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Interjurisdictional Coordination of Katella Avenue Traffic Signals

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ABSTRACT

INTERJURISDICTIONAL COORDINATION OF KATELLA AVENUE TRAFFIC SIGNALS

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In recent years, transportation planning has been experiencing an escalating emphasis towards increasing capacity and improving traffic management on urban streets and arterials to combat the effects of congestion. One measure which has proven to be particularly effective is the coordination of traffic signals. However, coordination efforts have traditionally been contained within city boundaries, with little or no communication between adjacent jurisdictions. This study details efforts to obtain regional coordination through the cooperative effort of five cities, the county, the state, and a regional funding agency. A traffic signal coordination project incorporating a forty-intersection expanse of a major arterial (Katella Avenue in the City of Anaheim, CA) is documented from concept to implementation. Of particular interest are the financial, administrative, and political implications of coordination, traffic control hardware and software considerations, and coordinated timing plan designs and their impact on traffic flow.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

INTERJURISDICTIONAL COORDINATION OF KATELLA AVENUE TRAFFIC SIGNALS

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1. OVERVIEW

In 1984, the daily costs of urbanized recurrent congestion were estimated at $7.2 million for the southern California region; the comparable 1995 estimate was more than triple this figure. With the costs and implementation times of increases in the freeway infrastructure becoming prohibitive, transportation planning is experiencing an escalating emphasis towards increasing capacity and improving traffic management on urban streets and arterials. Preliminary findings have shown that this approach has the potential of significantly reducing the growing problems that traffic congestion poses on our society

The Transportation Commission of Orange County, California (OCTC) and the City of Anaheim, California recognized the need to increase the vehicle capacity of the existing roadways both within their jurisdictions and in the surrounding areas. Each believed that through effective use of the regions' traffic signals, a measurable improvement in traffic flow could be realized. Through a combination of their respective funding and management capabilities, a cooperative effort to coordinate traffic signals between jurisdictions was undertaken on Katella Avenue, a major Orange County arterial.

1.1 Orange County "Super Streets"

In 1982, OCTC identified the concept of "Super Streets" to enhance mobility within the County. Super Streets are high volume, high capacity, conventional arterials with superior flow characteristics. They capitalize on a variety of measures which eliminate or reduce traffic conflicts, and can lead to substantial improvements in vehicle delay, number of stops, fuel consumption, and pollution emission. OCTC adopted a 220-mile Super Street network in 1984 consisting of twenty-one county arteries crossing city borders and providing for a Super Street or freeway at approximately four-mile intervals.

The twenty-one Super Streets were assigned to priority groups based on existing and future daily vehicle miles of travel and daily vehicle miles of travel per lane mile. Streets given a Priority 1 ranking included Katella Avenue. With the adoption of the network, it was recognized that costs, incompatibility with adjacent land use, and interjurisdictional relationships posed potential barriers to Super Street implementation. Thus, while the potential benefits of the Super Street network increases as the network becomes larger, it was accepted that the larger the network, the more difficult it would be to implement.

1.2 Orange County Unified Transportation Trust

A substantial number of California's transportation projects are funded through Local Transportation Funds (LTF) established by the State's Transportation Development Act. These funds are dedicated to support public transit services; for a number of years, OCTC set aside a portion of the LTF to finance future rapid transit development. OCTC proposed that the interest on this reserve be made available for non-transit purposes while the principal was retained; in 1985, State legislation created the Orange County Unified Transportation Trust (OCUTT) fund for this purpose. The interest on the transit reserves was estimated to be approximately $9 million annually and was administered by OCTC.

With OCTC having embraced the concept of a Super Street network, the entire FY1989-90 OCUTT fund was designated for use on arterial traffic signal coordination projects. Although projects on all major Orange County arterials were to receive consideration, priority was to be given to projects on the designated Super Streets. Due to the regional nature of this network, OCTC actively encouraged interjurisdictional cooperation and gave priority to jointly submitted proposals. Agencies receiving support were required to match OCUTT funds with local funds. Maintenance responsibilities remain with the agency having jurisdiction over the completed project.

1.3 The Anaheim Traffic Management System

The City of Anaheim is home to several major commercial/recreational activity centers, including Disneyland, Anaheim Stadium, and the Anaheim Convention Center, which are all major traffic generators located within a one mile radius of one another. Serious congestion problems were common to both special events and rush-hour traffic affecting visitors, citizens, and businesses alike. After surveying available traffic control technologies, the city selected a centralized system based on FHWA's Urban Traffic Control System (UTCS) Enhanced software. Anaheim's Traffic Management Center (TMC) opened in January, 1990 and can centrally control 400 traffic signals.

1.4 The Katella Avenue Signal Coordination Project

Katella Avenue, a priority-designated Orange County Super Street, is a primary east-west arterial which traverses Orange County from State Route 55 in the City of Orange westward to the Los Angeles County border at Interstate 605, parallel to two regional freeways. Six cities and Caltrans operate traffic signals along Katella; operational and/or financial responsibility for some intersections are shared between adjacent jurisdictions or with the County of Orange.

In response to OCTC's call for traffic signal coordination projects, the City of Anaheim submitted a proposal for the portion of Katella Avenue which extends from State Route 57 at Anaheim's eastern border to Interstate 605. The corridor incorporates a total of forty signalized intersections and is roughly divided by Beach Boulevard, a state route under the jurisdiction of Caltrans. Most of the intersections east of Beach were already operating under UTCS in a coordinated manner; Caltrans and the City of Garden Grove expressed interest in integrating their systems in this section. The cities west of Beach Boulevard proposed installing a closed-loop traffic signal system. The system's field master would be coordinated with Anaheim's UTCS via WWV universal time synchronization. Such time-based coordination negates the need for hardwired interconnect, thus reducing intertie costs.

The project was approved by OCTC in June 1989 at a total cost of $2.16 million; of this amount, OCTC was responsible for $1.3 million, the Super Street Program funded $0.33 million, and the five cities, Caltrans, and County of Orange covered the remaining $0.53 million. The interjurisdictional coordination of arterial traffic signals involves four primary elements: (1) hardware coordination, (2) traffic signal coordination, (3) inter-jurisdictional cooperation, and (4) financial considerations. The Federal Highway Administration sponsored this evaluation of the Katella Avenue case study as part of the Federally-sponsored demonstration of Anaheim's Traffic Management System.

2. PRIOR EXPERIENCE

Cooperation among adjacent jurisdictions to attain higher levels of transportation service is not new to the field of transportation engineering, although experiences coordinating traffic signals at the interjurisdictional level are either few or undocumented.

The barriers to successfully coordinating systems were more often found to be operational than regulatory in nature. Recurrent operational barriers included staffing and funding deficiencies and chronic problems which abound from agency "turfism." Interjurisdictional coordination was found to require a great expenditure of effort. A lack of concerted federal, state, or regional effort to coordinate transportation services was found to be a major hindrance. There are few incentives to and no penalties for not coordinating. This lack of effort and technical assistance from a higher level of government has led to both inadequate funding and project planning. Neighboring jurisdictions are in fact competing for limited funds; fiscal cooperation is further hampered when different jurisdictions have fundamentally different priorities and diverse fiscal capacities.

Governmental agencies have sought to combine their efforts to achieve a higher level of efficiency in a variety of transportation arenas. Both locally and regionally initiated efforts have been identified; conflicting conclusions were offered regarding which of these approaches is preferred. A number of key points which are applicable to all cooperative efforts have emerged, including:

(1) the more players involved, the greater the communication problems;
(2) multi-jurisdictional coordination is time consuming, this is especially important when considering staffing and funding requirements;
(3) it is essential that participants have realistic expectations of what improvements are achievable and what an appropriate time schedule may be for those improvements;
(4) a strong leader and/or a concerted effort at a higher level of government is necessary to ascertain that there is adequate planning and funding to ensure the success of the coordinated system;
(5) there will always be intergovernmental differences, including differences in priorities and funding capabilities;

(6) accomplishments don't end with initial implementation of a project, a level of continued effort is necessary to sustain a cooperative project.

3. AN INSTITUTIONAL PERSPECTIVE

Orange County's twenty-one Super Streets were identified for their potential ability to add capacity to the County's freeway corridors and to perform as high-capacity arterials. Specified to carry high volumes, these routes are expected to carry continuous flows with a minimum of stops and delay. While many cities have coordinated major arterial traffic signals within their jurisdictional boundaries to minimize stops and delay, the Super Streets typically traverse many jurisdictions. Until now, there has been little emphasis by regional or local agencies to coordinate the flow of traffic across jurisdictional boundaries.

The boundaries separating Orange County jurisdictions are political rather than functional. Commercial and residential development flow from one city to the next with little concern for jurisdictional control. The average commute spans several cities and bisects intersections which may be operated by local, County, or State agencies. The lack of coordination between agencies effectively mandates that travellers will encounter stops or delay at each jurisdictional boundary, a de facto policy which has little or no justification.

3.1 Countywide Signal Coordination Plan

In view of the perceived need for interjurisdictional coordination, OCTC commissioned a study to develop a plan for the coordination of traffic signals on Orange County's Super Streets which identified three means of coordinating hardware within the County: (1) implementation of a single master, Countywide traffic signal system, (2) installation of the same manufacturer's master and control equipment in all jurisdictions and intertying of the masters, and (3) utilization of a common time reference for all masters and signal controllers. It was believed that the first two alternatives would be unacceptable to the majority of agencies because, either local authority and control over traffic signals would be reduced, or requirements regarding the purchase and use of proprietary equipment would be imposed. The third alternative was deemed acceptable as it did not impose severe constraints on the individual jurisdictions through requirements of physical interconnection or the replacement of system masters and controllers in order to be consistent with neighboring jurisdictions. The report recommended the use of WWV broadcast time as a common, highly accurate time reference to establish the time of day. With the relatively small expenditure necessary to implement WWV time-based coordination, many of the signals within the County could be made to operate under coordinated control.

3.2 The Selection of Katella Avenue

Having taken steps to install a sophisticated traffic management system, the City of Anaheim looked to its neighbors and within its own arterial network for areas which held potential for coordination. The City contacted all surrounding communities to determine the level of interest in connecting signals to the Anaheim system and found that the majority of these cities were dedicated to their own systems. Anaheim next looked internally and identified Katella Avenue, a designated Super Street which traversed six cities and included intersections under Caltrans' jurisdiction. With the prospect of utilizing WWV broadcast time and coordinating with multiple manufacturer control equipment, Katella Avenue met all of OCTC's funding criteria.

The perceived disadvantages of coordinating Katella Avenue were that it was already coordinated within the City of Anaheim and that inadequate existing interconnect would require some new cable installation. In light of Katella Avenue's potential attraction to OCTC, Anaheim submitted a proposal for the coordination of Katella Avenue; OCTC accepted this proposal and allocated the requested funds for the project.

3.3 The Emergence of Multiple Traffic Management Systems

The Katella Avenue coordination project was originally conceived by Anaheim as a coordination effort tying all intersections along Katella Avenue between State Route 55 and Interstate 605 to the Anaheim Traffic Management System. A number of Anaheim's neighboring agencies were reluctant to relinquish control of their traffic signals to the City of Anaheim; the City of Orange, with jurisdiction over the eastern section of the corridor between State Routes 55 and 57, chose not to participate at all. The cities of Garden Grove and Stanton chose to connect the three intersections between Beach Boulevard and the City of Anaheim border to the Anaheim system. Caltrans elected not to tie the Beach Boulevard/Katella Avenue intersection to Anaheim's system. And the cities west of Beach Boulevard (Stanton, Cypress, and Los Alamitos) chose to install a new master controller and coordinate with Anaheim through a WWV time base. The resulting corridor extended from State Route 57 to Interstate 605, and embodied three alternate traffic control technologies: the Anaheim UTCS traffic management system, a Caltrans Type 170 Controller, and a Traconex Closed-Loop System.

During the planning stages of the Katella Avenue project, Caltrans was prepared to physically interconnect the Beach Boulevard/Katella Avenue intersection to the Anaheim system. While Caltrans' headquarter offices in Sacramento apparently wanted the hardwired intertie, Caltrans' district office chose not to relinquish control of Beach Boulevard to Anaheim since Beach Boulevard plays a more significant role in the County's transportation network. Instead, Caltrans chose to give the Beach master the ability to be accessed by Anaheim and utilize WWV time referencing for coordination.

As with the City of Orange, the western corridor cities felt that actual implementation of a fully-coordinated system was doubtful, and that the likelihood of Caltrans approving a hardwired intertie to Anaheim's system and the dilemma posed by the intersection of two coordinated arterials were significant obstacles to full coordination. The cities of Los Alamitos, Cypress, and Stanton chose to join together in the installation and operation of a closed-loop system and to coordinate with Anaheim through the use of the WWV time reference.

3.4 Rationale for the Anaheim System Intertie

The current emphasis on developing advanced transportation technology, or Intelligent Vehicle-Highway Systems (IVHS), involves the development of advanced traffic management systems (ATMS). Having demonstrated that coordinating traffic signals can improve traffic flow and decrease stops and delay associated with recurrent congestion, traffic engineers are designing systems that respond to nonrecurrent congestion on major traffic networks. Anaheim's traffic management system represents a developing implementation of an ATMS, utilizing centralized traffic signal control, variable message signs, closed-circuit television, highway advisory radio, and special event management. The Katella Avenue project entails collaborative actions between jurisdictions, another characteristic of ATMS.

The City of Anaheim implemented their traffic management system in an effort to actively manage their traffic control system, coordinate with neighboring jurisdictions, and coordinate with freeways with the priority of the overall management of traffic.

3.5 The Role of the Funding Agency

The Orange County Transportation Commission administered $3.9 million of FY 1989-90 OCUTT funding for traffic signal coordination projects, with the objective of improving the flow of traffic in regional corridors. The Commission was less concerned with the physical method of coordination than with the development of lines of communication between agencies, believing that the regional transportation system will be improved with interagency sharing of traffic operations information. OCTC's long-range vision is for a number of traffic operations centers, similar to Anaheim's, to operate in Orange County's major cities; ideally, smaller cities would tie into these traffic operations centers. The centers would then be linked to a larger regional traffic operations center providing one center with a complete regional picture.

4. INTERJURISDICTIONAL COOPERATION

Having made a substantial capital investment in a traffic management system with a primary goal of improving regional traffic flows, the City of Anaheim initiated the OCTC-funded, Katella Avenue traffic signal coordination project. While a total of forty intersections were ultimately coordinated by the project, only three non-Anaheim intersections were actually connected to Anaheim's system as initially envisioned. A primary obstacle cited by agencies to tying into the Anaheim system was the prior investment of both time and money in their own systems. A second obstacle cited concerned the issue of both physical and perceived control.

4.1 Project Management

The City of Anaheim assumed the role of lead agency by submitting the proposal; with the award of OCUTT funds, responsibility was placed with the City for the receipt and expenditure of those funds, and for overall project management. Because of the multi-system nature of the project, the management of the construction projects was divided between the City of Anaheim for the eastern (UTCS) section and with the City of Los Alamitos for the western (closed-loop system) section. The City of Anaheim hosted monthly project meetings where representatives from each agency discussed the progress of the project together with operational and policy concerns which arose.

4.2 Responsibility / Liability Issues

Many of the potential liability issues of interjurisdictional traffic signal operations were already identified; OCTC recognized that many Orange County cities already share jurisdiction for specific intersections with other agencies due to political boundaries. Consequently, cooperative maintenance agreements are common. The key legal issue is perhaps the liability for personal injury and property damage. Interagency agreements must define the legal accountability and liability of all parties. Three major documents addressing these issues were developed; the corridor agencies found the iterative process of writing and approving agreements to be particularly long and cumbersome.

The Memorandum of Understanding is a non-binding document which defines the multi-agency project. It was signed as a "show of good faith" by each of the participants to implement a coordinated signal timing plan and operate under the plan for a "fair" period of time. It was also written to help each agency establish a defense for the project in the event of any adverse pressure from the City Council or the general public.

The Interagency Signal Coordination and the Operations and Maintenance agreements are formal documents which: (1) define the responsibilities and specify the share of costs for each agency, (2) state agency responsibilities for the maintenance of the traffic signals, (3) call for a review of the system operations at regularly intervals, (4) specify that signal timings be mutually established and not modified without notification to and approval by all agencies, (5) require notification in the event of system failure, and (6) contain a "hold harmless" provision relative to mutual liability.

4.3 Financial Responsibility

The two lead agencies prepared estimates for the design and construction costs for their respective systems, and the City of Anaheim estimated the development costs for the signal timing plans. Each agency received an estimate of its total financial responsibility for the project at the time of the proposal submittal and accepted this responsibility by signing the signal coordination agreements.

Financial considerations that were not specified included cost overruns and the provision of funds to maintain the systems. Because responsibility for costs over the estimated budget were not specified, the lead agencies risked assuming responsibility for these costs as the contracting agencies. While overruns did not play a significant factor in the Katella Avenue project, this was a risk that the City of Anaheim recognized and was willing to assume, if necessary.

4.4 Project Administration

As lead agency, the City of Anaheim absorbed the responsibility for a majority of the administrative functions, and the City of Los Alamitos assumed responsibility for those functions that were unique to the closed-loop system. The administration of this multi-agency project proved to be much more time consuming than anticipated, due in part to a lack of precedence in developing legal agreements, the necessary review and approval delays of city attorneys and councils, and complexities in tracking project finances which was compounded by the number of agencies involved. Initially scheduled to be completed fourteen months after the notice of project approval from OCTC, the timing plans were implemented twenty-six months after the start date.

4.5 The Development of Signal Timing Plans

An engineering analysis of the corridor was performed, followed by round-table discussions of the analysis by project members. Individual agencies were reluctant to implement changes, lengthening the plan development process. A significant contributing factor to this delay was the multitude of possible combinations of system configurations.

The decision-making process incorporated a combination of the corridor analysis, individual and agency expertise and preferences, and compromise. The selected timing plans were not necessarily the plans that were most effective at decreasing arterial delay and travel times; rather, they were the plans that blended the need to achieve these goals while simultaneously fulfilling agency policy requirements.

4.6 The Cooperative Effort

Project participants was interviewed regarding the cooperative effort; each concluded that the project was a success on several levels. First, the project achieved its goal of improving the flow of traffic across jurisdictional boundaries, and traffic flow also was improved within jurisdictions. Capital and infrastructure improvements within the various jurisdictions were funded, and an application of centralized control in the City of Anaheim demonstrated the potential in regional coordination. The participants believe that the success of the project was due to the high-level of cooperative effort between agencies, the performance in project administration by the City of Anaheim, and the expertise of the various project participants.

The project took nearly 40 months of effort from the pre-proposal stage to the time of implementation. All participants agreed that the project will take continued effort from each agency to maintain the benefits achieved through coordination and all believe that the project agreements will remain as viable documents in the future.

5. TRAFFIC SIGNAL TIMING STUDY

A series of interjurisdictional traffic signal timing plans were developed with the TRANSYT-7F simulation model. Incorporated in the implemented timing plans were jurisdictional policies and the experience and judgement of the engineers representing the participating agencies.

It was demonstrated that arterial performance measures improve with higher cycle lengths and the improvement rate decreases as the cycle length increases. It was also shown that as cycle length increases, cross street queue lengths increase. This suggests that there is a boundary of cycle lengths within which an arterial will operate efficiently, and within this boundary there are trade-offs between various performance measures.

Alternate phasing and optimization strategies were explored and the resultant performance measures were evaluated by the corridor agencies. To facilitate the adoption of a timing plan, each agency formulated specific goals and criteria with which to evaluate the timing plans; the compilation of the various agencies' goals and criteria resulted in the development of four alternate time-of-day timing plans, two of which incorporated two subsystems operating at different cycle lengths.

"Before" and "after" time and delay studies were undertaken, the analysis of which demonstrated an average AM peak period arterial travelling speed of 30 mph, representing a 30.5 percent decrease in arterial delay. The previously uncoordinated sections of the arterial experienced the greatest improvement in stops and delay and the previously coordinated sections the least. However, the previously coordinated sections were improved significantly, highlighting the need to monitor and update coordinated timing plans as traffic flows change.

Finally, the areas immediately bordering and affected by the break in cycle lengths experienced significant improvement in performance. This suggests that large or diverse networks may be coordinated with timing plans which incorporate more than one cycle length within the network. In addition to suggesting that the constraint of a single cycle length may offset some of the benefits of coordination, it also suggests that when agencies are not in full agreement on timing policies or strategies, timing plans can be developed around these differences and improvements will be realized.

6. SUMMARY, FINDINGS, AND RECOMMENDATIONS

The purpose of the Katella Avenue case study has been to address the primary elements of interjurisdictional traffic signal coordination: (1) traffic control hardware, (2) signal timing plans, (3) interjurisdictional cooperation, and (4) financial considerations.

6.1 Traffic Control Hardware

The coordination of Katella Avenue resulted in the linking of three different control system technologies. Several issues were identified relative to hardware design. The issue of physical control was perhaps the primary consideration which led to the development of the four alternate control systems. For the most part, municipal agencies are reluctant to transfer control of their traffic signals to another agency unless there is an overwhelming advantage to be gained from such a transfer. While agencies have no objection to sharing information from their traffic control systems, this sharing can not interfere with the jurisdictional agency's accessibility to their signal control.

Each agency with jurisdictional control over traffic signals included in this project has made a substantial investment in their existing hardware. These control systems, manufactured by a variety of vendors, can not in general be integrated due to the incompatibility of their communications systems. Thus, full integration of neighboring traffic control systems requires either the replacement of existing local controllers or a new understanding between the controller manufacturers and traffic management systems.

Centralized control allows an entire network to be viewed and, theoretically, coordinated as one contiguous system. In addition to allowing for traffic responsive control, a control strategy which is also available with distributed systems, centralized control can accommodate the needs of more sophisticated IVHS technology. The City of Anaheim implemented its Traffic Management System with the intent that it would evolve with IVHS technology. The City realized a need to manage traffic on a regional rather than a strictly local basis, and was willing to both sacrifice some of the user-friendly features of smaller systems as well as to dedicate full-time personnel to actively managing their traffic system. However, as was demonstrated by those cities which decided not to participate in the project, and by the implementation of the closed-loop system, some traffic engineers are not convinced that the benefits of centralized control outweigh the disadvantages. It has not yet been adequately demonstrated that actively managing traffic yields better results than does the implementation of good timing plans.

6.2 Signal Timing Plans

A primary objective of the Katella Avenue project was to coordinate the timing of forty traffic signals across seven jurisdictions. For a combination of technical and institutional reasons, a result of the coordination effort was the operation of two individually coordinated subsystems during the AM and PM peak periods. In addition, the TRANSYT-7F analysis of the corridor suggested that an arterial may be able to sustain some level of non-coordination across boundaries (political or otherwise) without realizing a perceivable degradation in performance. This introduces the questions of what criteria should be used to divide the system, and whether coordination across jurisdictions or control systems is justified (and at what expense). Neighboring jurisdictions already recognize areas where coordination would prove expedient and do take steps locally to achieve coordination when it is beneficial.

The "before" and "after" time and delay studies demonstrated that the efficiency of traffic signal timing plans is ultimately dependent on timing plans being updated as traffic flows change over time. The need for timely data to produce optimized signal timing plans may justify the implementation of communications intensive systems due to their potential to collect data and indicate when timing plans should be revised. Coordinating traffic signal increase arterial capacity, which can induce increased demands along the corridor. Thus, timing plans which produce significant flow improvements can become outdated more quickly than what typically might be expected.

6.3 Interjurisdictional Cooperation

Complementing the technical considerations of coordinating traffic control hardware and timing plans was the cooperative effort necessary from all involved jurisdictions. Identified obstacles to cooperation included: (1) varying opinions on system benefits, (2) communication complications, (3) increases in administrative responsibilities, (4) scheduling problems, and (5) the need to maintain the coordinated systems. Agency "turfism" and a lack of effort at a higher level of government played only minor roles in the Katella Avenue coordination effort.

The Katella project resulted in three hardware technologies being coordinated. Strong proponents for each technology were present at both the east and west sections of the corridor, and with Caltrans at Beach Boulevard. As Caltrans was concerned with only a single intersection, the cooperative effort was concentrated between two section proponents. While OCTC financed a substantial portion of the project, they did not provide technical assistance. Given the financial incentive to implement a coordinated timing plan, the agencies were left on their own as to how to proceed.

The need for strong project leadership was met on several levels. The City of Anaheim succeeded in organizing the cooperative effort and, through their management of the project, ensured that the project was successfully implemented. The City's engineering staff garnered the support of the City Council, who authorized a significant expenditure of funds both for the project and for the Traffic Management System.

What remains to be seen from this effort is how well the agencies will continue to cooperate when there is no longer a financial incentive to work together.

6.4 Financial Considerations

The Katella Avenue project was possible due to the existence of a regional funding source, without which the corridor would have continued operating with little communication between and with deficient hardware within some of the jurisdictions. A significant opportunity to learn from the funding of thirty-eight other projects has been missed because OCTC requested no final report of the benefits achieved or the problems encountered from the participating agencies.

The funding agency had no technical expertise in the area that it was funding; consultants assisted OCTC in proposal evaluation but considered only estimated costs, not project viability and potential benefits. The OCUTT program was promoted as a traffic signal coordination program, yet, a significant portion of the Katella Avenue funds were spent on design studies and new infrastructure. Not all eligible agencies applied for funds with the restrictions that OCTC first mandated, but then changed, reducing the overall level of competition in the award process. If traffic responsive control is implemented as planned in the UTCS section, then the corridor will be effectively uncoordinated between systems. The decision to implement traffic responsive control, a decision which was made possible partially due to OCTC's funding of the UTCS infrastructure, seems to conflict with the published intent of the original program.

OCTC's main criterion for project funding was that coordination be achieved across jurisdictional boundaries, yet no criteria for improvement in traffic performance were set. The City of Anaheim selected Katella Avenue for coordination based on OCTC's criteria when, possibly, the coordination of a previously uncoordinated arterial may have had a greater impact on both local and regional traffic flow. If an external source does fund traffic signal coordination projects, it is suggested that the various agencies' interest in participating should be established prior to funding. Also, to achieve the greatest possible benefits from the available funds, each proposal should clearly document the projects objectives, methods to achieve those objectives, and criteria to assess the effectiveness after implementation.

CHAPTER 1: OVERVIEW

1.1 THE PROBLEM

In 1984, the daily costs of urbanized recurrent congestion were estimated at $7.2 million for the southern California region. The comparable 1995 estimate was more than triple this figure in constant dollars (SCAG, 1987).

Recurrent congestion, defined as the additional daily (i.e., weekday) travel time arising from reduced operating speeds caused by traffic volume surges, costs individuals and businesses in the form of travel time delay. This equates to lost time and productivity, and increased fuel consumption, which contributes to the declining air quality and U.S. reliability on oil imports. With the costs and implementation times of expanding or building freeways becoming prohibitive, transportation planning is experiencing an escalating emphasis towards increasing capacity and improving traffic management on urban streets and arterials. Preliminary findings have shown that this approach has the potential of significantly reducing the growing problems that traffic congestion poses on our society (Christiansen & Ward, 1988; JEF Engineering, 1982; SCAG, 1988; U.S. Department of Transportation, 1986).

The California Energy Commission (1984) estimates that fuel consumption on signalized streets accounts for over 30 percent of the state's total annual petroleum use. The California Department of Transportation (Caltrans) states that approximately 43 percent of the fuel used on signalized streets in urban California is lost in stop-and-go driving and idling. In suburban areas, where signals are more widely spaced, approximately one-third of the fuel used is due to stops and delay. In light of these statistics, Caltrans instituted the Fuel Efficient Traffic System Management (FETSIM) Program and found that improved traffic signal timings reduced vehicular delay and stops by 15 to 16 percent, travel times by 7.2 percent and cut fuel use by 8.6 percent (Skabardonis, 1988).

1.2 A CASE STUDY

The Transportation Commission of Orange County, California and the City of Anaheim, California recognized the need to increase the vehicle capacity of the existing roadways both within their jurisdictions and in the surrounding areas. Each believed that through effective use of the regions' traffic signals, a measurable improvement in traffic flow could be realized. Through a combination of their respective funding and management capabilities, a cooperative effort to coordinate traffic signals between jurisdictions was undertaken on Katella Avenue, a major Orange County arterial.

1.2.1 Orange County "Super Streets"

In 1976, the California State Legislature created the Orange County Transportation Commission (OCTC)[1] to provide for local decision making on

[1]A 1991 reorganization combined OCTC with other county transportation agencies creating the Orange County Transportation Authority (OCTA).

transportation issues. The Commission is responsible for short-range capital and service planning for transportation projects within the County and determines how state, federal, and certain local transportation resources available to the County are to be allocated.

