INTERJURISDICTIONAL COOPERATION OF PUBLIC AGENCIES IN THE OPERATION AND MAINTENANCE OF TRAFFIC SIGNAL SYSTEMS

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SUMMARY

Coordination of traffic signals across jurisdictional boundaries is an increasingly popular option to better utilize the capacity on existing arterials in an urban area. Providing coordination along arterials can reduce delay and travel time experienced by motorists as well as decrease pollutants emitted by vehicles. There will probably be no two urban areas in the United States, though, that are faced with exactly the same situation when trying to coordinate traffic signals across jurisdictional boundaries due to a variety of technical and institutional issues that may arise in the formation of interlocal agreements.

There are many different variations of interlocal agreements that can be formed between agencies. These will mostly depend on the resources available to each agency and the level of control that each agency wishes to maintain over their own signals. Interlocal agreements can vary from one agency being responsible for operation of all signals in each jurisdiction to each agency having control of their own signals with a common cycle length between jurisdictions. Maintenance agreements can also be included in interlocal agreements.

During this study, several agencies that currently had interlocal agreements were interviewed. Reports and articles prepared by the agencies and/or consulting firms involved with the interlocal agreements were obtained when possible as well as many of the actual interlocal agreements. The characteristics of each of these interlocal agreements are documented in this report. Although the urban areas presented in this paper show only a handful of the examples of interjurisdictional coordination that exist around the country, it was the intent of this paper to demonstrate some of the issues involved with and technologies available for coordinating traffic signals without regard to jurisdictional boundaries. It was also an objective of this paper to document some of the benefits that have been received by these urban areas.

Providing coordination along arterials can reduce the number of stops and delay experienced by motorists as well as provide environmental benefits in the form of decreased pollutant emissions. Travel time savings for motorists can range from 6% to 17%. A savings in overall delay from 32% to 38% can be seen as well as a decrease in the number of stops from between 42% to 48%. Average speed across the system can increase from between 8% and 20%. A reduction in fuel consumption from 5% to 25% was seen as well as a reduction in pollutant emissions of 3% to 25%.

 Agencies wishing to form interlocal agreements should assess of the needs of each agency involved in the agreement as well as the resources available to each agency. Depending on the current traffic control equipment that each agency has and the type of control system that is desired for the area, interjurisdictional coordination can be simple to very involved. From the characteristics of each of the systems described in this paper, suggestions are given as to options, benefits, and requirements of different methods of interjurisdictional coordination. These options are dependant on the resources available to each of the agencies involved and the preferences of each jurisdiction.
# TABLE OF CONTENTS

**INTRODUCTION**  .......................................................... I-1  
Scope  ................................................................. I-1  
Objectives  ............................................................ I-2

**INSTITUTIONAL ISSUES**  .................................................. I-3  
Defining Agency Responsibilities  ........................................ I-3  
Funding  ................................................................. I-4  
Legal-Risk Management  .................................................. I-5  
  *Distributed Control*  ............................................. I-5  
  *Centralized Control over Signal Timing*  ..................... I-5  
  *Centralized Control over Signal Timing and Signal Maintenance*  .......... I-6

**TECHNICAL ISSUES**  ...................................................... I-7  
Centralized System  ................................................... I-7  
  *Communication Media*  ............................................ I-7  
  *Data Sharing*  ................................................... I-8  
Distributed System  .................................................... I-8  
  *Time-based Coordination*  ..................................... I-8  
  *Common Time Reference*  ...................................... I-9  
  *National Traffic Controller Interface Communication Protocol (NTCIP)*  .......... I-9

**EXAMPLES OF EXISTING INTERLOCAL AGREEMENTS**  .................. I-10  
Distributed Control  .................................................. I-10  
  *North Dallas County, Texas*  ................................... I-10  
  *Orange County, California*  .................................... I-11  
  *Green River Valley, Washington*  ................................... I-11  
  *Seattle, Washington*  ............................................. I-11  
Centralized Control  .................................................. I-12  
  *Colorado Springs, Colorado*  .................................. I-12  
  *Las Vegas, Nevada*  ............................................... I-13  
Agreements for Operation and Maintenance  ................................ I-14  
  *Monroe County, New York*  ..................................... I-14  
  *Arlington, Texas*  ................................................ I-14  
  *Austin, Texas*  .................................................. I-14  
Summary of Interlocal Agreement Characteristics  ...................... I-15

**BENEFITS OF INTERJURISDICTIONAL COORDINATION**  .................. I-17  
Measured Benefits  ................................................... I-17

**EXAMINING AGENCY OPTIONS WITH AVAILABLE RESOURCES AND PREFERENCES**  .................................... I-19

**CONCLUSIONS**  .......................................................... I-20
RECOMMENDATIONS .................................................... I-21
ACKNOWLEDGMENTS ................................................... I-22
REFERENCES ............................................................ I-23
INTRODUCTION

As the vehicle demand on roadways increases in the United States, public agencies are being forced to find better ways to utilize the capacity of existing streets. Public agencies today are unable to build enough capacity to meet increasing vehicle demands. Public opposition to more roadways and increasing right-of-way costs in many cases makes it economically infeasible to build new roadways and or expand existing ones. Also, with the passage of the 1991 Clean Air Act Amendments, building capacity on roadways in non-attainment areas has become very difficult due to environmental concerns. Areas that meet certain pollutant standards are not allowed to take actions that would increase the vehicles miles of travel (VMT) in that area, including building new capacity.

The coordination of traffic signals to provide progression along arterials is one way to better utilize the capacity of the existing street system. Traffic signals are coordinated by setting the green times for a movement at each intersection along an arterial to start when the platoon of vehicles traveling from the upstream intersection is arriving. The green times for each intersection are offset according to the time it takes the platoon of vehicles to travel from intersection to intersection. If traffic signals along an arterial are properly coordinated, vehicles can progress through the arterial in platoons without having to stop more than once. Coordinating traffic signals can reduce stops, delay, vehicle operating costs, motorist time cost, accidents, fuel consumption, and pollutant emissions.

