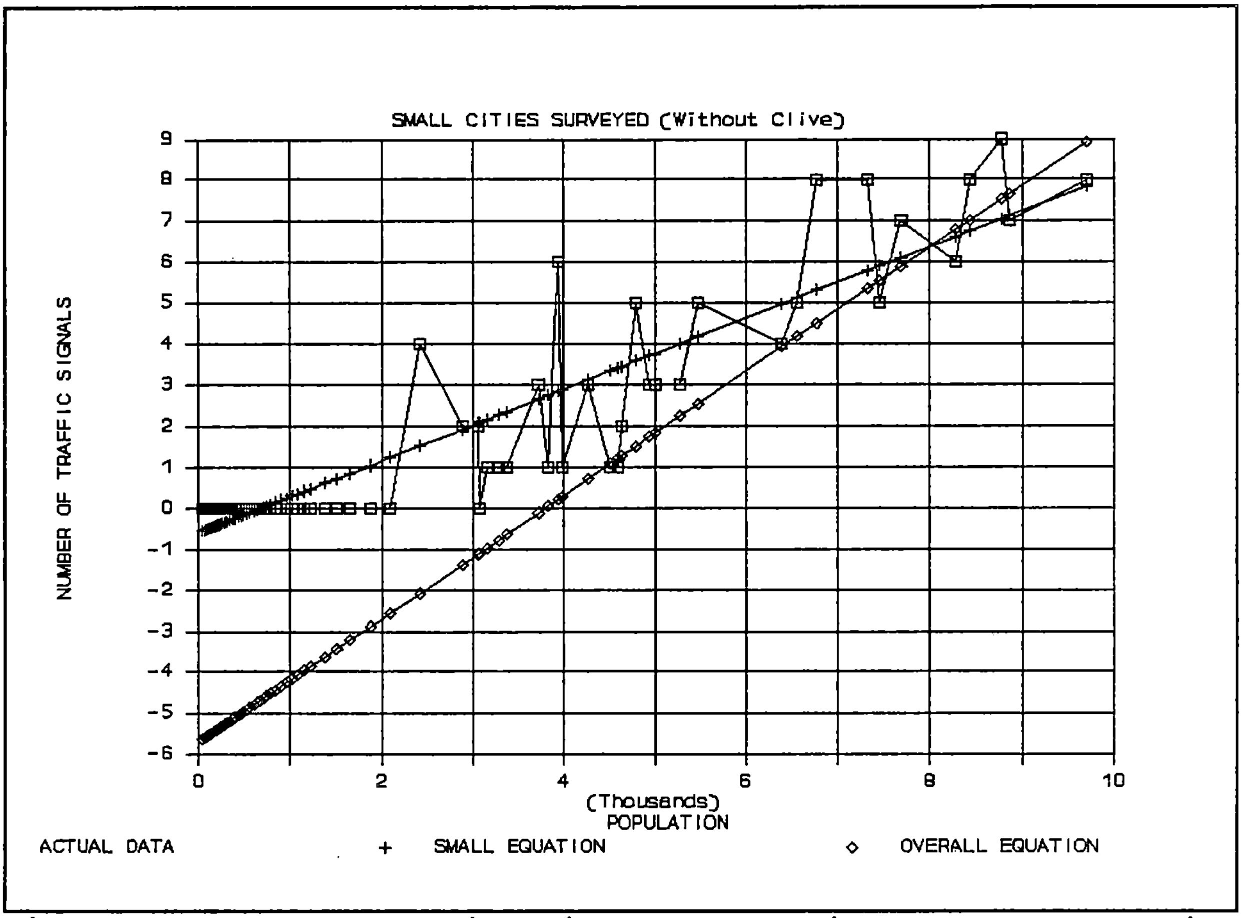

Figure 5-2, Number of Signalized Intersections Versus Population For Small Cities Sampled

Medium City Analysis. The analysis of medium cities includes data derived for 14 cities with populations between 10,000 and 50,000. The estimated relationship for medium cities is also statistically significant. The regression estimates are shown in equation 5-3. Figure 5-3 shows the relationship (equation) for only the medium cities and the relationship for the all the cities (the overall equation) in the sample.

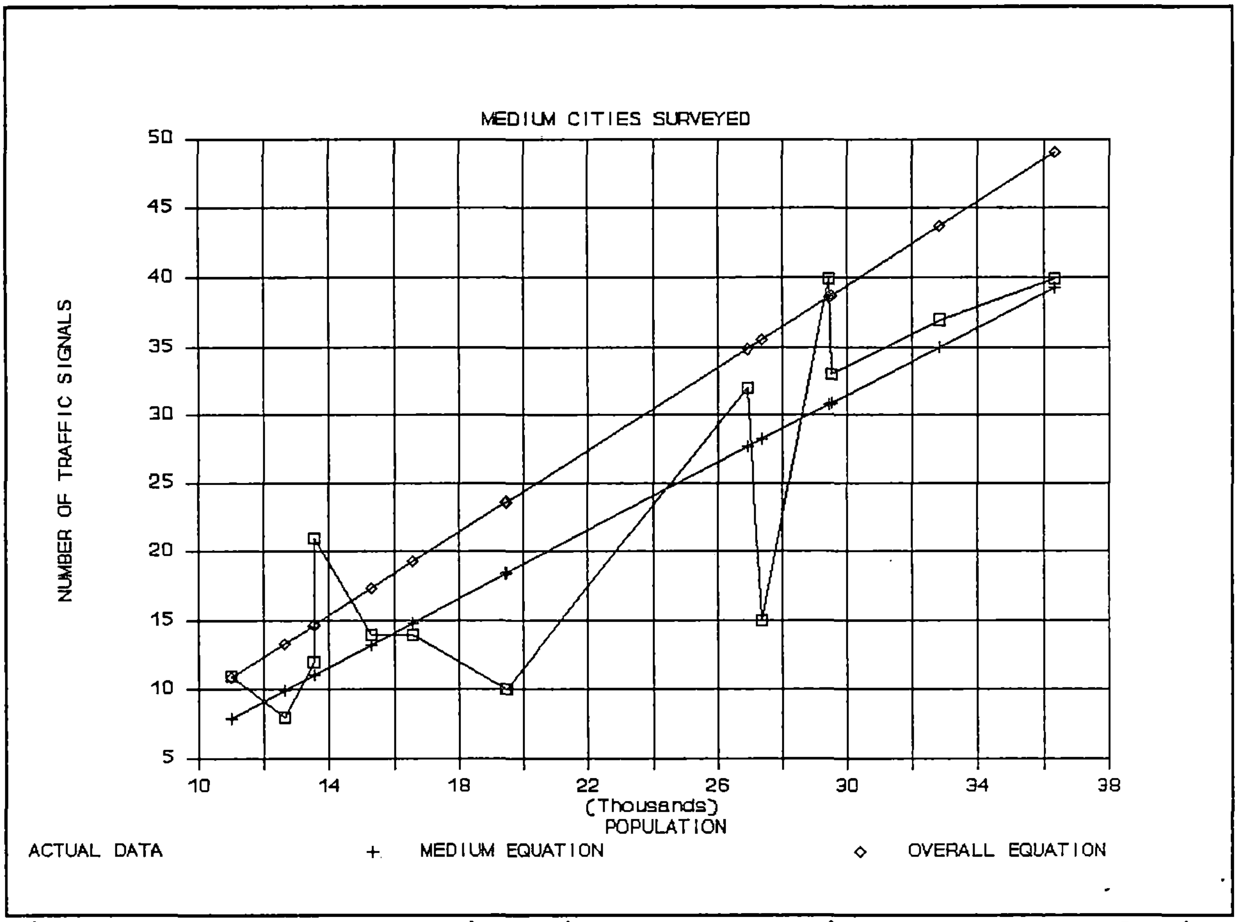

Figure 5-3, Number of Signalized Intersections Versus Population For Medium Cities Sampled

$$Y = -5.7 + \underset{(5.61)}{1.2}\ (X)^{3} \qquad R\text{-Squared} = 0.72 \qquad (5\text{-}3)$$

Where: X = The population of the city in thousands
Y = The number of signals in the city

Large City Analysis. There were only three large Iowa cities not included in the Iowa Motor Vehicle Fuel Reduction program. Clearly, more data are required to conduct statistical analysis. There are five large Iowa cities that are included in the program and a total of eight large cities in the entire

3. The numbers below the slope parameters are student's t-statistics.

state. To improve the confidence in the relationship, all eight cities are used in the estimation of the large city relationships between population and number of signals.