In 1982, OCTC identified the concept of "Super Streets" to enhance mobility within the County. Super Streets are high volume, high capacity, conventional arterials with superior flow characteristics. They capitalize on a variety of measures which eliminate or reduce traffic conflicts such as:

(1) traffic signal coordination
(2) removal of on-street parking
(3) bus bays or bus stop relocations
(4) access limitation - right turns only, or no access (streets and/or drives)
(5) lane restriping
(6) median modifications
(7) spot widening
(8) pedestrian grade separations
(9) intersection grade separations
(10) grade separated turning movements

Having commissioned a feasibility study (JEF Engineering, 1982) which found implementation of the high flow arterial concept could lead to substantial improvements in vehicle delay, number of stops, fuel consumption, and pollution emission, OCTC adopted a proposed 220-mile Super Street network in 1984 (see Figure 1-1). The network consists of twenty-one county arteries crossing city borders and it was selected on the basis of its ability to provide:

(1) freeway corridor replacements or freeway linkages,
(2) additional capacity in freeway corridors, and
(3) high-capacity arterials at regular intervals.

The designated network provides for a Super Street or freeway at approximately four-mile intervals and, as Super Streets are intended to carry continuous flows, no Super Street was specified with a length of less than four miles.

The twenty-one Super Streets were assigned to priority groups based on existing and future daily vehicle miles of travel (DVMT) and daily vehicle miles of travel per mile (DVMT/Mile). Five streets were given a Priority 1 ranking:

(1) Beach Boulevard
(2) Pacific Coast Highway
(3) Harbor Boulevard
(4) Imperial Highway
(5) Katella Avenue

With the adoption of the network, it was recognized that costs, incompatibility with

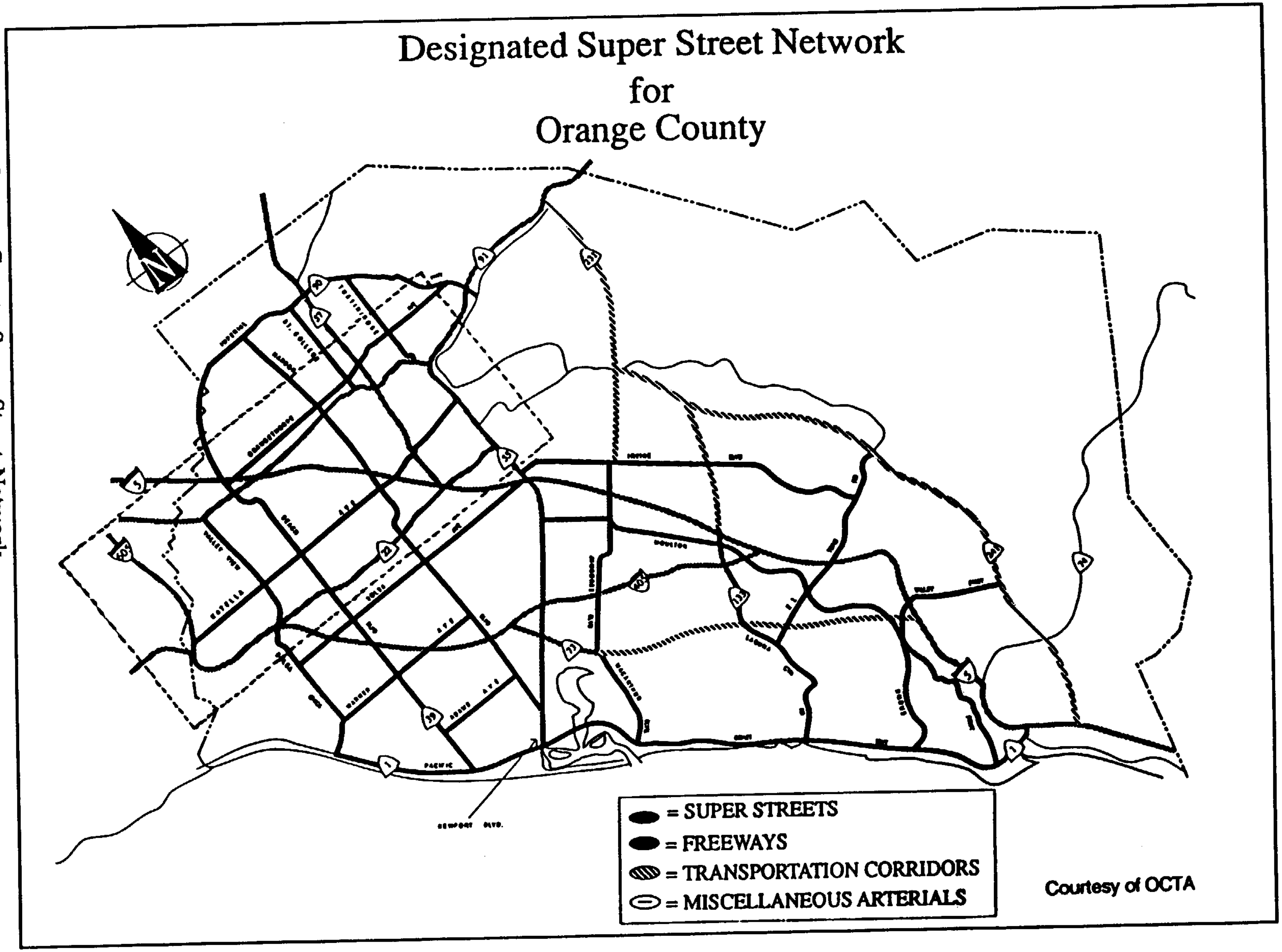

Figure 1-1. Orange County Super Street Network

adjacent land use, and interjurisdictional relationships posed potential barriers to Super Street implementation. Thus, while the potential benefits of the Super Street network increases as the network becomes larger, it was accepted that the larger the network, the more difficult it would be to implement.

1.2.2 Orange County Unified Transportation Trust

In addition to the prospective financial burdens of implementing a new county-wide program, OCTC critically needed to generate funds for transportation improvements to forestall the deterioration of the Orange County infrastructure. In 1984, the Commission estimated that $191 million was required as a one-time expense to bring the streets and roads system up to standards and an additional $23 million annually was needed to maintain them (OCTC, 1984).

A substantial number of California's transportation projects are funded through Local Transportation Funds (LTF) established by the State's Transportation Development Act. One quarter of one cent of the six cent retail sales tax collected in each county is deposited in the LTF. These funds are provided to support public transit services and expenditures of these funds on streets and roads in the more populous urban counties is prohibited. In less dense counties, expenditures for the maintenance, construction and operation of local streets and roads is permitted if there are no unmet transit needs; Orange County falls within the more populous, urban category.

OCTC and the Orange County Transit District (OCTD)[2] set aside a portion of the LTF for a number of years to finance future rapid transit development. A major source of new funding was unearthed when OCTC proposed that the interest on this reserve be made available for streets, roads, and freeway purposes while the principal was retained for rapid transit projects. In 1985, State legislation created the Orange County Unified Transportation Trust (OCUTT) fund for this purpose. The interest on the rapid transit savings account was estimated to generate approximately $8.5 to $9 million annually. The funds are administered by OCTC as empowered by the Governor of California. The state legislature reauthorized OCUTT funding in the fall of 1987 and provided for continued use of the interest on the rapid transit reserve until the principal expires. Under the reauthorized program, OCTC issues a call for projects annually to the County of Orange, the cities, and Caltrans.

With OCTC having embraced the concept of a Super Street network, and with the recommendations of an OCTC-commissioned county-wide signal coordination study, the entire FY1989-90 OCUTT fund was designated for use on arterial traffic signal coordination projects. Improvements for approximately 430 traffic signals were approved for OCUTT funds for the 1989-90 year.

Although projects on all major Orange County arterials were to receive consideration, priority was to be given to projects on the designated Super Streets. Due to the regional nature of the Super Street network, OCTC actively encouraged interjurisdictional cooperation and would give priority to jointly submitted proposals.

[2]OCTD merged into the Orange County Transportation Authority (OCTA) in 1991.

Candidate projects were also to be evaluated on the basis of the number of signals coordinated, justification, coordination of existing rather than new signals, financial need, and the relationship the project had on the regional system.

Local agencies receiving OCUTT funds were required to match the sum of the construction funds with funds of their own. OCUTT would fund design costs up to fifteen percent of the total construction costs and construction engineering costs up to ten percent of the total construction costs. Responsibility for upkeep and maintenance of the project lies with the agency having jurisdiction over the completed project. Also, funded projects needed to be in a state of readiness, as OCUTT funds were required to be spent within one calendar year of the award.

Items eligible for funding included installation of communications interconnect between signals and master computers, interties between existing masters, expansion of masters to tie together a coordinated system, traffic signal detector loops, and development of signal timing in conjunction with hardware improvements. New master equipment was omitted from this list in order to encourage jurisdictions without master control equipment to place their signals under the control of master equipment in adjacent jurisdictions. Single signals, signal display equipment, and roadway and geometric improvements were designated as ineligible in order to realize OCTC's objective of funding projects which directly improve coordination rather than general signal/roadway improvement[3].

1.2.3 The Anaheim Traffic Management System

The City of Anaheim, located in the northern half of Orange County, is home to several major commercial/recreational activity centers. Disneyland attracts 15 million visitors annually and 70,000 seat Anaheim Stadium is home for the California Angels baseball and Los Angeles Rams football teams. The Anaheim Convention Center services industry by providing meeting and conference facilities. These three activity centers, all major traffic generators, are located within a one mile radius of one another. Interstate 5, which bisects the County, is the primary means of access to this area.

With Anaheim's growth as an entertainment/trade center, the city experienced a boom in both the hotel industry and traffic congestion. Serious congestion problems were familiar both to special events and to rush-hour commuter traffic affecting visitors, citizens, and businesses alike. "Vision 2000," a survey distributed to city residents, identified traffic congestion and funding of traffic improvements as Anaheim's first and third major concerns, respectively.

The City Council formally adopted the "Vision 2000" results and the Public Works and Engineering Department embarked on a search for a complete traffic management program which would accommodate planned city growth. After surveying the available technologies and support, the city selected a computerized system based on

[3]The LTF transit reserve principal which generates the OCUTT funds has been steadily depleted. The dedication of funds to signal coordination projects (as in FY1989-90) has not been repeated.

the Federal Highway Administration's (FHWA) Urban Traffic Control System (UTCS) Enhanced software and contracted JHK & Associates as their system manager.

UTCS software runs on a 3212 Concurrent/Perkin-Elmer minicomputer which was installed in Anaheim's Traffic Management Center (TMC) in January, 1990[4]. The system can centrally control 400 traffic signals, 1600 system detectors, and 35 changeable message signs. It currently has the capability of controlling CSC T-1 and Caltrans Type-170 controllers. Personal computers are utilized for data base management and color graphics monitors display real-time signal information. The signal timing of all on-line traffic signal controllers can be changed through the central control at the TMC. Volumes, occupancies, and speeds can be displayed on the graphics screens where inductive loop detectors have been installed approximately 100-250 feet from an intersection approach. Traffic can also be viewed through closed circuit television (CCTV) at specially equipped intersections.

The graphics monitor displays four levels of information: regional highway network, Anaheim area network, Anaheim subnetworks, and individual intersections. The UTCS Enhanced software polls each intersection once-per-second and reports information from field signal controllers and detectors back to the TMC. Thus, TMC traffic engineers are made aware of signal controller status on a real-time basis.

1.2.4 The Katella Avenue Signal Coordination Project

Katella Avenue, one of the five Orange County Super Streets designated with a Priority 1 ranking, is a primary east-west arterial which traverses Orange County from State Route 55 (SR-55) in the City of Orange westward to the Los Angeles County border at Interstate 605 (Figure 1-2). It parallels State Route 91 (SR-91) to the north, and State Route 22 (SR-22) to the south. Six cities and Caltrans operate traffic signals along Katella. In addition, operational and/or financial responsibility for some intersections is shared between adjacent jurisdictions or with the County of Orange.

In response to OCTC's call for traffic signal coordination projects, the City of Anaheim, as lead agency, submitted a proposal for the portion of Katella Avenue which extends from State Route 57 at Anaheim's eastern border to Interstate 605. The corridor incorporates a total of forty signalized intersections and is roughly divided by Beach Boulevard, a state route (SR-39) under the jurisdiction of Caltrans. The City of Orange, situated between State Routes 57 and 55, elected not to participate in the project.

Most of the intersections in the eastern portion of the corridor (i.e., those within the City of Anaheim) were already operating under the UTCS in a coordinated manner. Caltrans and the City of Garden Grove, who with the City of Anaheim encompass the eastern portion of the corridor, expressed interest in integrating their systems with Anaheim's. It was proposed that this would be accomplished by writing software and developing an intertie system to allow Garden Grove's Multisonics master controller and

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[4]The Anaheim TMC has continued to expand in operations and scope, and has recently moved to a more advanced facility. In 1992, the City became a site for the Caltrans ATMS Advanced Testbed Project conducted by ITS, Irvine.

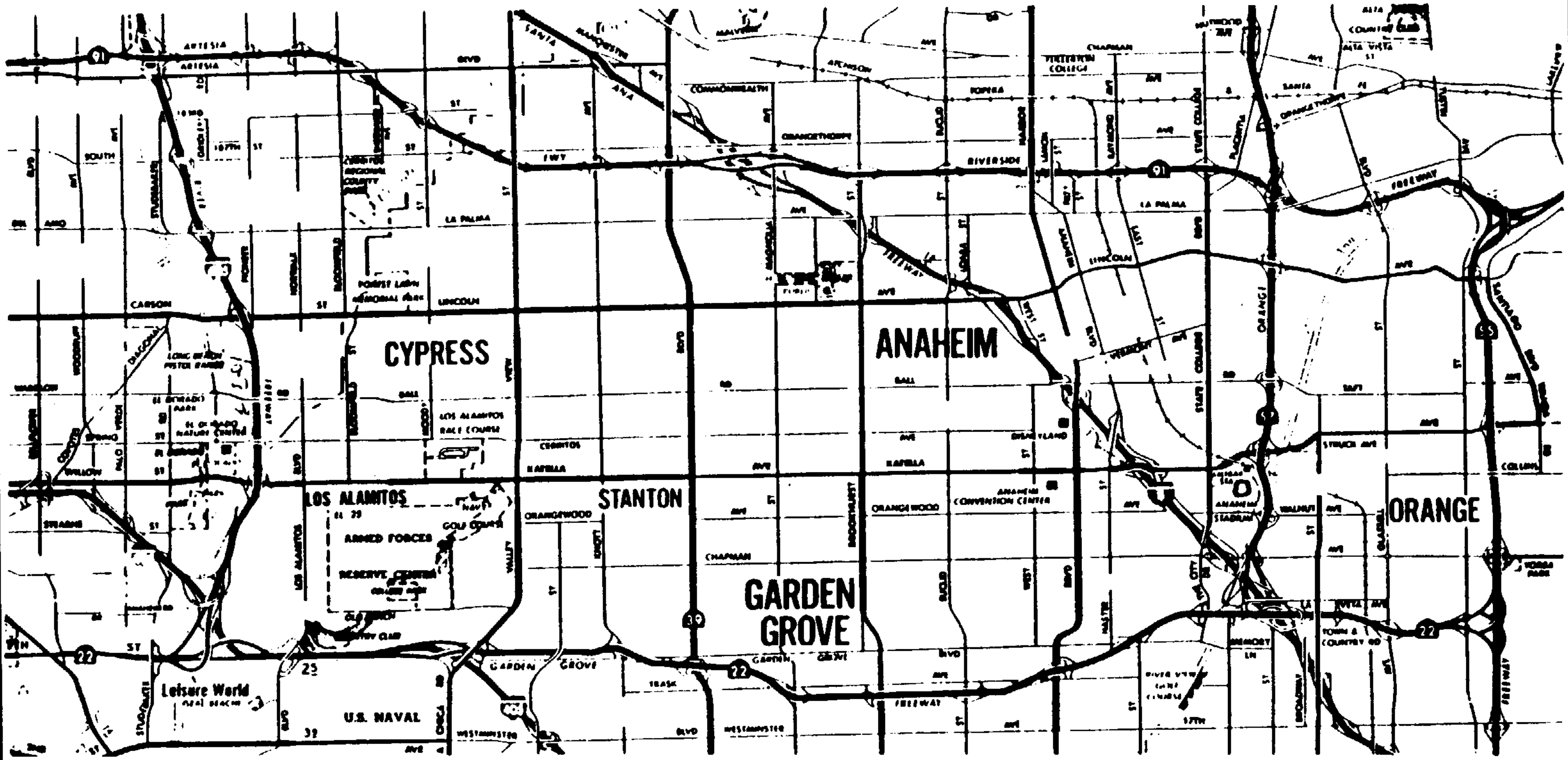

Figure 1-2. Katella Avenue

Caltrans' Type-170 controllers to communicate with Anaheim's central computer.

The cities west of Beach Boulevard (i.e., Los Alamitos, Cypress, and Stanton) proposed installing a Traconex closed-loop traffic signal system utilizing NEMA-type controllers. The system's field master would be equipped with a precision radio receiver which continuously receives Coordinated Universal Time (UTC) as broadcast by the National Institute of Standards and Technology over stations WWV and WWVH from Colorado and Hawaii. This time reference capability, from here on referred to as WWV, would enable the Traconex field master to coordinate with Anaheim's UTCS. The installation of a new master controller was approved for this portion of the corridor on the basis that the master controller would be utilized by three jurisdictions, and through time-based coordination, would negate the need for hardwired interconnect between the western and eastern portions of the corridor, thus reducing intertie costs.

In addition, Anaheim requested that the 50/50 construction funding split, and the limit on the design costs, be altered and proposed a funding formula which would result in OCUTT being responsible for 75 percent of the total project costs. The request was based on a combination of the high costs of communication cable needed to tie the intersections to the central computer, the expense of central computer hardware and software modifications necessary to accommodate the additional jurisdictions, and the ability of the participating agencies to fund the project. OCTC did not approve the use of additional OCUTT funds on the basis that such approval could set a precedent for agencies lacking financial resources to request the same type of agreement. However, because Katella Avenue is a designated Super Street, OCTC's Technical Advisory Committee recommended using funds from the Super Street Program to fund the additional monies needed to obtain a 50/50 match. The project was approved by OCTC in June 1989 at a total cost of $2,164,690. Of this amount, OCUTT was responsible for $1,303,465, the Super Street Program funded $330,600, and the five cities, Caltrans, and County of Orange covered the remaining $530,625.

1.3 PURPOSE AND ORGANIZATION OF THE STUDY

The interjurisdictional coordination of arterial traffic signals involves three primary elements:

(1) hardware coordination,
(2) signal coordination, and
(3) interjurisdictional cooperation.

The coordination of all three of these elements is, in general, problematic. In an effort to better understand the potential obstacles and advantages to coordinating these elements, the Federal Highway Administration (FHWA) sponsored this documentation and evaluation of the Katella Avenue case study as part of the Federally-sponsored demonstration of Anaheim's Traffic Management System.

The documentation and evaluation of the project led first to a review of earlier studies of cooperative transportation improvement efforts. These studies were reviewed to identify previously recognized obstacles to multi-jurisdictional projects together with strategies and recommendations for successful implementation of such projects. Documented studies of cooperative efforts included projects involving public transportation services, capital improvements, and one traffic signal coordination endeavor. These are briefly described in Chapter 2 (a more complete review can be found in Neenan, 1991).

Second, data was collected through: a review of background documents (e.g., reports, letters, proposals, etc.), surveys administered to project participants, interviews with project participants (both participating agencies and hired consultants), and attendance at project meetings. From this data, an understanding of both the compatibility of the respective systems' traffic control hardware, and the institutional implications of coordinating traffic signals and traffic signal hardware was developed and is presented in Chapter 3.

Chapter 4 synthesizes much of the collected data and describes the cooperative effort that was necessary to successfully implement a multi-jurisdictional traffic signal coordination project. Issues regarding liability and financial responsibility are addressed, as are the demands of the management and administration of the project.

A description of the signal timing plan development process, and the results of before and after time and delay studies, comprise Chapter 5. The development process focuses on an analysis of the corridor with the TRANSYT-7F computer model (McTrans, 1988), and on the ability of the participating agencies to agree upon a coordinated timing plan. The time and delay study analysis explores the effects of the coordinated timing plan on the corridor as a whole, and on individual sections of the arterial. A detailed technical presentation of additional simulation modeling performed to identify marginal contributions to system performance provided by interjurisdictional coordination of Katella Avenue is contained in Appendix A. This is accomplished by estimating certain performance measures for the system through TRANSYT-7F simulations of the corridor operating under interjurisdictionally coordinated conditions and under three alternate coordination strategies. The performance measures of the interjurisdictionally coordinated system are then compared to each of the alternate systems' performance measures to ascertain what gains in system performance were achieved. The alternate coordination strategies explored included:

(1) within, but not across jurisdictional boundaries,
(2) within like controller systems, and
(3) within subsystems as determined by corridor travel patterns.

Chapter 6 concludes the report with a summary of the study findings and recommendations for future projects.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Cooperation among adjacent jurisdictions to attain higher levels of transportation service is not new to the field of transportation engineering. Although experiences coordinating traffic signals at the interjurisdictional level are either few or undocumented, a number of studies have been conducted on coordinating public transportation services and on cooperative efforts to relieve congestion through capital improvements. These studies were reviewed to highlight similarities which exist among the various cooperation efforts, as well as to identify any potential issues that might impact the continuation of the Katella Avenue cooperative efforts once the traffic signal system and timings are implemented. An overview of the identified coordination efforts is presented below; an comprehensive review is provided by Neenan (1991).

2.2 COORDINATING PUBLIC TRANSPORTATION SERVICES

Several of the studies that were reviewed set out to evaluate the feasibility of coordinating public transportation efforts at a local level and identify any existing barriers to coordination. A study for the U.S. Department of Health, Education, and Welfare (Burkhardt,et al., 1980) found that:

> "coordinating is a more costly, complex, difficult, and time-consuming process than had been imagined. The process of coordination is arduous and does not end with initial accomplishments; some of the greatest achievements of the demonstration projects (particularly with regard to sources of funds and integration of funds) will require constant vigilance and work to ensure that the parties do not revert back to former attitudes and activities."

The barriers to successfully coordinating systems were more often found to be operational than regulatory in nature. Recurrent operational barriers included staffing and funding deficiencies and chronic problems which abound from the agency "turfism."

While saving money has traditionally been one of the basic selling points of coordinating public transportation, it was found that coordinated systems actually cost less only under special circumstances (Burkhardt, et al., 1980). Achievable goals of coordination included: improved service to riders; improved vehicle capacity utilization; lower costs per passenger trip; and higher passengers per trip (Walther, 1990).

Achieving these goals through interjurisdictional coordination was found to require a great expenditure of effort, however. It was overwhelmingly recognized by the investigators of the coordination studies that as the number of players involved in a project increased, so did the problems:

(1) communications were complicated by the number of agencies involved;

(2) each agency brought with them a number of elected officials whose understanding of the program was likely to be limited and whose support

was essential to the implementation of the program;

(3) objectives and priorities of the neighboring agencies were not always in accordance with each other, thus lengthy negotiations and compromises were necessary; and

(4) the increase in accounting and paperwork requirements when coordinating inter-agency systems was substantial.

Barriers to coordination also included:

(1) concerns that coordination was not beneficial or that clients may be adversely affected by coordination;

(2) the inability to fully allocate and identify costs;

(3) apprehension regarding the availability of continuous funding; and

(4) the absence of a strong local leader to ensure that coordination efforts were successful.

A lack of concerted federal, state, or regional effort to coordinate public transportation services was sighted as a major hindrance in several of the studies (Burkhardt,et al., 1980; Comptroller General, 1977; Walther, 1990). Coordination was seldom mentioned in program regulations and no mechanism existed to coordinate transportation activities. Program officials tended to be concerned solely with their own programs as there were few incentives to coordinate and no penalties for not coordinating.

This lack of effort from a higher level of government, and the subsequent lack of technical assistance, led to inadequate funding and planning of those systems that did attempt to coordinate. The need for comprehensive plan development and funding for this development was prevalent. There was a general absence of technical assistance, especially prior to system implementation; the technical assistance that these systems did receive was, without exception, after the systems were up and operating. Additionally, few system operators received regular publications from the federal government and several did not know of the existence of the U.S. Department of Transportation's (USDOT) technical information sharing networks.

The reviewed studies did not recommend mandating the coordination of public transportation services or providing incentives or rewards for coordination; it was felt that interest in undertaking this effort needed to begin at the local level. However, a number of recommendations were made to ensure that coordination, once determined to be desirable, was successful. These included:

(1) official endorsement of coordination by the federal government;

(2) provision of technical assistance, including information on demonstration projects, continual dissemination of technical guidance memoranda, and on-site technical assistance;

(3) research into high priority issues such as insurance, billing and accounting procedures, and training for managerial staff;

(4) development of model contractual formats, including agreements covering maintenance, purchase-of-service, and insurance agreements;

(5) development of standards or expected ranges for performance measures;

(6) the presence of a coordinating body, although deemed optional, was found to be especially beneficial where local turfism was strong.

A number of lessons in inter-agency coordination were learned from these case studies. Trust, both on the individual and agency level, was determined essential to successful coordination. This trust was most often built by performing as promised. Difficulties arose when there was no clear definition of the project objectives or expected achievements. Also, the expectations and time schedules for implementation needed to be reasonable. Several systems that were examined experienced initial difficulties by generating higher expectations for more rapid service improvements than reality permitted (Walther, 1990). Reasonable expectations also ensure that support of the local community is maintained.

Several key aspects of successful coordination efforts were identified. The project leader should be someone who has both the talent and energy needed to carry the project through to the end. A lead agency with sufficient financial resources should be selected. Personnel skills and job requirements should be appropriately matched and care should be taken that staff is not overworked.

Major problems need to be resolved before the system is operating. The project must be monitored and evaluated, and the flexibility to make changes when ideas don't "pan out" is necessary.

2.3 COORDINATING CAPITAL IMPROVEMENTS

The reasons for multi-agency capital transportation improvements are similar to those for coordinating signal-timing and for public transportation: a desired efficiency may be obtained by pooling financial, technical, and human resources of neighboring jurisdictions. The federal government, together with many state and local governments, is facing great fiscal difficulty due to continued overspending and underfunding. As a result, the volume and magnitude of traditional funding sources of capital road improvements are diminishing. In addition, unbalanced population and employment growth has created rapid increases in traffic congestion in many regions. Often, this growth has been too fast for city planning and engineering departments, and their limited staff, to handle.

Frustration over such problems was prevalent in south King County, Washington, where four cities and the county had made plans for road improvements but lacked the funding needed to build more than a few of the major projects (Bernstein and Billing, 1988). This lack of funding led to difficulties coordinating and prioritizing many of the planned improvements that involved more than one jurisdiction. The Council of Governments in cooperation with the cities, county, and the state department of transportation, developed a unified multi-jurisdictional implementation and financing plan. The council of governments prioritized projects on the basis of region-wide importance and with respect to each jurisdiction based on local impact and importance. Projects deemed to require extraordinary interjurisdictional cooperating and funding sources were so identified. It was recommended that a permanent committee be created to coordinate planning, financing, and construction of projects and to lobby for needed legislative changes.

In suburban Massachusetts a Governor's Special Commission was formed to investigate issues resulting from growth and change. The study (Gakenheimer, et al., 1990) found that there almost certainly would be intergovernmental differences when attempting to alleviate suburban congestion. These problems were found to be compounded by the structure of New England government where the government is generally considered unimportant. Without major unincorporated areas, there is no notable intermediary level of government between cities and the state. Furthermore, the historical development of the area has resulted in significant differences in socio-economics and value systems in neighboring towns, with associated differences in goals and scope of planning efforts. Regional planning agencies are not sufficiently empowered to perform a significant role in the planning process. The Governor's Special Commission found a prevalence of turfism, where the individual cities were more likely to reflect on how congestion affected their jurisdiction rather than exhibit a system-wide concern. The Commission recommended financially rewarding cooperation between jurisdictions (via a range of incentives include priority consideration for state grants and program funding) and concluded that future state action was likely to be the most effective means of settling intergovernmental differences.

2.4 FINANCING COORDINATED EFFORTS

A review of interjurisdictional and multi-jurisdictional financing of transportation projects reveals many of the same issues as stated previously. In the case of public transportation, an inherent need for federally subsidized public funding accentuates the notion that neighboring jurisdictions are in fact competing for a limited amount of subsidies. Fiscal cooperation is further hampered when different jurisdictions have fundamentally different priorities for public transportation, differences in fiscal philosophy, and diverse fiscal capacities.

Issues which arise when considering the financial aspects of coordinated transportation efforts include:

(1) the difficulty of finding a conceptually, technically, and politically acceptable basis for distributing subsidies;

(2) the hardships that unexpected rates of inflation pose on individual jurisdictions and cooperatives;

(3) the restrictions that tax rate ceilings and constitutional debt limits pose on program expansion and improvement; and

(4) the inability to commit to continued coordinated efforts without appropriating the necessary future funds.