Some of the potential benefits of traffic signal coordination may not be gained, though, as motorists travel from jurisdiction to jurisdiction if signal timing philosophies differ in these jurisdictions and there is no coordination of the traffic signals across jurisdictional boundaries. A lack of signal coordination may cause congestion along the arterial which could lead to traveler delay, air pollution, driver frustration, and under utilization of the arterial. The implementation of interjurisdictional traffic signal coordination is becoming more of a necessity as increasing vehicle demands are becoming detrimental to air quality. Motorists and public agencies both benefit from the perception of a ‘seamless’ system from jurisdiction to jurisdiction. Although there are many institutional and technological issues to be dealt with when coordinating traffic signals across jurisdictional boundaries, advancing technology and a growing need for interjurisdictional coordination are giving public agencies more options for the coordination of signals within an area.

Scope

This paper addresses some of the institutional issues and technological issues faced by public agencies when deciding to coordinate traffic signals across jurisdictional boundaries. The paper considers alternatives available to public agencies interested in interjurisdictional cooperation for the operation or operation and maintenance of traffic signals and reviews existing agreements between agencies in several areas across the United States. Finally, this paper reports on the benefits received by areas that currently have such agreements.
Objectives

The objectives of this paper are:

1. To address institutional issues of interlocal agreements including agency responsibility, funding, and liability.

2. To address technical issues of how coordination can be achieved.

3. Examine various interlocal agreements for the operation and/or maintenance of traffic signals.

4. Report benefits being received because of these interlocal agreements.
INSTITUTIONAL ISSUES

There are several institutional issues that need to be addressed when bringing agencies together. These issues involve establishing and documenting agency relationships and responsibilities. Institutional issues of interjurisdictional coordination may be difficult to resolve in some cases because agencies may have contradicting goals or simply because there is not a history of communication between these agencies. Contradicting goals may be an issue if a jurisdiction’s goal is to move local traffic efficiently and the goal of interjurisdictional coordination is to move traffic through the area. In most cases, though, if a common objective can be defined and agreed upon it will give each of the agencies something to work towards together. Meetings of agency representatives can provide a forum to discuss the needs of individual agencies as well as define common goals.

Some of the major institutional issues that need to be resolved by agencies when cooperating for the operation and maintenance of traffic signals include issues of agency responsibilities, funding, and liability. As will be seen in examples of agency cooperation later in this paper, there are many forms that interlocal agreements can take and choosing the right combination of alternatives can be important in the lasting cooperation of agencies in an area.

Defining Agency Responsibilities

The level of involvement that each agency desires along with the level of control that each agency wishes to maintain over the signals in their jurisdiction are important issues that must be addressed from the beginning of the relationship. Some agencies may be willing to give complete control of their signals over to another agency while some agencies are not willing to give up any control of their signals. Fears may need to be addressed as some agencies may feel that they could lose autonomy over signals in their jurisdiction and do not wish to.

Interjurisdictional coordination may be accomplished by a common agreement between neighboring jurisdictions or through the creation of a separate agency that is represented by each of the jurisdictions involved. There are three main types of interlocal agreements that are examined in this paper but it should be kept in mind that there is a wide continuum of options that agencies have in forming interlocal agreements. The three types of interlocal agreements discussed in this paper are:

1. Distributed Control - all traffic control is done at the individual intersections

2. Centralized Control - generally there is one master computer and each of the intersections in the system are controlled from it.

3. Centralized Control of Timing and Responsibility for Signal Maintenance - along with timings being implemented by one agency there is a contract for maintenance also included

The relationship of the agencies involved in interlocal agreements must be defined on the basis of the level of involvement desired by each agency. There are a wide range of alternatives
available and different options work best in different areas. A few examples of agency relationships are described below:

- one controlling agency makes the decisions to varying degrees and implements them;
- a Steering Committee may be formed to make decisions with a representative from each agency and it is the responsibility of each individual agency to implement the decisions made by the committee;
- an independent agency could be formed that represents each of the parties involved; and
- there may be no actual agency or committee formed but only formal or informal meetings of traffic engineers from each jurisdiction.

There are several alternatives and variations possible for each of these options, but is important that each agency be allowed to keep the level of control that they desire and that communication be open and available between agencies at all times.

Another important institutional issue that should be considered is whether the interlocal agreement will be for the operation only or for the operation and maintenance of the traffic signals in the system. This issue also regards the level of control that each agency wishes to maintain over their own signals. Other factors involved in this decision include response time to signal malfunctions along with staff and equipment requirements for the maintenance of signals.

There are at least two alternatives if maintenance is included as part of the agreement. In the first alternative, one agency would assume responsibility for all signal timing coordination and the operation/maintenance of signal controllers and communications equipment. Individual jurisdictions would still maintain the street furniture portions of signal installations such as signal heads and lamps. Other alternatives are more comprehensive where one jurisdiction could control and maintain all signal equipment including the street furniture (1).

The development and implementation of signal timings is another issue that must be addressed under agency responsibilities. The timing patterns should be developed jointly by the traffic engineers in adjacent jurisdictions and agreed upon by all agencies. This could be the key to successful implementation and operation of coordinating signals across jurisdictional boundaries. This effort requires that the parties involved agree on the time of implementation, the cycle length, and direction of preferential flow. Although traffic engineers may not always agree on these timing elements, it is important that the engineers understand that they must cooperate to settle these issues before interjurisdictional coordination can be achieved (1).