The relationship for all eight large cities did prove to be highly statistically significant. The regression estimates are shown in equation 5-4. A plot of the data is included in Figure 5-4. In Figure 5-4 the relationship (equation) estimated for only the large cities and the relationship for all the cities (the overall equation) in the sample are drawn.

$$Y = 5.5 + \underset{(7.03)^{4}}{1.4}\,(X) \qquad \text{R-Squared} = 0.89 \qquad (5\text{-}4)$$

Where: X = The population of the city in thousands
Y = The number of signals in the city

Having developed an overall and three individual regression relationships, the next step is to select the best predictor of the number of traffic signals in those cities not included in the sample. In most cases, the most disaggregate analysis provides more accurate predictions. In this case, because the individual equations have good statistical properties, use of the three individual equations for prediction purposes is believed to provide less error in predicting the number of signals in cities outside of the sample. To estimate the number of signals in Iowa, city populations were input into the regression relationship according the appropriate population category. The results of these calculations are shown in Table 5-4. In the

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4. The numbers below the slope parameters are student's t-statistics.

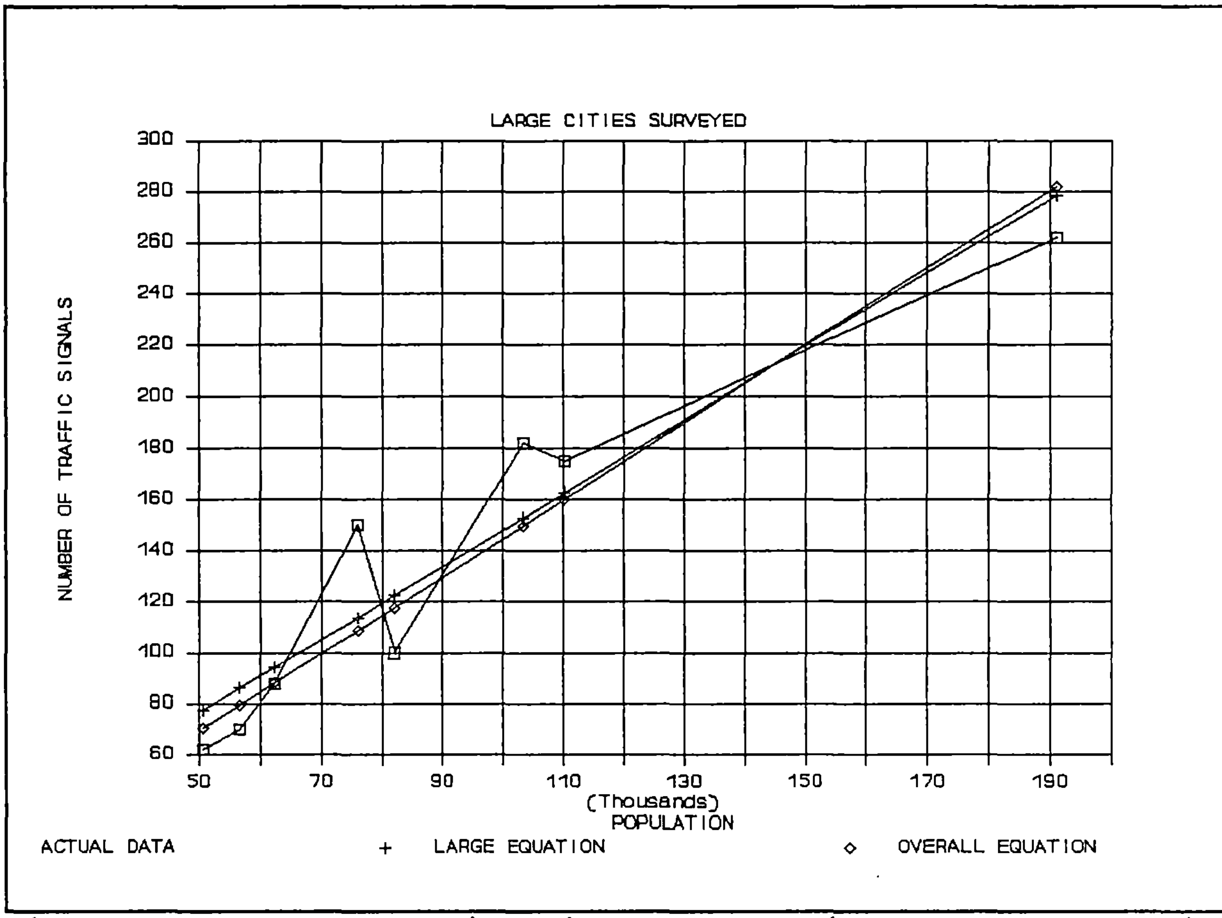

Figure 5-4, Number of Signalized Intersections Versus Population For Large Cities Sampled

Table 5-5, Estimated Number of Signals In Iowa Cities

Population	Number of Iowa Cities	Estimated Number of Signals	Signals Improved By Project	Remaining Number of Signals
Small	923	355	29	326
Medium	21	463	91	372
Large	8	1086	179	907
Total	**952**	**1904**	**299**	**1605**

third column of Table 5-4 is listed the number of signals that were upgraded through the Iowa Motor Vehicle Fuel Reduction program. Listed in the fifth column are the estimated number of signals in Iowa that were not involved in the program.

In addition to estimating the total number of traffic signals in Iowa, it is also important to determine the number of small cities with two or fewer signals. In cities with less than three signals, it is unlikely that there will be any opportunity for coordination of traffic. Therefore, it would be inappropriate to project benefits based on the likely benefits of coordination in small cities with two or fewer signals.

Table 5-6 includes estimates of the number of small cities with less than three signals. It is estimated that out of the 355 signals in small cities, 106 are in towns with less than three signals.

Table 5-6, Small Cities With Less Than Three Signals

Number of Signals	Number of Cities	Estimated Number of Signals	Project Signals	Non-Project Signals
< 3	83	106	0	106
> 3	55	249	29	220
Total	138	355	29	326

V.C Potential Benefits and Costs of Additional Improvements

The potential benefits and costs of improving the signals in those Iowa communities which were not part of the Iowa Motor Vehicle Fuel Reduction program assumes:

1. All improvements will include hardware upgrading similar to those made at project cities.

2 The benefits and costs of the 19 program cities are indicative of what will be experienced with similar upgrades throughout Iowa.

The first assumption is probably the most suspect. The equipment upgrades that were installed in each of the program cities are not likely to be needed at intersections throughout Iowa. However, it is likely that many signals could be improved and similar benefits would result by retiming existing equipment. In discussing traffic signal operating practices with the cities in the survey sample, very few regularly checked the efficiency of timing plans or retimed signals. For example, the City of Des Moines has three traffic engineers but does not regularly retime signals. In fact, prior to the Iowa Motor Vehicle Fuel Reduction Program, the last time the City of Des Moines retimed any signals was during its participation in a 1981 signal-retiming demonstration project in which the Federal government paid to have signals retimed.

Because equipment upgrades are expensive compared to the cost of retiming, the cost estimates are likely to be higher than those of a program that employs retiming as an alternative to equipment upgrades.

The before-and-after studies of the program cities employed four measures of traffic flow performance for purposes of economic evaluation: number of stops, intersection delay, fuel consumption, and travel time. At isolated intersections, travel time is not an appropriate measure and is not used. To arrive at a range of estimates (low, medium, and high values) the results of the program cities are extrapolated to similar sized non-program cities. For example, the benefits accrued at isolated intersections in the small-population program cities are extrapolated to arrive at estimates of similarly conditions in small-population non-program cities.

When the improvement in the traffic flow performance is estimated for non-program cities, the values are multiplied by the appropriate dollar values. The values used for calculating benefits are $0.0145 per stop, $0.313 per vehicle-hour of delay, $1.00 per gallon of fuel, and $3.35 per vehicle-hour of travel time. At isolated intersections the value for fuel savings is $0.538 per vehicle-hour of idling.

Where more than one project used a specific technology in program cities of the same population category, a range of values is derived for applying the same technology to similar sized cities. For example, two small-population cities implemented time-based coordination (TBC). For the low potential-benefit estimate, the lower benefit-per-intersection result is used. The high estimate uses the benefit-per-intersection from the project with the highest benefit-to-cost ratio. The medium estimate uses the average of the two. Low-, medium-, and high-cost estimates of the improvements are arrived by similarly using the high- and low-cost project results.