To avoid annual appropriations battles, many transportation professionals urge the adoption of earmarked revenue sources. These have included:

(1) dedicated motor vehicle excise tax (based on motor vehicles sales),
(2) dedicated sales tax,
(3) payroll tax (for employees in a designated geographic area),
(4) auto license tag, and
(5) dedicated property tax (for property owners within a specific area)

Pragmatically, however, it is difficult to obtain voter approval for such measures and there is intense competition for these funds from a variety of other public needs.

While the federal and state role in financing local projects is declining, funds are still available through federal and state grants and state low interest loans. These sources, however, along with dedicated sources such as state gas taxes all have restrictions on how the money can be used. As a result, planners and politicians have increasingly been financing transportation improvements through impact fees, developer agreements, and assessments of special districts.

Criteria for evaluating potential financing arrangements are presented by Kidder (1980) in an UMTA sponsored report on the financing of multi-jurisdictional public transportation services. Kidder also indicates that there is little consensus on the relative importance of the various, and frequently competing criteria.

When deciding upon interjurisdictional financing arrangements the transportation professional should also realize that once arrangements have been agreed upon, they may be difficult to alter. If the allocation formula were to be changed, some jurisdictions would necessarily benefit while other jurisdictions would be disadvantaged. Also, the process of negotiating new arrangements introduces the possibility of delays in payments and cash flow problems.

2.5 AN INTERJURISDICTION TRAFFIC SIGNAL COMMITTEE

In 1989, an effort was undertaken in Santa Clara County, California to coordinate traffic signals across jurisdictions (Helmer, 1990). While in the process of installing a centralized signal operations center (similar to Anaheim's), the City of San Jose formed an interjurisdictional traffic signal committee comprising eleven other cities in the County, the County of Santa Clara, and Caltrans. The committee was formed to:

(1) exchange information on existing traffic control hardware and systems,
(2) discuss operational strategies,
(3) develop a common time reference point,
(4) develop standard equipment specifications for new installations, and
(5) describe the capabilities of the planned signal operations center.

The committee is voluntary, receives no outside funding, and has chosen not to affiliate with any governmental body. It's primary objective is to improve regional traffic flow through effective use of new and existing traffic signal and ramp metering systems. Prior to achieving interjurisdictional coordination, the committee recognized a need to:

(1) identify major arterials,
(2) inventory existing equipment,
(3) identify existing coordinated systems, and
(4) identify existing and planned capital improvement projects.

Each agency inventoried their own jurisdiction and the information was compiled and made available to all members. The committee concluded that utilizing a common time reference was the most effective way to achieve coordination and approximately half of the agencies have installed the necessary equipment. Approximately two years after the formation of the committee, the Cities of San Jose and Campbell are in the process of finalizing Santa Clara County's first interjurisdictional timing plan.

2.6 SUMMARY

Governmental agencies have sought to combine their efforts to achieve a higher level of efficiency in a variety of transportation arenas. Both locally and regionally initiated efforts have been reviewed; conflicting conclusions were offered regarding which of these approaches is preferred. A number of key points which are applicable to all cooperative efforts have emerged from these studies and should be considered in the evaluation of this case study:

(1) the more players involved, the greater the communication problems;
(2) multi-jurisdictional coordination is time consuming, this is especially important when considering staffing and funding requirements;
(3) it is essential that participants have realistic expectations of what improvements are achievable and what an appropriate time schedule may be for those improvements;
(4) a strong leader and/or a concerted effort at a higher level of government is necessary to ascertain that there is adequate planning and funding to ensure the success of the coordinated system;
(5) there will always be intergovernmental differences, including differences in priorities and funding capabilities;
(6) accomplishments don't end with initial implementation of a project, a level of continued effort is necessary to sustain a cooperative project.

CHAPTER 3: AN INSTITUTIONAL PERSPECTIVE

3.1 INTRODUCTION

Orange County's twenty-one Super Streets were identified for their potential ability to add capacity to the County's freeway corridors and to perform as high-capacity arterials. Specified to carry high volumes, these routes are expected to carry continuous flows with a minimum of stops and delay. While many cities have coordinated major arterial traffic signals within their jurisdictional boundaries to minimize stops and delay, the Super Streets typically traverse many jurisdictions. Until now, there has been little emphasis by regional or local agencies to coordinate the flow of traffic across jurisdictional boundaries.

3.2 INTERJURISDICTIONAL TRAFFIC SIGNAL COORDINATION

Orange County is a multi-agency, urban area. The boundaries separating the County's agencies are, for the most part, political boundaries rather than functional. Commercial and residential development flows from one city to the next with little or no concern for jurisdictional control. Similarly, a single activity may cause a traveller to cross indifferently through multiple jurisdictions.

Orange County's urban area arterials are commuter thoroughfares during peak hours. The average commute spans several cities and bisects intersections which may be operated by a local, County, or State agency. The commuter wishes to navigate routes within a seamless transportation network. Yet travellers are faced with varying traffic standards, coordination, and management policies which bring changes in traffic signal control and operation to their attention. The lack of coordination between agencies effectively mandates that travellers will encounter stops or delay at each jurisdictional boundary, a de facto policy which has little or no justification.

3.3 COUNTYWIDE SIGNAL COORDINATION PLAN

In view of the perceived need for interjurisdictional coordination, OCTC commissioned a study to develop a plan for the coordination of traffic signals on Orange County's Super Streets (JHK, 1989). The report identified three means of coordinating hardware within the County:

(1) Implementation of a Countywide traffic signal system with one master controlling all signals in all jurisdictions.

(2) Installation of the same manufacturer's master and control equipment in all jurisdictions and intertying of the masters.

(3) Utilization of a time reference which has the ability of being common to all masters and signal controllers.

It was believed that the first two alternatives would be unacceptable to the majority of agencies because, either local authority and control over traffic signals would be reduced, or requirements regarding the purchase and use of proprietary equipment would be imposed. The third alternative was deemed acceptable as it did not impose severe constraints on the individual jurisdictions through requirements of physical interconnection or the replacement of system masters and controllers in order to be consistent with neighboring jurisdictions.

The report recommended the use of WWV broadcast time as a common, highly accurate time reference to establish the time of day. WWV time is the National Institute of Standards and Technology time and is broadcast via radio from Colorado and Hawaii. Special radio receivers, commonly available as a part of the standard product lines of a number of traffic signal control manufacturers, are capable of receiving WWV time throughout Orange County.

The WWV broadcast time acts as a base reference time for all control equipment in a traffic signal network. The zero reference point for all cycle lengths is established by having the master calculate back to a base reference time prior to the cycle length being utilized. This allows all common cycle lengths on all masters in the traffic signal network to be synchronized whether or not they went into effect at the same time. Each day the zero reference points are resynchronized at a base reference time (typically in the early morning when the synchronization is least likely to disrupt the flow of traffic). The accuracy and automation provided by WWV time eliminates the need to physically reset clocks which have wandered, eliminating much of the labor-intensive maintenance costs traditionally associated with time-based traffic signal coordination.

Consequently, with the relatively small expenditure necessary to implement WWV time-based coordination, and the use of a common cycle length, many of the signals within the County could be made to operate under coordinated control.

3.4 THE SELECTION OF KATELLA AVENUE

Having taken steps to install a sophisticated traffic management system, and wishing to submit a proposal to OCTC for OCUTT funding of a traffic signal coordination project, the City of Anaheim looked to its neighbors and within its own arterial network for areas which held potential for coordination. The City contacted all surrounding communities to determine the level of interest in connecting signals to the Anaheim system and found that the majority of the cities either had their own systems or were in the process of implementing new systems.

Anaheim next looked internally and identified two arterials with coordination potential: La Palma Avenue and Katella Avenue. La Palma Avenue, a major east-west arterial, was not yet coordinated within the City of Anaheim, making the project particularly attractive to Anaheim. However, Katella Avenue was a designated Super Street, encompassed six cities, and would also involve intersections under Caltrans' jurisdiction. With the prospect of utilizing WWV broadcast time and coordinating with Multisonics control equipment, Katella Avenue met all of OCTC's funding criteria.

The disadvantages perceived by the City of Anaheim of coordinating Katella Avenue included: (1) Katella Avenue was already coordinated within the City of Anaheim, and (2) inadequate existing interconnect would require the installation of new interconnect cable. Since interconnect traditionally represents one of the most expensive components of a traffic management system, Anaheim could not justify this expense for the marginal improvement interjurisdictional coordination would bring to the City. However, in light of Katella Avenue's potential attraction to OCTC, Anaheim submitted a proposal for the coordination of Katella Avenue and requested that 75 percent of the interconnect costs be funded by OCTC. OCTC accepted this proposal and allocated the additional funds requested for the project from the Super Street Program.

3.5 THE EMERGENCE OF MULTIPLE TRAFFIC MANAGEMENT SYSTEMS

The Katella Avenue coordination project was originally conceived by Anaheim as a coordination effort tying all intersections along Katella Avenue between State Route 55 and Interstate 605 to the Anaheim Traffic Management System. The proposed plan involved the hardwired connection of all intersections to the Anaheim TMC; and developing a communications device, or "black box," and software with which to equip incompatible intersection controllers. The participating agencies would retain complete control over the operation of their traffic signals via a computer terminal linking their offices to Anaheim's central computer.

As foretold in the signal coordination study commissioned by OCTC, a number of Anaheim's neighboring agencies were reluctant to relinquish control of their traffic signals to the City of Anaheim. The City of Orange, with jurisdiction over the eastern section of the corridor between State Routes 55 and 57, choosing not to participate, pursued their own coordination effort on Katella Avenue. The cities of Garden Grove and Stanton chose to connect the three intersections between Beach Boulevard and the City of Anaheim border to the Anaheim system. Caltrans elected not to tie the Beach Boulevard/Katella Avenue intersection to Anaheim's system. And the cities west of Beach Boulevard (Stanton, Cypress, and Los Alamitos) chose to install a new master controller and coordinate with Anaheim through a WWV time base. The resulting corridor extended from State Route 57 to Interstate 605, and embodied three alternate traffic control technologies: the Anaheim UTCS traffic management system, Caltrans Type 170 Controller, and a Traconex Closed-Loop System.

3.5.1 Operational versus Interjurisdictional Emphasis

The City of Orange disagreed with the interjurisdictional emphasis of the proposed project. It has been their experience that coordination, while effective, is a difficult enough task within the boundaries of one jurisdiction. They felt it was necessary to achieve intrajurisdictional coordination prior to effectively implementing coordination measures across city boundaries. This is primarily due to the existence of natural boundaries that either prohibit coordination, or preclude the need for coordination.

The City of Orange typically segments arterials within the city into zones through identification of natural boundaries (for example, potential subsystem boundaries include the intersection of two major arterials, and intersections spaced greater than 1/2-mile apart); the resulting zones, or subsystems, may then be coordinated. With this approach, a greater emphasis is placed on studying the operations of specific subsystems; the City of Orange believes this results in a more effective arterial progression.

In addition, the City of Orange's signals operate under the control of a

Multisonics VMS 220 system. To tie into Anaheim's computer system, a "black box" capable of interfacing with the Multisonics system would have to be developed, or the City's controllers would have to be replaced. The City of Orange was uncomfortable with the idea of utilizing an, as yet, undeveloped communications device in the control of their intersections and was equally dissatisfied with the concept of replacing control equipment in order to be compatible with Anaheim's system. (WWV time-based coordination was not considered a viable solution during the early stages of project planning because the existing Multisonics equipment was not WWV compatible.)

Multisonics is the predominant control system across Orange County cities. The City of Orange is open to coordinating traffic signals between jurisdictions, if the timing needs of adjacent arterial subsystems are compatible, and if the control systems are compatible. A considerable amount of money has been invested in signal timing hardware in the County over the years. The City of Orange believes the agencies now have to invest time and money into conducting studies, implementing timing plans, and maintaining those plans.

3.5.2 The Hardwired Link

The City of Garden Grove was enthusiastic about pursuing a communications link between Anaheim's and Garden Grove's traffic signal systems. Economically less advantaged than Anaheim, Garden Grove saw Anaheim's offer to share the capabilities of their traffic management system as an opportunity for it to utilize sophisticated computerized traffic control at an affordable cost.

Garden Grove controls just a few intersections on Katella Avenue either singularly, jointly with Stanton, or jointly with Stanton and the County, but they share a number of other major arterials with Anaheim which could benefit from a cooperative effort. During the initial planning stages, it was thought that together with Anaheim's Katella Avenue signal coordination proposal, Garden Grove would submit a similar proposal for Harbor Boulevard, a north-south designated Super Street which traverses both cities.

Having already invested a considerable amount of money in Multisonics control equipment, and having recently committed to a Federal Aid grant to upgrade their system, Garden Grove eagerly sought the emergence of the "black box" communications device which would allow UTCS to communicate with Multisonics control equipment. The City, however, was unsuccessful in their effort to get Multisonics to cooperate with Anaheim's systems manager in the development of such a device.

Garden Grove's Traffic Manager was also unsuccessful in obtaining authorization from his superiors to fund the coordination of Harbor Boulevard and subsequently did not submit an application to OCTC for the project. An intertie study commissioned for Katella Avenue with OCUTT funds divulged that connection between either UTCS and the Multisonics master or UTCS and the Multisonics Type 911 controllers would not provide parameter upload/download capabilities, prohibiting full integration into the Anaheim system. In addition, with just two Multisonics controllers proposed to be operating on the coordinated corridor, the cost effectiveness of developing software to tie them into Anaheim's system was questioned. Ultimately, the participating project agencies together with the consultant conducting the intertie study, decided to replace the two Multisonics controllers and a third electro-mechanical controller operated by the City of Stanton, with UTCS compatible, CSC T-1 controllers.

Anaheim's UTCS controls the CSC T-1 controllers. Originally scheduled to have a remote terminal installed in their offices to operate the intersections, the City of Garden Grove elected not to spend the $10,000 (50% of the terminals $20,000 cost) required, as they would be merely observing these intersections.

3.5.3 Beach Boulevard

Beach Boulevard is a State highway which is operated and maintained by Caltrans. Together with Katella Avenue, it is one of five Super Streets with a Priority Group 1 ranking. In 1986, OCTC approved $4 million in OCUTT funding for the construction of Super Street improvements for Beach Boulevard. Those improvements are currently underway and Beach Boulevard is the only Super Street to have received construction funding to date.

During the planning stages of the Katella Avenue project, and at the time of Anaheim's submission of the proposed project, Caltrans was prepared to physically interconnect the Beach Boulevard/Katella Avenue intersection to the Anaheim system. Software was written to allow UTCS to control the Caltrans Type 170 controller, a dial-up remote workstation which would allow Caltrans operational control of the signal was installed at the Caltrans office, and cable was to be laid linking the signal to Anaheim's central computer.

The Katella Avenue intertie study identified the need for Anaheim to have control over the Beach Boulevard intersection to enable specific timing plans to be selected and implemented for this intersection from the Anaheim Traffic Management Center. Caltrans would have the capability to monitor their intersection and have the same degree of control as Anaheim. However, as the Anaheim system has a limited number of concurrent users, Caltrans would be allocated a lower priority than the permanently connected Anaheim terminals.

While Caltrans' headquarter offices in Sacramento apparently wanted the hardwired intertie, Caltrans' district office chose not to relinquish control of Beach Boulevard to Anaheim as Beach Boulevard plays a more significant role in the County's transportation network. Instead, Caltrans elected to replace the software in their arterial master and add hardware to give the master the ability to:

(1) be accessed by Anaheim with a BiTran QuicNet PC-based closed loop central, and

(2) utilize WWV time referencing for coordination.

The QuicNet Traffic Management System provides control and monitoring facilities via a central personal computer and a field master controller. When a dial-up phone link is used to access the field master a number of independent QuicNet PC's can gain access, enabling monitoring and control from a number of locations.

The software developed to integrate the Caltrans Type-170 controller with UTCS is currently being utilized at the I-5/Katella Avenue intersection located within Anaheim City limits. Anaheim controls this intersection together with two other Caltrans-owned intersections at SR-57 and Katella Avenue.

3.5.4 The Traconex Closed-Loop System

Prior to Anaheim's initiation of the Katella Avenue project, the City of Cypress had plans to install a Traconex time-based, closed-loop coordination system to operate their Katella Avenue intersections. At this time, both Cypress and the City of Los Alamitos were contracting traffic operations services from BSI Consultants, Inc. These two cities, together with the City of Stanton, control the intersections west of Beach Boulevard to I-605.

The City of Anaheim initially proposed the "black box" concept to coordinate these three cities with Anaheim's central computer. The cities' consultant, BSI Consultants, was familiar with the black box concept as it had been discussed at past meetings held by a council of Orange County traffic engineers. The consultant expressed misgivings about the concept on the basis that it would not take advantage of the local controllers' microprocessing capabilities as the distributed, closed-loop system does. The consultant, like the City of Orange, was also disinclined to bank on a product not yet developed.

A probable alternative in the event the black box did not materialize, was to replace the controllers west of Beach Boulevard with UTCS compatible CSC T-1 controllers. The consultant visited Anaheim's Traffic Management Center and assessed UTCS to be less user-friendly than a closed-loop system. With little non-recurrent congestion on the west end of the corridor, the consultant saw few advantages of tying into the centralized system.

The closed-loop system planned for implementation in Cypress had many of the traffic control capabilities of UTCS, including traffic responsive control. However, it had been the consultant's experience that traditional time-of-day plans generated from good data, combined with a thorough understanding of coordination theory (i.e., effective use of cycle length, phasing, yield points, and offsets), produced the most effective timing options.

Also like the City of Orange, the consultant felt that actual implementation of a fully-coordinated system was doubtful. The likelihood of Caltrans approving a hardwired intertie to Anaheim's system, and the dilemma posed by the intersection of two coordinated arterials, were also cited as obstacles to full coordination.

Viewing data collection as the only significant competitive advantage of the Anaheim system, the consultant believed that the expense of developing new communications software and hardware, combined with the expense of installing cable to hardwired the west-end controllers to Anaheim's central computer, was not justified. The consultant advised the cities of Los Alamitos, Cypress, and Stanton, to join together in the installation and operation of the Traconex closed-loop system and to coordinate with Anaheim through the use of WWV time.

3.6 RATIONALE FOR THE ANAHEIM SYSTEM INTERTIE

There is currently both a national and international emphasis on developing advanced transportation technology, or Intelligent Vehicle-Highway Systems (IVHS). IVHS, based on modern communications, computer, and control technologies, are expected to play a significant role in the continuing development of our freeway and arterial highway system.

One of the initial components of IVHS involves the current development of advanced traffic management systems (ATMS). Having demonstrated that coordinating traffic signals can improve traffic flow and decrease stops and delay associated with recurrent congestion, traffic engineers are designing systems that respond to nonrecurrent congestion and are capable of adequately coping with major traffic networks. An advanced traffic management system:

(1) works in real time,

(2) responds to changes in traffic flow before congestion occurs by informing drivers in advance of alternate routes and modes, advising them to delay trips, and modifying control system strategies,

(3) includes areawide surveillance and detection systems in order to devise optimal strategies for the system,

(4) integrates control of various facilities (e.g., freeways and arterials),

(5) implies collaborative actions between jurisdictions, and

(6) utilizes rapid response incident management strategies.

The Katella Avenue project currently fulfills only one of these requirements; it entails collaborative actions between jurisdictions. However, Anaheim's traffic management system fulfills, or has plans to fulfill, all of the above requirements through the use of centralized traffic signal control, variable message signs, closed-circuit television, highway advisory radio, and special event management. Additionally, during the construction phase of the project, the City of Anaheim introduced the idea of implementing real-time traffic control on Katella Avenue -- a project which is now scheduled for implementation in 1993. However, this will entail only on that portion of the corridor which is tied to Anaheim's central computer.

The City of Anaheim implemented their traffic management system in an effort to actively manage their traffic control system, coordinate with neighboring jurisdictions, and coordinate with freeways. The City's priority is the overall management of traffic, and is not necessarily limited to optimal signal timing. While this approach may have some disadvantages at a local level, the City feels that those disadvantages are more than compensated for by the benefits achieved on a regional level. The basis of IVHS is data collection. Anaheim is working toward changing the region's infrastructure to accommodate the need for data.

3.7 THE ROLE OF THE FUNDING AGENCY

The Orange County Transportation Commission administered $3.9 million of FY 1989-90 OCUTT funding for traffic signal coordination projects. Based on previous studies and the regional perspective of the agency, OCTC stated that priority would be given to projects on designated Super Streets and projects which involved more than one agency. OCTC's objective was to improve the flow of traffic in regional corridors.

Sixteen agencies submitted thirty-nine signal coordination applications for OCUTT funding. The projects were evaluated for eligibility and costs, with OCTC staff evaluating the project eligibility and OCTC staff and three consultants (JHK & Associates, FPL & Associates, and Kimley-Horn & Associates) evaluating proposed costs. All thirty-nine projects received OCUTT funding. These included:

(1) fifteen Super Street projects,
(2) WWV timing implementation on over one-half of the projects, and
(3) twenty-four projects involving more than one agency.

The Commission was less concerned with the physical method of coordination than with the development of lines of communication between agencies. OCTC believes the regional transportation system will be improved with interagency sharing of traffic operations information.

OCTC is not involved with OCUTT projects beyond the funding point. They do not offer any technical advice; instead, they rely on the funded agency's expertise regarding system intertie and timing. OCTC did not request funded agencies either to perform traffic studies quantifying improvements in traffic flow or to submit a final report of their projects. As a result, with 50% of the FY 1989/90 projects completed, OCTC stated it was difficult to evaluate what had been gained.

OCTC's long-range vision is for a number of traffic operations centers, similar to Anaheim's, to operate in Orange County's major cities. Ideally, smaller cities like Garden Grove and Stanton would tie into these traffic operations centers. The centers would then be linked to a larger regional traffic operations center providing one center with a complete regional picture. This regional operations center would most likely be Caltrans' as a regional perspective of the arterial network could then be combined with Caltrans' existing freeway network.

3.8 SUMMARY

A need for drivers to be able to travel through a seamless transportation network has been recognized and efforts to produce such a network are underway through coordination of neighboring jurisdictions' traffic signals. The interjurisdictional coordination of traffic signals is initiated with the coordination of traffic control hardware, and a desire on the part of the component agencies to cooperate in order to achieve coordination.

The rationale for intertying neighboring traffic control systems centers around the advancement of IVHS technology, a series of technologies designed to cope with nonrecurrent congestion and major traffic networks. However, the incompatibility of existing control systems combined with a wish to maintain local authority and control over traffic signals, present real obstacles to coordination and have been addressed in this chapter. An overview of the cooperative effort necessary to successfully implement such a project once the hardware specifications have been agreed upon are presented in Chapter 4.

In addition, the disbelief that implementation of fully coordinated traffic signal timing plans is likely, and an absence of demonstrated evidence of benefits achievable through interjurisdictional coordination, have been found to diminish the desire to extend the effort necessary to achieve coordination. This study addresses those questions, with the timing plan development and results of implementation presented in Chapter 5 and an analysis of the benefits of interjurisdictional coordination presented in Appendix A.

CHAPTER 4: INTERJURISDICTIONAL COOPERATION

4.1 PROJECT CONCEPT

Having made a substantial capital investment in a traffic management system, and realizing that Anaheim is not an isolated jurisdiction, the City of Anaheim invited neighboring agencies to join them in the OCTC-funded traffic signal coordination effort. The City sent a letter to nine north Orange County cities, the County, and the State, outlining the benefits of connecting their signals to Anaheim's system. Those benefits included:

(1) an opportunity to implement sophisticated traffic signal control at a significantly lower initial cost,

(2) the increased coordination with Caltrans for signal timing and traffic progression, and future potential for coordination of Caltrans' traffic signals and ramp metering signals,

(3) the integration of Super Street traffic signals into a coordinated system,

(4) no duplication of initial capital cost for a new system or replacement of an outdated system, which can be extensive when considering personnel, office space and central computer equipment,

(5) the ability for their agency to maintain "local engineering control" of the day to day operation of your traffic signals,

(6) the future use of the system as an effective method to communicate traffic information to the public and the news media, through the use of computer bulletin boards and graphics,

(7) the future use of Knowledge-Based-Expert-System (KBES) technology for detecting and responding to incident traffic congestion, and

(8) the ability to be part of the system as it evolves into a world class Traffic Management System.

Anaheim concluded that the primary benefit was to have a large portion of north Orange County traffic signals coordinated and working as efficiently as possible. Interested agencies were invited to attend a presentation of Anaheim's system and were encouraged to contact the City directly with any questions.

The result of Anaheim's efforts was the Katella Avenue coordination project. While a total of forty intersections were ultimately coordinated by the project, only three non-Anaheim intersections were actually connected (as initially envisioned) to Anaheim's system. A primary obstacle cited by agencies to tying into the Anaheim system was that they had invested both time and money in their own systems. A second obstacle cited concerned the issue of both physical and perceived control:

(1) The City of Anaheim believes that the perception of control by one city over another city's traffic system was a factor in the City of Orange's decision not to participate in the proposed coordination project.

(2) The City of Garden Grove, although aware of control issues, was willing to relinquish control of their intersections in return for a more efficient operation.

(3) Having originally agreed to connect Beach Boulevard to the Anaheim system, Caltrans later would consent to only time-based coordination.

(4) West of Beach Boulevard, there was an initial perception of being overpowered by the City of Anaheim. However, once the cities of Los Alamitos, Cypress, and Stanton decided to implement the Traconex closed-loop system and coordinate through a WWV time-base, this perception dissipated.

4.2 PROJECT MANAGEMENT

Having initiated the project, the City of Anaheim assumed the role of lead agency by submitting a proposal to OCTC. With the award of OCUTT funds, responsibility was placed with the City of Anaheim for the receipt and expenditure of those funds, and for project management.

Because of the multi-system nature of the proposed project, the management of the construction projects was divided between two agencies. The City of Anaheim was responsible for the expansion of their system and the City of Los Alamitos was responsible for the implementation of the Traconex closed-loop system. Los Alamitos delegated this responsibility to their contracted consultant, BSI Consultants.

The City of Anaheim hosted monthly project meetings where representatives from each agency discussed the progress of the project together with operational and policy concerns which arose. The minutes from each meeting were recorded and distributed to participants and to OCTC. The first monthly meeting was held in July, 1989. One of the initial project tasks undertaken was the preparation of interjurisdictional liability agreements.

4.3 RESPONSIBILITY / LIABILITY ISSUES

Many of the potential liability issues of interjurisdictional traffic signal operations were identified in the "Comprehensive Signal Coordination Plan for Orange County" (JHK, 1989). This report to OCTC recognized that many Orange County cities already share jurisdiction for a particular intersection with another city due to the alignment of city boundaries. Consequently, cooperative maintenance agreements are common. In most cases, these agreements are reviewed by participating cities' attorneys and approved by their city councils.

The key legal issue identified in the report was the liability for personal injury and property damage; interagency agreements must define the legal accountability and liability of all parties. The authors of the report found, through a series of interviews, that the assumption of a maintenance function by one city over another city's signals raised the greatest concern with city risk managers. Risk managers prefer that their signals are maintained by their own city crew or contractor.

The project committee determined that the participating agencies must enter into three types of agreements for the project:

(1) a Memorandum of Understanding (a non-binding agreement),
(2) a Signal Coordination Agreement, and
(3) an Operations and Maintenance Agreement.

Although sample agreements were provided to the City of Anaheim by OCTC, the Katella Avenue agencies found the process of writing and approving agreements to be particularly long and cumbersome. Caltrans stated at the outset that their process of approving agreements was extraordinarily lengthy, therefore, it was decided that the City of Anaheim would enter a separate agreement with Caltrans in order to expedite agreements between other agencies. It was also recognized that producing a multi-agency agreement could result in many stumbling blocks and delays. Wishing to meet OCTC deadlines for committing funds, it was decided that the two lead agencies, Anaheim and Los Alamitos, would enter an initial agreement allowing contractors and consultants to be hired. This was to be superseded with a multiple-agency agreement. However, the risk manager for the City of Anaheim advised that liability concerns would make it difficult for Anaheim to enter into a signal operations agreement with the cities operating under the closed-loop system. As a result, each of the lead agencies was responsible for instituting a signal coordination agreement and an operations and maintenance agreement with the respective agencies within their systems.

Even with the resulting decrease in the number of agencies per agreement, the writing of the agreements was an iterative process. Agreements were drafted and distributed to each agency for review. Agencies' comments were used to revise the drafts and the agreements were again distributed. This process was repeated until a draft agreement received verbal approval from each agency; the final draft was then produced and circulated from one agency to another for signature.