**Funding**

It is important that funding be addressed and agreements be documented early in the relationship between agencies. There are a variety of ways that the cost of the agreement can be handled. A set annual fee can be paid by agencies that have handed over the control of their intersections to other agencies and/or maintenance and equipment costs can be reimbursed on an as needed basis. Agencies can contribute to operating costs dependant on the number of intersections in their jurisdiction. Funding may also be available from outside sources such as federal funds or bond elections for the initial construction and operation costs.
Legal-Risk Management

Commonly, the key legal issues related to interjurisdictional signal coordination are liability for personal injury and property damage. While liability concerns will vary according to the particular situations, some common concerns may arise. Some jurisdictions even pay into a common insurance fund or could be required to maintain specific liability reserves.

Risk management issues can be viewed in a cost/benefit analysis where anticipated motorist and agency benefits are weighed against potential risks. Insurance, specific contract language, and careful engineering can effectively manage the potential risks. Operational issues and/or monetary issues must be clearly defined by each participating agency in order for cooperative agreements to be implemented and maintained (1).

Some common provisions usually set forth in any traffic signal agreements include hold harmless clauses, mutually agreed upon timings, and ongoing signal timing evaluations. Hold harmless clauses which relieve an agency from the responsibility for the acts of another are standardly required in traffic signal related contracts. Each agency agrees to indemnify the other from its own negligent acts and each agency is responsible only for its own negligent acts (1).

When all participants share input into the development and implementation of a timing plan, the plan should be set forth in writing and signed by all participants. Also, because traffic patterns fluctuate over time, these agreements should include a provision for the ongoing evaluation of signal timing plans. Other legal issues will be discussed in regard to the three main categories of control listed earlier.

Distributed Control

The most common form of distributed control is the use of a common time clock or sharing a common time reference. Because of its relative simplicity, no major legal issues are involved with sharing of common time across jurisdictions. However, it is suggested that a formal resolution in support of the use of a common clock or common time be adopted by each participating agency. Formal adoption will underscore each agency’s support for cooperative traffic signal management (1).

Centralized Control over Signal Timing

Because centralized control involves the control of one jurisdiction’s signals by another agency, some liability issues are raised. Each situation must be evaluated individually from a liability perspective. Specifically, the risk managers, agency attorneys, and traffic engineers must communicate to uncover any perceived liability risks. The risk management assessment of signal coordination arrangements will vary from jurisdiction to jurisdiction depending upon the jurisdiction’s need for traffic improvements and upon its particular risk management philosophy. Risk managers differ in philosophy on whether assuming or yielding control over signal coordination is a justifiable risk. A significant benefit, though, can justify the assumption of an acceptable risk (1).
Centralized Control over Signal Timing and Signal Maintenance

Some risk managers will view the assumption of a maintenance function as doubling of the potential liability for their agencies. Risk managers as a whole are more comfortable with their own agency’s crews or contractors maintaining the traffic signals in their jurisdiction. This may not always be the most economic, convenient, or practical solution, though, as some jurisdictions do not have the resources to keep their own crews. If one jurisdiction is to assume the maintenance of another’s traffic signals, a clear and comprehensive description of maintenance functions and schedules is imperative. A clear definition of responsibility also must be defined. For example, an agency that assumes responsibility for signal operations and maintenance may want to avoid liability for design-related issues over which it has no control (1).
Once the institutional issues of agency cooperation are resolved, another major obstacle in achieving the goal of a ‘seamless’ system is how the traffic signals in the system will be coordinated. The technical issues in achieving coordination involve mainly equipment and communication. There are several options that can be used to facilitate coordination and several forms of control that can be used.

**Centralized System**

A centralized system generally operates using one signal system master. A central computer directs the actions of all traffic signals on the system. This approach requires a powerful central computer and demands a very reliable communications capability between the central computer and the intersection controllers (2). In a centralized system, traffic signal control is generally assumed by one agency over another. The timing plans are selected remotely by one master. The plans may either remain resident at each local computer, or they may be resident at the central computer (1).

**Communication Media**

There is a variety of communications media available today for the control of signalized intersections. This media varies widely in installation costs and continuing costs as well as effectiveness. Several different communication media can be used in a single system.

*Twisted-Pair Cable.* Jurisdiction-owned twisted-pair cable is one of the most widely used communication media for traffic control systems. Twisted-pair consists of individually insulated copper wires twisted into pairs and combined into a shielded cable. This cable provides a voice grade transmission link between a central computer or master and each intersection. Typically, the central computer or master will communicate over the same multipoint channel. A channel consists of one or two twisted-pair cable depending on the transmission technique used by the communications system. Twisted pair cable can be installed underground or aerial (1).

*Leased Communications Network.* Two main options for leased communication networks include leasing communication lines from a local telephone company and leasing coaxial cable communication (CATV) from a cable company. When the cable service area is extensive, the cost of conducting traffic system communications via leased cable can be lower than telephone communications. For remote traffic signal locations that are not close to a cable route, telephone service is lower in cost (3). The initial capital expenditures for leased networks are significantly less than initial capital expenditures required for the installation of city-owned cable. The drawbacks are on going lease costs and reliance on the telephone or cable company for maintenance and repairs which are subject to tariff increases and will likely escalate over time (1).

Computer-based traffic control systems requiring two-way communication can use CATV cable that is routed near roadway intersections. Since most CATV revenue is from the sale of programming to paying subscribers, typical cable systems are designed as “one-way” for program distribution from a central point. The cost of converting one-way cable to two-way cable is usually negotiated between the agency and the cable company (3).
A signal being sent from the master traffic computer is sent to local controllers through the CATV cable via a modem and a RS232 port on the controller. State-of-the-art modems can provide a range of features including advanced error detecting/correcting algorithms, data compression to increase throughput, encryption, multiplexing, voice and data support, and multiple speeds. The use of such modems can provide the traffic engineer with equipment to alleviate some of the noise on coaxial networks (3).

