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CASE STUDIES

FINAL REPORT

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16. Abstract

Numerous areas throughout the country are benefiting from traffic signal coordination within their own communities and increasingly across jurisdictional boundaries into neighboring communities. There are a number of technical challenges to accomplish traffic signal coordination which include

1) using wireline or wireless interconnection or highly accurate time-based coordinators to provide a common cycle length;
2) systematically optimizing the interval settings for actuated signals and optimizing the parameters of pre-timed signals; and
3) using a computer system or Advanced Transportation Controller to provide real-time traffic-responsive or traffic-adaptive traffic control.

The technical challenges associated with coordinating traffic signals, however, become more problematic when working across operating jurisdictions. It is sometimes difficult to implement technical solutions when there are no operating agreements in place to direct coordination policies. In addition, jurisdictions may have incompatible hardware or traffic signal control standards that inhibit the ability to implement cross-jurisdictional coordination. The five case studies presented in this report demonstrate that cross jurisdictional signal coordination is an achievable goal for any size community regardless of the number of jurisdictions involved, the type of hardware and equipment, or even the philosophical differences in timing approaches. While some agencies enter into formal agreements for maintenance of another agency's signals, informal agreements are more common for coordinating the traffic signal at a common border. The most important factor in achieving coordination across jurisdictional boundaries is not the technical or equipment challenges. The most important factor is cooperation and communications among the agencies. The benefits that can be achieved from cross-jurisdictional signal coordination are not only seen alleviating traffic congestion, improving air quality, and improving safety, but can also be realized in other ways as in the case of Tucson, which has realized cost efficiencies for the purchase and installation of traffic control equipment for region.

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1. EXECUTIVE SUMMARY

Numerous areas throughout the country are benefiting from traffic signal coordination within their own communities and increasingly across jurisdictional boundaries into neighboring communities. Experience shows that interconnecting traffic signals and optimizing the traffic signal timing can result in travel time reductions ranging from 8% to 25%[1[1]] along a corridor or arterial. There are a number of technical challenges to accomplishing traffic signal coordination which include

1) using wireline or wireless interconnection or highly accurate time-based coordinators to provide a common cycle length;
2) systematically optimizing the interval settings for actuated signals and optimizing the parameters of pre-timed signals; and
3) using a computer system or Advanced Transportation Controller to provide real-time traffic-responsive or traffic-adaptive traffic control.

The technical challenges associated with coordinating traffic signals, however, become more problematic when working across operating jurisdictions. It is sometimes difficult to implement technical solutions when there are no operating agreements in place to direct coordination policies. In addition, jurisdictions may have incompatible hardware or traffic signal control standards that inhibit the ability to implement cross-jurisdictional coordination.

A number of agencies have developed innovative approaches to managing the institutional challenges associated with cross-jurisdictional traffic signal coordination. A cross section of lessons learned are shared in the five case studies presented in this report. These case studies can be used by other agencies as models and to provide guidance for establishing successful programs to coordinate traffic signals across neighboring boundaries. The case studies include Philadelphia, Pennsylvania; Montgomery County, Maryland; Monroe County, New York; Tucson, Arizona; and the City of Greenwood Village, Colorado.

The initial criteria for selecting the case study locations were diversity in geographic location, size, technical or institutional focus, and level of system interconnectivity. One source that was used to identify potential communities that met the initial criteria was the FY 2000 update to the Metropolitan ITS Deployment Tracking Survey[2[2]] database. Nearly 30 communities were contacted, and a telephone survey was conducted to determine if the community met additional criteria. The additional criteria included an arterial(s) that crossed at least one jurisdictional boundary; coordination of the traffic signals on the arterial(s); and coordination of the traffic signals across the jurisdictional boundary, no matter what the means.

The telephone survey asked a number of questions including how many jurisdictions were involved in the signal coordination effort, what type of signal equipment was used, and whether any equipment needed to be changed to accommodate the coordination effort. Other questions

1[1] Meyer, M. ed., *A Toolbox for Alleviating Traffic Congestion*, Institute of Transportation Engineers, Publication No. IR-054B, Washington DC, 1997.