Estimates will be made for each population category of cities (small, medium, and large). Within each category, benefits and costs are calculated for the entire population of non-program cities for every technology applied (actuated-isolated signals, and TBC and closed-loop control arterial systems). Later the results will be averaged to derive an aggregate "ball park" estimate of the statewide savings from applying a mixture of technologies.

The results of the economic analysis for the projects in Muscatine and Sioux City are not included in the projections of statewide benefits. Both are considered to be unique. Sioux City had a very large economic payback due to the maintenance difficulties of its network system which is unique in Iowa. The Muscatine project resulted in a very low evaluation because the planned improvements were not completed.

Very Small City Isolated Intersections. There were 83 cities with less than three signalized intersections. Within the 83 cities, it is estimated that there are 106 signalized intersections. The potential benefits of upgrading these intersections to fully actuated are based on the benefits and costs found in Algona and Monticello (these are summarized in Table 5-7). The estimated potential benefits and costs are reported in Table 5-8. The high estimate of the benefit and the low-cost estimate are extrapolated from Algona results. If all

Table 5-7, The Benefits and Costs of Improving Isolated Intersections To Fully Actuated

		Annual Savings per Intersection			
Program Cities	Cost per Intersection	Vehicle Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Algona	$14,114	116,000	1,211	650	-
Monticello	$43,840	0	0	0	-

106 projects generate the benefits equivalent to the Algona results, the savings statewide would be $287,477 annually.

Table 5-8, Potential Benefits and Costs of Improving Isolated Intersections in Small Population Cities*

Potential Benefit Level	Statewide Costs	Annual Statewide Potential Savings: Number of Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Low	$4.65	0	0	0	-
High	$1.49	12.29	0.12	0.06	-

* All numbers reported in millions.

Small City Signal Systems. There are 55 small-population cities in Iowa with three or more signalized intersections. Within the 55 cities there are 220 signals. It is likely that these signals are along a major highway through the community and are therefore potential candidates for coordination. The benefits and costs of upgrading signals to a TBC system in the program cities are listed in Table 5-9, and the potential benefits of upgrading throughout Iowa are listed in Table 5-10. The low-benefit and high-cost estimates (low potential level) are

Table 5-9, The Benefits and Costs of Improving Signalized Intersections With TBC Technology in Small-Population Program Cities

Program Cities	Cost per Intersection	Annual Savings per Intersection: Vehicle Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Webster Cty	$ 8,164	870,055	1,125	1,142	2,134
Storm Lake	$16,838	143,616	417	169	221

based on the Storm Lake results; the medium estimates use the average results; and the high uses the results of the Webster City project. Assuming that TBC technology would be applicable to all 220 signals, the statewide annual savings would be $0.68

million (low), $2.68 million (medium), or $4.67 million (high).

Table 5-10, The Potential Benefits and Costs of Improving Intersection With TBC Technology In Small-Population Cities*

Potential Benefit Level	Statewide Costs	Annual Statewide Potential Savings Number of Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Low	$3.70	31.59	0.09	0.03	0.04
Medium	$5.50	111.50	0.16	0.14	0.25
High	$1.79	191.41	0.24	0.25	0.46

* All numbers reported in millions.

There are two small-population program cities that installed a closed-loop, distributed system. Because of the sophistication of closed-loop, distributed systems and because most cities with populations less than 10,000 will not have trained staff to dedicate to monitoring the system, it is questionable whether

Table 5-11, The Benefits and Costs of Improving Signals With Closed Loop Technology in Small-Population Program Cities

Program Cities	Cost per Intersection	Annual Savings per Intersection Vehicle Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Decorah	$17,210	444,631	1,136	826	1,445
Atlantic	$16,825	170,493	1,123	1,384	2,323

such systems should be installed in small cities. Nevertheless, the benefits and costs of upgrading signals to a closed-loop, distributed system in the program cities are listed in Table 5-11. The potential benefits of upgrading throughout Iowa are listed in Table 5-12. The low-benefit and high-cost estimates (low potential level) are based on the Atlantic results; the medium estimate uses the average results; and the high estimate uses the results of the Decorah project. Assuming that closed-loop, distributed technology would be applicable at all 220 signals, the savings for the low, medium, or high estimates would be $2.63, $2.69, or $2.74 million annually, respectively.

Table 5-12, The Potential Benefits and Costs of Improving Signals With Closed Loop Technology In Small-Population Cities*

Potential Benefit Level	Statewide Costs	Annual Statewide Potential Savings: Number of Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Low	$3.70	37.50	0.24	0.30	0.51
Medium	$3.74	67.66	0.24	0.24	0.41
High	$3.78	97.81	0.24	0.18	0.31

* All numbers reported in millions.

Medium-Population Cities. The isolated-intersection project in a medium population city (Bettendorf) provided no economic benefit. Therefore, the economic benefits of upgrading to fully actuated are considered negligible.

Table 5-13, The Benefits and Costs of Improving Medium-Population Project Cities With TBC Technology

Program Cities	Cost per Intersection	Annual Savings per Intersection: Vehicle Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Indianola	$14,671	125,497	3,636	3,507	5,836

There was only one medium-population program city that upgraded a signal system using TBC technology (Indianola). The benefits and costs of the Indianola project are listed in Table

5-13. There are 372 signals in medium-population non-program cities. The potential cost of applying TBC technology to all 372 signals is $5.45 million and the estimated stops, hours of delay, gallons of fuel, and travel-time hours saved are 465.92, 1.35, 1.30, and 2.17 million, respectively. Assuming that TBC technology was applicable at all 372 signals, the statewide benefits (using the Indianola data) would be $15.75 million annually.

Four medium-population cities implemented closed-loop, distributed systems. The costs and benefits of those installations are listed in Table 5-14. The potential benefits and costs of applying closed-loop technology to all of the 372 signals in medium-population non-program cities are listed in Table 5-15. The low estimate uses the Spencer data, the medium

Table 5-14, The Benefits and Costs of Improving Medium Population Project Cities With Closed Loop Technology

		Annual Savings per Intersection			
Program Cities	Cost per Intersection	Vehicle Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Ames	$ 6,168	159,058	2,368	1,070	1,956
West DSM	$29,922	789,724	4,434	4,178	6,412
Spencer	$13,051	288,000	1,165	894	1,533
Mason City	$12,000	1,313,478	1,818	1,882	3,072

estimate uses the average of the four projects, and the high estimate uses the Mason City data. The dollar value of the potential savings, assumes the applicability of closed-loop technology to all 372 signals. The dollar values are $3.93,

$8.51 and $11.82 million annually based on the low, medium and high estimates.

Table 5-15, The Potential Benefits and Costs of Improving Signals With Closed Loop Technology In Medium Population Cities

Potential Benefit Level	Statewide Costs	Annual Statewide Potential Savings: Number of Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Low	$4.85	107.13	0.43	0.33	0.57
Medium	$5.68	237.17	0.90	0.74	1.20
High	$4.46	488.61	0.67	0.70	1.14

* All numbers reported in millions.

Large-Population City Signal Systems. Although there were five large cities that participated in the program, there are six large city projects because the City of Des Moines participated in two projects. Because of the uniqueness of the Sioux City project, it is not included in this analysis. Also, because a number of technologies were applied in the Des Moines project (the other Des Moines project was conducted jointly with the City of Urbandale), it also not included in this analysis.

The remaining four projects involved the implementation of

Table 5-16, The Benefits and Costs of Improving Large-Population Project Cities With Closed-Loop Technology

Program Cities	Cost per Intersection	Annual Savings per Intersection: Vehicle Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Urdale/DSM	$33,961	2,425,019	8,979	7,707	13,308
Waterloo	$12,703	76,853	259	0	0
Council Bf.	$ 9,162	125,355	545	719	1,237
Iowa City	$12,000	1,241,586	5,858	5,298	9,203

closed-loop, distributed systems. The benefits and costs of the four projects are listed in Table 5-16. It is estimated that there are 907 signals in large-population cities that were not part of the program. Assuming the applicability of closed-loop technology to the entire 907 signals, the potential benefits and costs of applying closed-loop technology to all non-Program signals is listed in Table 5-17.

The low estimate in Table 5-17 is based on the results of the Waterloo project; the medium estimate uses the average of all four projects; and the high estimates are based on the result of the Iowa City project. Assuming the applicability of closed-loop technology to all 907 signals, the low, medium and high estimates of savings statewide are $10.84, $35.09, and $50.75 million annually, respectively.