Fiber-Optic Cable. Fiber-optic technology represents a dramatic improvement in telecommunications and offers advantages of capacity and signal protection. One fiber of fiber-optic cable has the same capacity as 900 pairs of copper cable, weighs nearly 1/10th, and is stronger. Using fiber optic cable increases the capacity of existing conduits and allows for faster and cheaper installation with fewer personnel. Fiber optic light frequencies are much higher than the highest radio frequencies and allow high capacity, high speed transfer of data, and low losses. Fiber optic technology does not radiate energy and is nearly impossible to tap. It can handle any type of communication signal which reduces or eliminates need for future upgrades (3).

Data Sharing

As the technology for communication improves, adjacent jurisdictions will be able to better operate their systems by knowing what is occurring immediately upstream and downstream of their respective systems. Communication may also be beneficial in knowing agency construction information, special event schedules, or real-time freeway congestion data (4).

Distributed System

Traffic signals can also be coordinated across jurisdictional boundaries using a distributed system. A distributed system is decentralized and all the individual traffic signal control is contained at the intersection. This approach allows the system to provide reliable operation even when communication has failed. A distributed system can also be used when money is not available for communication or intertying the intersections in a system or if there is different proprietary equipment in the system that is not capable of communicating. A distributed system is only as good as the control and equipment at the individual intersections. The most common method of coordinating traffic signals in a distributed system is time-based coordination with or without the use of a common time clock. Signal manufacturers will soon be required to use a common protocol, NTCIP, which will allow equipment from different manufacturers to communicate.

Time-based Coordination

Time-based coordination is provided by an internal clock in each controller. Splits and offsets are chosen by a time-of-day plan. The clocks in each controller are synchronized throughout the system but are allowed to keep time on their own. This is a fairly simple way of achieving coordination but may not be completely reliable because time in individual controllers may drift.
Common Time Reference

A more accurate way of achieving time-based coordination is through the use of a common time clock. The most common time used is WWV. WWV is a time broadcast via radio from Colorado and Hawaii. The broadcast time is the National Bureau of Standards (NBS) time derived from a cesium time reference. The WWV (Colorado) radio signal is broadcast on 5 different frequencies and the WWV (Hawaii) radio signal is broadcast on three different frequencies. WWV radio receivers can be installed in on-street masters or individual intersections. These receivers scan all frequencies to find the strongest and then lock in on the signal. This method provides long term accuracy with negligible drift. Power line frequency may also be maintained via WWV time. This element has great benefit in the coordination of non-interconnected signals if the controller can receive its time-of-day from the power line frequency (1).

National Traffic Controller Interface Communication Protocol (NTCIP)

A national traffic control communication protocol, NTCIP, is currently under development. NTCIP is a standard, non-proprietary communication protocol for interfacing between traffic control devices of all types. This protocol will embrace the best features of several existing world wide communications standards. It will allow any device to communicate directly with any other device. It will also allow for the use of shared communication channels and the interconnection of devices manufactured by different companies.

The goal of NTCIP is to be a non-proprietary protocol that meets existing traffic control requirements, supports traffic management communications, accommodates future technology growth, and conforms to existing software and communications standards to the extent feasible. This protocol will be general in nature and not application specific. It is intended to be a common communication protocol that will provide accurate communications between devices in advanced traffic systems over a variety of media (2). This protocol will allow for communication between controllers of different manufacturers which is one of the major impediments in coordinating signals between jurisdictions.
EXAMPLES OF EXISTING INTERLOCAL AGREEMENTS

Some examples of interlocal agreements that have been established around the country in various metropolitan areas will be examined in this section. These examples are being provided to show the range and diversity of interlocal agreements that is available. These interlocal agreements are reviewed in three categories: distributed control, centralized control, and agreements involving both operations and maintenance. The information provided on each of these interlocal agreements has been obtained from reports and articles prepared by the agencies and/or consulting firms involved with the agreements.

Distributed Control

Distributed control of signal coordination allows agencies to retain control and autonomy over their traffic signals but still accomplish the goal of coordination through the system. This type of control can be accomplished through only the agreement of a common cycle length and does not require compatible equipment.

North Dallas County, Texas

An interlocal agreement between Dallas County and 6 cities in the North Dallas County area was first established in 1985. This agreement provided for the coordination of 224 intersections in the cities of Dallas, Addison, Carrollton, Farmers Branch, Garland, and Richardson. A motorist traveling east or west could travel across the jurisdictional boundaries of all six cities in a distance of 12 miles. A motorist traveling north or south could pass over the boundaries of four cities in one mile. The need for coordination of signals across jurisdictional boundaries was apparent and a $4 million bond package was passed for signal improvements (6).

Each of the cities in the project was represented on a Steering Committee by the professional most responsible for signal timing and operation in their city. The Steering Committee was responsible for guiding the program through the bond election, developing guidelines for administering the program, and selecting an engineering consultant to provide signal design, timing development, and a before-and-after study (6).

Some new equipment was purchased to support signal timing improvements where needed, but this did not include central hardware or physical interconnect. The coordination of signals in this program was done by time-based coordination. Existing equipment was used to the greatest extend possible but upgrades of equipment were done on an as-needed basis. Equipment that was purchased included some new NEMA actuated controllers and cabinets, local intersection detectors, replacement of 8" signal lenses with 12" lenses, and any additional heads, signs, or wiring that were necessary to support revised phasing. Signal timing software programs were also purchased by each of the cities and training courses were provided by the consultant (6).
Orange County, California

In a desire to coordinate major arterials within Orange County, both within and across jurisdictional boundaries, it was necessary to define a concept which would allow for interjurisdictional coordination but which would not impose severe constraints on the individual jurisdictions. It was decided that a county wide signal system with one master controlling all signals in all jurisdictions would be found unacceptable to the majority of jurisdictions, because it would take away their authority over the traffic signals within their city boundaries and would place the responsibility for operation of all signals with only one operating agency. It was also concluded that utilization by all jurisdictions of the same manufacturer’s master and control equipment and then intertying the masters would be unacceptable, because it would impose requirements and restrictions upon the traffic departments to buy and install a specific type of equipment (1).