2[2] ITS Joint Program Office, FY 2000 Metropolitan ITS Deployment Survey, Federal Highway Administration.

included what type, if any, of communications was used across jurisdictional boundaries, whether any agreements, formal or informal, were put into place; and whether there were any issues to overcome to implement a successful cross-jurisdictional signal coordination project.

The survey team successfully interviewed agencies in 26 locations across the country. The results were summarized, and the locations were categorized by size: large area (more than 500,00 population), medium area (between 250,000 and 500,000 population), and small area (fewer than 250,000 population). Five locations were selected as case studies. Further interviews were conducted, and additional information was collected for these locations. The overwhelming conclusion from each of the locations studied was that there is always a means of overcoming technical or institutional barriers to cross-jurisdictional traffic signal coordination. Furthermore, in all the cases studied, the benefits associated with improving traffic signal coordination outweighed the difficulties encountered in establishing the program.

The five case studies presented in this report demonstrate that cross-jurisdictional signal coordination is an achievable goal for any size community regardless of the number of jurisdictions involved, the type of hardware and equipment, or even the philosophical differences in timing approaches. While some agencies enter into formal agreements for maintenance of another agency’s signals, informal agreements are more common for coordinating the traffic signal at a common border.

The most important factor in achieving coordination across jurisdictional boundaries is not the technical or equipment challenges. The most important factor is cooperation and communications among the agencies. The benefits that can be achieved from cross-jurisdictional signal coordination are not only seen alleviating traffic congestion, improving air quality, and improving safety, but can also be realized in other ways as in the case of Tucson, which has realized cost efficiencies for the purchase and installation of traffic control equipment for the region.

2.1 Philadelphia, Pennsylvania

- 3 agencies – City of Philadelphia lead agency
- Electromechanical, NEMA-type, and Type 170 controllers
- Informal agreements
- Each agency controls its own system
- Information shared verbally
- Each agency is responsible for own timing plans
- Hardwire interconnect and central type system

The city of Philadelphia is the second largest city on the East Coast, with a metropolitan population of 5.8 million.[3[3]] Philadelphia is located in southeast Pennsylvania and is bordered by the Delaware River on the east. The Traffic Signal Unit of the Department of Streets maintains 2,860 signals. The majority of the city's traffic signal controllers are electro-mechanical. These controllers are slowly being replaced with Type 170 controller equipment. The city uses Escort, a centralized distributed traffic control system, to provide time of day to local controllers and a master time clock to provide a timing synchronization pulse to the electromechanical controllers.

The city has several informal agreements with neighboring townships to provide arterial signal coordination. Two agreements have been in place for at least 20 years, with one agreement in place for 31 years. There are no other agreements, written standards, or procedures.

Currently three agencies are involved: the city of Philadelphia, Upper Darby Township, and Springfield Township. In one agreement, three of six intersections are maintained by the township, and three intersections are maintained by the city even though the intersections are outside the city limits. In another agreement, the city maintains 25 intersections for the township, while the township pays for the electricity. In the third agreement, the township's traffic signals are coordinated with the city's system through a hardwire interconnect cable. The city provides a timing synchronization pulse over the interconnect cable to provide coordination. The city has added additional cable and equipment to the intersections within this system to isolate the city's equipment from the township's equipment. This investment ensures any equipment problems within the township system will not affect the operation of the city's system.

The city is interested in agreements with additional townships; however, there are both technical and institutional issues. The majority of the city's traffic signals use electromechanical controllers. Only 600 traffic signal controllers have been upgraded or are scheduled for upgrades (in the next 3 years) to Type 170 solid-state controllers. The townships use NEMA-type traffic control equipment. While this presents some problems, a solution can usually be worked out. Some equipment changes were made to accommodate the signal coordination effort. Institutional

3[3] www.phila.gov, January 2002.

issues seem to be more difficult to work out at times. The smaller municipalities with part-time administrators prefer formal agreements that must be reviewed by their legal counsel. This leads to additional time and effort to structure an agreement that satisfies the legal representatives.