Few major discussions ensued regarding the content of the agreements, but the questions which did arise needed to be examined and any resulting changes to the agreements needed to be approved by each agency. For example, a number of efforts were made to incorporate legal statements in the Memorandum of Understanding, a document developed specifically to be non-legal and non-binding. Also, there was a request by one city attorney to purchase a combined insurance policy. The city risk managers, however, agreed that this was unnecessary and that the cost of such a policy would be prohibitive. There were also a number of relatively minor incidents which contributed to the length of the agreement process resulting from the logistics of navigating the paperchain within the various agencies within each city. It was suggested that many of these problems could have been avoided by "walking the agreements through" rather than circulating them by mail. However, this suggestion was rejected because it may have carried an implication of pressure to sign the agreements.

The Memorandum of Understanding is a non-binding document which defines the multi-agency project. It was signed as a "show of good faith" by each of the participants to implement a coordinated signal timing plan and operate under the plan for a "fair" period of time. It was also written to help each agency establish a defense for the project in the event of any adverse pressure from the City Council or the general public. The interagency signal coordination and the operations and maintenance agreements are formal documents which:

(1) define the responsibilities of each party and specify the share of costs to be borne by each agency,

(2) state that each agency is responsible for the maintenance of the traffic signals under their jurisdiction,

(3) call for a review of the system operations at regularly scheduled intervals,

(4) specify that traffic signal timings be mutually established by participating agencies and that no agency modify those timings without notification to and approval by the other agencies unless required to do so in an emergency,

(5) require that each agency is notified in the event of system failure, emergency repair, or power failure affecting the interconnected system,

(6) contain a "hold harmless" provision relieving a city from the responsibility for the acts of another city and state that each agency agrees to indemnify the other cities from its own negligent acts.

Copies of the final agreements are presented in Appendix B of this report. Additional arrangements were also made between individual agencies to prevent potential liability problems. For example, the City of Anaheim arranged to have maintenance personnel from the City of Garden Grove or the City of Stanton accompany them if they needed to access those cities' controller cabinets. Without this arrangement, a question of liability would undoubtedly arise if a problem were to occur after Anaheim personnel had opened a controller cabinet.

4.4 FINANCIAL RESPONSIBILITY

The two lead agencies prepared cost estimates for the design and construction costs of their respective systems, and the City of Anaheim estimated the costs of the development of the signal timing plans. A "worst case plus 15%" scenario was used to estimate costs.

OCTC, through either OCUTT or Super Street funds, assumed responsibility for:

(1) 100 percent of the design costs,
(2) 75 percent of the hardware modifications to Anaheim's central computer,
(3) 75 percent of the interconnect costs, and
(4) 50 percent of all other construction costs.

Fifty percent of the signal timing plan development costs were funded with OCUTT funds, and 50 percent was divided equally among the five cities, the County, and the State. There was some discussion regarding the equity of this arrangement when a more appropriate arrangement might have been to divide the costs by the number of intersections within each agency's jurisdiction. However, it was pointed out that the signal timing plans were developed for the corridor, not for individual intersections, and an equal financial responsibility for these plans equated to an equal voice in their development.

The remaining construction costs were divided among the agencies responsible for the respective systems, with each agency roughly responsible for the work within its jurisdiction. The allocation of this responsibility was somewhat subjective at times, due to the interweaving of jurisdictional boundaries. When it was not clear where the financial burden should be placed, the lead agency had to decide whether to place it with the agency within whose physical boundary a work item may lie, or with the agency or agencies who realized the greatest benefits from the work. Each agency received an estimate of its total financial responsibility for the project at the time of the proposal submittal and accepted this responsibility by signing its respective signal coordination agreements. Several of factors caused actual expenditures to deviate from the estimates:

(1) The "black box" communications devices were not developed.

(2) Caltrans did not interconnect Beach Boulevard to the Anaheim system, thereby reducing interconnect costs.

(3) The cost of the fiber optics cable specified for UTCS was considerably more than originally estimated, therefore, the cable was not installed.

(4) Loop detectors which were not originally specified, were installed at one intersection.

(5) It was discovered during the construction phase that some existing conduit was damaged and needed to be replaced.

(6) Estimates were based on 1989-90 prices and purchases were generally made at inflated 1990-91 prices.

The overall result was that construction costs ran over budget and design costs ran under budget. OCTC approved the transfer of design funds to cover construction overages, and stated that the only constraint on the final expenditure of funds was that no additional OCTC funds would be allocated to the project. The "worst case plus 15%" estimation scenario was probably not adequate in light of inflation; however, because some budgeted items were omitted from the project, the final project expenditures were within 0.3% of the estimated costs.

Financial considerations that were not specified within the project estimates or agreements included the allocation of responsibility for overruns and the provision of funds to maintain the systems. Because responsibility for costs over the estimated budget were not specified, the lead agencies risked assuming responsibility for these costs as the contracting agencies. While overruns did not play a significant factor in the Katella Avenue project, this was a risk that the City of Anaheim recognized and was willing to assume, if necessary. The City of Los Alamitos, however, was not financially prepared for this additional burden.

A financial item not addressed was the funding required to maintain the systems. The need for this funding became evident with regard to the following:

(1) The City of Los Alamitos, contracting their traffic engineering services, requested that their consultant restrict their attendance at project meetings toward the final stages of the project in order to conserve expenses.

(2) After the implementation of new timing plans, the City of Cypress' Engineer, concerned that Cypress' portion of the corridor remain coordinated with the other jurisdictions, requested funds from his City Director to retain contracted traffic operations services.

(3) The efficiency of signalized traffic operations is dependent upon the employment of timing plans which are based on accurate turn-count volumes. While the need for a review of signal operations was recognized with an agreement by the agencies to meet on a quarterly basis, no budget was estimated to assess or update coordinated timing plans.

4.5 PROJECT ADMINISTRATION

As lead agency, the City of Anaheim absorbed the responsibility for a majority of the administrative functions, and the City of Los Alamitos assumed responsibility for those functions that were unique to the closed-loop system. During the initial phases of the project, the City of Anaheim hired a traffic engineer to manage Anaheim's new traffic management center and to administrate the Katella Avenue coordination project. However, the administration of this multi-agency project proved to be more time consuming than originally anticipated.

The administration of the coordination project had been anticipated to be a supplementary responsibility to the management of the Anaheim Traffic Management

Center; however, meetings, paperwork, and the lack of prior experience in working with multi-agency cooperative projects, elevated the level of effort which was necessary to ensure that the project progressed adequately.

During the timing plan development phase, the frequency of the project meetings was increased from monthly to bi-weekly or weekly in an effort to expedite the implementation of the timing plans. In addition to conducting the meetings, Anaheim's Traffic Engineer compiled and distributed the minutes, a task which often took one-half of a work day.

Drafting, revising, and distributing the agreements was also a considerable effort. In addition to having to incorporate changes from as many as seven agencies, the process of passing the multi-agency documents was cumbersome. Difficulties arose finding the right person within each agency for communication regarding the agreements.

Tracking project finances proved to be an immense administrative task which was compounded by the number of agencies involved. Each agency and each contractor had a unique format to document project costs. The City of Anaheim was responsible for consolidating these costs into one document which would meet the funding agency's requirements. It was also necessary for Anaheim to allocate these costs and bill the appropriate agencies for them. Additionally, as some construction work was performed by City of Anaheim maintenance personnel, it was necessary to account for these non-billed items.

Originally scheduled to be implemented fourteen months after the notice of project approval from OCTC, the timing plans were implemented approximately twenty-six months after approval of the project. Much of the delay can be attributed to the lengthy review of agreements by city attorneys and to the process of having agreements and work orders approved by City Councils. For example, a request to contract services for the collection of turn-counts was not brought before each agency's City Council prior to the end of the school year; consequently, this effort was delayed several months until school was again in session in the fall. Additionally, there were delays in reducing the turn-count and geometric data once it was collected, and the time estimated by UCI to develop signal timing plans was grossly inadequate considering the dynamics of a multi-agency, multi-criteria review process. The City of Anaheim also felt that the project would have been expedited if the project management had been someone's primary responsibility.

4.6 THE DEVELOPMENT OF SIGNAL TIMING PLANS

The development of the interjurisdictional signal timing plans was two-fold. First, an engineering analysis of the corridor was performed, timing plans were developed, and their resultant performance measures were noted. Second, round-table discussions of the analysis were conducted by the project committee members. During these discussions, the concerns and policies of individual agencies were communicated and, subsequently, timing plans were produced incorporating these measures. Thus, the effects that these measures had on the corridor performance measures could be analyzed.

The timing plan development proved to be a much lengthier process than originally anticipated. There was a tendency among the agencies to want to maintain the "status quo." Individual agencies knew from experience what worked for their intersections and, as a result, were reluctant to implement changes. This slowed the decision-making process as the committee members were never in complete agreement. The City of Anaheim reminded the committee that the project was designed to promote coordination along the corridor, and asked that each agency exhibit a level of flexibility in accepting timing plan designs.

Agency representatives identified a range of timing plans that they would accept, and a consensus began to develop. Each agency demonstrated a willingness to make concessions regarding cycle length, pedestrian phase minimums, time-of-day implementation, etc. There were also some measures on which agencies were not willing to compromise. However, with frequently scheduled meetings, and discussions between the agencies, agreements were made.

Possibly the most significant contributing factor to the length of the timing plan development and selection process was the multitude of possible combinations to consider. For example, measures which were implemented in one section of the corridor, such as double cycling two-phase intersections, did not have to be implemented on all such intersections. The corridor could operate under either one cycle length or under a series of cycle lengths. Attending the frequently scheduled meetings, yet not realizing measurable progress, began to wear on the morale of the committee. However, once the committee agreed to stop searching for a "better plan" as defined by model-estimated performance measures, final timing plans were produced and implemented swiftly.

The decision-making process incorporated a combination of: the corridor analysis, individual and agency expertise and preferences, and compromise. The selected timing plans were not necessarily the plans that were most effective at decreasing arterial delay or at reducing travel time along the corridor; rather, they were the plans that blended the need to achieve these goals while at the same time fulfilled agency policy requirements.

Having decided to work as a group to coordinate arterial traffic signals across jurisdictions, there was little or no observed struggle for control in the committee meetings. The cities of Garden Grove and Stanton saw themselves as small cogs in the Anaheim system. They were generally willing to go along with Anaheim's wishes regarding such issues as phasing and cycle lengths, despite having conducted some arterial analysis with the PASSER II arterial signalization model that supported altering existing phasing policies to improve arterial progression.

Caltrans' primary concern was that Beach Boulevard remain coordinated, and consequently asked that the regional importance of Beach Boulevard be recognized by the committee. While the City of Anaheim, as the project leader, maintained that the aim of the project was to coordinate Katella Avenue and that other considerations were secondary, it was recognized (via observed turn-counts) that the traffic volume on Beach Boulevard was double the volume on Katella Avenue.

The three cities operating under the closed-loop system are all smaller cities which lack in-house expertise in the area of signalized traffic systems. As such, all three charged the consultant implementing the system with responsibility for ensuring that their intersections were appropriately timed. This was advantageous to the coordination effort in that these three agencies effectively acted as one in the negotiation of the signal timing plan development.

4.7 THE COOPERATIVE EFFORT

Each of the committee members was surveyed regarding the cooperative project, with a number of the surveys being followed up with personal interviews. The project participants concluded that the effort was a success on several levels. First, the project achieved its goal of improving the flow of traffic across jurisdictional boundaries. Secondary effects, but also of primary importance to the participating agencies included:

(1) traffic flow was improved within jurisdictions,

(2) capital and infrastructure improvements to the various agencies' traffic signal systems were funded, and

(3) design elements were funded that allowed the City of Anaheim to better understand their system and how it can coordinate with other systems.

The participants believe that the success of the project was due to the high-level of cooperative effort between agencies. This effort was sustained by consistent attendance at the regularly scheduled committee meetings. The influence that the meetings had on the project was emphasized because they served, in addition to keeping the agencies abreast of project developments, as forums for discussions of signalized traffic control procedures, practices, and strategies. The success of the project was also attributed to the excellent project administration by the City of Anaheim, and the expertise of the project participants.

The project took nearly 40 months of effort from the pre-proposal stage to the time of implementation. Project participants estimated that it should take anywhere from 20 to 48 months. Regardless of which bound is more reasonable, the participants advised that agencies contemplating a similar project should realize that the project management, administration, and process of formalizing agreements, are both time-consuming and lengthy. All participants agreed that the project will take continued effort from each agency to maintain the benefits achieved through coordination and all believe that the project agreements will remain as viable documents in the future.

CHAPTER 5: TRAFFIC SIGNAL TIMING STUDY

5.1 ENGINEERING STUDY

A signal timing study was undertaken to achieve coordination along the multi-jurisdictional Katella Avenue corridor. Because the City of Anaheim had previously been successful working within the structure of California's FETSIM project, the Katella Avenue timing study was structured similarly. As with FETSIM, the TRANSYT-7F computer model was the primary evaluation tool utilized in the development of timing plans. Because the timing plans would be implemented according to a time-of-day schedule, timing plans were prepared to correspond with the AM, Noon, and PM peak, and an off-peak, weekday time period.

BSI Consultants was selected to conduct the necessary traffic study and data collection; the timing plans were developed by the Institute of Transportation Studies (ITS) at the University of California, Irvine (UCI). This cooperative arrangement evolved from the desire to economically utilize available resources, as both organizations were already involved in the project in other capacities.

All pertinent traffic related data were collected for the forty intersection system including turn count data for each of the intersections, estimated representative saturation flows, headways, and spot speeds. A "before" travel time and delay study was also performed. These data, together with the arterial geometries and existing phasing plans, were coded for TRANSYT-7F analysis using the CHAOS (Leonard, 1990) preprocessor for TRANSYT-7F.

The Katella Avenue signal coordination project was undertaken as a Super Street project, dictating that the timing plans strive to provide for superior flow characteristics on the arterial. To achieve this aim, the TRANSYT-7F model was coded to minimize stops and delay along the arterial. A subordinate consideration in the optimization of the timing plans was the stops and delay accrued by vehicles on the cross streets.

5.2 JURISDICTIONAL POLICIES AND RESTRICTIONS

An integral part of the timing plan development was the incorporation of individual jurisdictions' policies regarding traffic signal operation and staff members' own conventions regarding signal timing. The City of Anaheim does not implement lagging left turns and favors protected/permissive left turns as a means of increasing turning capacity. Caltrans and the cities under the umbrella of the closed-loop system (Los Alamitos, Cypress, and Stanton) use lead-lag left turn phasing extensively and do not enlist protected/permissive phasing. Anaheim also requires that all phases show at least sixteen seconds of green, all two-phase intersections be double-cycled, and pedestrian clearance intervals be exclusive of yellow and red time. The cities west of Anaheim did not elicit such precise requirements, rather, they permitted a level of flexibility within the constraints of accepted traffic control practices.

The agencies under the control of the closed-loop system also asserted that it was unnecessary to implement the pedestrian clearance intervals associated with the cross street movements at all but two of their seventeen intersections. The remaining fifteen intersections within the closed-loop system experienced low pedestrian activity and it was ascertained that arterial flow would be best served by allowing the controller to go off-line to accommodate the occasional pedestrians. The alternative would be to allocate the time necessary for pedestrian crossings and have any unused green time on the cross street (e.g., the pedestrian button was not pushed) revert to the arterial through recall. However, as the pedestrian actuations are infrequent, the offsets, and therefore the arterial progression, would be suboptimal.

5.3 INITIAL TIMING PLANS

An initial set of timing plans was developed for each of the time periods at a variety of cycle lengths. The cycle lengths initially examined ranged from a low of 110 seconds to a high of 130 seconds. The lower bound was set by minimum phase length constraints (which included pedestrian clearance intervals), while practical experience and engineering judgement set the upper limits. All cycle lengths were even numbered to accommodate the double cycling of Anaheim's two-phase intersections.

5.3.1 Systemwide Average Delay Per Vehicle

The timing plans and system cycle length alternatives were presented to the corridor agencies through graphical representations of their performance measures. The data presented in this chapter refer to the AM peak period, a representation of the system's performance. As is illustrated in Figure 5-1, average vehicle delay for the system improved as the system cycle length increased. Additionally, the rate of improvement decreased as the cycle length increased. Average delay decreased approximately seven seconds or twenty percent by increasing the cycle length from 110 to 120 seconds, while the difference in average delay produced with 120- and 130-second cycle lengths was less than two seconds, or seven percent.

5.3.2 Systemwide Percent Stops

Exhibiting a similar trend, albeit less pronounced, the rate of change in the percent of vehicles stopped (percent stops) decreased as cycle length increased (Figure 5-2). Percent stops decreased by nine percent when cycle length was increased from 110 to 120 seconds and only decreased four percent between 120 and 130 seconds.

5.3.3 Intersection Levels of Service

Figure 5-3 presents the level of service (LOS) at which the forty intersections operate at various cycle lengths between 110 and 130 seconds. The lower cycle lengths have a higher number of intersections operating at level of service E and F than do the timing plans with higher cycle lengths. Also, there is little change at the higher cycle lengths; one intersection "flip-flops" from LOS A to LOS B between cycle lengths of 126 and 130 seconds.

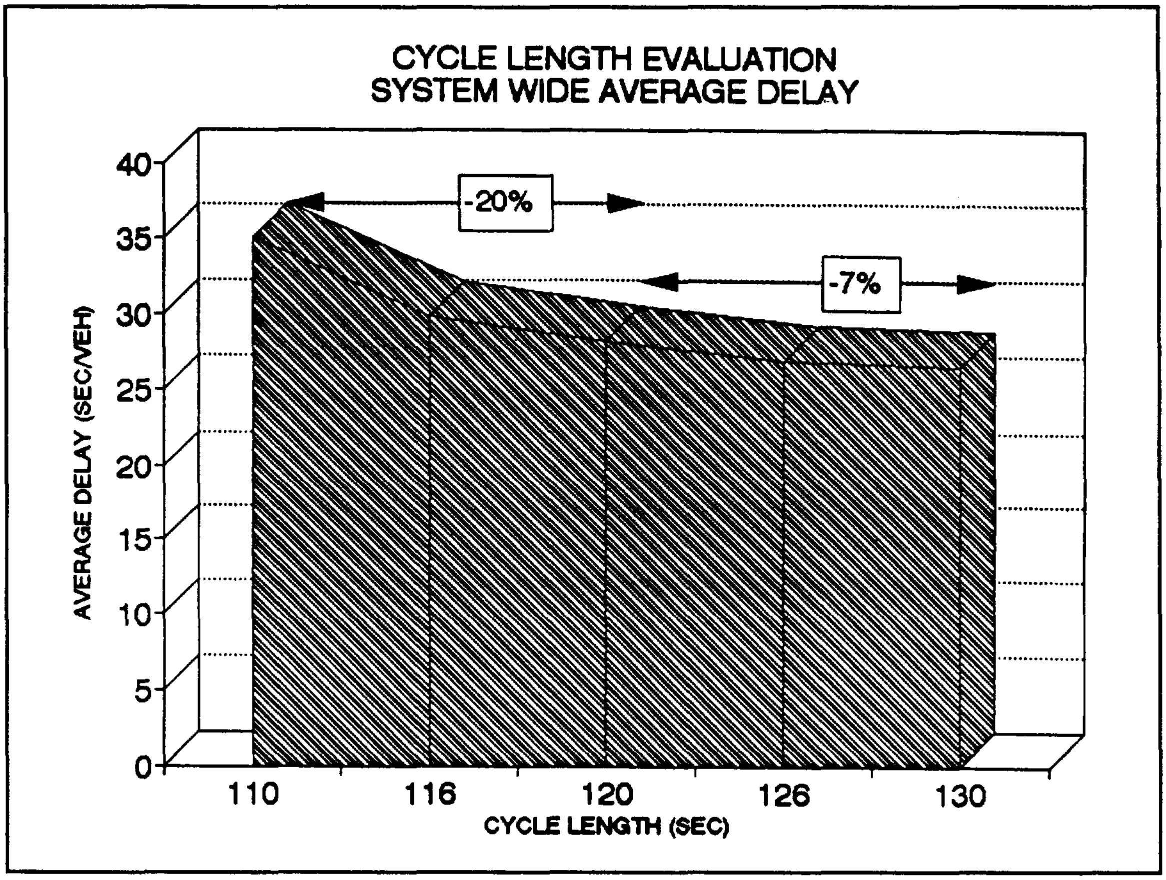

Figure 5-1 Systemwide Average Delay

5.3.4 Arterial Speed

Finally, the arterial speed presents the same scenario as the previous performance measures (Figure 5-4). Speed increases markedly between timing plans operating at 110- and 116-second cycles, and the increase begins to level off between 126 and 130 seconds.

5.3.5 System Queue Lengths

This suggests that while higher cycle lengths produce a lower level of stops and delay on the Katella corridor, thus increasing traffic flow, there may be a point beyond which the marginal increase in benefit achieved by increasing the cycle length is negligible. This is compounded with the knowledge that as cycle length increases, queue lengths increase. Figure 5-5 illustrates the affect that longer cycle lengths have on average maximum back of queue (the maximum number of vehicles to join the back of a queue averaged over all links).

The cycle length appears to have a marginal affect on the arterial queues, but a greater affect on the cross street queues. Here, a cycle length increase from 110 seconds to 130 seconds increased the average maximum back of queue length on the cross streets by 0.5 vehicles. To interpret the significance of this increase, the maximum back of

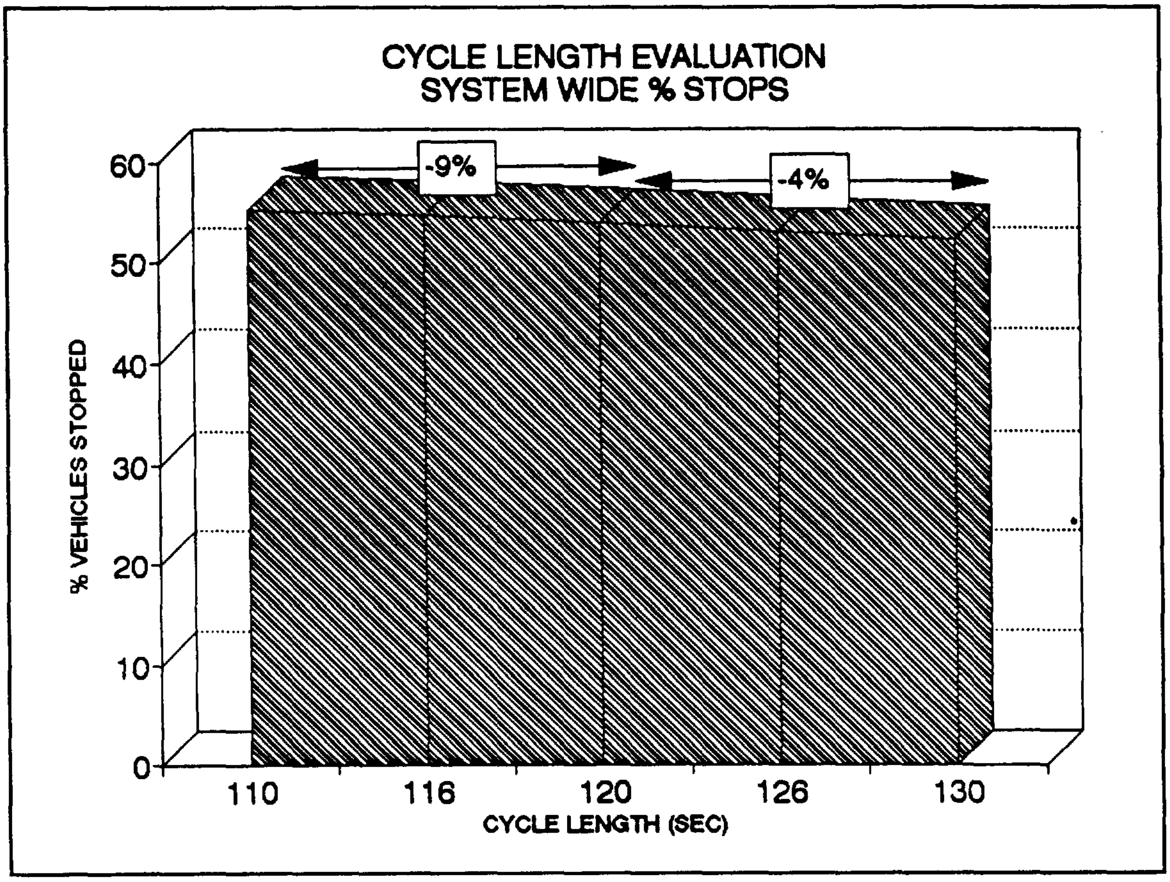

Figure 5-2 Systemwide Percent Stops

queue is plotted for a single link in Figure 5-6. The maximum back of queue increased by six vehicles on this cross street "through movement" link when the cycle length was increased by twenty seconds.

5.4 ALTERNATE PHASING STRATEGIES

In an attempt to improve upon these initial timing plans, a number of strategies were presented as possible means to increase traffic flow on the arterial. The first two strategies examined were: (1) eliminating double cycling, and (2) identifying areas of the UTCS portion of the arterial where pedestrian clearance intervals could be eliminated due to low pedestrian activity.

Each of these strategies was examined alternatively, and in combination. Elimination of double cycling affected five intersections in the eastern half of the arterial. Six intersections under UTCS control were determined to have low pedestrian actuation and their cross street green phase minimums were reduced as a result.

Examining some of the same performance measures as were introduced previously, both of these strategies proved to reduce average delay and percent stops, and increase arterial speed.

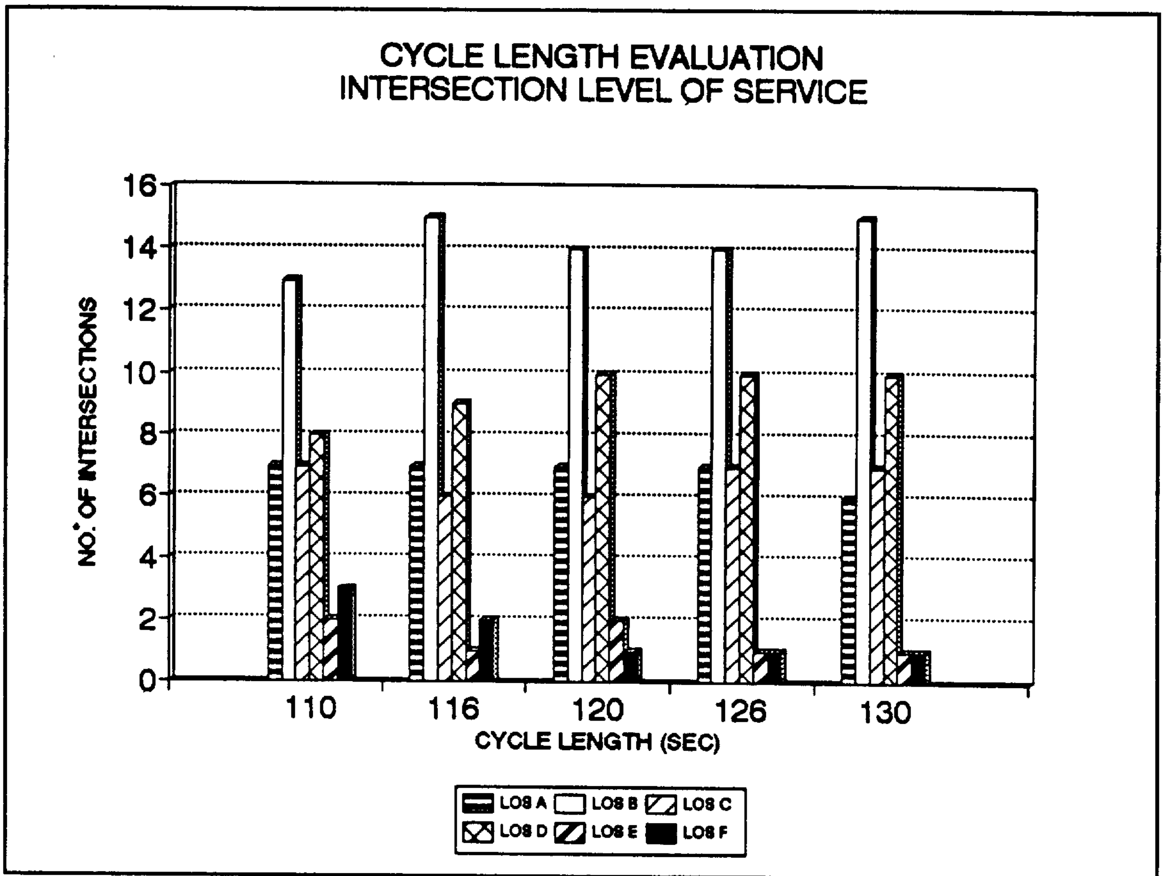

Figure 5-3 Intersection Level of Service

5.4.1 Systemwide Average Delay Per Vehicle

Figure 5-7 presents systemwide average delay under four alternate timing plans. Displayed from back to front in Figure 5-7, these are:

(1) The original timing plan
(2) Elimination of double cycling at five intersections
(3) Reduced cross street phase minimums at six intersections
(4) The combination of (2) and (3)

The combination of no double cycling and reduced phase minimums has the greatest effect, resulting in a five percent decrease in average delay at a 120-second cycle length. This represents 1.5 seconds per vehicle, or a decrease in total delay of 62 vehicle-hours per hour. Examining these strategies individually, reduced phase minimums decreased average delay by 1.4 seconds (4.9 percent), while the elimination of double cycling resulted in a one second (3.0 percent) decrease in average delay.