It was therefore suggested that a common time reference be used by all masters and signal controllers which would be synchronized, thereby enabling all signals to be synchronized with each other. The time reference used in this system is the WWV time broadcast from Colorado and Hawaii. Each jurisdiction can have an independent central system, on-street masters, or individual time based coordinators at each intersection. The only constraint is the choice of a common cycle length by traffic engineers in adjacent jurisdictions and, in certain cases, periodic field inspection to insure that the equipment is functioning properly (1).

Getting WWV receivers into all signals or masters was determined to be a long term project and several steps were taken towards coordination across jurisdictions in the interim. Cities that were adjacent to cities that had compatible control equipment could put their signals under the control of the adjacent city. This would require communications interconnect between the signals and the master as well as compatible controller equipment (1).

Green River Valley, Washington

In the Green River Valley, traffic signals are controlled and maintained by a variety of jurisdictions including cities, counties, and the State of Washington. The Green River Valley Interagency Signal Coordination Committee is comprised of five jurisdictions including the City of Tukwila, the City of Renton, the City of Kent, Washington State Department of Transportation, and King County. The committee is not a separate legal entity but is an administrative entity which has the authority to apply for and accept grants, distribute resources, and implement traffic signal control improvements. In the initial phases of the project, two main corridors through these jurisdictions with a total of 30 intersections were coordinated through time-based coordination (7).

Seattle, Washington

Signal coordination across jurisdictions in the Seattle area has taken place as part of an entire integrated traffic control system. The local jurisdictions were interested in improved communications and coordination, and in exchanging traffic and/or signal timing data with neighboring jurisdictions. The North Seattle ATMS project is a two year effort begun in November 1994 (5). The jurisdictions included in this project were the cities of Seattle, Lynnwood, Everett, Marysville, Edmonds, Mill Creek, Montlake, Terrace, and Bothell, King County, Snohomish County,
and the State of Washington (8). The WSDOT has overall project responsibility but the project is owned by each of the various agencies and their involvement in the development and implementation of the project is critical (4).

The intent of the Seattle Area Integrated Traffic Control Network (INTER-NET) is to develop and implement a multi-jurisdictional data sharing and monitoring system. This will allow all jurisdictions in the region to have real-time information on traffic and transit conditions. The proposed approach will not simply join many signals systems into a single well-timed signal system, but will establish a multi-jurisdictional surface transportation mobility strategy in the north Seattle area. The system will be designed as an ITS test bed that will initially include technology for the sharing of arterial and freeway data for control system coordination and the provision of traveler information systems that would include freeway and arterial routes (8).

The Seattle area project will utilize existing traffic management hardware infrastructure already in place in each jurisdiction. This is one of the main operational issues being faced by the program due to the presence of multiple manufacturer’s equipment in the region. The North Seattle ATMS project is being designed communicate with all the existing devices. They are currently evaluating the impact of implementing the National Traffic Controller Interface Communication Protocol (NTCIP) on the cost and schedule of project implementation (5).

The architecture developed for regional implementation by the University of Washington provides for a geographically distributed traffic management and information system. One key function of the architecture is that it guarantees that existing agencies retain autonomous use of the sources they currently control while at the same time providing access to information previously unavailable to them. The regional architecture framework is comprised of three systems; a data sources system that is the supplier of data, a data fusion system that must obtain and combine data from the various devices in the data source system, and the delivery/display system.

Using the standards and protocols of the INTERNET which allows every process on the network to communicate with any other process and developing the network on a client/server model strengthens the concept of allowing agency autonomy. The regional framework allows for easy addition of new data sources onto the communications backbone as well as allowing developers of new applications access to all the region’s data invisible to an agency’s day to day operations (4).

Centralized Control

Systems with centralized control vary widely in size and methods of communication for control. In systems with centralized control, it is important that the needs of each individual agency are addressed and jurisdictions retain the necessary level of control that they desire.

Colorado Springs, Colorado

Colorado Springs has a centralized signal system where all signals within the system are controlled through a 486 microprocessor based system. Currently there are 280 intersections on-line with the computer system. The computer based system is fully graphic and user-friendly. The computer system is capable of controlling over 4,000 intersections and 10,000 system detectors. The
command structure is window-based and is capable of trapping errors made by a system operator if their commands do not fall within specified limits. The system is also capable of paging the on-call technician with a verbally recorded message if there is a signal failure.

Colorado Springs has recently underwent steps towards the goal of having a completely interconnected signal master system. There are 410 signalized intersections within the cities jurisdiction and the city is currently connecting 50 other signals in the region to the system including signals belonging to the state, the county, and other small communities that do not have their own system. The region has 280 intersections connected via voice grade telephone line and fiber-optic cable. The rest of the intersections are connected through spread spectrum radio (9).

Colorado Springs has integrated intersections outside their jurisdiction into their system through separate work stations and a partitioned database. The workstations can mimic the master in all forms, including graphics, in order to view the entire signal system. However, the security system prohibits interference with signals to other jurisdictions (9).