Table 5-17, The Potential Benefits and Costs of Improving Signals With Closed-Loop Technology in Large-Population Cities

		Annual Statewide Potential Savings			
Potential Benefit Level	Statewide Costs	Number of Stops	Hours of Delay	Gallons of Fuel	Hours of Travel Time
Low	$11.52	69.71	0.23	0.0	0.0
Medium	$16.04	885.41	3.54	3.11	5.38
High	$13.55	1126.11	5.31	4.80	8.34

* All numbers reported in millions.

Table 5-18, Likely Benefit-Cost Ratio For Installation of Each Level of Technology In Cities In Each Population Category

City Pop. Category	Number of Non-Program Intersections	Estimated of Potential Benefits of Each Level of Technology: Fully Actuated B/C	TBC B/C	Closed Loop B/C
Very Small	106	Low 0 High 1.78	NA	NA
Small	220	Low 0 High 1.78	Low 1.72 Med 4.52 High 24.13	Low 6.60 Med 6.66 High 6.71
Medium	372	0	26.76	Low 7.50 Med 13.87 High 24.55
Large	907	NA		Low 0.00 Med 13.87 High 34.70

Overall Evaluation. Listed in Table 5-18 are the ranges of the benefit-to-cost ratios for all levels of technology utilized in the program for each population category. A range of values is given for each technology. The ranges are intended to recognize the variation in the results that are likely from the installation of each technology.

In Figure 5-5 is shown the likely benefits of implementation of statewide signalization improvements that are similar to those applied in the Motor Vehicle Fuel Reduction program. At the base of each bar are the benefits that were achieved for each population category as a result of the program. The upper segment of the bar represents a conservative estimate of the additional benefits from a mixture of improvements to non-program signals.

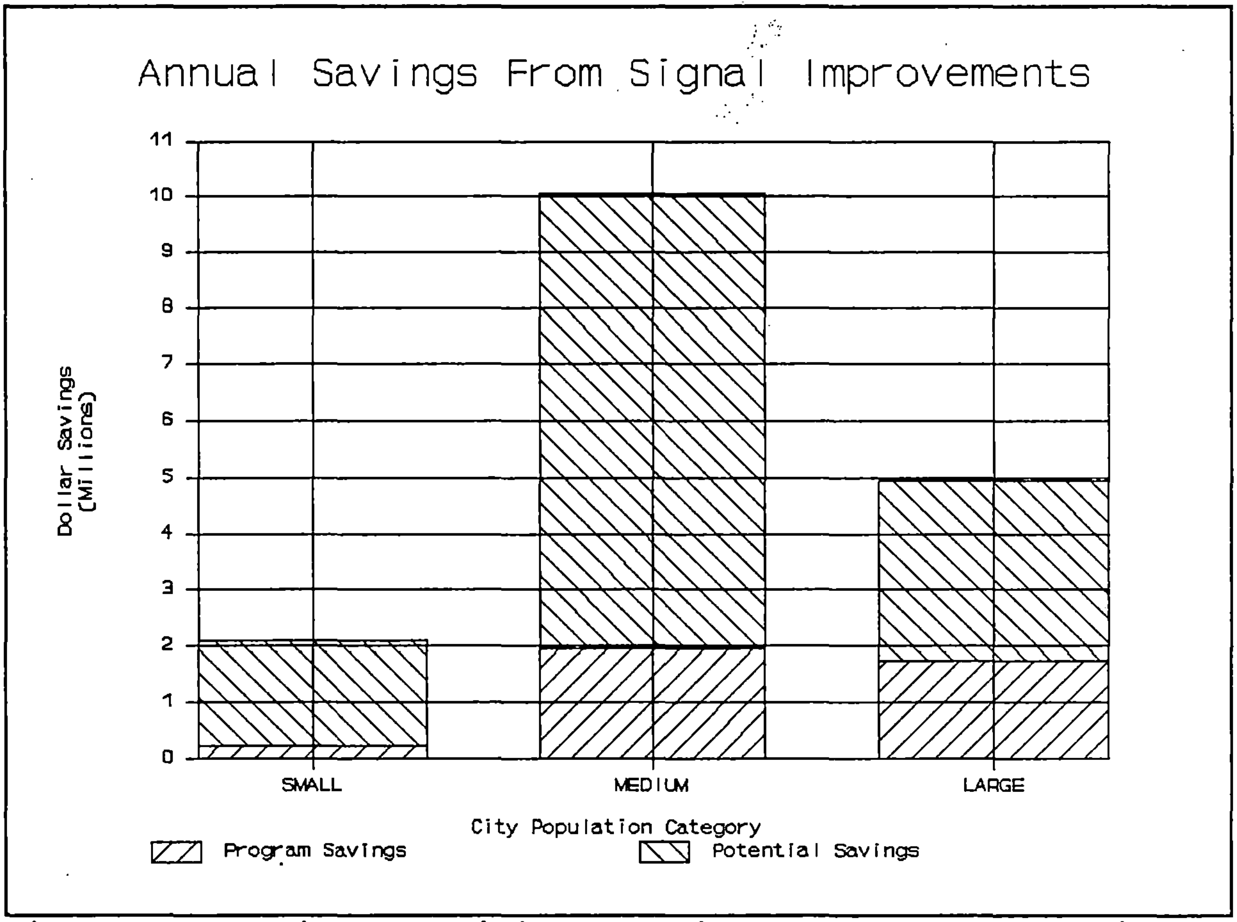

Figure 5-5, Likely Additional Savings From Implementation of Statewide Traffic Signal Improvements

The estimate of potential savings for small-population cities is derived from the average savings realized in small cities through upgrades of isolated intersections to fully actuated and through upgrades of arterial systems with TBC and closed-loop, distributed control. The potential statewide savings for small cities are estimated to be $1.9 million per year.

For the medium cities, the estimate is arrived at by averaging savings from fully actuated improvements in medium cities (0 savings) and the medium estimated savings from TBC and closed-loop, distributed system installations. The medium city potential statewide savings are estimated to be $8.1 million per year.

For the large cities, the estimate is arrived at by using the savings accrued in the Des Moines project. The Des Moines project was a mixture of improvements. Because it included a variety of improvements it is considered to be representative of the variety of improvements that are likely to be needed within a large-city. The large-city potential statewide savings are estimated to be $3.2 million.

CHAPTER VI
TRAFFIC SIGNAL OPERATION AND MAINTENANCE STAFFING LEVEL IN SURVEYED IOWA CITIES

During telephone interviews, surveyed cities were asked questions about staffing levels and qualifications of those responsible for traffic signal operation and maintenance. Depending on their qualifications, the employees were categorized as either electrician, technician, or traffic engineer. Information about staffing levels was needed to determine the state-of-practice of staffing in Iowa communities.

There are a variety of attributes which should dictate the number of city personnel with traffic signal responsibilities. For example, older traffic signals are likely to be more maintenance intensive and require more staff time. Smaller communities are likely to rely more on outside contractors and larger cities will rely on their own staff. None of these unique features are taken into account. However, the greatest obstacle in the survey was the difficulty in arriving at commonly understood definitions of the city staff's qualifications. For example, during interviews it was difficult to determine if an employee was an electrician, or a true traffic signal technician, with primary responsibility for traffic signal maintenance. Also unclear were the differences between a municipal engineer with traffic and transportation responsibilities and a traffic engineer.

As with the analysis in the previous chapter (in which the number of traffic signals are statistically related to population), staffing levels and qualifications are related to the number of traffic signals in a city (or population). To increase the data used in the analysis, the staffing levels at the 19 demonstration projects are included in the analysis along with the data from the cities surveyed.

VI.A Traffic Signal Technicians

A traffic signal technician is defined as an individual whose primary duty is to operate and maintain traffic signals. The technician may have other responsibilities. For example, their duties may include installing, maintaining and replacing signs. However, his or her primary responsibility is operating and maintaining signals.