Timing plan changes have been infrequent. Philadelphia usually takes the lead on timing issues. The city currently operates a number of their traffic signals on a single time-of-day plan. Two major corridors with approximately 75 intersections change progression patterns by time of day through offset changes, while phase splits remain the same.

The city believes that the coordination agreement has resulted in an improvement to operations in terms of more consistent speed, fewer accidents, and reduced air pollution. Congestion is minimized, and queue lengths and overall delay are shortened. While the city recognizes the benefits of cross-jurisdictional traffic signal coordination, the same effort to maintain coordination is not seen throughout the region. The maintenance of the traffic signals and the communications equipment by some of the townships is not given the same priority as it is in the city, and coordination may suffer when communication or coordination equipment fails and is not repaired in a timely manner.

2.2 Montgomery County, Maryland

- 3 agencies – no lead agency
- No formal agreements addressing signal timing
- NEMA-type TS 1, NEMA-type TS 2 and Type 170 control equipment
- Each agency controls its own system
- Information shared informally
- Each agency is responsible for maintaining own timing plans
- Common time synchronization (WWV clock)
- 2 central traffic control systems and 1 time-based control system

Montgomery County, Maryland, is located in the Washington, D.C., metropolitan area and shares borders with the District of Columbia to the south and Prince George's County to the east. The county's population is 855,000 residing in a 497 square mile area[4[4]]. The Montgomery County Department of Public Works and Transportation (DPWT), Division of Traffic and Parking Services controls over 700 intersections on their Advanced Transportation Management System (ATMS). The DPWT is responsible for maintaining county-owned and state-owned traffic signals. There is a formal agreement between the Maryland State Highway Administration (MdSHA) and Montgomery County for the maintenance of state-owned traffic signals. This agreement specifies the responsibilities of each party for traffic signal timing and signal operation.

The general public and political leaders in the metropolitan area have been placing an increasing emphasis on providing travelers with a seamless transition between neighboring traffic control systems. Informal agreements that had been in place in the past and fallen into disuse are now being re-evaluated. Currently two efforts are underway in Maryland and the District of Columbia to provide coordination on several primary arterial roadways leading into and out of the District of Columbia.

In one effort, a recent proposal by a land developer to change the signal timing in the Friendship Heights area (a region that straddles the Montgomery County and Washington, D.C., border) as part of a high density land development plan brought the county and the city back to the table to discuss coordination of traffic signals in this area. In the past, county and city traffic signals along Wisconsin Avenue were coordinated through a hardwire interconnect cable to each traffic signal. However, this arrangement fell into disuse many years ago. No records of an agreement for this arrangement appear to exist. As a result of the development proposal, the city and the county began discussing the possibility of again coordinating the traffic signals along two arterial roadways, Wisconsin Avenue and Western Avenue in the Friendship Heights area. The goal is to eliminate unnecessary delays caused by the lack of coordinated operation. These discussions have lead to consideration of additional arterials for future coordination.

4[4] www.co.mo.md.us, January 2002.

The Montgomery County ATMS interfaces with its COMTRAC[5[5]] computerized traffic signal system. This system provides once-per-second traffic signal monitoring and control to each intersection. Traffic signal timing plans are implemented by time-of-day operations and can be overridden manually for special events. Traffic signal control equipment is NEMA-type TS-1 or TS-2 controller units. Communications to each of the intersections is provided over a county-owned fiber optic network.

The District of Columbia, Department of Public Works, District Division of Transportation controls over 1,355 city-owned traffic signals on its QuicNet/4 Advanced Traffic Management System[6[6]]. The QuicNet/4 system is a distributed computerized traffic control system that monitors and stores timing plan data. Timing plans are stored on the local controller but are managed from the central computer by time of day. Timing plans can be overridden manually. The local traffic signal control equipment is Type 170 with BI Tran Systems' Program 215 (fixed-time, interval based control) and Program 233 (actuated control) controller software.