Las Vegas, Nevada

The Las Vegas Area Computer Traffic System (LVACTS) was established in 1983 as one of the only multijurisdictional centralized traffic signal systems in the United States. The LVACTS is an agency that is jointly managed by the City of Las Vegas, Clark County, the City of North Las Vegas, the Clark County Regional Transportation Commission, and the Nevada Department of Transportation. There are 480 intersections connected to the system that was built with federal and state funds. Each agency pays towards the operating cost in proportion to the number of signals it has on the system. Each agency has a monitor and a teletype which it can monitor and control intersections within its boundaries. The LVACTS acts a supervisor to all system signals, allowing signals to be coordinated across city/county boundaries (10).

The LVACTS is currently replacing its highly centralized system with a distributed system. Currently, a large central mainframe computer is being replaced with a network of microcomputers. A very powerful traffic signal controller based on powerful and reliable industrial microcomputers is being installed at each intersection. The new system will be the first large-scale implementation of the Advanced Transportation Controller (ATC) (2).

The LVACTS system designers have devised a two-tiered network of communication to provide LVACTS operators with access to the intersection controllers and video cameras. The system has been divided into nine regions, and all the intersection controllers within each region will be tied to a hub located within the region. These regional hubs will be connected into a backbone communications system using high-frequency microwave. Several different communication technologies are being utilized including data radio, ultra-high frequency microwave, fiber-optic cable, and special equipment to move video signals along existing copper cable to carry video and controller signals from the cameras and intersections to their respective hubs (2).
Agreements for Operation and Maintenance

It is important that agreements between agencies for the operation and maintenance of traffic signals across jurisdictional boundaries benefit both agencies as well as the user of the system. It is important to define liability issues in maintenance contracts when entering such a relationship.

Monroe County, New York

The Rochester/ Monroe County Computerized Signal System was constructed by the New York State DOT and is operated and maintained by Monroe County. There are 360 signals in the system, 60 of which are the belong to the state. Signal timings through the system are developed and implemented by the County without approval needed from the state. Any other changes to the system require approval from the State. The County also maintains the system and the state reimburses the County for work performed and equipment supplied. The County must obtain an annual work permit agreement for maintenance of those parts of the system located in State right-of-way (11).

Arlington, Texas

The City of Arlington has an interlocal agreement to operate and maintain 22 signalized diamond interchanges that are owned by the State. The diamond interchanges along with 5 intersections of the City of Pantego’s have been put on the City of Arlington’s computer signal system. Pantego is a city of around 2,500 people that is completely surrounded by the City of Arlington.

Austin, Texas

The City of Austin has an agreement with Travis County to install, upgrade, and maintain traffic control devices situated within the boundaries of Travis County and not within the boundaries of the City of Austin. A designated contact person within each transportation division is responsible for overseeing the projects and transmitting, receiving, and coordinating information and service requests. The City bills the County for project costs including labor, material, equipment acquisition, equipment operation, computer time, bench time, vehicles, repair and maintenance and indirect costs. The City submits written documentation to the County on the work performed, the manner of performance, and the rate of progress. The City at the expense and request of the County maintains and repairs the County’s system.

The County is responsible for notifying the City of system malfunctions. The City maintains a log of all “trouble calls” received from the County and bills them for all the maintenance and repairs that the City performed. The County can not make any adjustments to the traffic signal operation or the installation design without first notifying the City. If the system malfunctions, the City can make timing adjustments as needed without prior approval from the County. The City must notify and receive approval from the County, though, before making any phasing changes.

The County assumes responsibility for system design, installation, location, and upgrades of all traffic control devices installed or maintained by the City. The County holds harmless the City against all claims, suits, demands, or damages except that which is caused by the negligence of the City.
Summary of Interlocal Agreement Characteristics

Because each urban area in the United States has different philosophies of how signal operation and maintenance should be performed and because there are varying relationships between neighboring jurisdictions, there is no set way of forming an interlocal agreement. As was demonstrated by the various examples of interlocal agreements presented in this paper, there are a variety of options available for these agreements. Interlocal agreements can be as involved as each of the agencies are comfortable with, and each agencies can retain as much autonomy over their signals as they desire. A summary of the characteristics of each of the interlocal agreements discussed in this paper can be seen in Table 1.

The type of system employed by the urban area can range from a highly centralized system utilizing one master computer to control each of the signals such as is currently in place in Las Vegas and Colorado Springs to a decentralized system where control takes place at the individual intersections. Currently, the LVACTS is upgrading the control equipment at each of the intersections to ATCs and will be changing from a highly centralized system to a decentralized system with powerful controllers running each intersection. A commonly used type of system is decentralized using time-based coordination but each of the jurisdictions may have a masters running individual systems in each jurisdiction. Examples of this type of system are in North Dallas County and Orange County where each jurisdiction had a least some of their signals coordinated within the jurisdiction before coordinating them with neighboring jurisdictions (12).

The relationship of the agencies involved in the interlocal agreement can vary, also. For the systems in Orange County and Green River, Washington, there are no controlling agencies. This is in contrast to the LVACTS which was created to control traffic signal operation in the Las Vegas area. Other areas such as North Dallas County and the Seattle area formed a Steering Committee made up of representing traffic engineers from each of the jurisdictions involved. The examples given that had one controlling agency out of each of the agencies involved also included maintenance contracts. These areas were Monroe County, Arlington, and Austin, Texas (12).

The methods of coordination also varied among the different systems examined. For systems with incompatible control equipment, time-based coordination was used. North Dallas County used time-based coordination set in the controller. Orange County and Green River Valley used WWV time to coordinate their signals. The Seattle area has different manufacturer’s equipment throughout each jurisdiction but is currently planning to implement the National Traffic Controller Interface Protocol so that the incompatible equipment can communicate. Systems with compatible equipment employed a number of different communications media including spread spectrum radio, high-frequency microwave, twisted-pair cable, leased communications, and fiber optics. Each of the centralized systems used one or a combination of these technologies (12).
Table 1. Summary of Interlocal Agreement Characteristics.