Using regression analysis, a relationship was found between the number of traffic signals within a city and the number of traffic signal technicians employed by the city. The regression analysis results are shown in Equation 6-1. The number of traffic signals accounts for almost 70 percent of the variation in the number of traffic signal technicians and the estimate of the slope parameter is highly statistically significant.

$$Y = 0.071 + \underset{(12.16)^{1}}{0.071}\,(X) \qquad \text{R-Squared} = 0.68 \qquad (6\text{-}1)$$

Where: X = The number of signals in a city
Y = The number of signal technicians employed by the city

1. The numbers below the slope parameters are student's t-statistics.

The results indicate that there is approximately one signal

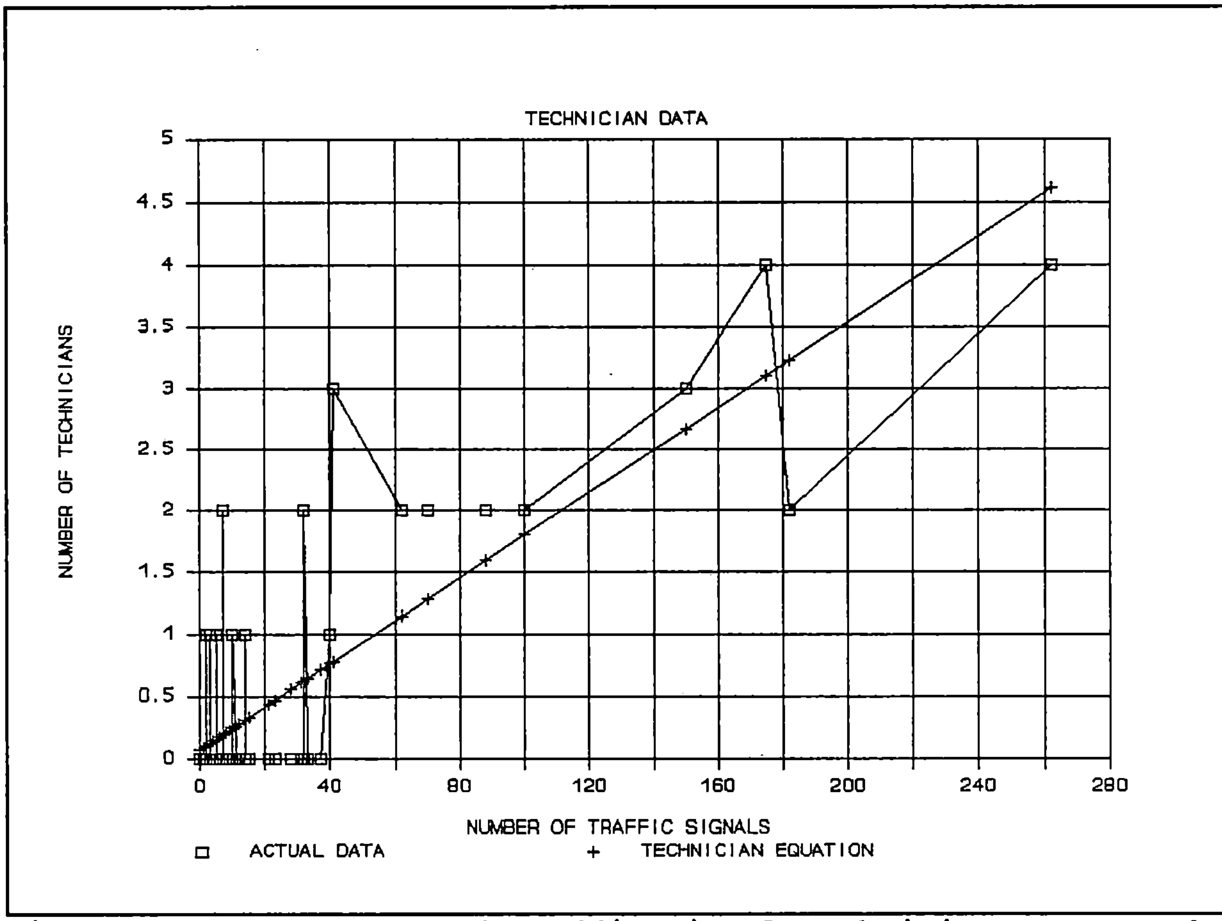

Figure 6-1, The Number Of Traffic Signal Technicians Versus The Number of Traffic Signals

technician per 54 traffic signals. In Figure 6-1 is a graph illustrating the relationship between the number of traffic signals and the number of traffic signal technicians. Both the data and the regression equation are plotted on the graph.

Through inspection of the data in Figure 6-1, it appears that a threshold value is reached at 40 traffic signals. Cities with more than 40 signals have more than one traffic signal technician. Cities with less than 40 signals generally have one or no traffic signal technicians. However, two cities with less than 40 signals have two traffic signal technicians. One city is truly an outlier. It operates only seven traffic signals and reported two technicians. The other city with two technicians and less than 40 traffic signals is West Des Moines. West Des Moines has 32 traffic signals (nearly 40) and the city is experiencing rapid growth.

Above the threshold level of 40 signals, the City of Ames appears to be another outlier. Ames has 41 signals and three traffic signal technicians. The need for Ames to have a relatively large number of technicians may be related to the maintenance-intensive Opticom pre-emption system installed at each intersection.

There is a fairly linear increase in the number of traffic signal technicians employed by cities which have 60 to over 100 signals. However, the two cities with the most signals (Cedar Rapids and Des Moines) fall below the regression line. These two cities tend to compensate for the staffing below the technician trend line by employing more electricians.

VI.B Electricians

An electrician is defined as an employee that works on the wiring and installation of either or both electromechanical or solid-state controllers and related equipment. In the interviews, cities were asked not to include city electricians whose primary responsibility is to inspect buildings or perform facility maintenance.

Using regression analysis, a relationship was found between the number of traffic signals within a city and the number of electricians employed by the city. The regression analysis results are shown in Equation 6-2. The number of traffic signals accounts for only 39 percent of the variation in the number of electricians. Therefore, the majority of the variation in the number of electricians is related to other variables. However, the slope parameter estimate is highly statistically significant thus suggesting that the number of traffic signals is an important variable in predicting the number of electricians, but another variable(s) accounts for more variation.

$$Y = 0.021 + \underset{(6.64)}{0.01}(X) \qquad \text{R-Squared} = 0.39 \qquad (6\text{-}2)$$

[2]

Where: X = The number of signals in a city
Y = The number of electricians employed by the city

The results indicate that there is about one electrician for every 55 traffic signals. In Figure 6-2 is a graph illustrating the relationship between the number of traffic signals and the number of electricians. Both the data and the regression equation are plotted on the graph.

Cities with less than 40 signals generally have one to two electricians. Small and medium cities that primarily have electromechanical controllers predominately rely on electricians to handle trouble shooting and routine maintenance. Marshalltown

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2. The numbers below the slope parameters are student's t-statistics.

exceeds the typical number of electricians: the city employs three electricians and operates 32 signals.

Cities with 40 to 100 traffic signals usually operate numerous solid-state controllers and thus need the skills of a technician. Figure 6-2 shows that no cities that operate 40 to