The county and the city have met informally and agreed upon common cycle lengths for the Wisconsin Avenue/Western Avenue coordination effort. Offsets were developed using time-space diagrams to be implemented for the a.m. and p.m. peak periods. One technical issue that needed to be addressed prior to implementing the new offsets was ensuring that the traffic signal systems for both agencies were set to the same time of day. This is being accomplished through the use of WWV clocks and dialup to WWV-referenced clocks. The coordinated timings will be implemented in early 2002. The National Institute of Science and Technology (NIST) radio station WWV broadcasts time and frequency information 24 hours per day, 7 days per week to millions of listeners worldwide. WWV is located in Fort Collins, Colorado, about 100 kilometers north of Denver. The broadcast information includes time announcements, standard time intervals, standard frequencies, UT1 time corrections, a BCD time code, geophysical alerts, marine storm warnings, and Global Positioning System (GPS) status reports.

The second coordination effort is the result of an initiative by the Metropolitan Washington Council of Governments (MWCOG), Traffic Signal Operations Working Group to evaluate the benefits of cross-jurisdictional signal coordination. Two corridors have been selected for evaluation, one in Virginia and the other in the Maryland/Washington, D.C., region. The Maryland/Washington, D.C., corridor is New Hampshire Avenue (Route 650), which traverses three jurisdictions, Montgomery County, Prince George's County, and the District of Columbia. The traffic signals in Prince George's County are owned and maintained by MdSHA.

The state-owned traffic signals are NEMA-type TS-1 and TS-2 and are not part of a central traffic signal system or closed-loop system. These intersections will run time-of-day timing plans through the controller's time-based control feature.

The county, state, and city met informally to determine how to develop and implement coordinated timings. The state agreed to develop the timing plans using the timing optimization program Synchro. The county and city provided traffic signal timing and phasing data; however, it was noted that a common data format will help on future timing projects. The city's use of

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5[5] Eagle Traffic Control Systems, Austin, Texas.
6[6] BI Tran Systems, Inc. A Division of McCain Traffic Supply, Sacramento, California.

fixed-time interval controller software does not always easily translate to NEMA-type phasing conventions. The state has performed travel-time runs to collect “before” data and has completed the timing plan development. Implementation of the new timing plans is expected by the end of February 2002. Each agency will be responsible for its own implementation. The state will perform “after” travel-time runs to evaluate the benefits of coordination.

The reference time for the start of the cycle length is preset by the manufacturer to start the zero point in the cycle based on the number of completed cycle times starting at 3:15 a.m. It has not been determined whether the county or the city’s systems can be adjusted to accommodate the time-based system, or whether the controllers will have to be reprogrammed.

Montgomery County and the District of Columbia have already identified additional corridors for cross-jurisdictional coordination in the near future and, in addition, are working toward developing an interagency protocol for notifying and responding to traffic incidents or other emergencies that affect these corridors.

2.3 Tucson, Arizona

1. ➢ 7 agencies – City of Tucson lead agency
2. ➢ One central traffic control system
3. ➢ Leased lines between central and devices

- ➢ NEMA-type TS-2, Type 170 and 2070 controllers
- ➢ Each agency maintains own signals
- ➢ Each agency develops and implements own timing plans
- ➢ Timing plan data shared with other agencies for timing plan development
- ➢ No formal agreements
- ➢ Monthly meetings through the Pima Association of Governments

The city of Tucson is located in Pima County in southern Arizona and is one of the oldest towns in the United States. The 2000 population was 486,699. The city is 156 square miles in area.7[7] The city of Tucson, Department of Transportation's Traffic Control Center supports the ATMS for the region. The ATMS is one of four integrated components of the ITS Strategic Deployment Plan for the Tucson metropolitan area. The Pima Association of Governments Transportation Planning Division (PAGTPD) coordinates the development and implementation of ITS systems. The objective of the deployment is to provide an ITS program that is regional and seamless in scope.8[8]

In 1996 the Tucson area received a federal grant to study the application and benefits of ITS for the region. Traffic signal coordination was recognized as one of the applications that would provide benefits to the region. However, implementing a computerized traffic signal system for each of the agencies that maintains traffic signals in the region would have been cost prohibitive. The city that maintains the largest number of traffic signals in the metropolitan area and has had a computerized traffic signal system since the 1970s agreed to host the regional traffic control system.