<table>
<thead>
<tr>
<th></th>
<th>North Dallas Co. TX</th>
<th>Orange Co. CA</th>
<th>Green River Valley WA</th>
<th>Seattle WA</th>
<th>Co. Springs CO</th>
<th>Las Vegas NV</th>
<th>Monroe Co. NY</th>
<th>Arлингтон, TX</th>
<th>Austin TX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Control</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Distrib Control</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No head Agency</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steering Commit.</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate Control Agency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Control Agency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>TBC Cntrlr</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WWV</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spread Spectrum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber Optic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coax</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Leased</td>
<td></td>
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<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Common Protocol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Same Manuf.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Various Manuf.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
BENEFITS OF INTERJURISDICTIONAL COORDINATION

There are many benefits that can be received through interagency cooperation for the operation only or the operation and maintenance of traffic signals. Some of these benefits can be measured and some cannot. A motorist is generally not aware of when they cross jurisdictional boundaries nor would they normally care. Motorists are aware, though, of how well or how poorly the lights that they pass through daily are operating.

Most of the benefits received through coordination of systems across jurisdictional boundaries are benefits to the motorist. Reduced number of stops, reduced delay, and reduced travel time not only save the motorist money but give the motorist a better perception of how well the public agencies are operating their signals. Public agencies not only receive the benefit of better public perception but also establish important communication links between neighboring jurisdictions.

Interjurisdictional coordination is also important today in a time of increasing vehicle demand when agencies do not have the resources to increase capacity on arterials throughout the area. The efficient operation of the arterial street system in an area is important to optimally utilizing the capacity that is available. Congestion on these street systems is increasing as vehicle demand increases. Efficient operation and coordination of traffic signals can reduce fuel consumption and pollutant emissions, thereby providing not only an energy savings but a benefit to air quality. This is important especially today as metropolitan areas are subject to punitive actions if they do not fall below specified pollutant standards as prescribed by the 1991 Clean Air Act Amendments.

Measured Benefits

A few agencies have actually quantified the benefits received from coordination through before and after travel time runs or through the use of computer simulation programs. Table 2 shows the benefits received from coordinating traffic signals through jurisdictions and across jurisdictional boundaries as measured in three urban areas examined in this report.

Saving time for motorists can save money for the motorist. All three of the agencies that quantified these benefits noticed motorist time benefits of decreased travel time, a decrease in overall delay, and an increase in average speed. Travel time savings for motorists ranged from 5.7% to 17% over the various systems. A 32% to 38% savings in overall delay was seen, and average speeds increased from between 8% and 20%.

These before-and-after studies also showed that coordination across jurisdictions can reduce vehicle operating costs by reducing the number of stops experienced through the system and decreasing fuel consumption. The number of stops experienced by motorists decreased from between 42% and 48%. A 5% to 25% reduction in fuel consumption was seen.

Environmental benefits for the area were also quantified. By reducing the number of stops and delay experienced by motorists, pollutant emissions from vehicles traveling through the system can be reduced. A 3% to 25% reduction in pollutant emissions was seen across the various systems.
Table 2. Summary of Benefits Received by Interjurisdictional Coordination (10,6,7).

<table>
<thead>
<tr>
<th></th>
<th>LVACTS</th>
<th>Dallas Co.</th>
<th>Green River Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>-17%</td>
<td>-5.7%</td>
<td>N/A</td>
</tr>
<tr>
<td>Overall Delay</td>
<td>-38%</td>
<td>-33.7%</td>
<td>-32%</td>
</tr>
<tr>
<td>Average Speed</td>
<td>N/A</td>
<td>+8.0%</td>
<td>+20%</td>
</tr>
<tr>
<td>Number of Stops</td>
<td>-48%</td>
<td>-42.7%</td>
<td>N/A</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>-23%</td>
<td>-4.9%</td>
<td>-10% to -25%</td>
</tr>
<tr>
<td>CO Emissions</td>
<td>-24%</td>
<td>-5.2%</td>
<td>-14%</td>
</tr>
<tr>
<td>HC Emissions</td>
<td>N/A</td>
<td>-5.8%</td>
<td>-16%</td>
</tr>
<tr>
<td>NO Emissions</td>
<td>N/A</td>
<td>-4.7%</td>
<td>-3%</td>
</tr>
</tbody>
</table>

N/A - not available
EXAMINING AGENCY OPTIONS WITH AVAILABLE RESOURCES AND PREFERENCES

Agencies wishing to form interlocal agreements should assess the needs of each agency involved in the agreement as well as the resources available to each agency. Depending on the current traffic control equipment that each agency has and the type of control system that is desired for the area, interjurisdictional coordination can be simple to very involved. Table 3 demonstrates a few of the options, benefits, and requirements for different levels of available resources and different agency preferences.

Table 3. Decision Matrix for Sample Agency Requirements.

<table>
<thead>
<tr>
<th>Agency Position</th>
<th>Options</th>
<th>Benefits</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>lack of resources available to maintain signals</td>
<td>• agency can give control of their signals to neighboring jurisdiction</td>
<td>• economies of scale • ‘seamless’ system</td>
<td>• strong legal agreements necessary as to liability and performance</td>
</tr>
<tr>
<td>no master but similar equipment as neighboring jurisdiction</td>
<td>• agency can place signals under master of neighboring jurisdiction</td>
<td>• coordination across jurisdictional boundaries and along arterial where coordination was not previously possible</td>
<td>• additional communications capability set up between master and additional signals</td>
</tr>
<tr>
<td>desire to coordinate signals across jurisdictional boundaries but retain autonomy over signals</td>
<td>• create Steering Committee represented by each agency • hold formal or informal meetings of traffic engineers to decide signal timings</td>
<td>• ‘seamless’ system • with good communications traffic data can be shared across jurisdictions to react to situations areawide</td>
<td>• neighboring jurisdictions must have compatible control equipment or • must use time-based coordination such as WWV time which requires receivers</td>
</tr>
<tr>
<td>desire to create uniform traffic control system that encompasses entire urban area without regard to jurisdictional boundaries</td>
<td>• separate agency can be created to oversee operations of signals • one lead agency can control signal operations</td>
<td>• will create cohesive and reactive system that can be monitored and adjusted across all jurisdictions</td>
<td>• funding arrangements for separate agency, system implementation, and/or system upkeep • extensive communications capabilities required • liability issues</td>
</tr>
</tbody>
</table>
CONCLUSIONS