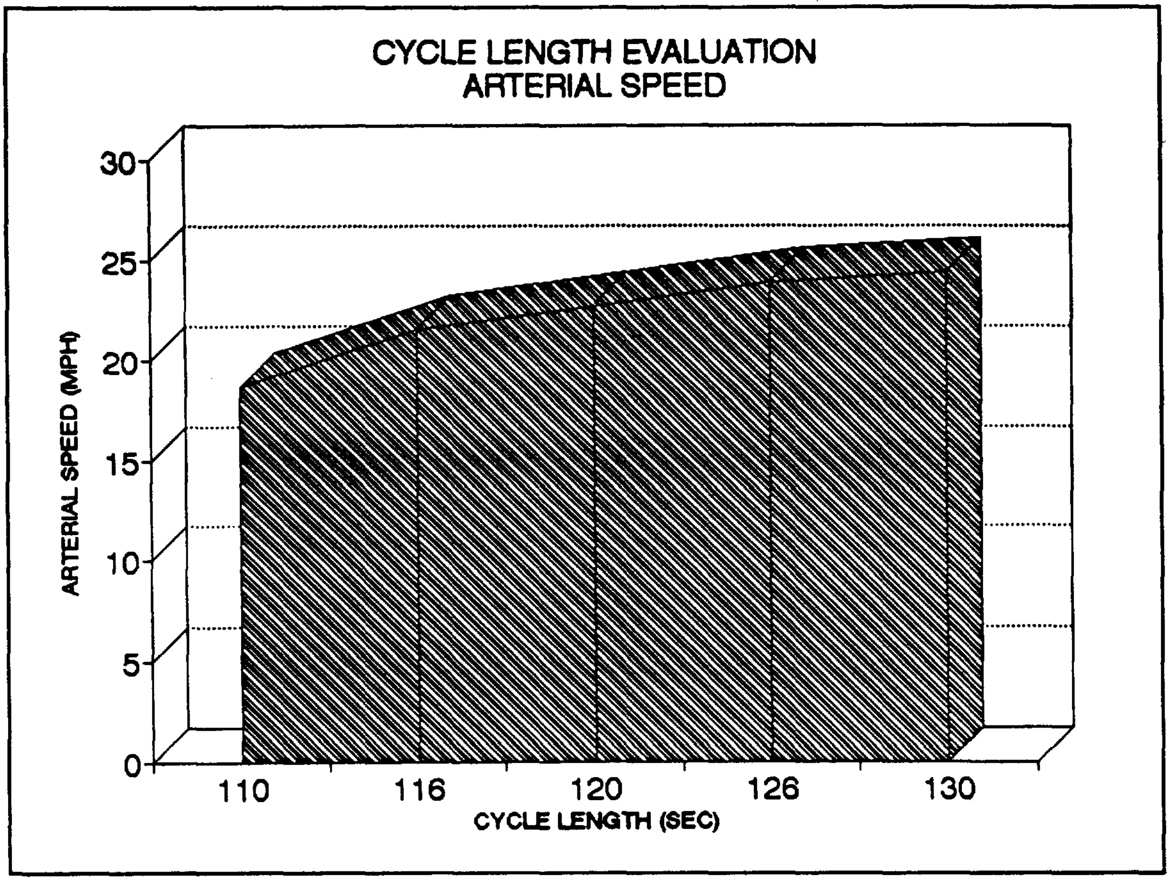

Figure 5-4 Arterial Speed

5.4.2 Systemwide Percent Stops and Arterial Speed

Systemwide percent stops and arterial speed were affected similarly by the combined timing strategy with percent stops decreasing from approximately 54 percent to approximately 50 percent, a 6.5 percent reduction (Figure 5-8), and arterial speed increasing 0.5 miles per hour (6.3 percent) at a 120-second cycle length (Figure 5-9).

5.4.3 Arterial Average Vehicle Delay

Finally, focusing on arterial progression, average delay on the arterial was reduced by 2.5 seconds per vehicle (13.5 percent) by eliminating double cycling and reducing selected phase minimums (Figure 5-10). This translates to a decrease of 64 vehicle-hours per hour for the arterial. As the overall system decrease was 62 vehicle-hours per hour, the cross streets experienced an increase in delay of two vehicle-hours per hour as a result of these timing strategies.

5.5 MULTI-CYCLE LENGTH SYSTEM

The possibility of operating the arterial under a timing plan which utilizes more than one cycle length was also explored. A common cycle length had been identified

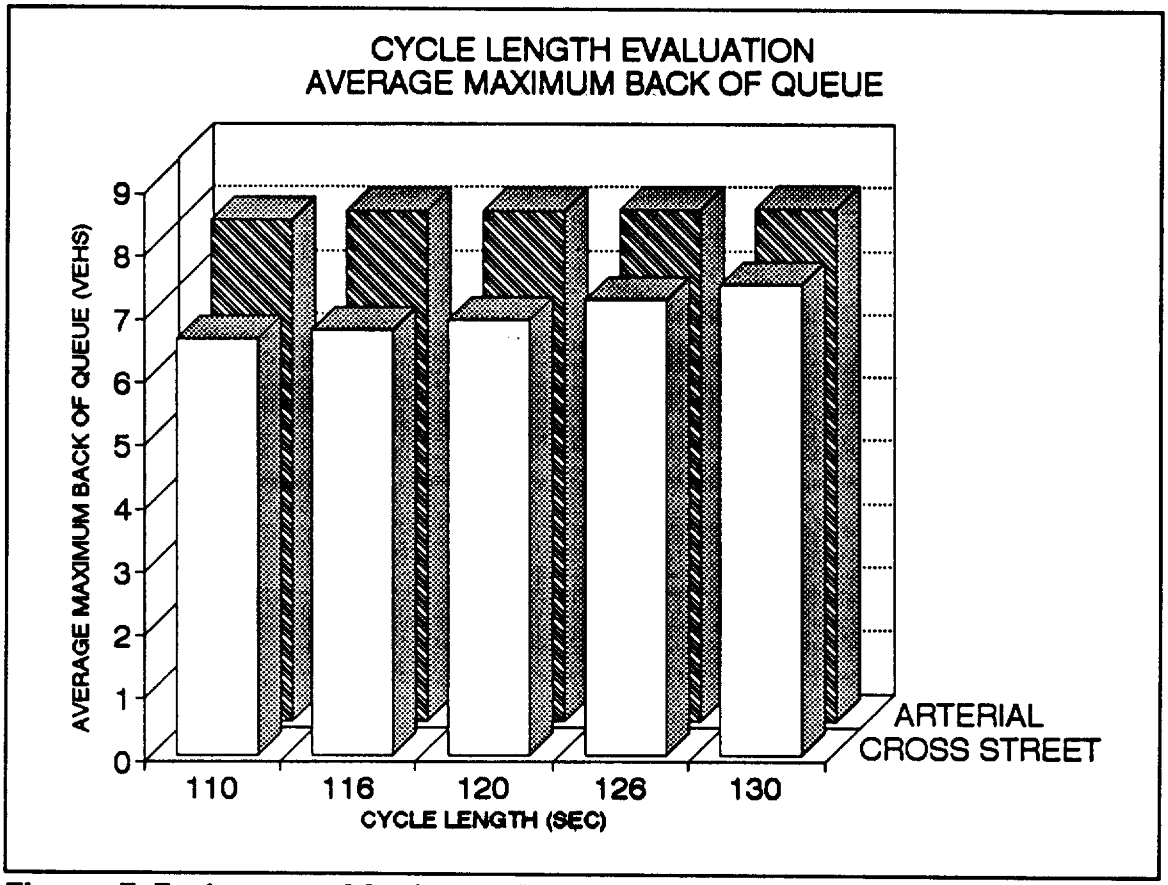

Figure 5-5 Average Maximum Back of Queue

previously as a constraint of interjurisdictional coordination (JHK, 1989), and traffic engineering texts have promulgated this concept:

> "It should be noted first that all but the most complex coordination plans require that all signals have the same cycle length. While some signals might hold stopped vehicles for longer than they have to for strictly local purposes, the overall effect will be beneficial. If the overall effect is not beneficial, then the coordination serves no purpose." (McShane and Roess, 1990, pg. 527)

However, it was perceived that the variation in traffic patterns, geometry, and land-use along the arterial might support the decision to impose one or more physical breaks in the arterial timing plan. For the initial analysis, the arterial was divided immediately west of Beach Boulevard which was selected as the dividing point of the arterial since:

(1) Beach has the highest cross street volume on the corridor,
(2) Katella's major traffic signal control systems are separated at Beach, and
(3) Beach marks the division of differing agency policies and practices.

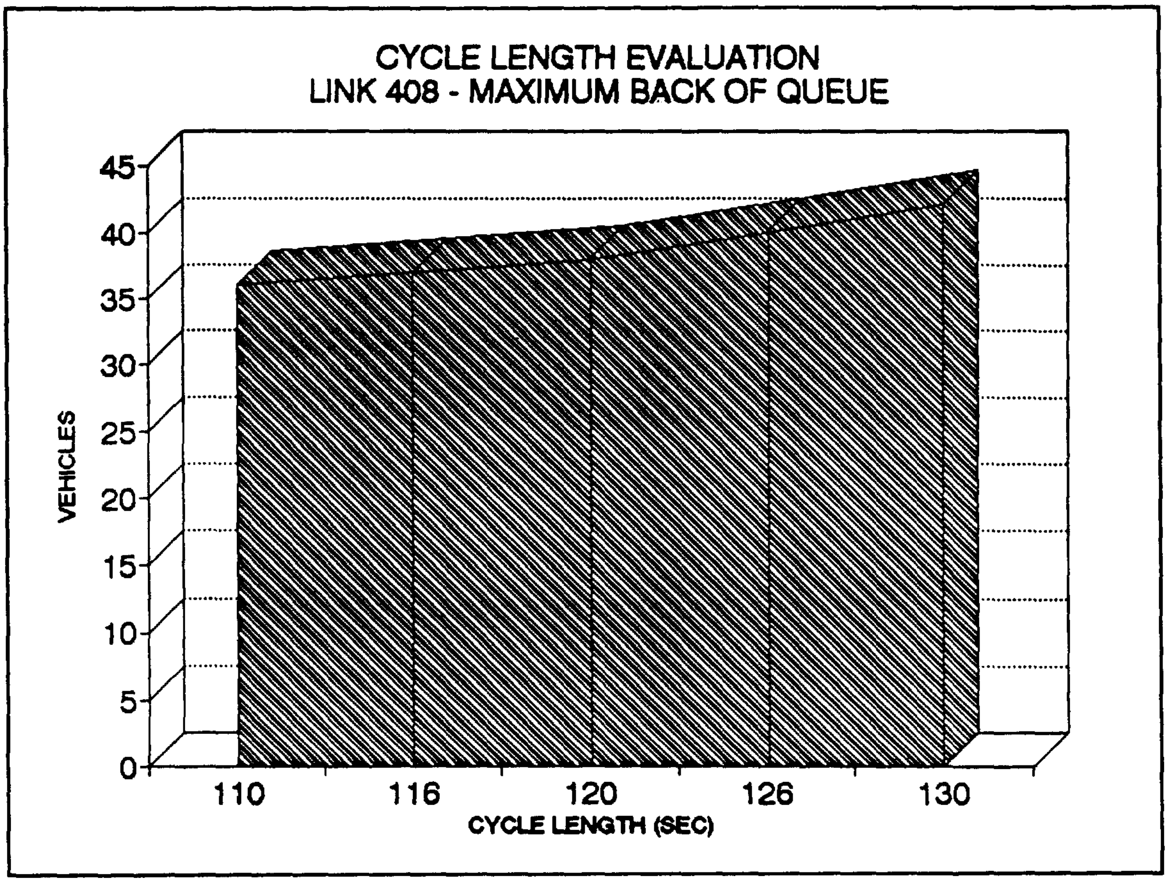

Figure 5-6 Maximum Back of Queue - Link # 408

The system was split west of Beach Boulevard because the high volumes and saturation rates on Beach were more characteristic of the eastern portion of Katella Avenue.

A comparative analysis of arterial performance was performed for each of the two subsections at 120- and 130-second cycle lengths. The 130-second cycle was selected because arterial stops and delays were minimized at this cycle length when the arterial was optimized as one system. An alternate, lower cycle length of 120 seconds was chosen for comparative analysis in deference to a strong desire expressed by some agencies to utilize a 120 second cycle.

Intersections 1 through 17 operated marginally better at a 130-second cycle length, with speed being improved by 0.8 miles per hour, average delay being decreased by 0.2 seconds per vehicle, and percent of vehicles stopped declining by two percent (Figure 5-11).

Intersections 18 through 40 produced noticeably superior performance measures when operating at a 130-second cycle length. Arterial speed increased 3.5 miles per hour, average delay decreased by seven seconds per vehicle, and percent stops decreased by 3.6 percent (Figure 5-12).

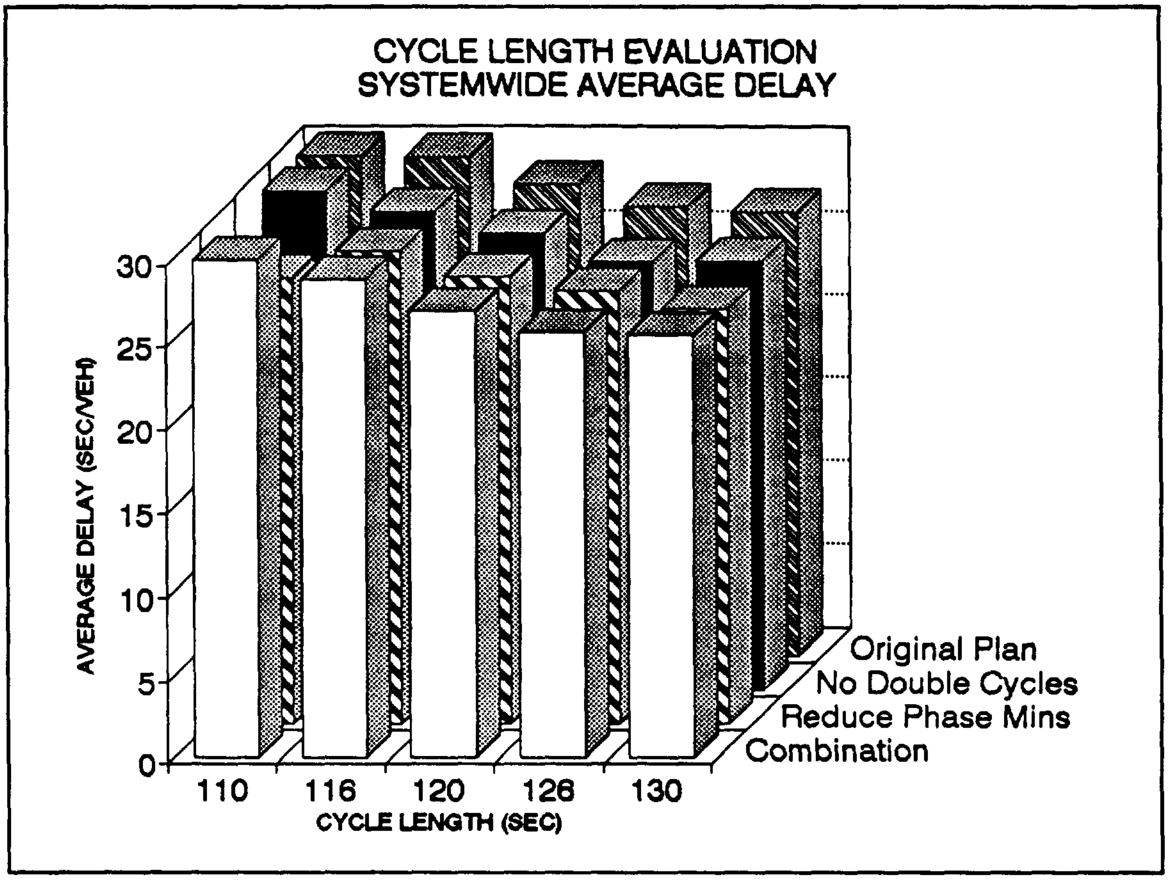

Figure 5-7 Systemwide Average Delay

5.6 ALTERNATE OPTIMIZATION PROCEDURE

As an additional measure to improve upon the optimization procedure, it was theorized that the performance measures of a portion of an arterial would improve if that subsection were optimized as a stand-alone section rather than as part of the larger arterial. Because TRANSYT-7F's "optimization" technique is, in fact, a heuristic hill-climbing process driven by specified step sizes, the model does not necessarily produce the globally optimum timing plan. Also, each intersection offset is predicated on the offsets already determined for the intersections preceding it in the optimization process. Therefore, different relative offsets would be expected as a result of a subsection being optimized as a stand-alone section rather than as part of a larger arterial.

This optimization strategy was applied by creating eight, five intersection subsystems from the 40-intersection arterial. Each subsystem was then optimized at a 120-second cycle length with two additional intersections added to each end of the section to mitigate the boundary effects at the subsystem borders. Assuming the subsystem optimization procedure produced better performance measures, the subsections would then be melded together ensuring that the offsets between subsections were optimal.

As predicted, the relative offsets of the intersections varied between the two

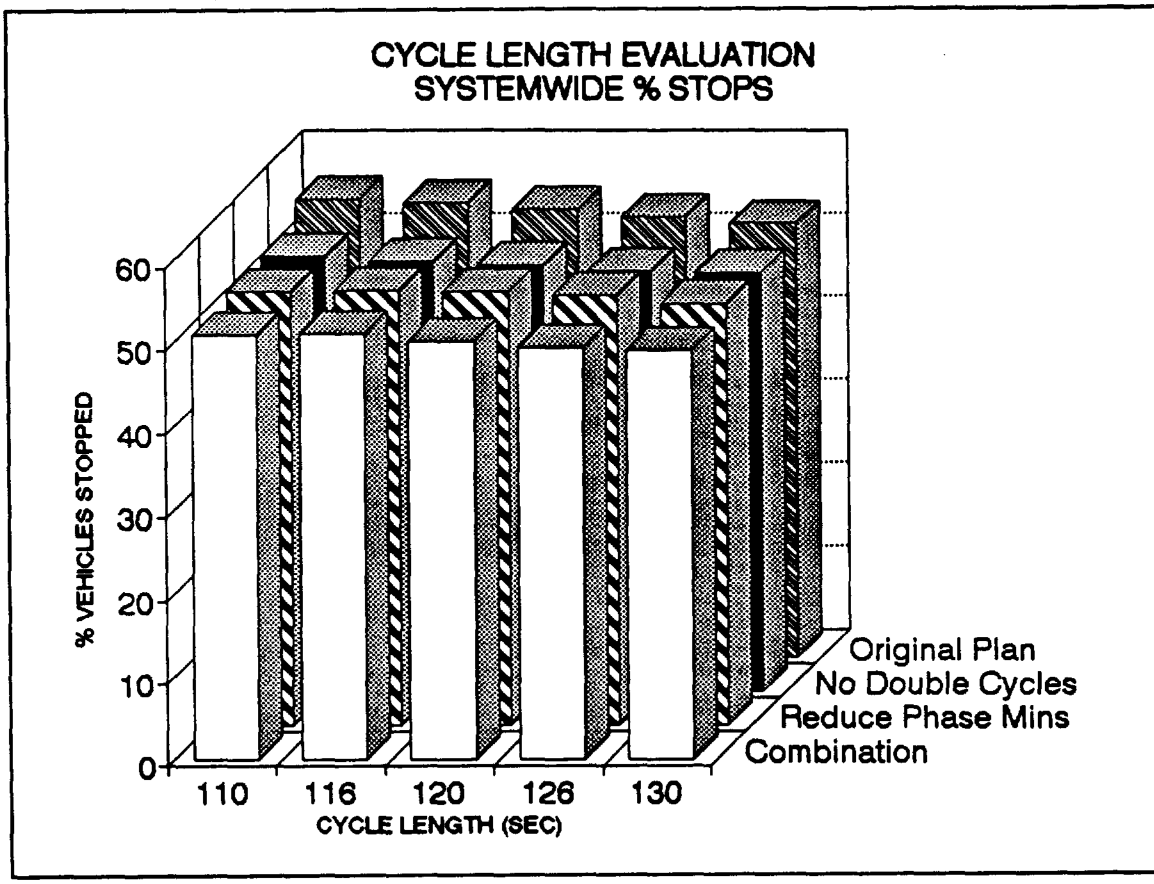

Figure 5-8 Systemwide Percent Stops

optimization procedures. However, the summation of the performance measures for the forty intersections as optimized in subsections was marginally higher than when the same forty intersections were optimized as a single system (Table 5-1). On the basis of these results, this optimization technique was not pursued further.

Table 5-1 Performance Measures: System vs Subsystem Optimization

	System Performance Measures		Arterial Performance Measures	
Optimization	Total Time (veh-hrs)	Total Delay (veh-hrs)	Total Time (veh-hrs)	Total Delay (veh-hrs)
Single System	1949	1173	1037	429
Eight Subsystems	1956	1180	1041	433

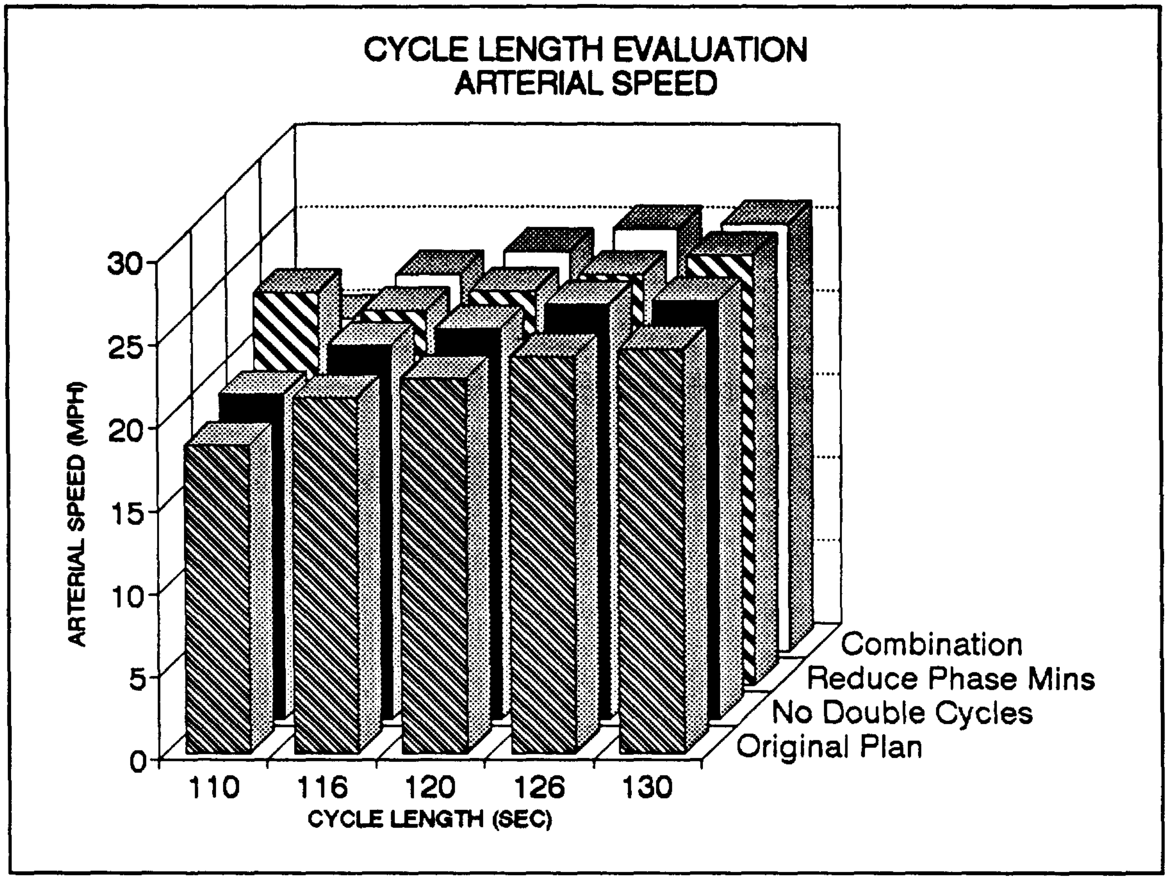

Figure 5-9 Arterial Summary: Average Speed

5.7 PERFORMANCE CRITERIA

Confronted with a variety of performance measures on both a systemwide and arterial-only basis, it was necessary for each agency to define their own objectives for coordination. Not until the individual agencies established coordination objectives could work be accomplished toward a collective optimization strategy.

The agencies east and west of Beach Boulevard preferred signal timing plans that favored improvements in arterial measures. Specific goals cited included achieving a travel speed of thirty miles per hour during the peak periods and reducing travel time across the corridor by twenty percent.

The closed-loop system agencies were disinclined either to implement a cycle length greater than 120 seconds or to subdivide their intersections. The City of Anaheim desired that their two-phase intersections be double cycled but stated that they would consider omitting this requirement during the AM and PM peak periods. Anaheim also was agreeable to developing the timing plans with lower cross street minimum green requirements at the intersections that were previously identified as having low pedestrian actuation.

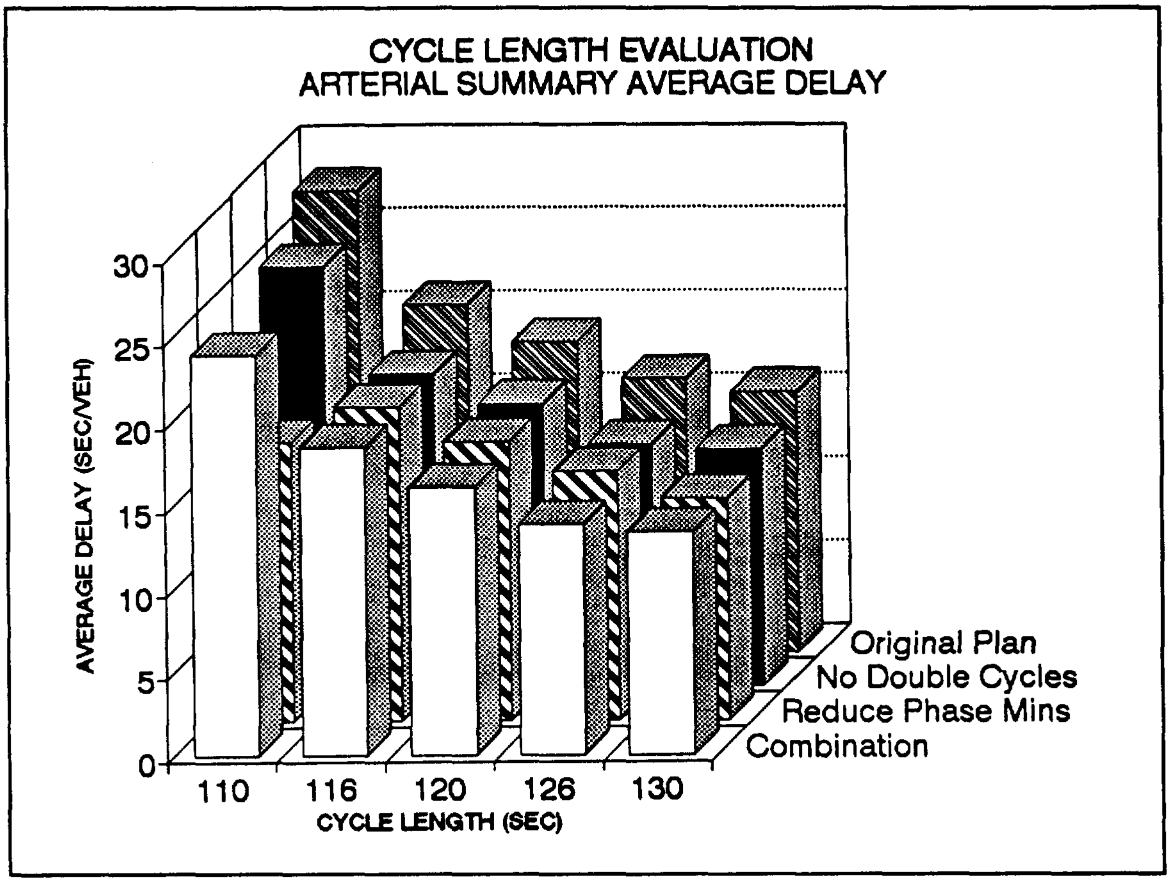

Figure 5-10 Arterial Summary: Average Delay

All agencies involved recognized that Beach Boulevard, a designated Super Street carrying more than twice the volume of Katella Avenue, may function as a "natural" arterial break point, and thus a natural timing plan boundary. Caltrans' concerns were confined to maintaining a 120-second cycle length along the length of Beach Boulevard, including at the intersection of Beach Boulevard and Katella Avenue. In addition, in the absence of a significant improvement in efficiency with any other cycle length, the agencies west of Beach Boulevard preferred a 120-second cycle length during the AM and PM peak periods so as not to disrupt their coordinated cross streets.