Currently the ATMS monitors and controls over 400 traffic signals for 7 agencies (all of southern Arizona) including Pima County, the Town of Marana, the city of South Tucson, Arizona Department of Transportation, and others through the city's *Icons*9[9] traffic management system. *Icons* is an integrated, centralized hybrid control and management system that supports NTCIP and AB3418 communications protocols.

The central server resides at the city of Tucson. Traffic signals and other field devices communicate with the central server over leased telephone lines. Currently, the system communicates with predominantly NEMA-type TS 2 controllers. The few Type 170 controllers are being phased out, and several 2070 ATC controllers are being installed for test purposes. Each agency is responsible for maintenance of its own field hardware and communication

7[7] www.ci.tuscon.az.us.
8[8] www.pagenet.org/its/its_atms.
9[9] *Icons* is the Trade Mark of Econolite Control Products, Inc. Anaheim, California.

systems.

The shared use of the traffic system allows each agency to more easily coordinate its traffic signals with others and provide a seamless transportation system. Each agency develops, implements, and maintains its own timing plans. The agencies share timing plan data with each other for the development of timing plans on arterials that cross jurisdictional boundaries. Where possible the agencies try to match cycle lengths and adjust offsets accordingly. However, because of philosophical differences in providing left-turn phases and pedestrian movements, it is not always possible to agree upon a common cycle length.

Currently, the city of Tucson operates and maintains the server at no cost to the other agencies. In the future, each agency will have a remote workstation and will be able to monitor and control its signals from its own operations facilities. In addition, a fiber network is planned and will be implemented as additional federal funds become available for ITS deployment.

The monthly PAG meetings are used as forum to discuss the issues pertaining to ATMS. There are no formal agreements yet for operating and maintaining the system.

The most obvious benefits of the regional signal coordination program are reducing travel time and delay. In addition, the PAG and its participating agencies have realized cost efficiencies through pooling of the regional funding resources for the purchase and installation of traffic signal coordination equipment.

2.4 Monroe County, New York

- 3 primary agencies – Monroe County lead agency
- NEMA-type TS 1, NEMA-type TS 2 and Type 179 control equipment
- Central computerized traffic signal system
- Memorandum of Understanding to address maintenance
- Information shared verbally only
- County and State share operations in new Traffic Management Center
- Currently working on Interagency Operations Plan
- Timing plans developed and maintained by

Monroe County located in the Genessee Valley in upstate New York is over 663 square miles in area and has a population of 750,000[10[10]]. The city of Rochester is located within the county. The county's Department of Transportation is responsible for the maintenance of over 735 traffic signal devices in the city and the county. The county is responsible for maintenance of traffic signals on city-owned (360 intersections) and county-owned (240 intersections) roadways and has an agreement with the state for maintenance of 60 traffic signals on state-owned roads.

Traditionally, the county was responsible for maintenance of traffic signals on county-owned roads, the city for traffic signals on city-owned roads, and the New York State Department of Transportation (NYSDOT) for traffic signals on state-owned roads. However, in the early 1970s the county and the city agreed to consolidate services. This resulted in the county taking responsibility for traffic engineering and operations including the maintenance of all city-owned traffic signals. In addition, through a Memoranda of Understanding (MOU) with the state, the county has assumed maintenance of state-owned traffic signals on several arterials where coordination and monitoring are desirable. A flat-rate annual fee has been established for the maintenance of the signals and includes equipment replacement and upgrades. The state continues to maintain a number of isolated and closed-loop or hard-wired systems within the county. In addition, the county maintains a small number of traffic signals in several townships and has similar MOUs for maintenance.