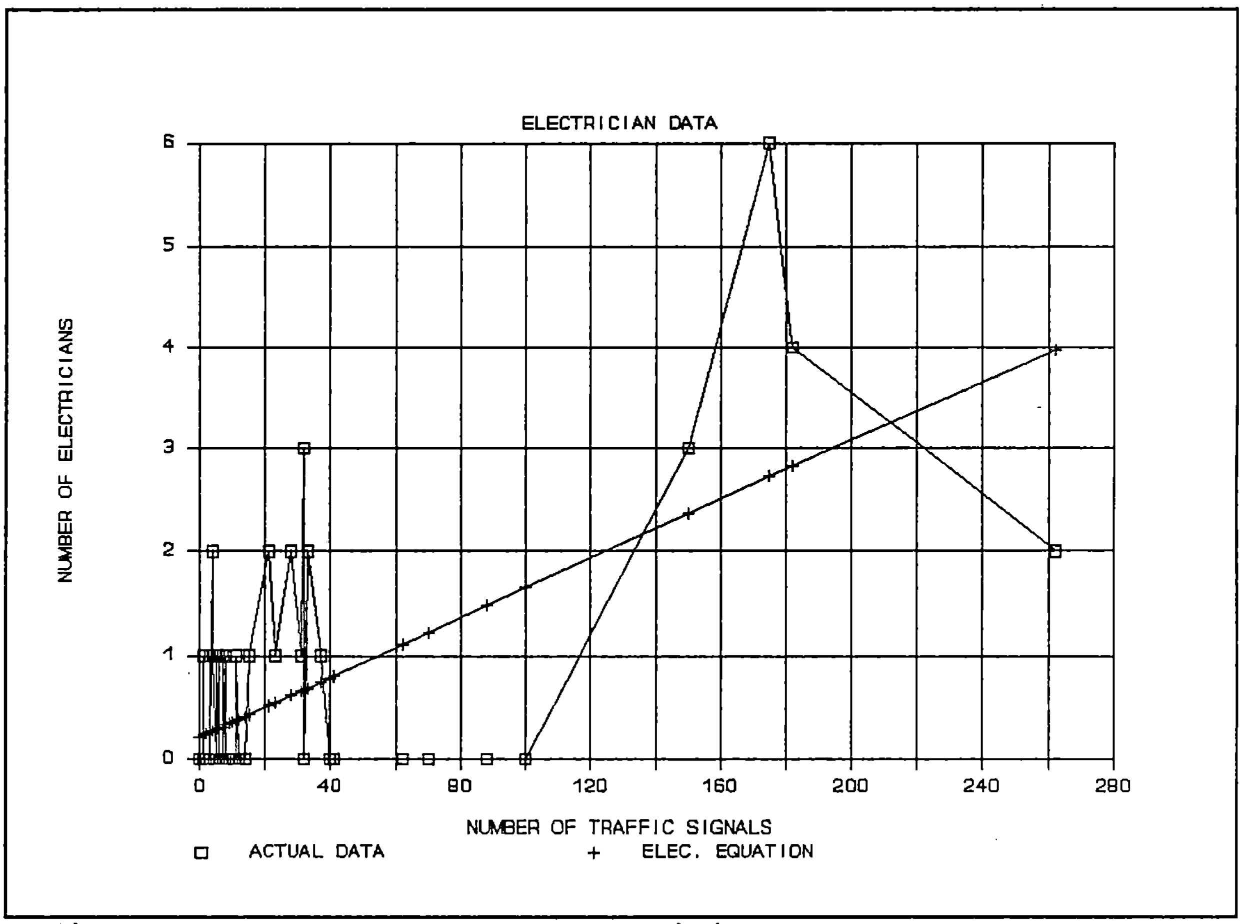

Figure 6-2, The Number of Electricians Versus The Number Of Traffic Signals

100 signals employ any electricians.

Cities with more than 100 signals vary between two and six electricians. The staffing levels of larger cities depend on the philosophy of the organization. Some cities have their traffic signal technician perform many of the traditional tasks of electricians. However, when the need arises, a technician, rather than an electrician, is available to perform higher level traffic signal maintenance functions.

VI.C Traffic Engineers

Traffic engineers are defined as engineers whose primary task is to operate and maintain traffic signals, monitor traffic counts and patterns, maintain and monitor traffic control devices, develop traffic safety improvement programs, and other common traffic engineering functions. Traffic engineering staffing levels are found to be more highly correlated with population than with traffic signals. The regression analysis results are shown in Equation 6-3. Population accounts for 73 percent of the variation in traffic engineering staffing levels and the regression slope parameter is highly statistically significant.

$$Y = -0.13 + \underset{(6.64)}{0.017}\,(X) \qquad R\text{-Squared} = 0.72 \qquad (6\text{-}3)$$

[3]

Where: X = The population of a city in thousands
Y = The number of signal technicians employed by the city

The results indicate that there is about one traffic engineer for every 70,000 residents in a city. In Figure 6-3 is a graph illustrating the relationship between population and the number of traffic engineers. Both the data and the regression

[3]. The numbers below the slope parameters are student's t-statistics.

equation are plotted on the graph. Although the correlation between the number of traffic signals and traffic engineers is not as strong as the relationship with population, there is about

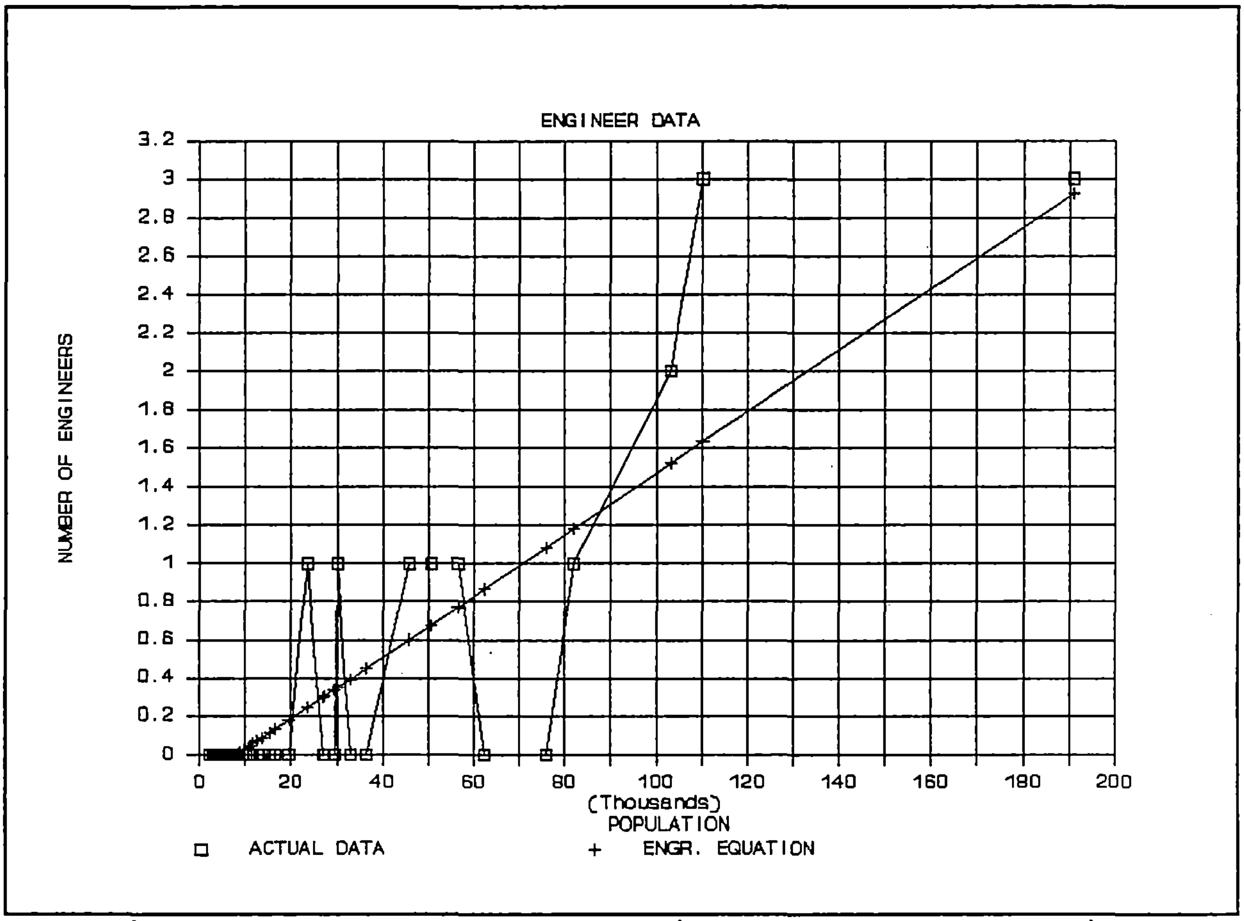

Figure 6-3, The Number of Engineers Versus Population

one traffic engineer for every 97 traffic signals.

Cities with populations of less than 20,000 do not have traffic engineers. Cities with populations between 20,000 and 80,000 tend to vary: some do have a traffic engineer and some do not. Cities with populations above 80,000 have one or more traffic engineers.

VI.D Staffing Levels of All Employees With Traffic Signal Responsibilities

Analyzed were the staffing levels of all employees with specific traffic signal responsibilities. This was done by summing the number of traffic engineers, traffic signal technicians, and electricians.

The sum of all three staffing levels is found to be highly related to the number of traffic signals in a city. The regression analysis results are shown in Equation 6-4. The number of traffic signals accounts for 80 percent of the variation in total staffing levels and the regression slope parameter is highly statistically significant.

$$Y = 0.23 + \underset{(16.62)^{4}}{0.04}\,(X) \qquad R\text{-Squared} = 0.80 \qquad (6\text{-}4)$$

Where: X = The number of signals in a city
Y = The total traffic signals related employee staffing level

In Figure 6-4 is a graph illustrating the relationship between population and the sum of the number of traffic engineers, traffic signal technicians, and electricians. Both the data and the regression equation are plotted on the graph. There is roughly one staff member per 18 signals.

Cities with between zero and 40 traffic signals have staffs with one to two employees. Cities with between 40 to 100 traffic

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4. The numbers below the slope parameters are student's t-statistics.