In light of the stated preferences of the corridor agencies, the focus was turned to arterial performance measures. As with arterial speed (Figure 5-9) and average arterial delay (Figure 5-10), performance of the arterial improved with regard to percent stops as the cycle length increased (Figure 5-13). Arterial performance was also improved by the elimination of double cycles and a reduction in minimum phase lengths at selected intersections.

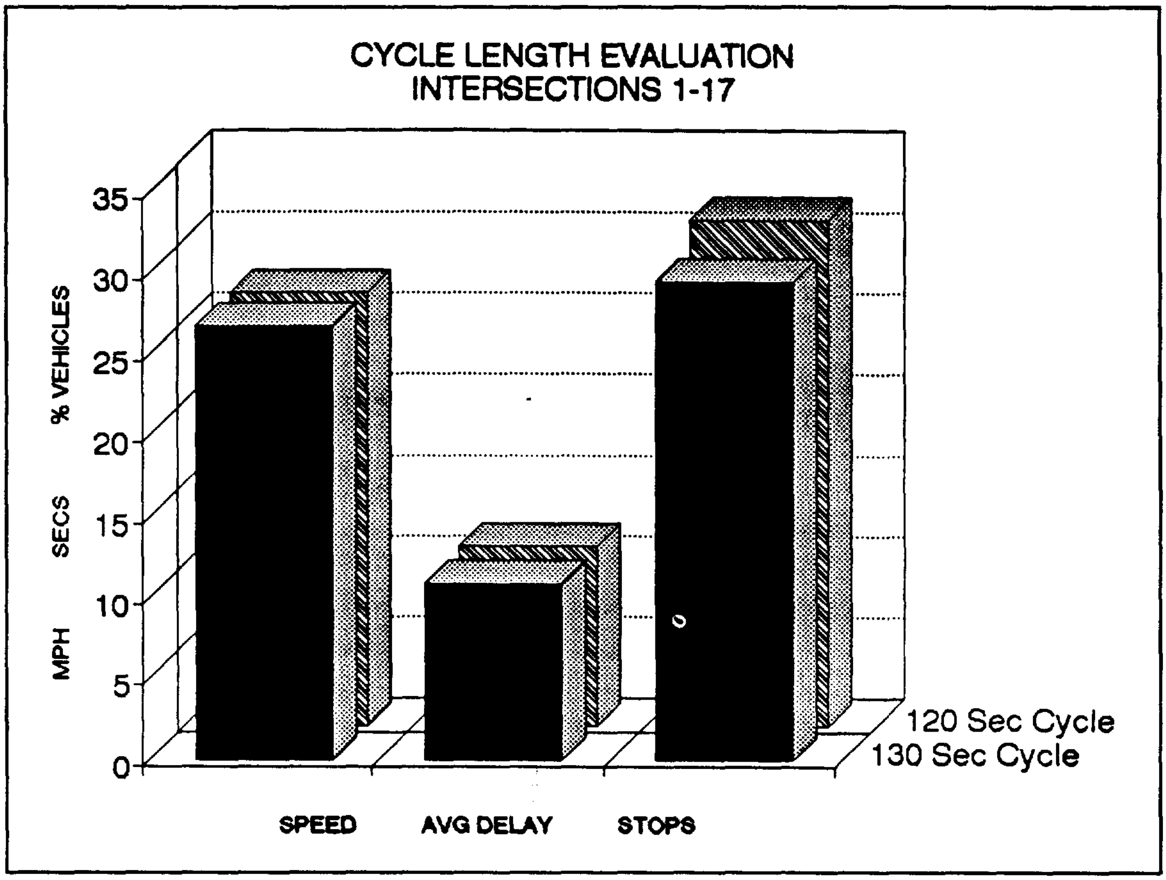

Figure 5-11 Intersections 11-17

5.8 PLAN SELECTION

The findings of these timing plan strategies were presented to the corridor agencies for their consideration together with representative time-space diagrams. The group weighed the relative merits of the cycle lengths, the timing strategies, and their resulting performance measures. Experience with the arterial as well as engineering judgement were contributing factors to the timing plan selection. The plan selected for the AM peak period included double cycled two-phase intersections in the City of Anaheim, reduced minimum phase lengths at selected intersections under UTCS control, and utilized two different cycle lengths. The arterial was divided between intersections 26 and 27, within the City of Anaheim. It had been Anaheim's experience that traffic varied greatly on either side of these intersections. Breaking the corridor at this point effectively divided the commercial/recreation area from the rest of the corridor. It was also surmised, and later verified, that it was the eastern-most intersections that caused the eastern portion of the arterial (intersections 18-40) to operate significantly better at a 130-second cycle length than at a 120 second cycle length (Figure 5-12). The cycle lengths decided upon by committee were 120 seconds for intersections 1 through 26 and 126 seconds for intersections 27 through 40.

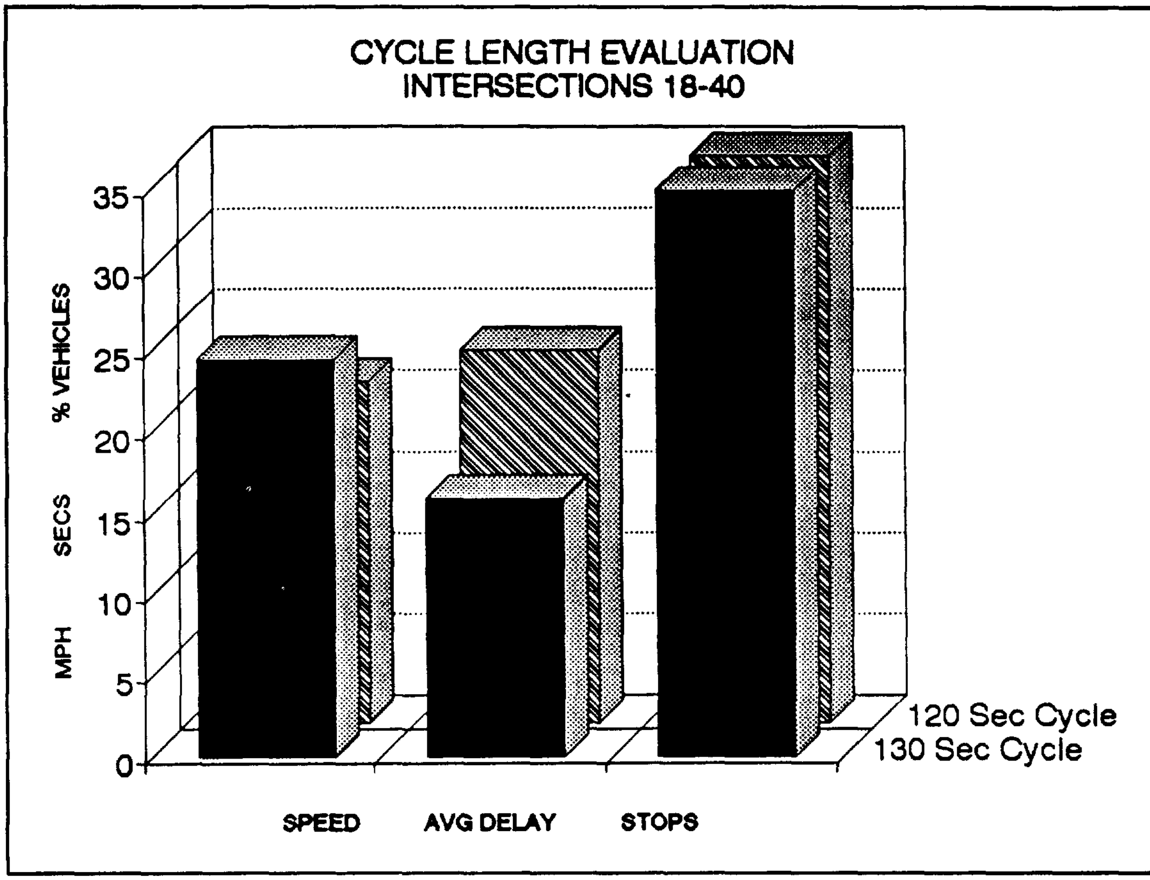

Figure 5-12 Intersections 18-40

The PM peak period showed trends in performance measures that were similar to the AM period but with higher volumes. The corridor agencies chose to implement a similar plan in the PM peak period, instituting a 120-second cycle on the western portion of the arterial and a 130-second cycle from intersection 27 to the eastern boundary of the system. After deciding upon a time-of-day schedule, the corridor agencies selected noon and off-peak timing plans to implement. The cycle length implemented with the noon timing plan was 120 seconds for the entire corridor. The off-peak plan, scheduled to run from 9:00 AM to 11:00 AM, utilized a 100-second cycle length. To accommodate a 100-second cycle length, Anaheim adapted the phasing plans of several of their intersections and Caltrans instituted a 100-second cycle length along the entire length of Beach Boulevard during the noon period. Once cycle lengths and splits were set, the consultant adjusted phasing plans for the intersections under control of the closed-loop system to maximize arterial progression.

5.9 IMPLEMENTATION RESULTS

The quantitative goals of the project included: (1) a 20 percent reduction in travel time along the length of the arterial and (2) achieving an average travel speed of 30 miles

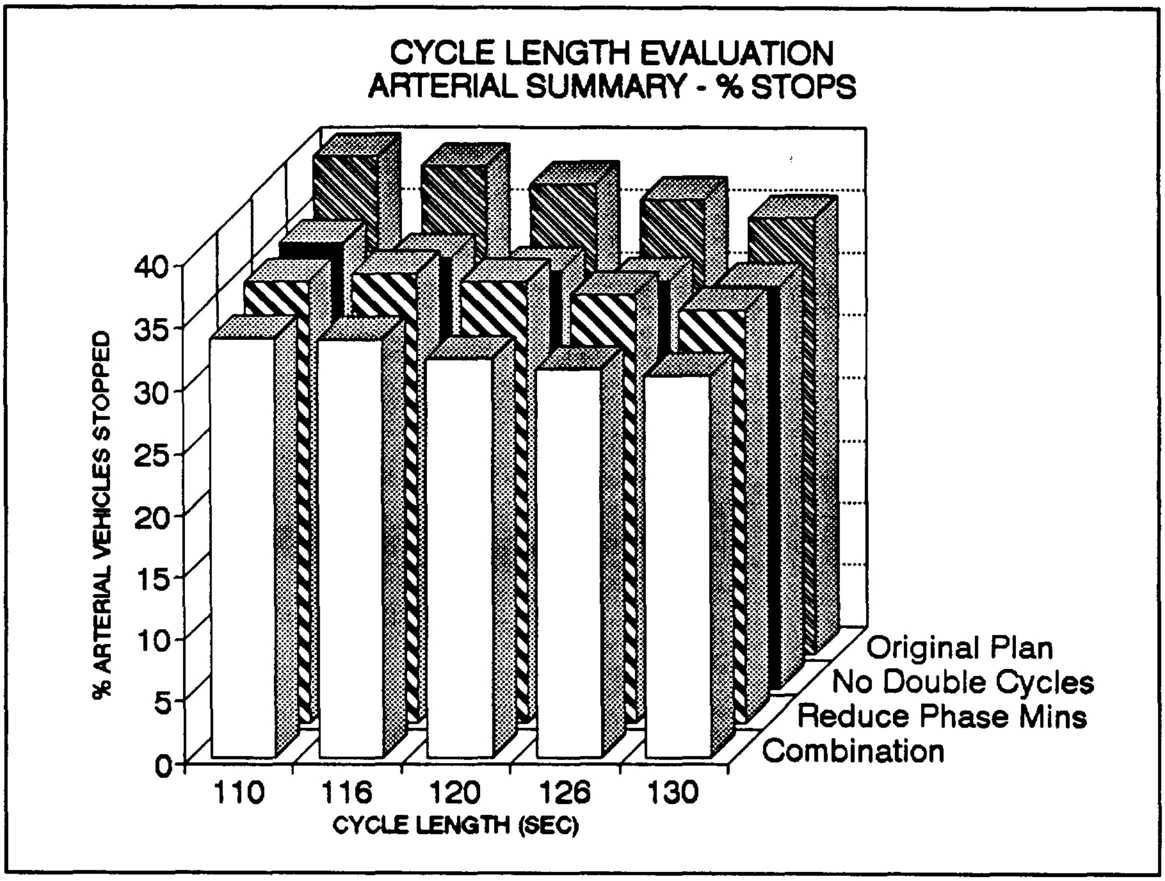

Figure 5-13 Arterial Summary: Percent Stops

per hour. To evaluate the effectiveness of the new timing plans, and to ascertain if these goals were achieved, BSI Consultants performed a series of travel time and delay studies. The studies were conducted both during the initial data collection effort (the "before" study) and after implementation of the coordinated timing plans (the "after" study). The collected data included the following measures of system performance:

(1) travel time between intersections,
(2) delay time at each intersection, and
(3) stops encountered on the corridor (total number and location of each stop).

The analysis of the data consisted of comparisons of the before and after performance measures for the system as a whole, and for individual sections of the arterial. The individual sections examined incorporated the following portions of the arterial (with included intersection numbers):

(1) Traconex Closed-loop controlled intersections (1-17)
(2) BiTran QuicNet controlled intersection (18)
(3) UTCS controlled intersections (19-40)

(4) previously coordinated Anaheim intersections (22-40)
(5) previously coordinated Caltrans/Los Alamitos/Cypress intersections (1-10)
(6) previously uncoordinated Cypress/Stanton/Caltrans/Garden Grove intersections (11-21)
(7) UTCS intersections operating at 120 second cycle length (22-26)
(8) UTCS intersections operating at 130 second cycle length (27-40)
(9) intersections immediately east of the 120/126 second cycle break (27-29)*
(10) intersections immediately west of the 120/126 second cycle break (24-26)*

* Note: The inclusion of three intersections in these sections adequately represented the affect of the cycle length break on system performance.

Without exception, the system as a whole as well as each of subsections, exhibited superior performance measures in the after study.

5.9.1 Systemwide Performance Measures

The average percent change in system performance was calculated for the AM peak period, for the system as a whole and separately for eastbound and westbound traffic. In addition, the average travel speed was calculated for each of these cases (Table 5-3). The average decrease in delay for the arterial was 30.5 percent, exceeding the stated goal. Additionally, the average travel speed observed in the after study was 29.8 miles per hour, approximately equal to the desired speed of 30 miles per hour.

Interestingly, while the eastbound and westbound "before" performance measures were of a similar magnitude, the improvement in the eastbound direction was markedly greater than the improvement in the westbound direction (e.g., the eastbound direction experienced a 46 percent decrease in delay while the westbound direction experienced an 11 percent decrease). This suggests that the TRANSYT-7F "optimization" of the system assigned a greater importance to the timing of the eastbound direction. Upon examination, it was found that the eastbound through volumes are approximately 14 percent greater than the westbound through volumes during the AM peak, explaining the need for greater improvement in the eastbound direction.

5.9.2 Sectional Performance Measures

The average percent change exhibited in system performance between the before and after time and delay studies was calculated for each of the arterial sections cited previously (Table 5-4). Each of the sections exhibited a decrease in travel time and delay, and a decrease or no change in stops.

The percent change in average delay observed in the after study ranged from a low of 24 percent to a high of 42 percent. As was anticipated, the greatest decrease was experienced in the section incorporating the previously uncoordinated Cypress, Stanton, Caltrans, and Garden Grove intersections. The least improvement was experienced in the section incorporating the previously coordinated Anaheim intersections. However, the improvement (24 percent) was significant, as was the improvement in the previously coordinated Traconex intersections (33 percent). Coordinated last in 1988 and 1987

Table 5-2 Systemwide AM Peak - Before/After Comparison

	Before	After	Change (%)
System Average:			
Time (secs)	26.97	23.76	-11.9
Delay (secs)	7.06	4.91	-30.5
Stops	14.75	8.80	-40.3
Travel Speed (mph)	26.24	29.80	13.6
Eastbound:			
Time (secs)	27.78	22.86	-17.7
Delay (secs)	7.84	4.22	-46.1
Stops	14.50	7.60	-47.6
Travel Speed (mph)	25.45	30.93	21.5
Westbound:			
Time (secs)	26.17	24.67	-5.7
Delay (secs)	6.28	5.59	-11.0
Stops	15.00	10.00	-33.3
Travel Speed (mph)	27.02	28.66	6.1

respectively, these figures give an indication of the magnitude of deterioration which can be experienced in timing plan efficiency over three and four years.

The UTCS intersections operating at a 120-second cycle length experienced a greater improvement in performance than did the intersections operating at a 126-second cycle length (37 percent and 24 percent decrease in average delay respectively). However, as the 120-second section incorporates three previously uncoordinated intersections and the 126-second section includes only previously coordinated intersections, this difference is not an indication of the appropriateness of the cycle lengths (the exclusion of the three previously uncoordinated intersections from the 120-second section causes the percent change in average delay to drop to 22 percent).

The intersections which border the 120/126-second cycle length break (Intersections 27-29 eastbound and Intersections 24-26 westbound) were analyzed to discern what affect the split in the system operation, due to the implementation of two cycle lengths, had on the performance measures. Examining only the respective directional flows affected by the cycle length break, the intersections east of the break experienced a 24 percent decrease in delay and the intersections west of the break experienced a 32 percent decrease in delay. While it is intuitive to believe that the cycle length break would have an adverse affect on the performance of the intersections bordering the break, the change in performance measures for these intersections are in

Table 5-3 Sectional Performance Measures: Before/After Comparison

Subsystem	Intersections	Measure	Before	After	Change(%)
Whole System	1-40	Time (sec)	26.97	23.76	-11.9
		Delay (sec)	7.06	4.91	-30.5
		Stops	14.75	8.80	-40.3
Traconex	1-17	Time	10.09	8.92	-11.6
		Delay	2.18	1.35	-38.2
		Stops	5.50	2.80	-49.1
Beach Blvd	18	Time	1.52	1.37	-10.2
		Delay	0.68	0.58	-15.6
		Stops	0.88	0.80	-8.6
UTCS	19-40	Time	15.36	13.48	-12.3
		Delay	4.20	2.98	-23.4
		Stops	8.38	5.20	-37.9
Previously Coord/Traconex	1-10	Time	5.24	4.64	-11.6
		Delay	0.96	0.64	-33.4
		Stops	2.88	1.00	-65.2
Previously Uncoordinated	22-40	Time	12.87	11.44	-11.1
		Delay	3.89	2.98	-23.4
		Stops	7.38	5.20	-29.5
Previously Uncoordinated	11-21	Time	8.86	7.68	-13.3
		Delay	2.21	1.29	-41.8
		Stops	4.50	2.60	-42.2
120 Second UTCS	19-26	Time	7.48	6.44	-13.9
		Delay	1.64	1.04	-36.7
		Stops	3.75	2.10	-44.0
126 Second UTCS	27-40	Time	7.89	7.04	-10.7
		Delay	2.55	1.94	-24.0
		Stops	4.63	3.10	-33.0
Subsystem Border/Eastbound	27,28,29	Time	2.41	2.15	-10.7
		Delay	0.98	0.75	-23.7
		Stops	1.00	1.00	0.0
Subsystem Border/Westbound	24,25,26	Time	2.59	2.31	-10.9
		Delay	0.96	0.66	-31.5
		Stops	2.00	1.60	-20.0

line with the changes exhibited by other sections. This suggests that large or diverse networks may be suitably coordinated with timing plans which incorporate more than one cycle length in their design. This is a concept which is explored in greater detail in Appendix A.

Finally, the before and after performance measures for the remaining three time periods are presented in Table 5-5. Again, without exception, system performance was improved after implementation of the coordinated timing plans.

Table 5-4 Systemwide Performance: Time-of-Day Before/After Comparison

Time-of-Day	Before	After	Change (%)
Noon Peak			
Time (secs)	26.27	21.85	-16.8
Delay (secs)	5.40	3.19	-40.9
Stops	14.50	8.40	-42.1
PM Peak			
Time (secs)	31.22	25.83	-17.3
Delay (secs)	9.14	5.64	-38.3
Stops	20.30	12.98	-36.1
Off-peak			
Time (secs)	29.23	23.28	-20.4
Delay (secs)	7.42	4.27	-42.5
Stops	17.50	10.37	-40.7

5.10 SUMMARY

A series of interjurisdictional traffic signal timing plans were developed with the TRANSYT-7F simulation model. Incorporated in the implemented timing plans were jurisdictional policies, and the experience and judgement of the engineers representing the participating agencies.

It was demonstrated that arterial performance measures improve with higher cycle lengths and the improvement rate decreases as the cycle length increases. It was also shown that as cycle length increases, cross street queue lengths increase. This suggests that there is a boundary of cycle lengths within which an arterial will operate efficiently, and within this boundary there are trade-offs between various performance measures (e.g., arterial delay versus cross street delay).

Alternate phasing and optimization strategies were explored and the resultant performance measures were evaluated by the committee of corridor agencies. In order to agree upon the adoption of a timing plan, the multi-jurisdictional committee first needed to formulate specific goals and criteria with which to evaluate the timing plans. The compilation of the various agencies' goals and criteria resulted in the development of four alternate time-of-day timing plans, two of which incorporated two subsystems operating at different cycle lengths.

"Before" and "after" time and delay studies were undertaken, the analysis of which demonstrated an average AM peak period arterial travelling speed of 30 mph, representing a 30.5 percent decrease in arterial delay. The previously uncoordinated sections of the arterial experienced the greatest improvement in stops and delay and the previously coordinated sections the least. However, the previously coordinated sections were improved significantly, highlighting the need to monitor and update coordinated timing plans as traffic flows change.

Finally, the areas immediately bordering and affected by the break in cycle lengths experienced significant improvement in performance. This suggests that large or diverse networks may be coordinated with timing plans which incorporate more than one cycle length within the network. In addition to suggesting that the constraint of a single cycle length may offset some of the benefits of coordination (a concept explored in Appendix A), it also suggests that when agencies are not in full agreement on timing policies or strategies, timing plans can be developed around these differences and improvements will be realized.

CHAPTER 6. SUMMARY, FINDINGS, AND RECOMMENDATIONS

6.1 INTRODUCTION

The purpose of the Katella Avenue case study has been to address the three primary elements of interjurisdictional traffic signal coordination:

(1) traffic control hardware,
(2) signal timing plans, and
(3) interjurisdictional cooperation,

and to identify the key issues concerning these components that help or hinder coordination efforts. Each of these elements is discussed in turn in this report summary. A fourth element, a regional funding source, is also an essential component of the coordination effort and is discussed under the heading of Financial Considerations.

6.2 HARDWARE COORDINATION

The coordination of Katella Avenue resulted in the linking of three different control system technologies:

(1) the Traconex closed-loop system,
(2) the BiTran QuicNet system for Caltrans' Type 170 controllers, and
(3) the Urban Traffic Control System - Enhanced (UTCS).

A fourth section of the arterial, that within the City of Orange and under control of Multisonics equipment, is operating independently from the remainder of the corridor.

Several issues came to the forefront during the process of planning the corridor's hardware design:

(1) Retaining primary control and/or responsibility for one's intersections is fundamental to most jurisdictions.
(2) Jurisdictions tend not to want to see their hardware replaced in order to communicate with neighboring systems.
(3) Jurisdictions associate a varying range of importance to the current and potential technical capabilities of traffic management systems.

6.2.1 Physical Control

The issue of physical control was probably the primary consideration which lead to the development of the four alternate control systems. For the most part, municipal agencies are reluctant to transfer control of their traffic signals to another agency unless there is an overwhelming advantage to be gained from such a transfer (e.g., when two or more agencies share jurisdiction over a traffic signal it is advantageous to transfer control to one agency, and the City of Garden Grove found it advantageous to tie into Anaheim's Traffic Management System, a technology that they would not have been able to afford on their own).

While jurisdictions have no objection to sharing information regarding, or gathered by, their traffic control systems, this ability to transfer information can not interfere with the jurisdictional agency's accessibility to their signal control. This is evident from Caltrans' decision not to intertie with the Anaheim UTCS, and instead, implement the BiTran QuicNet system which allows Anaheim to monitor the intersection from a personal computer if they so choose.

In comparison, these same agencies have not exhibited a reluctance to transfer control, or at least responsibility for system operations, to a consultant. However, this is a delegation, not a release, of control. An advantage of this type of delegation is that with a central, objective system manager, such as a contracted consultant, an integrated interjurisdictional system such as the Traconex closed-loop system on the western portion of Katella Avenue can emerge. The disadvantages of contracting a consultant's services to oversee signal operations include:

(1) the funds to retain the consultant's services must be regularly allocated by the agency, and
(2) agency staff will not necessarily have the expertise to operate the system.

Also, the likelihood that a larger-sized agency which has a substantial investment in a traffic control system, would delegate control of their system to a consultant is small.

6.2.2 Existing Hardware

Each agency with jurisdictional control over traffic signals included in this project has made a substantial investment in their existing hardware. Much of this hardware is relatively new and was selected to meet the agency's traffic control needs from what was, or now is, the current state-of-the-art technology. It is reasonable that these agencies wish to see their purchases utilized for the extent of their full expected life-span.

However, these purchasing practices have resulted in the installation of a variety of control systems manufactured by a variety of vendors. In general, the existing control systems can not be integrated due to the incompatibility of their communications systems. This is also true of the integration of UTCS with most existing controllers. While communications devices have been developed to integrate UTCS with two makes of controllers (CSC Type 1 and Caltrans Type 170), there has been an unwillingness on the part of some manufacturers to cooperate in the development of such devices. This is understandable since, in the case of UTCS, the centralized control diminishes the importance of the local controller and dispenses with the need for that manufacturer's master controllers. Thus, full integration of neighboring traffic control systems requires either the replacement of existing local controllers or a new understanding between the vendors of existing controllers and traffic management systems.

6.2.3 Technology

With the advent of microprocessors in the 1970's, the emphasis in traffic signal control hardware involved distributing the intelligence of systems to areas of local control. This decreased central computer and communications requirements, which in turn, reduced costs and increased the reliability of traffic control systems by minimizing the amount of data that had to be transferred between local and central control units. The recent emergence of IVHS technology, and the associated need for data, has reallocated some of that emphasis back to centralized traffic control. However, this has raised questions concerning which control structure is more efficient in terms of costs, operations, and traffic control.

Centralized control allows an entire network to be viewed and, theoretically coordinated as one contiguous system. With proper communications channels, it permits large amounts of data to be transferred between system detectors, controllers, and the central computer on a continuous basis. In addition to allowing for traffic responsive control, a control strategy which is also available with distributed systems, it is envisioned that centralized control will accommodate the needs of more sophisticated IVHS technology (for example, Advanced Traveler Information Systems (ATIS), which must provide drivers with accurate information on current and predicted traffic conditions and the best route alternatives.).

Thus, the City of Anaheim implemented its Traffic Management System with the intent that it would evolve with IVHS technology. They saw a need to manage traffic on a regional rather than a strictly local basis. They were willing to both sacrifice some of the user-friendly features of smaller systems as well as to dedicate full-time personnel to actively managing their traffic system.

However, as was demonstrated by the City of Orange's decision not to become involved in the project, and by the implementation of the Traconex closed-loop system, some traffic engineers are not convinced that the benefits of centralized control outweigh the disadvantages. It has not yet been adequately demonstrated that "actively managing" traffic yields better results than does the implementation of good timing plans. In light of this, some engineers would prefer to see time and money put into collecting and analyzing data (specifically traffic turn counts) to produce superior timing plans rather than into replacing hardware. They believe that there has been too little emphasis placed on sound timing principles and too much emphasis placed on new technology.

6.3 SIGNAL TIMING

A primary objective of the Katella Avenue coordination project was to coordinate the timing of forty traffic signals across seven jurisdictions. For a combination of technical and institutional reasons, a result of the coordination effort was the operation of two individually coordinated subsystems during the AM and PM peak periods. In addition, the TRANSYT-7F analysis of the corridor suggested that an arterial may be able to sustain some level of non-coordination across boundaries (political or otherwise) without realizing a perceivable degradation in performance. This raises two fundamental questions:

(1) If a system does not operate most efficiently fully coordinated under one cycle length, what criteria should be used to divide the system?