The county has been coordinating traffic signals since the 1970s. In 1978, Sperry Systems Management was contracted to design and implement a computerized traffic control system to improve the county's ability to provide coordination. The system communications uses coaxial cable. The system currently monitors and controls over 360 intersections on a once-per-second basis. The county does not use time-based coordination because of the tendency of the controller time clocks to drift, making it difficult to maintain coordination. The county is in the process of replacing the Sperry system with a Transcore Series 2000 system.

All of the county and city traffic signals are NEMA-type TS-1 or TS-2 controller equipment. The

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10[10] www.co.monroe.ny.us.

NYSDOT controllers are Type 179. The county prefers to replace the Type 179 equipment with NEMA-type equipment when they assume maintenance of the state-owned intersections. However, the county has been able to interconnect some of the state systems into the county traffic control system with the Type 179 equipment.

The county takes the lead for developing and implementing timing plans on those arterials where it is responsible for maintaining all of the traffic signals. This may include county-owned, city-owned, state-owned, or township-owned traffic signals.

Until recently information sharing has been limited. In January 2002, the county and state traffic signal operations moved into a joint Transportation Management Center (TMC). The county was the lead agency in the construction of the joint TMC, which also houses the state police and the airport authority. It is anticipated that information sharing and feedback will improve with the county and state housed in the same facility. In addition, the two agencies are working on an interagency operations plan.

The county anticipates assuming maintenance of an additional number of systems of state-owned traffic signals in the near term.

2.5 City of Greenwood Village, Colorado

- 4 agencies – Denver Regional Council of Governments coordinating agency
- Agreements in place addressing signal timing
- Information shared verbally only
- NEMA-type TS-2 and Type 170 control equipment
- 3 Traffic control systems, 2 different controllers, and 3 types of communications
- Radio, telephone, and fiber optic communications
- Each agency maintains own traffic signal controllers and system
- System time referenced to Universal Time Clock in Boulder
- Timing plans developed and maintained by DRCOG

The city of Greenwood Village is located immediately south of Denver. The city's residential population is approximately 16,000 inhabitants with a "daytime" population of over 75,000 people who are employed in the city.[11][11]

Located within the city of Greenwood Village, Colorado, the primary arterial Arapahoe Road was retimed and coordinated to reduce the delay caused by the traffic signals. This project was led by the Denver Regional Council of Governments (DRCOG) in partnership with the Colorado Department of Transportation (CDOT), Arapahoe County, and the city of Greenwood Village. The project encompassed 24 traffic signals along an 8-mile arterial. Three of the signals are owned by the city of Greenwood. The hardware includes Type 170 traffic signal controllers, and telephone and fiber optic communications are used. The CDOT owns 11 traffic signals using Type 170 controller equipment and communicating using radio. The remaining ten signals are owned by Arapahoe County, using NEMA-type controller equipment and leased telephone communications. The timing plans are based on common cycle length and split patterns, and the reference point is based on the Universal Time Clock in Boulder.

The DRCOG has been working with the CDOT since 1989 on the Traffic Operations Program to coordinate traffic signals on major roadways in an effort to reduce traffic congestion and improve air quality. This program is part of the Traffic Signal System Improvement Program (TSSIP), which has a capital improvement element to fund system hardware improvements and a signal timing improvement element to fund the development of new traffic signal timing plans.[12][12]

One of the Traffic Signal Timing and Coordination Improvement projects sponsored by DRCOG involved installing, retiming, and coordinating 49 traffic signals on 4 arterials in the southeastern metro region and installing a traffic signal system in the city of Greenwood Village. CDOT operates 18 traffic signals on 3 arterials using a Translink system and Type 170 controllers with radio communications in this region. The city maintains 21 traffic signals on 4 arterials with the

11[11] www.greenwoodvillage.com.
12[12] www.drcog.org.

newly installed TCS-II[13[13]] traffic control system. The city uses Type 170 controllers and telephone and fiber optic communications. Arapahoe County maintains ten intersections on one arterial using an Aries System[14[14]] with NEMA-type TS-2 control equipment and leased telephone communications. The system time for each of the three systems is referenced to the Universal Time Clock in Boulder, Colorado, to ensure cycle lengths and offsets are synchronized.