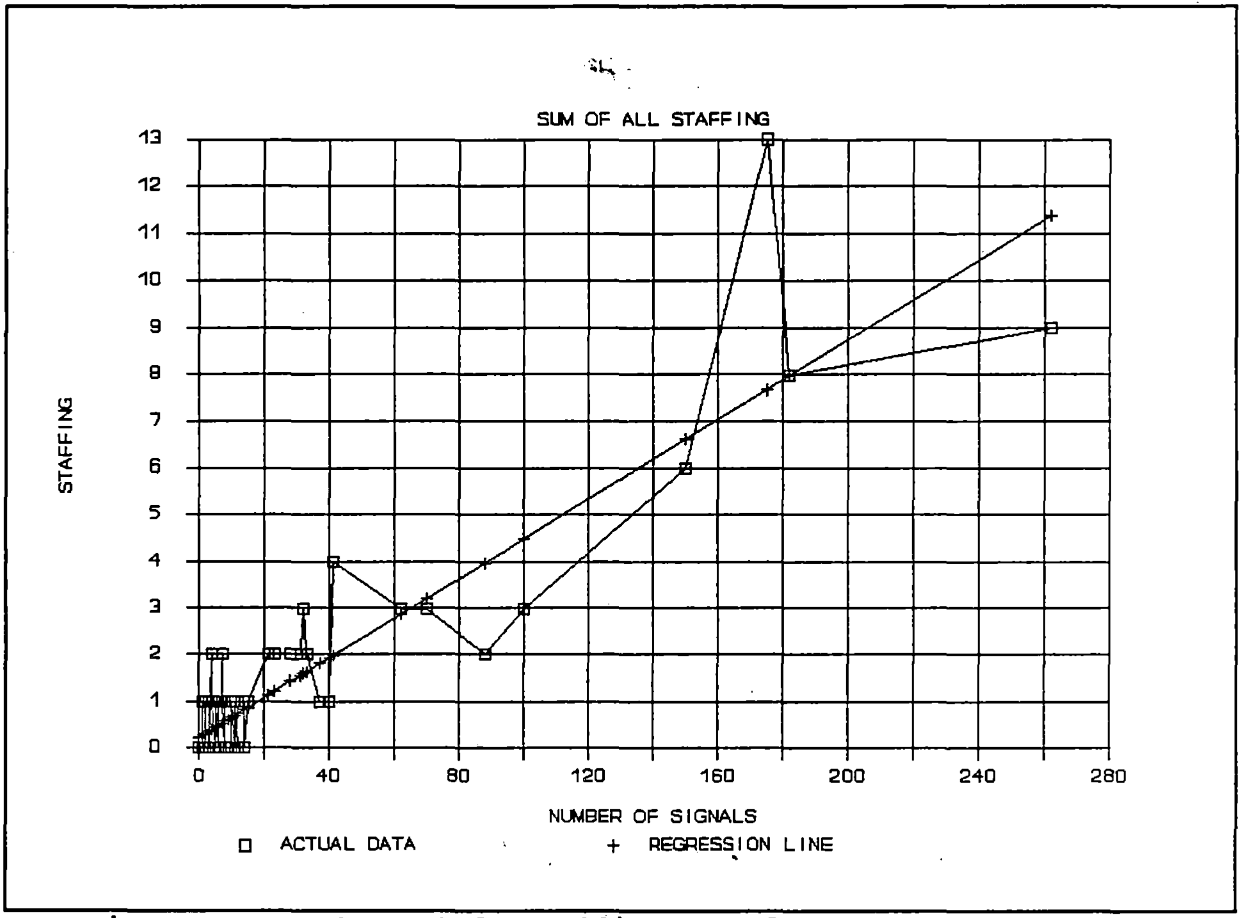

Figure 6-4, The Total Staffing Level Versus The Number of Traffic Signals

signals commonly have two to three employees with traffic signal responsibilities. Cities with more than 100 signals increase from three to eight employees. Cedar Rapids has the most employees with traffic signal responsibilities and employs thirteen individuals: four technicians, six electricians, and three traffic engineers.

VI.E Staffing Level Conclusions

The purpose of this analysis is not to recommend staffing levels or to suggest that those found in the 97 cities surveyed are adequate. No analysis was conducted on the adequacy of the staffing levels. The analysis simply portrays general trends in staffing levels in Iowa cities.

Furthermore, staffing is dependent on the level of traffic signal maintenance service provided by cities. Signal maintenance capabilities can be divided into three levels.

The lowest level of maintenance is where the city provides only minor maintenance, relamping, repainting of mast arms and poles, straightening of heads, etc.; but the city is dependent on contractors for routine preventive maintenance and for the repair of controller malfunctions.

At the next level, when a traffic signal malfunctions, city employees can determine the signal control component that is malfunctioning. They are able to swap-out the malfunctioning unit but are dependent on the manufacturer to fix the component.

The highest level is where city employees can diagnose and repair most signal malfunctions.

Clearly, larger cities tend to have staffs that can apply the highest level of maintenance and smaller cities will employ staffs with the lowest level of traffic signal maintenance capabilities. However, the divisions between levels and the relationship to the number of signals within a city is blurred and dependent on the philosophy of the city's top management. The level of maintenance provided by a city will dictate the level of skills of their employees.

CHAPTER VII
CONCLUSIONS AND RECOMMENDATIONS

The results of the program are clearly positive. Although some individual projects did not provide positive results according to the traffic flow performance-attributes measured, undoubtedly the improved equipment and upgraded operation will provide benefits in areas not measured. For example, in programs in other states where signals were similarly upgraded, traffic safety improvements resulted. Although a dollar value can be associated with traffic safety improvements, it usually takes between three and five years of accident data to provide a statistically significant increase in safety. Thus the needed accident data will not be available for a number of years. Other unquantified benefits are reduced maintenance costs, improved equipment reliability, improved pedestrian safety, and improved non-traffic related safety through emergency vehicle pre-emption.

However, based only on improved traffic flow performance, the overall program resulted in benefits that were 14 times the cost of the program (including local and oil overcharge funds).

In this chapter, a critical review is made of the program elements and features. This review is followed by recommendations for future actions.

VII.A A Critical Review of the Program's Features and Elements

The Iowa Motor Vehicle Fuel Reduction Program included five elements. They were: (1) administration of the program by the Iowa Department of Transportation and the Iowa Department of

Natural Resources; (2) the individual projects; (3) technical assistance and before-and-after studies performed by Johnson, Brickell, Mulcahy, and Associates, Inc.; (4) a public awareness campaign performed by the Local Transportation Information Center, Iowa State University Extension Service; and (5) a comprehensive technology transfer program performed by the Local Transportation Information Center, Iowa State University Extension Service. The following sections review all of the elements except the program administration.

VII.B Projects.

Project Distribution. The program administrators made a deliberate effort to evenly distribute the individual project cities with regards to geographical location and to population. This is seen as a very positive element, and particularly important to small Iowa communities.

Smaller communities often see modern techniques and technology to be within the domain of larger cities. By specifically including small cities, the applicability of the technology to all locations is highlighted.

Project Technology. A positive attribute of the variation in projects is the variety of technology selected. The variety provides an excellent demonstration of the applicability of various technologies and the likely traffic flow performance improvements that resulted from each technology.

On the other hand, the program tended to focus on hardware solutions to improve traffic flow performance. Only parts of the

Des Moines project involved just retiming existing signals; no new hardware was involved. Other states have had very successful programs that concentrated on improving traffic signal efficiency through retiming. For example, the North Carolina program resulted in a 143-to-one benefit-to-cost ratio and the only improvements were the retiming of signals. Demonstrating the benefits of improved signalization through equipment tends to gloss-over the more cost effective traffic flow improvements that are available through periodically retiming, regardless of the technology employed.

Local Control. The program allowed each of the project cities to enjoy a great deal of autonomy in the specification/design of equipment and systems, the purchase procedures, and future operation of the signals. Allowing each project this flexibility had several benefits.

Several of the projects purchased equipment through a bid selection process that included criteria other than low price. They included such criteria as compatibility with existing equipment, experience with suppliers, service, and other attributes that helped them to purchase the equipment that they desired rather than the lowest priced equipment. When asked about their procurement process, cities that chose to use other criteria were very pleased with the results.

The project cities were also allowed to design into their improvements features that were important to the individual cities. For example, the City of Decorah felt that pre-emption capabilities were important and emergency vehicle pre-emption capabilities were designed into the hardware.

A potentially negative result of placing a minimum of requirements on the individual cities relates to their future operation and stewardship of their equipment. For example, the California program felt that it was so important that individual cities have the know-how to keep signals operating at peak efficiency, they required cities receiving grants to send city personnel to extensive training programs.