(2) If a system operates most efficiently under a series of coordinated subsystems, is coordination across jurisdictions or across control systems justified, and at what expense?

The second question, concerning justification for coordination across jurisdictions and/or control systems, is further compounded by the knowledge that some level of coordination existed on Katella Avenue between jurisdictions and between control systems prior to the initiation of this project (the City of Los Alamitos coordinated with Caltrans at the intersection of Interstate 605, and the City of Anaheim coordinated with Caltrans at the intersections of Interstate 5 and State Route 57). This suggests that neighboring jurisdictions recognize areas where coordination would prove expedient and do take steps locally to achieve coordination when it is beneficial.

The "before" and "after" time and delay studies demonstrated that the efficiency of traffic signal timing plans is ultimately dependent on timing plans being updated as traffic flows change over time. The need for timely data to produce optimized signal timing plans may justify the implementation of communications intensive systems due to their potential to collect data and indicate when timing plans should be revised.

Another consideration is that Orange County's Super Street network was designated for its ability to move more traffic, as well as to move existing traffic more efficiently. With this in mind, as Super Street improvements such as coordinated traffic signal timings are implemented and arterial capacity is increased, more travellers will choose to utilize these Super Streets. Thus, the newly implemented timing plans will be outdated more quickly than what might be expected for an average arterial in the region.

6.4 INTERJURISDICTIONAL COOPERATION

Complementing the technical considerations of coordinating traffic control hardware and timing plans, is the cooperative effort necessary on the part of all affected jurisdictions. A number of potential obstacles to such cooperative efforts were identified in the literature review. Those obstacles which were applicable to the Katella Avenue coordination project include:

(1) concerns that coordination will not be beneficial,
(2) the complication of communications due to the sheer number of agencies involved,
(3) a significant increase in administrative responsibilities,
(4) the need for a realistic time schedule, and
(5) the need for continued work to assure that the benefits achieved through coordination are maintained in the future.

Agency "turfism" and a lack of effort at a higher level of government played minor roles in the Katella Avenue coordination effort. Agency "turfism" was discernable only with regard to who had control of the traffic signal operations; here, the obstacle was more a factor of neighboring agencies' objectives and priorities not being in accordance, than a true matter of "turfism." Again, the coordination project resulted in three hardware technologies, rather than seven agencies, being coordinated. A leader existed for the technologies at both the east and west ends of the corridor, and Caltrans represented the third technology which comprised a single intersection. As Caltrans was concerned with only what was implemented at that single intersection, and not with what was implemented on the remainder of the corridor, the cooperative effort was concentrated between two defined leaders. Attendance at regularly scheduled meetings and the absence of any real source of conflict, laid the groundwork for a successful project.

While OCTC financed a substantial portion of the project and commissioned a number of studies that lead to the project concept, they did not have technical knowledge of either traffic signal operations or coordinating signals between agencies; thus, they were not available to provide technical assistance during the course of the project. Given the financial incentive to implement a coordinated timing plan, the agencies were left on their own as to how to proceed.

Concerns which posed potential hindrances but were sufficiently addressed were:

(1) adequate finances,
(2) the need for clearly defined objectives and expected achievements, and
(3) the need for a strong leader.

The project began with the general objective of improving traffic flow along Katella Avenue and upgrading systems/equipment. However, during the course of the project the objectives were fine tuned. The need for a strong leader was met on several levels. The City of Anaheim succeeded in organizing the cooperative effort and, through their fine management of the project, ensured that the project was successfully implemented. In addition, the City of Anaheim's traffic engineering staff garnered the support of the Anaheim City Council, who authorized a significant expenditure of funds both for the project and for the implementation of their Traffic Management System.

What remains to be seen from this effort is how well the agencies will continue to cooperate when there is no longer a financial incentive to work together. The UTCS portion of the corridor (incorporating Anaheim, Garden Grove, and a portion of Stanton) is preparing to implement traffic responsive control. When this is implemented, the following questions must be addressed:

(1) Will the UTCS agencies continue to work with the segments of the corridor that are under control of the Traconex closed-loop system or the Bitran QuicNet system?
(2) Or will the operation of Katella Avenue revert to segments operating independently of one another?
(3) If so, what, if any, operational efficiency will be lost?

6.5 FINANCIAL CONSIDERATIONS

The Katella Avenue Coordination project was possible because of the existence of a regional funding source, OCTC. Without this source, the corridor would have continued operating with little communication between the jurisdictions and with deficient hardware within some jurisdictions. Additionally, a number of studies (for example, the intertie study) would not have been funded. However, this was one of thirty-nine projects representing an expenditure of approximately $4,238,000 of regional funds. Tragically, a significant opportunity to learn from this investment of funds has been missed because OCTC requested no final report of the benefits achieved, or the problems encountered, from the participating agencies.

In the Katella Avenue project alone, a number of alternate approaches to interjurisdictional coordination were implemented. This is an indication of the evolution in traffic control which is now occurring. Alternate approaches and new concepts such as interjurisdictional coordination must be evaluated to ascertain that improvements in traffic control technology and procedures continue to develop. To assist in these evaluations, standards or expected ranges of performance measures must be established. An accounting of the improvements achieved in the thirty-nine independent interjurisdictional coordination efforts funded through OCUTT would have been a significant contribution to such an effort.

As stated earlier, the funding agency had no technical expertise in the area that it was funding. Consultants assisted in the evaluation process of the proposals, but they only evaluated the estimated costs of the projects, not the viability or sense of the project. All thirty-nine projects submitted received funding; the Katella Avenue project represented one third of the total money allocated. Still, the entire $4.5 million of OCUTT funds available for signal coordination was not spent, with approximately $600,000 being carried forward into the following year. This represents a problem because, in general, with a lack of competition for available funds, projects may receive funding whether they possess merit to be funded or not.

Additionally, one of the consultants who evaluated the cost proposals, also wrote the report upon which OCTC based its decision to fund interjurisdictionally coordinated signal timing projects, and was the City of Anaheim's System Manager. When a funding agency does lack technical expertise, care must be taken to ensure that potential conflicts of interest do not arise from their efforts to seek such expertise from an outside source.

The OCUTT program was promoted as a traffic signal coordination program. Yet, a significant portion of the Katella Avenue funds were spent on design studies and the creation of a new infrastructure. If OCTC had intended for the program to do more than fund signal timing efforts, then that intent should have been published to encourage competition among proposals. Additionally, with the implementation of traffic responsive control on the UTCS portion of the corridor, the corridor will be effectively uncoordinated between systems. The decision to implement traffic responsive control, a decision which was made possible partially due to OCTC's funding of the UTCS infrastructure, seems to conflict with the published intent of the OCUTT program.

OCTC's main criterion for project funding was that coordination be achieved across jurisdictional boundaries, yet no criteria for improvement in traffic performance were set. The City of Anaheim selected Katella Avenue for coordination based on OCTC's criteria when, possibly, the coordination of a previously uncoordinated arterial such as La Palma Avenue may have had a greater impact on both local and regional traffic flow.

Higher-level funding sources can play a significant role in the advancement of interjurisdictionally coordinated projects. However, as the review of the Santa Clara County interjurisdictional traffic signal committee pointed out, an external funding source is not necessary to implement coordinated timing plans.

If an external source does fund traffic signal coordination projects, OCTC has suggested that the various agencies' interest in participating should be established prior to funding a study of the project's potential. Additionally, to achieve the greatest benefits from the available funds, minimally, the following criteria should be met:

(1) the funded program's criteria and objectives should be well developed and published with a request for proposals,
(2) funded projects should be required to demonstrate how their project is designed to achieve those objectives, and
(3) a quantifiable and/or a qualitative assessment of the results of the project should be required.

6.6 RECOMMENDATIONS FOR FURTHER STUDY

The evaluation of the Katella Avenue Signal Coordination project has raised a number of questions which merit additional consideration. These may be categorized by the primary elements of signal coordination: control hardware, traffic signal timing, and agency cooperation.

6.6.1 Control Hardware

The benefits and disadvantages of alternate control technologies should be analyzed. Does one control system offer more efficient regional or local performance at the expense of another, and if so, can this be alleviated through more effective use of signal timing principles?

The benefits of "actively managing" traffic versus time-of-day timing plan implementation should be studied by reevaluating the Katella Avenue corridor at a future time (say one or two years). Has one system proven more capable of maintaining or increasing its efficiency? What is the reason for this variation if it exists (e.g., the control system, agency priority, funding)?

6.6.2 Signal Timing

Additional studies concerning the potential benefits of interjurisdictional coordination of traffic signals should be conducted. These would involve the question of whether the constraint of a common cycle length counters the benefits of interjurisdictional or inter-control system coordination. The TRANSYT-7F analysis presented in this report, which estimates performance measures of coordinated and non-coordinated systems with a macroscopic simulation model, may be supplemented with microscopic studies that can accurately simulate the stops and delay encountered at the border of independent subsystems. If a common cycle length proves to be inefficient, a study of what criteria should be used to designate subsystems would be beneficial.

6.6.3 Cooperation

Model contractual forms from this project should be made available to other agencies interested in similar projects. The Katella Avenue project agencies can be asked to evaluate and modify these forms as the cooperative effort continues.

6.7 POST-PROJECT EVALUATION

Project participants were interviewed regarding the cooperative effort; each concluded that the project was a success on several levels. First, the project achieved its goal of improving the flow of traffic across jurisdictional boundaries, and traffic flow also was improved within jurisdictions. Capital and infrastructure improvements within the various jurisdictions were funded, and an application of centralized control in the City of Anaheim demonstrated the potential in regional coordination. The participants believe that the success of the project was due to the high-level of cooperative effort between agencies, the performance in project administration by the City of Anaheim, and the expertise of the various project participants.

The project took nearly 40 months of effort from the pre-proposal stage to the time of implementation. All participants agreed that the project will take continued effort from each agency to maintain the benefits achieved through coordination and all believe that the project agreements will remain as viable documents in the future.

REFERENCES

Bernstein, Robert and James Billing (1988). "Green River Valley Transportation Action Plan: The Development of A Successful Interjurisdictional Road Improvement Plan," Transportation Research Board, Washington, DC.

Burkhardt, Jon E., Sue F. Knapp, , and Mark J. Ramsdell (1980). Coordinated Transportation Demonstration Results, prepared by Ecosometrics Incorporated for the Department of Health, Education, and Welfare, Bethesda.

California Energy Commission (1984). Fuel-Efficient Traffic Signal Management, Results from the 1983 Program

Christiansen, Dennis L. and W. V. Ward (1988). An Enhanced Role for the Arterial Street System in Texas Cities, Texas State Department of Highways and Public Transportation, Austin, Texas.

Dey, Donald (1990). "Anaheim's Integrated Traffic Management System," Compendium of Technical Papers, Institute of Transportation Engineers, District 6 43rd Annual Meeting.

Dunphy, Robert T. and Ben C. Lin (1990). Transportation Management Through Partnerships, Washington, D.C., ULI-the Urban Land Institute.

Gakenheimer, Ralph, T.F. Humphrey, J.G. Allen, J. Ostler, A. Hsu (1990). Intergovernmental Differences in Suburban Congestion Policy, Final Report prepared for USDOT Urban Mass Transportation Administration.

Helmer, James R.(1990). "Interjurisdictional Traffic Signal Committees - Do They Work?", Compendium of Technical Papers, 60th Annual Meeting, Institute of Transportation Engineers, Washington, D.C.

Hindrances To Coordinating Transportation of People Participating In Federally Funded Grant Programs, Volume I, Report of the Comptroller General of the United States, October 17, 1977.

JEF Engineering (1982). High Flow Arterial Concept Feasibility Study, prepared for Orange County Transportation Commission.

JHK & Associates (1989). Comprehensive Signal Coordination Plan for Orange County -Phase 2 Report, prepared for Orange County Transportation Commission.

JHK & Associates (1990). Katella Avenue Intertie Project, Design Study Report, Draft Final Report prepared for the City of Anaheim.

Kidder, Alice E. (1980). The Financing of Multijurisdictional Public Transportation Services, Washington, D.C., U.S. Department of Transportation.

Leonard, John D. (1990). CHAOS User's Manual, Institute of Transportation Studies, University of California, Irvine, Ca.

McShane, William R. and Roger P. Roess (1990). **Traffic Engineering**, Prentice Hall, Englewood Cliffs, New Jersey.

Neenan, Barbara (1991). Interjurisdictional Coordination of Katella Avenue Traffic Signals, unpublished Masters Thesis, Department of Civil Engineering, University of California, Irvine.

Neudorff, Louis G. (1988). Guidelines for Successful Traffic Control Systems, Volume II, Final Report, McLean, Virginia, Office of Safety and Traffic Operations R&D, Federal Highway Administration.

Orange County Transportation Commission (1984). Orange County Annual Report on Transportation: FY 1983-1984.

Orange County Transportation Commission (1986). Orange County Annual Report on Transportation: FY 1985-1986.

Orange County Transportation Commission (1987). "Challenge & Change", Orange County Annual Report on Transportation: 1986/1987.

Rowe, S. Edwin (1990). "Transportation in the 1990s: a Historical Juncture," **ITE Journal**, Volume 60, No. 12.

Southern California Association of Governments (1987). Costs of Congestion - Draft, Economic Planning and Development Program, Prepared for the Regional Institute of Southern California.

Southern California Association of Governments (1988). Congestion in the Los Angeles Region: Costs Under Future Mobility Strategies - Draft, Economic Planning and Development Program.

Skabardonis, Alexander, R. Singh and E. Deakin (1988). The Fuel-Efficient Traffic Signal Management Program: Evaluation of the Fourth and Fifth Funding Cycles, Research Report to the California Department of Transportation.

Van Dell and Associates (1984) Super Streets Program for Orange County - Draft, prepared for Orange County Transportation Commission by Van Dell and Associates, Basmaciyan-Darnell, and Rutan and Tucker.

U.S. Department of Transportation (1986). Transportation Management for Corridors and Activity Centers: Opportunities and Experiences, Washington, DC.

Wallace, C.L.,et al. (1988). TRANSYT-7F User's Manual, Federal Highway Administration, Washington, DC.

Walther, Erskine S.(1990). Coordination of Rural Public Transportation Services in Three Southeastern States, US Department of Transportation, Washington, DC.

APPENDICES

A. AN ANALYSIS OF INTERJURISDICTIONAL COORDINATION ALTERNATIVES

B. SAMPLE AGREEMENTS

Memorandum of Understanding
Signal Coordination Agreement
Operations and Maintenance Agreements

APPENDIX A: TABLE OF CONTENTS

APPENDIX B: SAMPLE LEGAL AGREEMENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX A

TECHNICAL ANALYSIS OF INTERJURISDICTIONAL COORDINATION ALTERNATIVES

A1. MOTIVATION FOR ALTERNATIVE ANALYSIS

To effectively evaluate the benefits of interjurisdictional traffic signal coordination (i.e., all intersections in the network coordinated under one cycle length), an analysis of alternate coordination strategies was undertaken. The analysis was designed to identify improvements in traffic performance measures gained through interjurisdictional coordination. Of primary interest was the determination of interjurisdictional coordination's marginal contribution to system performance assuming each jurisdiction's own system was already coordinated. Similarly, an investigation into the gains in system performance obtained by interconnecting controller systems when each controller subsystem was already coordinated (and therefore is also coordinated between jurisdictions) was undertaken. Finally, an effort was made to determine if the system could operate more efficiently as a series of independent subgroups rather than as one continuous system.

A2. ALTERNATE COORDINATION STRATEGIES

In light of the impracticality of field implementation of a number of alternate coordination strategies, the alternatives were analyzed via simulation modeling using TRANSYT-7F. The AM peak period was chosen for analysis because it represented a prime travel period (morning commute) which experienced a significant amount of recurrent congestion yet it was not so severely congested that intersections were over-saturated (a condition TRANSYT-7F does not simulate accurately). TRANSYT-7F data sets were created from a base data set for each of the following coordination strategies:

(1) Optimizing the arterial as a single, 40 intersection system with one common cycle length throughout.
(2) Breaking the arterial at jurisdictional boundaries and optimizing each of the resulting subsystems independently. Thus, each subsystem would operate at its own optimal cycle length and adjacent subsystems would not be coordinated.
(3) Breaking the arterial at control system boundaries and optimizing the resulting subsystems independently.
(4) Breaking the arterial at points where significant changes in through volumes occurred, thus letting traffic flow patterns determine the subsystems.

The first strategy, operating the arterial as a single system, involved an analysis of the system's performance measures when optimized at a succession of cycle lengths. The timing plan/cycle length which produced a combination of the lowest stops and delay was chosen as the optimal timing plan.

The analysis of the remaining three coordination strategies, all involving subsystems, was not as straightforward. Intuitively, it was believed that stops and delay would be increased between subsystems as a result of the subsystems operating independently. Therefore, to accurately compare these alternatives to the full corridor coordinated system, a procedure to model stops and delay generated at the boundaries of two independent subsystems needed to be developed.

A3. MODELING SUBSYSTEM STOPS AND DELAY

A series of alternate hypothesis were tested to quantify the stops and delay generated at subsystem boundaries. Specifically, the percent change in stops and delay generated by a single system being divided into two subsystems was sought.

A3.1 Hypothesis 1: Negligible Percent Change

Through TRANSYT-7F simulations of a system encompassing two subsystems which operate at different cycle lengths, it was found that the most significant change in stops and delay occurred at the intersections directly bordering the subsystems' boundary. Therefore, subsystem performance measures were evaluated for these intersections only.

It was initially hypothesized that the increase in stops and delay generated by a coordinated arterial being broken into two independent subsystems would be insignificant on an intersection-by-intersection basis. Because the suboptimal offset resulting from two subsystems operating independently affects only one of four approaches to a single intersection (Figure A-1), and because the optimal offset as determined by TRANSYT-7F may be less than optimal for that approach because it was calculated to serve traffic flowing in two directions, it was assumed that any additional stops and delay resulting from the suboptimal offset at that intersection would be insignificant.

A3.1.1 Methodology: Hypothesis 1

A total of fourteen intersections (Intersections 22 through 35) representing varying traffic volumes and intersection spacing were selected to define the "system." The system was divided into two subsystems (Figure A-2) and TRANSYT-7F was utilized to simulate the interaction between the two independent subsystems. To examine the effects of a system break under different conditions (e.g., distance between the intersections, cross street volumes), the process was repeated with the same system using alternately defined subsystems. The resultant subsystem performance measures were compared to the single system performance measures and the percent change was noted.

Subsystems A and B were defined by breaking the system between intersections 30 and 31. Subsystem A was defined as operating at a 120-second cycle length, Subsystem B at 130-seconds. To simulate traffic flowing east to west, from Subsystem B to Subsystem A, the following procedure was followed:

(1) The entire system, represented in one TRANSYT-7F data set, was optimized at a 120-second cycle length.

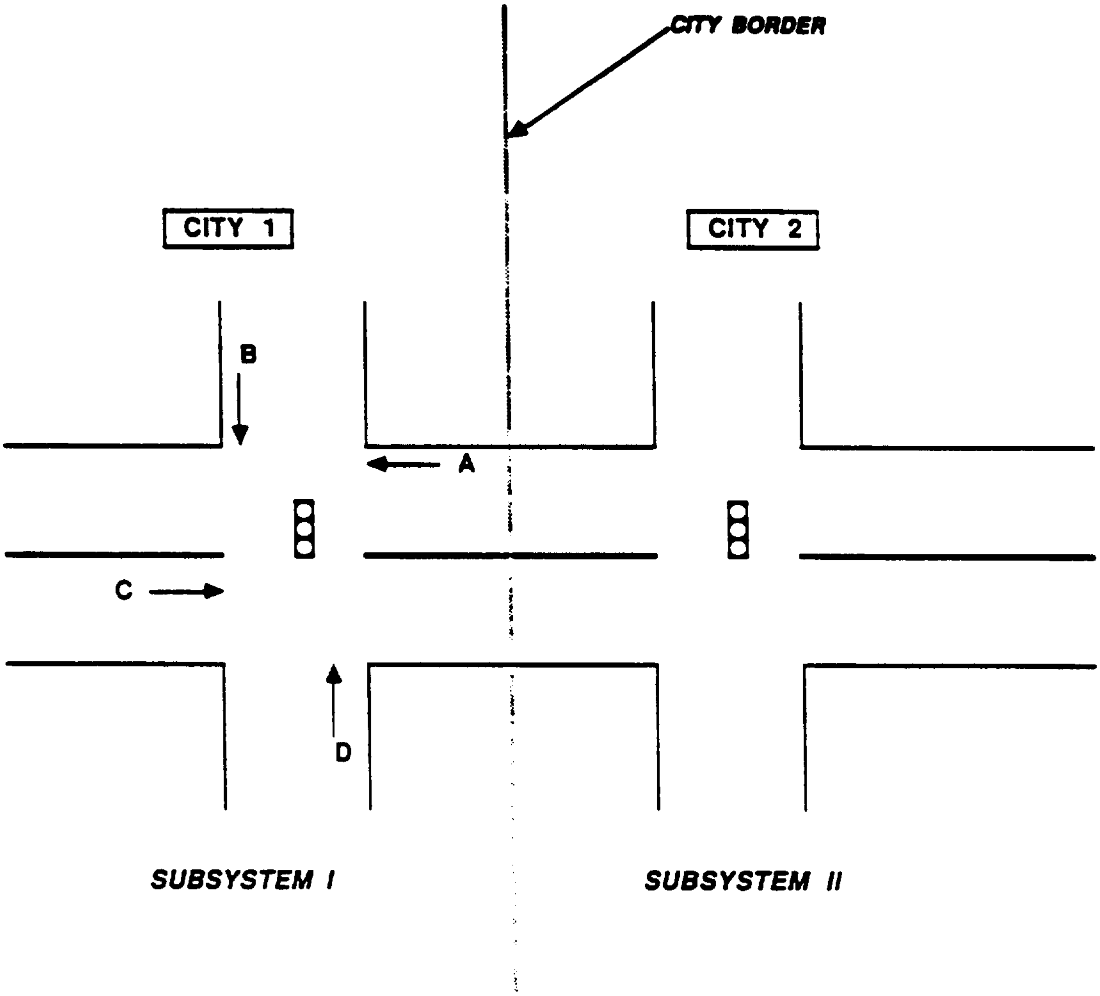

Figure A-1. Effect of a Suboptimal Offset on a Single Intersection

(2) The relative offsets of Subsystem B were noted.

(3) The offset of intersection 31, the intersection immediately east of the break in Subsystem B, was arbitrarily changed to zero. The offsets of the remaining intersections in Subsystem B were changed to maintain the same relative offsets as found under optimized conditions. Thus two optimized and independent subsystems resulted.

(4) A TRANSYT-7F simulation produced a set of performance measures for Subsystem A.

(5) The offsets of Subsystem B were increased uniformly by 10 seconds, the difference between Subsystem A's and B's cycle length. A second TRANSYT-7F simulation produced a new set of performance measures

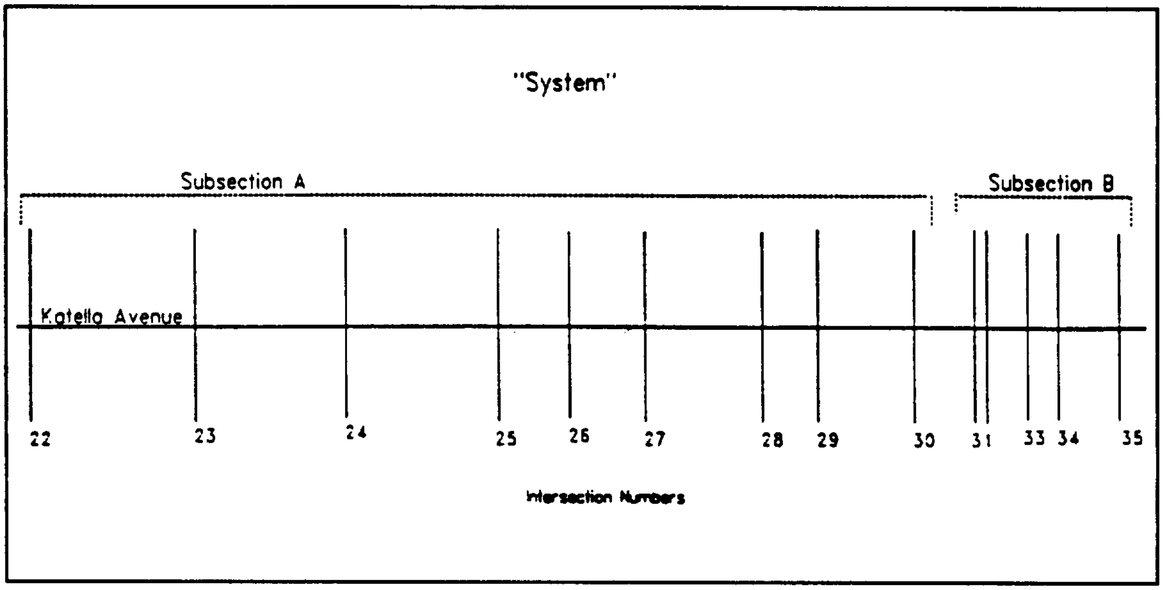

Figure A-2. Sample System Broken into Two Subsystems

for Subsystem A.

(6) Step 5 was repeated until a total of twelve simulations, the number of cycles after which the Subsystems would be temporarily "in sync" again, were completed (Table A-1).

(7) The twelve sets of performance measures were averaged to produce the average measure of stops and delay encountered by vehicles approaching Subsystem A.

This procedure was repeated to produce performance measures for Subsystem B by optimizing the system at a 130-second cycle length and holding Subsystem B's offsets constant while "circling" through Subsystem A's offsets.

The second pair of subsystems was obtained by splitting the system between intersections 26 and 27. The subsystem west of the break operated at a 120-second cycle and the subsystem east of the break operated at a 130-second cycle. The same procedure as described above was used to estimate performance measures for the subsystems.

A3.1.2 Analysis: Hypothesis 1

Figure A-3 displays the percent change in average vehicle delay at intersection 30 due to Subsystems A and B operating independently. Each marker represents one of the twelve simulation runs. The simulations produced a cyclical pattern of net increasing and decreasing changes in delay suggesting that the hypothesis may be correct: on average, gains and losses in stops and delay due to subsystems operating independently may be somewhat compensatory, and as a result, insignificant.

While a decrease in average vehicle delay due to a suboptimal offset is contrary to intuitive thinking, recall that each offset directly affects traffic flow at two intersections. The optimal offset is determined by the relative weights (Volume x

Table A-1. Simulated Offsets of Two Independent Subsystems

	Subsystem A									Subsystem B				
Intersection:	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Optimal Offset:	94	5	21	59	24	109	6	25	43	21	13	52	33	33
Simulation Offsets:														
Run 1	"	"	"	"	"	"	"	"	"	0	112	31	12	12
Run 2	"	"	"	"	"	"	"	"	"	10	2	41	22	22
Run 3	"	"	"	"	"	"	"	"	"	20	12	51	32	32
Run 4	"	"	"	"	"	"	"	"	"	30	22	61	42	42
Run 5	"	"	"	"	"	"	"	"	"	40	32	71	52	52
Run 6	"	"	"	"	"	"	"	"	"	50	42	81	62	62
Run 7	"	"	"	"	"	"	"	"	"	60	52	91	72	72
Run 8	"	"	"	"	"	"	"	"	"	70	62	101	82	82
Run 9	"	"	"	"	"	"	"	"	"	80	72	111	92	92
Run 10	"	"	"	"	"	"	"	"	"	90	82	1	102	102
Run 11	"	"	"	"	"	"	"	"	"	100	92	11	112	112
Run 12	"	"	"	"	"	"	"	"	"	110	102	21	2	2

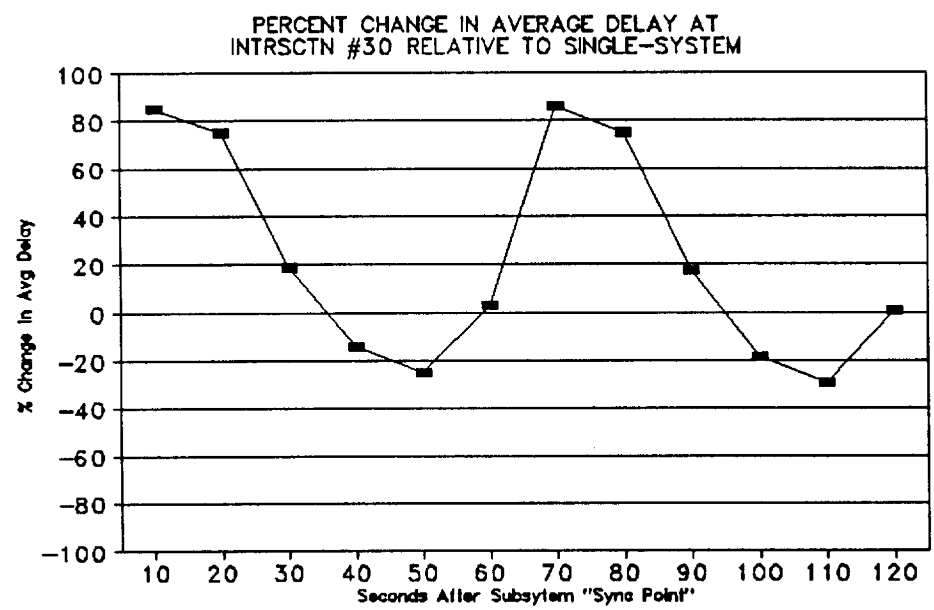

Figure A-3. Percent Change in Average Delay: Intersection 30

Average Delay) of two adjacent intersections, explaining why the "optimal" offset may be less than optimal for at least one of the two intersections. For example, Figure A-4 indicates the change in average delay at intersection 31 under these same conditions.