DRCOG collected all of the data and developed the optimized signal timing plans. Each agency was provided the timing plans for its signals for review and comment. Based on the comments received, DRCOG modified the plans and submitted the plans to the local agencies for final approval. The local agencies implemented the new timings. DRCOG checked the plans after implementation to make sure they were implemented correctly and performed travel-time and delay runs to evaluate the performance of the new timing plans. The new timing plans resulted in a 13% reduction in travel time system wide and a 17% improvement in travel speed system wide.[15[15]]

A written agreement is in place that includes the TSSIP. The agreement outlines the establishment of a Traffic Signal Committee made up of traffic engineers and public works officials from the local agencies and an ad-hoc committee. Either of these bodies can propose changes to the TSSIP. The DRCOG Board of Directors approves the plans and any updates that are proposed.

The success of this program depends on the willingness of the local agencies to work together. This sometimes involves compromises and even sacrifices on the part of one or more agencies in achieving a common cycle length. This is made difficult at times because each agency has to answer to its own constituents.

13[13] AECOM Systems Integration Group, Colorado Springs, Colorado.
14[14] Econolite Control Products, Inc. Anaheim, California.
15[15] "Traffic Signal Timing/Coordination Improvements – Southeast Area Arterials", DRCOG Technical Brief, T00-2, Denver, Colorado, March 2000.

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3. SUMMARY AND CONCLUSIONS

The five case studies presented in this report demonstrate that cross-jurisdictional signal coordination is an achievable goal for any size community regardless of the number of jurisdictions involved, the type of hardware and equipment, or even the philosophical differences in timing approaches. While some agencies enter into formal agreements for maintenance of another agency's signals, informal agreements are more common for coordinating the traffic signal at a common border.

Equipment and system differences sometimes pose difficult technical challenges to coordinating traffic signals across boundaries; however, with cooperation between the agencies, these challenges can always be worked out. It is not necessary to have a single system to maintain coordination between systems. Three of the case studies (Montgomery County, Monroe County, and Greenwood Village) have successfully implemented coordination between centrally controlled systems and closed-loop systems or time-based control systems. At the same time, a single system does not mean that one agency has control, as in the Tucson system where multiple agencies use a common traffic control while still maintaining their own field equipment and timing.

As demonstrated in Montgomery County, Monroe County, and Greenwood Village case studies, it is not even necessary to interconnect the intersections or use the same type of communication systems to establish coordination. MdSHA will be using time-based control, and CDOT is using radio communications. Monroe County is using both wireline and wireless communication. All of these case studies demonstrate that wireline and wireless applications can be used to coordinate signals across jurisdictional boundaries.

In each of the case studies, the agencies are coordinating more than one type of traffic signal controller equipment. These studies show that all types of control equipment—NEMA-type, Type 170, Type 2070, and even electromechanical controllers—can be integrated to provide coordination.

The most important factor in achieving coordination across jurisdictional boundaries is not the technical or equipment challenges. The most important factor is cooperation and communications among the agencies. In three of the case studies, the regional government agencies (MWCOG, PAG, and DRCOG) have been instrumental in bringing the agencies together and developing working plans for coordination. To successfully implement cross-jurisdictional signal timing, each of the agencies must be willing to compromise at times to achieve the common goal of a seamless transition across neighboring boundaries. At the same time, each of the agencies must be able to respond to the needs of its constituents. This requires open communication between the agencies.

The benefits that can be achieved from cross-jurisdictional signal coordination are not only seen alleviating traffic congestion, improving air quality, and improving safety, but can also be realized in other ways as in the case of Tucson, which has realized cost efficiencies for the purchase and installation of traffic control equipment for the region.

For the case studies cited in this report, the coordination of traffic signals across jurisdictional boundaries is a win-win situation. The traveler sees a reduction in unnecessary delay, and the agency has fewer complaints to which it must respond.

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