The Iowa program provided training free-of-charge to all grant recipients and some of the cities took advantage of the training and some did not. Unfortunately, there is no way to ensure that those that did attend training programs will apply the techniques they learned and routinely update signal timings, apply routine preventive maintenance, and develop prudent corrective maintenance and emergency response procedures. However, it is extremely unlikely that those project cities that did not participate in the training programs will improve their stewardship.

VII.C Before-and-After-Studies

Johnson, Brickell, Mulcahy, and Associates, Inc. performed the before-and-after studies through actual site measurements of traffic flow performance. This was done on arterial systems with an instrumented car measuring the traffic flow performance while floating in traffic. At isolated intersections an observer performed a delay study. The advantage of this method is that it provides tangible evidence with actual field-collected data. Field-collected data may seem more credible than alternatively developing performance projections using computer simulation.

The major problem with field-collected data is that the collection is labor intensive and expensive. Also the data are only a snap shot of performance during one day, and traffic patterns tend to vary from day-to-day. As a result, the snap shot may not be representative of the overall performance. To avoid the problems associated with field-collected data, other states have used simulation models to estimate performance improvements. California's program has compared estimated performance using computer models with field-collected data and found only negligible differences.

VII.D Public Awareness Campaign

It is difficult to evaluate the success of the public awareness campaign without conducting a survey of the public's knowledge before and after the program. However, it is clear that the public must become aware of the importance of traffic signal operation and the importance of other transportation infrastructure if communities are to become supportive of transportation infrastructure improvements.

VII.E Technology Transfer

The major portion of the technology transfer program was devoted to presenting training for three audiences; traffic engineers, signal technicians, and elected and appointed officials.

<u>Traffic Engineers.</u> The engineering level training consisted of a workshop on a comprehensive traffic signal timing plan optimization microcomputer package (Arterial Analysis Package). The workshop was held in Ames and lasted three days. It provided engineers with the skills required to develop efficient timing plans. However, it is likely that only attendees from the very largest cities will ever apply what they have learned to calculate efficient timings and retime traffic signals. Small and medium size cities are likely to continue to depend on consultants for signal retiming.

The traffic signal timing plan course's greatest value was in teaching city staff members that computer packages are available to calculate signal timings and to provide them with an understanding of signal timing optimization. It is likely that a much shorter and less expensive training program could have accomplished the same purpose.

<u>Traffic Signal Technicians.</u> Traffic signal technician training was accomplished through a three-day workshop on NEMA traffic controllers held in Ames and through five one-day workshops held throughout Iowa. Both programs were well received. However, the one-day workshop was probably much more beneficial because it reached several staff members from small communities that had never had formal training on traffic signal maintenance.

<u>Elected and Appointed Officials.</u> Eight two-and-one-half hour elected and appointed officials training programs were planned. Two were cancelled due to lack of attendance and six were presented. At all but one presentation, the city staff members in attendance out-numbered the elected officials. Although this is a key audience to reach, the workshops were not as well attended as expected. All presentations were very well received.

VII.F Recommendations

The Iowa Motor Vehicle Fuel Reduction Program's success conclusively identifies the effectiveness of traffic signal improvements. Because this program is a demonstration program and positive results have been demonstrated, it is unlikely that more traffic signal equipment will be purchased by Iowa cities using oil overcharge funds. The program does prove that similar improvements are beneficial and therefore, it is recommended that cities should pursue similar state-of-the-art equipment improvements through routine funding channels.

More specific recommendation include the following:

1. Governor Branstad signed into Iowa law on June 3, 1989 a bill requiring cities to coordinate traffic signals ("Synchronize") to increase energy efficiency. Senate File 419, Section 7 states, "After July 1, 1992, all cities with more than three traffic lights within the corporate limits shall establish a traffic light synchronization program for energy efficiency in accordance with rules adopted by the state department of transportation. The state department of transportation shall adopt rules required by this section by July 1, 1990."

   From the results of the survey in Chapter V, it is estimated that there are between 80 and 90 Iowa cities with three or more traffic signals. Several of these cities will have signalized arterials where the new law will require coordination. The difficulty of coordinating signals depends on the type of signal control equipment in-place and the condition of the equipment. It is recommended that a survey be conducted to determine the type and condition of existing equipment before the Iowa Department of Transportation adopts rules for compliance with the new law.

2. There are still unmet technology transfer needs. The popularity of the traffic engineering and traffic signal maintenance programs provide a clear indication of the need for additional training and information sharing. Training of elected and appointed officials on intersection traffic control and on other transportation issues is clearly needed and important. However, a more efficient approach is needed to attract officials to training programs. The Local Transportation Information Center, the American Public Works Association, and other organizations that provide training to local officials and professionals should be encouraged to use the training programs and materials developed to continue to provide traffic signal related training opportunities.

3. The simultaneous statewide improvement of several locations provides a rare opportunity to quantify the traffic safety improvement of upgraded traffic signals. After three to five years, the accident rates at project locations could be compared to their before accident rates and to control locations to determine the impact of various signal improvements. The study would require a modest level of effort and would take advantage of the rare opportunity of having nineteen well-documented signal improvement projects.

4. Iowa cities surveyed and program cities generally did not have written maintenance policies and procedures. Furthermore, all of the cities surveyed and all the program cities that rely on contractors for maintenance services, do so without a written maintenance agreement. The lack of written maintenance policies and procedures, and contracting for maintenance services without a written contract, represents an area of almost unlimited potential legal liability for Iowa cities. The development of guidelines for developing written maintenance policies and procedures and for maintenance contracting and contract administration is strongly recommended.

   Any guidelines developed should be drawn-up with the consultation of maintenance contractors and signal vendors that provide services to Iowa cities. The development of guidelines should be followed-up with the development of workshops covering the guidelines. The workshops should be offered at locations throughout the state.

REFERENCES

1. Arnold, E.D., "Signal Timing Optimization: A Review of State Programs," Virginia Transportation Research Council, Charlottesville, Virginia, 1988

APPENDIX A
SURVEY QUESTIONNAIRE

To whom it may concern:

This questionnaire is in reference to the Iowa Motor Vehicle Fuel Reduction project which is sponsored by the Iowa Department of Transportation, and Department of Natural Resources. A follow up study for the program is being conducted by the Iowa State University Business and Engineering Extension group.

One of the objectives of the follow up study is to access the state-wide potential for additional signalization improvements, and to gauge potential benefits and resource demands.

Please take a moment to complete the enclosed questionnaire and return it as soon as possible. Your efforts are greatly appreciated!!!

Does your City have any **Signalized** Intersections? **Yes / No**

If Yes, who could we contact for additional information concerning these signals?

Name______________________________

Position__________________________

Address___________________________

____

Phone #__________________________

Please sign and return this portion of letter.

APPENDIX B
SURVEY QUESTIONNAIRE

CITY__________________PERSON______________________PHONE#___________

* How many signals are in your town?

	# Pre-timed	# Semi-actuated	# Full-act.
Electromech.			
Solid state			

* What types of signals do you have (NEMA, 170'S,OTHER?)

* How many of these signals are at isolated intersections?

* Is there any coordination OR progression along any arterials?

* If so, how many intersections are connected together per arterial?

* How is progression allowed (hardwire, time-base coord.)

* Who makes admin. and operational decisions about traffic signals?

* Within this department, what is the Manpower, Experience?(qualify)

* Who maintains your traffic signals (city, consultant, manufacturer)?

* Does the maintenance group have any other responsibilities? %Time?

* Who installs your traffic signals (city, contractor, other)?

* Has there ever been any training (What did it cover, who trainer)?

* How frequently are signals retimed? If so by whom, when?

* Are there any plans for future timing updates, by who,?

* What types of maintenance is performed?

Preventative? (not just relamping) pm checksheets — Response? — Emergency?

* Is there a written maintenance policy outlining any of the above?

* CITY/CONTRACTOR upon failure of a solid state device, can the crew identify the problem in the field and replace it?

CITY___________________

* Is the majority of SS equip. repaired in CITY/CONTRACTOR shop?

* After failure, is operation returned w/ 24 hours?

* What is AADT along busiest arterial?

* What planned signal improvements do you have?

* What type of equipment do you have(Eagle, Multi, TCT, Winkomatic?)

* Has a TEAP study ever been performed? What said about signals?

* What type of procurement practices are done?

Low-bid Life-cycle cost

* What are the criteria for selecting new equipment?

* Is a performance specification written to ensure compatibility or performance?

* How was your last signal equipment procured?

* Is the city contemplating replacing signal equipment?

* If you had equip. tomorrow, is staff trained to operate it?