There will probably be no two urban areas in the United States that are faced with exactly the same situation when trying to coordinate traffic signals across jurisdictional boundaries. The urban areas presented in this paper show only a handful of the examples of interjurisdictional coordination that exist around the country today. It was the intent of this paper to demonstrate some of the issues involved with and technologies available for coordinating traffic signals without regard to jurisdictional boundaries. It was also the intent of this paper to document some of the benefits that have been received by these urban areas.

Benefits that can be received through interjurisdictional coordination of traffic signals include user benefits, environmental benefits, and agency benefits. The coordination of traffic signals across jurisdictional boundaries can reduce stops, delay, vehicle operating costs, motorist time cost, accidents, and fuel consumption. These factors play an important role in reducing vehicle emissions especially in congested and non-attainment areas. Agencies involved in these interlocal agreements receive the benefits of better communications with neighboring jurisdictions and better public perception if the motorist can drive through a ‘seamless’ system. Agencies may also receive the benefit of economies of scale if maintenance agreements are included in the interlocal agreements.

Resolving the legal issues involved with the agreements between agencies could be the longest step in the process of forming interlocal agreements but are important to keeping the relationships between agencies healthy. Good communications between the agencies through the entire process is essential in developing a long lasting relationship. It is important that each agency understand the goals of other agencies in the agreement and that the goals of the entire agreement are defined and agreed on.

It is possible for agencies to retain as much autonomy over their own traffic signals as desired and still achieve interjurisdictional coordination. Jurisdictions that do not have compatible equipment are currently faced with coordinating the traffic signals between the jurisdictions without communication between the signals. The National Traffic Controller Interface Protocol being designed will allow communication between different manufacturer’s equipment in the future, giving these agencies more options. Jurisdictions that do have communications capabilities can share data and even monitor the entire system but may only have access to the signals within their jurisdiction.

There are many issues to be dealt with when trying to achieve coordination across jurisdictional boundaries including institutional issues of the relationship between the agencies involved and technical issues of how coordination can be achieved. Every urban area in the United States will be faced with different issues but there are some excellent examples in various urban areas of how these issues can be dealt with. As long as the needs of each jurisdiction involved are met and communications are kept open, everyone involved should receive benefits from interjurisdictional cooperation for the operation and maintenance of traffic signals.
RECOMMENDATIONS

Coordinating traffic signals within and across jurisdictional boundaries, can provide benefits to the agencies involved and especially to the motorists using the system. Providing coordination can reduce motorist delay and costs as well as help to reduce pollutant emissions caused by uncoordinated systems. This is important to any urban area but especially those concerned with meeting attainment requirements designated by the 1991 Clean Air Act Amendments.

Because there are so many options available for achieving interjurisdictional coordination, this is something that every metropolitan area no matter how large or small has the potential and capability of doing. As it becomes necessary to better utilize the capacity on existing street systems, as the motorist and environmental benefits are understood, and as the technology improves, the importance of interjurisdictional coordination will be more fully realized.

For small cities, it may be financially impossible to purchase equipment needed for the maintenance of traffic signals and for agencies that only have a few traffic signals, it may not be feasible to buy the equipment or keep crews needed to maintain them. Giving control of these signals to a larger neighboring jurisdiction could save money for both jurisdictions under the theory of economies of scale. Money could be saved if it was not necessary for neighboring jurisdictions to each have the equipment necessary for maintenance of traffic signals. It may more difficult, though, for larger agencies to share maintenance due to extra resources that would be needed by one agency to control and maintain a large number of extra signals. An additional factor of response times to breakdowns and problems should be taken into consideration when combining agency resources for the operation and maintenance of traffic signals.

It is recommended for areas that currently do not attempt to coordinate their traffic signals with those in neighboring jurisdictions, that the most important step in this process to take is to begin communication between officials and/or traffic engineers in each of the respective jurisdictions. Open communication is the key to forming any agreements and will benefit both agencies greatly for years. The motorist does not realize that they are crossing jurisdictional boundaries and are the ones to gain the most through interjurisdictional coordination of traffic signals. As was seen in this paper, there are many options available for coordination, and an option should be chosen that each agency involved is comfortable with.

For urban areas that do currently have some form of coordination across jurisdictional boundaries, it is recommended that each agency keep abreast of the new technology. Technology is changing rapidly in the transportation profession and especially in the traffic signal industry. Improved communications media such as fiber optic and spread spectrum radio have significantly improved the communications capability and quality. Significant advancements in the control equipment are also currently taking place. The Advanced Traffic Controller (ATC) is nearing the final stages of development, as is the National Traffic Controller Interface Protocol for the NEMA controllers and the NEMA TS-2 controllers. These technologies should significantly improve traffic control and help to facilitate coordination within and across jurisdictional boundaries.
ACKNOWLEDGMENTS

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Mr. Richard Peterson - Dallas County
Mr. Mike Swires - Washington State DOT
Mr. Frank Dolan - Monroe County, New York
Mr. Barry Marrus - JHK & Associates
REFERENCES


11. Agreement with the County of Monroe, regarding a computerized traffic signal system in Rochester/Monroe County P.I.N. 4750.40

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