Intersection 31, being the more heavily weighted (i.e., congested) intersection of the 30-31 pair, experienced only a net increase in average delay due to a suboptimal offset. However, since the net difference at intersection 31 fluctuated in the range of 0 to 20 percent, with its peaks roughly corresponding to valleys in the corresponding plot for intersection 30, the hypothesis of compensatory changes is not refuted.

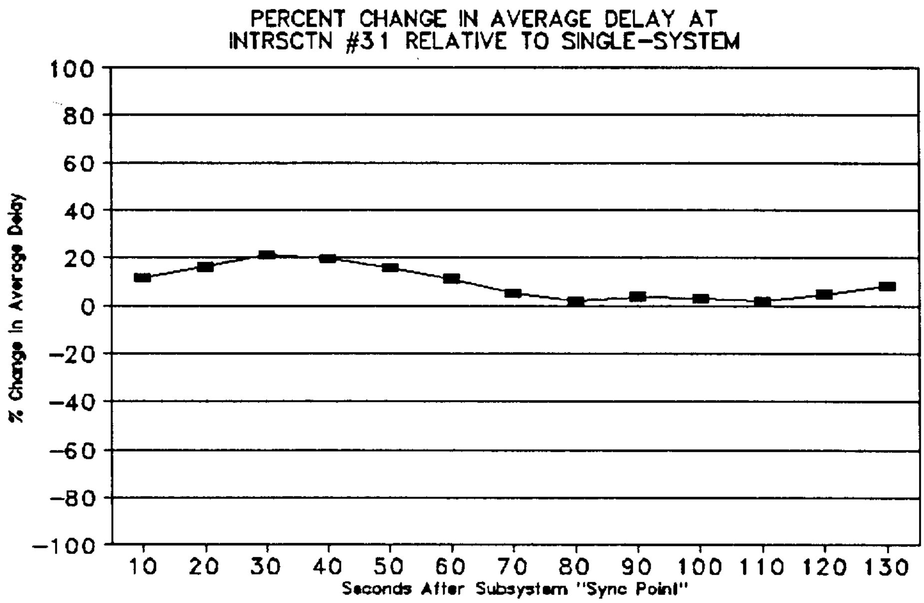

Figure A-4. Percent Change in Average Delay: Intersection 31

To determine the significance of the differences in stops and delay attributed to breaking the system into two subsystems, Student's t-scores were computed for the intersections immediately bordering the subsystems. As is indicated by the t-scores in Table A-2, the null hypothesis that the sample delays were drawn from a population of equal means could not be rejected at a five percent level of significance for every case. While the differences were statistically insignificant at intersections 27, they were significant at intersection 31. The results for intersection 26 and 30 were mixed with average delay not being significantly affected and percent of vehicles stopped (percent stops) being significantly affected.

In some cases, the TRANSYT-7F simulations proved to be sensitive to the additional stops and delay generated by operating two subsystems independently, therefore, the null hypothesis was rejected and further analysis was pursued.

A3.2 Hypothesis 2: Identification of the Arrival Pattern

The primary effect of operating one system as two independent subsystems is the alteration of the quality of progression at the border intersections. Consequently, the

Table A-2. Stops and Delay: Single System vs Independent Subsystems

Sub-system	Intersection	Measure	Avg Delay (secs) System	Avg Delay (secs) Subsystem	Change (%)	Standard Deviation	t-Score	Significant?
A	30	Avg Delay	3.0	3.7	22.78	1.31	1.75	No
		Stops (%)	20.1	26.8	33.17	10.06	2.20	Yes
B	31	Avg Delay	47.9	52.5	9.64	3.14	5.10	Yes
		Stops (%)	88.8	85.5	-3.64	3.03	-3.70	Yes
C	26	Avg Delay	12.5	12.6	0.75	0.46	0.68	No
		Stops (%)	49.7	53.0	6.56	2.82	3.84	Yes
D	27	Avg Delay	40.2	41.7	3.76	2.44	2.15	No
		Stops (%)	79.3	81.9	3.19	5.00	1.76	No

Two-tailed Test with a 0.05 Level of Significance

stops and delay generated at those intersections increase. Because the quality of progression at an intersection is largely influenced by vehicle arrival patterns on the intersection approaches, an attempt was made to identify the arrival pattern at the interface of the independent subsystems.

It was hypothesized that the arrival patterns generated at the interface of two independent subsystems would be bounded by arrival patterns that are more easily modeled by TRANSYT-7F.

A3.2.1 Methodology: Hypothesis 2

In this test, the simulated stops and delay for the intersections bordering the break between Subsystems A and B were compared to stops and delay for those intersections as determined by three other arrival types:

(1) Platoons arrive at or near the beginning of the green interval. Additional intersections were added to the subsystem borders prior to optimization, thus platoons developed and arterial progression was obtained. This is the most favorable assumption regarding platoon formation.

(2) Vehicles arrive uniformly throughout the cycle. The subsystems were optimized and the border intersections acted as external links.

(3) Platoons arrive at or near the beginning of the red interval. The offsets in the optimized subsystem obtained in arrival type (1) were altered so that the resultant platoons would arrive at the beginning of the red phase. This is the least favorable of platoon conditions.

Average stops and delay for the intersections bordering Subsystems A and B are presented in Table A-3 for the three arrival types noted above and for the previously simulated case of independent subsystems bordering one another. As anticipated, stops and delay were minimized when platoons arrived at the border intersections on the green interval and were maximized when platoons arrived on the red interval. Uniform arrivals produced performance measures which fell in between those generated by arrivals on green and arrivals on red. The one exception to this is Intersection 31's percent stops: fewer vehicles stopped when arriving at Intersection 31 uniformly than when arriving on the green interval.

Table A-3. Stops and Delay by Arrival Type

Arrival Type	Intersection 30		Intersection 31	
	Avg Delay (sec/veh)	Stops (%)	Avg Delay (sec/veh)	Stops (%)
Arrive on Green	45.60	64.09	23.15	50.00
Uniform Arrivals	45.74	64.91	24.16	47.12
Arrive On Red	46.20	66.79	25.57	56.85
Independent Subsystems	45.69	65.21	24.14	46.79

The independent subsystems' performance measures, those measures which represent the average conditions vehicles will encounter at border intersections when two subsystems are operating independently, compared to the defined arrival types as follows:

(1) Average delay was greater than with arrival on green, and less than with uniform arrivals, for both Intersection 30 and 31.
(2) Percent stops for Intersection 30 was greater than for uniform arrivals and less than for arrival on red.
(3) Percent stops for Intersection 31 were less than for arrival on green and for uniform arrivals.

A3.2.2 Analysis: Hypothesis 2

As has been shown, on average, platooned arrivals on green will produce the lowest level of stops and delay and platooned arrivals on red will produce the highest. Consequently, the stops and delay generated at the interface of two independent subsystems are bracketed by the stops and delay of platooned arrivals on green and platooned arrivals on red.

Assuming the worst case scenario that independent subsystems produce stops and delay equal to those produced by vehicles arriving on red, then the marginal disbenefits in terms of stops and delay incurred at the bordering intersections by vehicles arriving on red versus arrivals in a coordinated system range from 1.3 to 20.6 percent (see Table A-4). Due to the range and diversity of these figures, no conclusive statements can be made about the percent or net increase in either stops or delay due to a system being broken into two independent subsystems.

To proceed with an alternative analysis, one option would be to develop a regression model that could accomplish this task. This, however, would require the generation of multiple subsystems and the identification of a number of independent variables such as total volume, major versus minor street volume, and intersection spacing. A second option would be to identify the ranges, on a case-by-case basis, within which the stops and delay produced by two independent subsystems would fall. The second option was chosen for the analysis of the Katella Avenue alternate coordination strategies and is described in the following sections.

Table A-4. Stops and Delay: Marginal Disbenefits for Arrivals on Red

	Intersection 30		Intersection 31	
	Avg Delay	Stops (%)	Avg Delay	Stops (%)
Percent Increase	1.3	4.2	10.5	20.6
Net Increase	0.6 secs	2.7% of cars	2.42 secs	9.74% of cars

A4. COORDINATION WITHIN JURISDICTIONS

To determine what marginal contribution, if any, can be achieved by coordinating traffic signals across jurisdictional boundaries, stops and delay generated by an interjurisdictionally coordinated arterial timing plan were compared to those generated by the sum of the jurisdictional subsystems comprising the corridor. As the analysis described earlier indicates, the lack of interjurisdictional coordination results in stops and delay bracketed between those measures generated by platooned arrivals on green and platooned arrivals on red.

With interjurisdictional coordination, vehicles generally arrive platooned on the green interval by design (subject to other system-wide performance criteria). This implies that the marginal contribution of coordinating traffic signals across jurisdictional boundaries is approximately equal to the difference between stops and delay generated between subsystems by arrivals on green and by the subsystems operating independently. However, since the subsystems in the jurisdictionally coordinated case are independent, they are not constrained to one cycle length as are the interjurisdictionally coordinated systems. The common cycle length constraint imposed by interjurisdictional coordination may, in fact, offset the benefits gained from coordination.

A4.1 Methodology

In the jurisdictional analysis, the arterial was broken into subsystems as determined by jurisdictional responsibility for the forty intersections. Due to the interweaving of jurisdictions, a total of fifteen subsystems resulted (Table A-5).

Table A-5. Katella Avenue: Jurisdictional Subsystems

Subsystem	Intersections	Jurisdiction
1	1	Caltrans
2	2-7	Los Alamitos
3	8	Cypress
4	9	Los Alamitos
5	10-15	Cypress
6	16-17	Stanton
7	18	Caltrans
8	19	Garden Grove
9	20	Stanton
10	21	Garden Grove
11	22-32	Anaheim
12	33	Caltrans
13	34-37	Anaheim
14	38-39	Caltrans
15	40	Anaheim

A number of cycle lengths were explored for each system/subsystem. The cycle length producing the lowest combination of stops and delay was chosen as optimal. Three alternate scenarios were produced:

(1) Interjurisdictional Coordination: The entire 40 intersection arterial was optimized as one system.

(2) Jurisdictional Coordination with Platoons Arriving on Green: Each subsystem was optimized with intersections added to either side of the subsystem to create platoons of vehicles.

(3) Jurisdictional Coordination with Platoons Arriving on Red: Each subsystem was optimized with intersections added to either side of the

subsystem to create platoons. The offsets of the added intersections were altered by a phase shift of one half of the optimum cycle length, resulting in the main portions of the platoons arriving during the red interval.

A sampling of the results is presented graphically in the following figures.

A4.2 Analysis

In the jurisdictional subsystem alternative, both intersections 8 and 9 are operating as isolated intersections. As expected, the interjurisdictional coordination generates less delay than platoons arriving on red, and equal or less delay than platoons arriving on green (Figure A-5). This is emphasized further by an examination of the percent of cars stopping at these intersections (Figure A-6).

Intersections 16 through 21 represent five jurisdictional subsystems: a two intersection subsystem (16 and 17) and four isolated intersections. As this section represents the largest previously uncoordinated section of the arterial, it had been anticipated that interjurisdictional coordination would generate the greatest improvement. However, only at intersection 18 (Beach Boulevard) is the interjurisdictional delay less than the delay generated by arrivals on red. Elsewhere, the interjurisdictional delay is equal to or greater than that of arrivals on red (see Figures A-7 and A-8). While this result was not anticipated, it may be a factor of one or both of the following:

(1) Average delay and percent stops are balancing one another. While average delay is lower for platooned arrivals on red than for

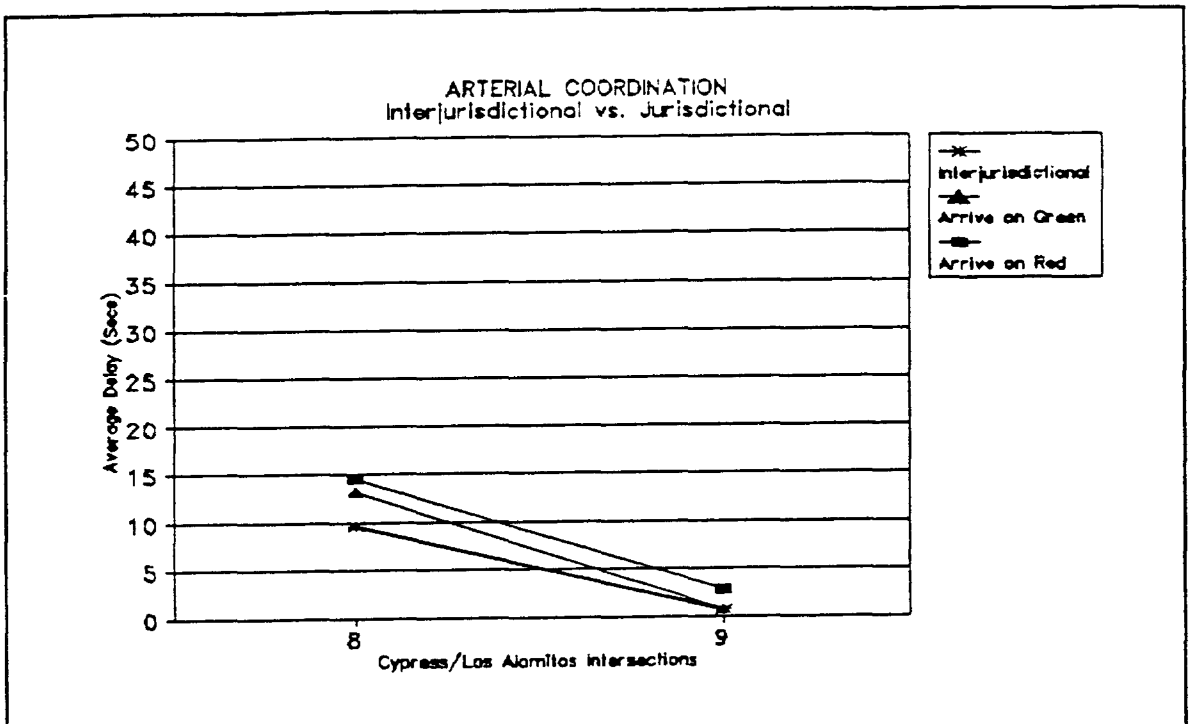

Figure A-5. Average Delay: Intersections 8 and 9

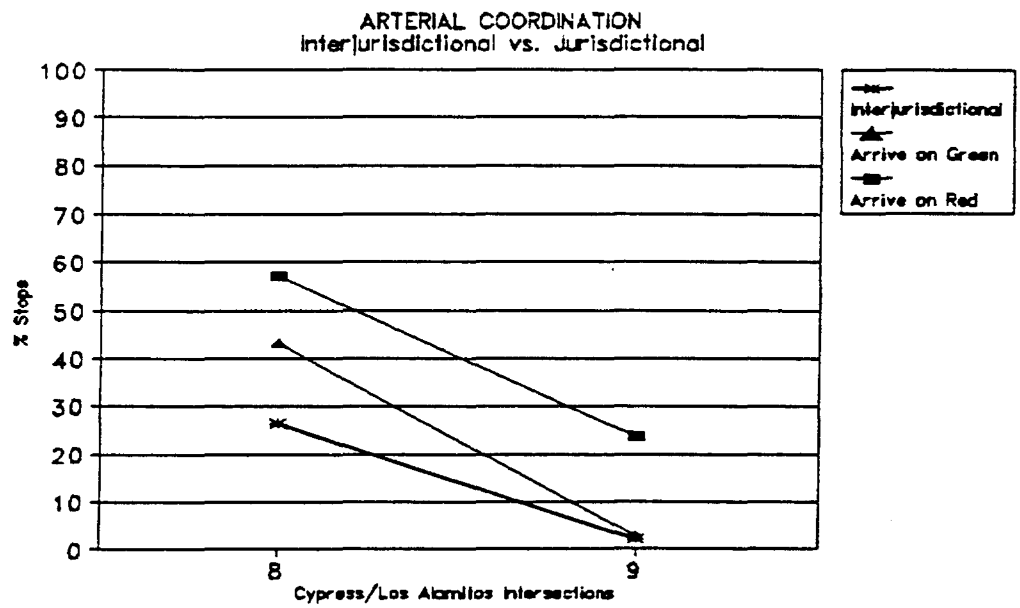

Figure A-6. Percent Stops: Intersections 8 and 9

interjurisdictional coordination, percent stops is higher. Because TRANSYT-7F minimizes the combination of average delay and percent stops when optimizing timing plans both measures must be considered.

(2) The cycle length is driving the stops and delay of these intersections. The subsystems were all optimized at shorter cycle lengths than was the interjurisdictionally coordinated system. While the longer cycle length is optimal when considering all forty intersections, it may be contributing to the delay incurred throughout this section of the arterial.

Intersections 34 and 37 represent the borders of a four-intersection subsystem (see Figures A-9 and A-10). The measures of stops and delay at Intersection 34 show that arrivals on red produced higher stops and delay than arrivals on green and that interjurisdictional coordination produced lower measures than either of the subsystems. At intersection 37 the opposite occurred: interjurisdictional coordination produced higher measures of stops and delay than either of the subsystems. This dichotomy suggests that the results of interjurisdictional coordination at one intersection may counter those at another intersection. This is also represented by the intersections within the subsystem: stops and delay increase at Intersection 35 and decrease at Intersection 36 with interjurisdictional coordination. Therefore, the alternatives were examined by comparing the performance measures for the entire forty intersections (Table A-6).

Assuming the worst case scenario for uncoordinated jurisdictions (platooned

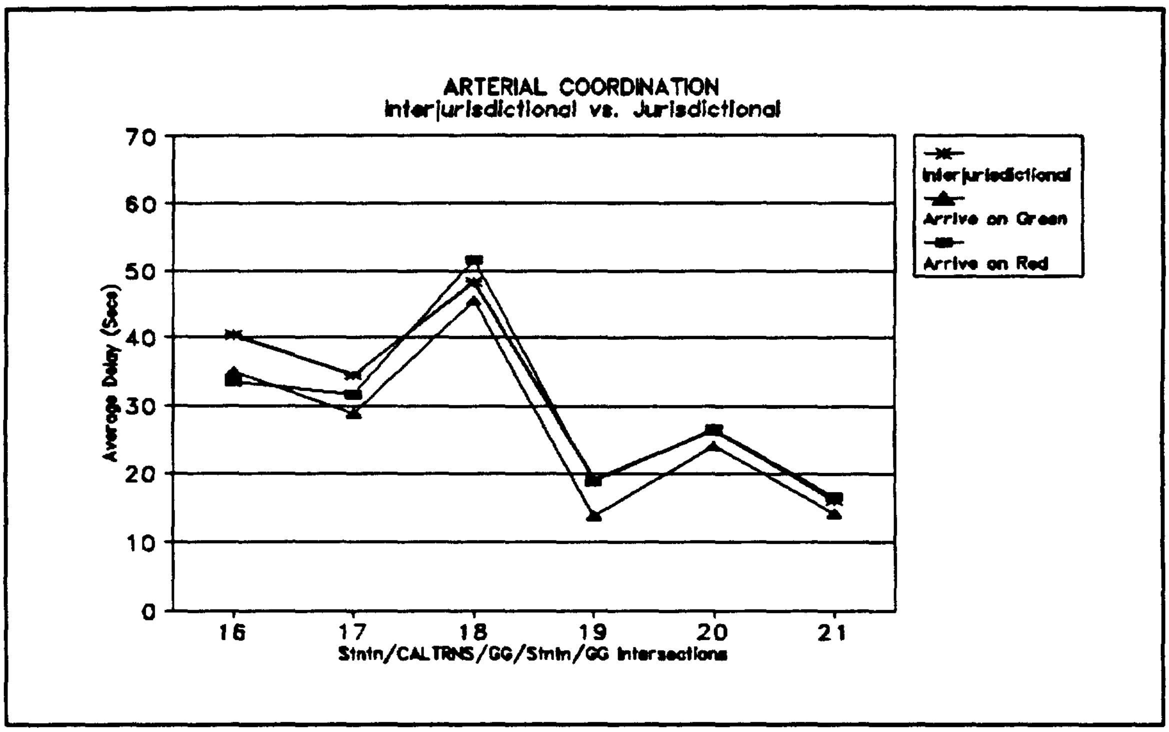

Figure A-7. Average Delay: Intersections 16-21

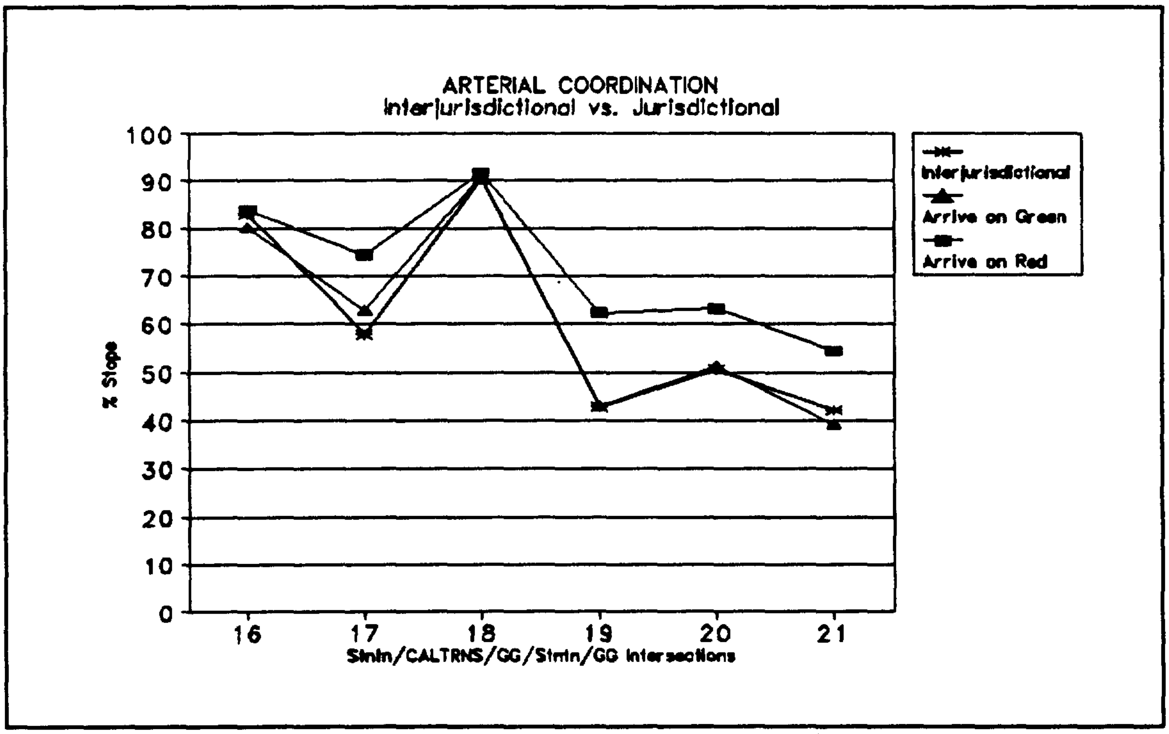

Figure A-8. Percent Stops: Intersections 16-21

Table A-6. System Performance: Interjurisdictional vs. Jurisdictional

Arrival Type	Total Time (hrs)	Total Delay (hrs)	Avg Delay (secs)	No. of Stops	% Stops
Interjurisdictional	1863	1087	24.94	79,490	50.67
Jurisdictional:					
On Green	1867	1091	25.03	80,643	51.40
On Red	1948	1172	26.90	89,903	57.00

arrivals on red), interjurisdictional coordination will, at most, decrease average delay by 1.96 seconds and reduce the percent of cars stopping from 57 to 51 percent on Katella Avenue, represents a seven and twelve percent decrease, respectively. T-tests were used to ascertain if there is a true difference in the average stops and delay produced by interjurisdictionally coordinated and jurisdictionally coordinated systems. To minimize the influence of the individual intersection characteristics on the statistic, a paired samples design was utilized. At a five percent significance level, interjurisdictional coordination produced performance measures which were significantly better than independent subsystems with vehicles arriving on the red interval. The t-tests indicated there was only a 4.5 percent probability that delay generated by independent subsystems was in actuality equal to the delay generated by an interjurisdictionally coordinated system (Table A-7); for stops this percentage was 0.3 (Table A-8).

Table A-7. System Delay: Interjurisdictional vs Jurisdictional Red Arrivals

Arrival Type	Mean	Standard Deviation	t-Score	2-Tail Probability
Interjurisdictional	27.17	29.54		
Jurisdictional:				
Arrival on Red	29.30	30.90	-2.07	0.045

A5. COORDINATION WITHIN CONTROLLER SYSTEMS

The second coordination strategy followed the system's traffic control hardware design. Subsystems were created by identifying the intersections' master controller (Table A-9). With this strategy, neighboring jurisdictions would coordinate their traffic signals, but only if the signals were already compatible with the same master controller.

A5.1 Methodology

As with the jurisdictional subsystems, two alternate optimization procedures were pursued for the controller subsystems:

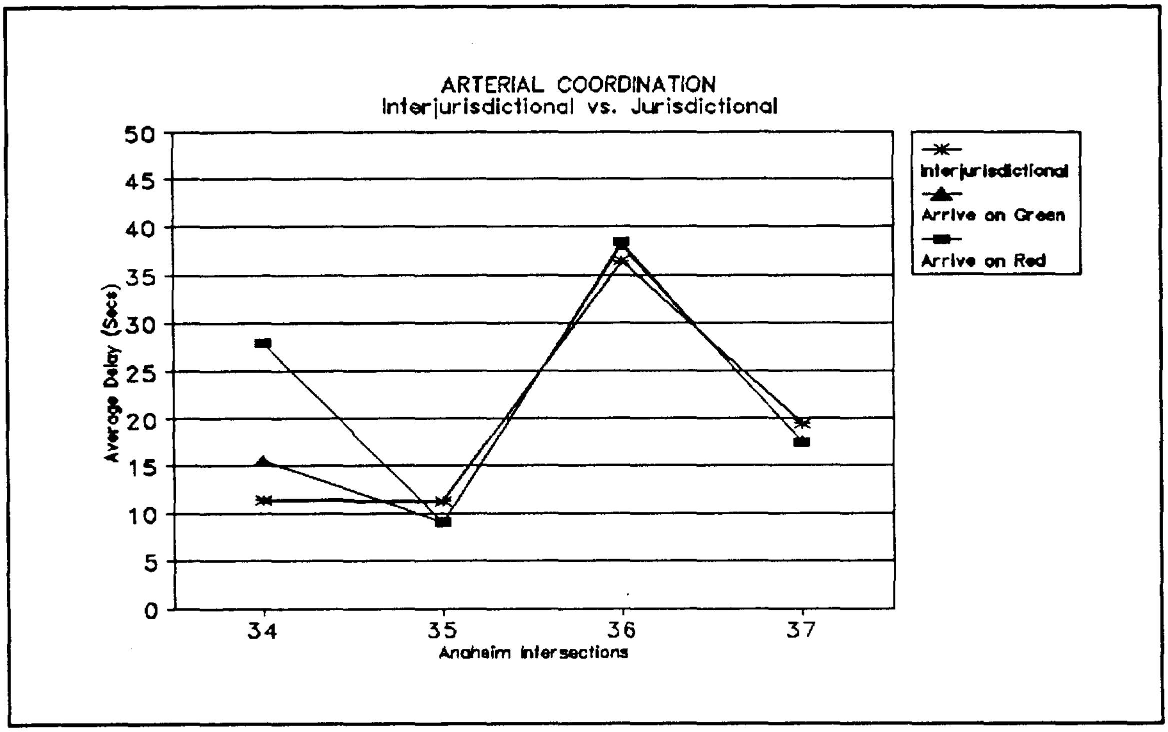

Figure A-9. Average Delay: Intersections 34-37

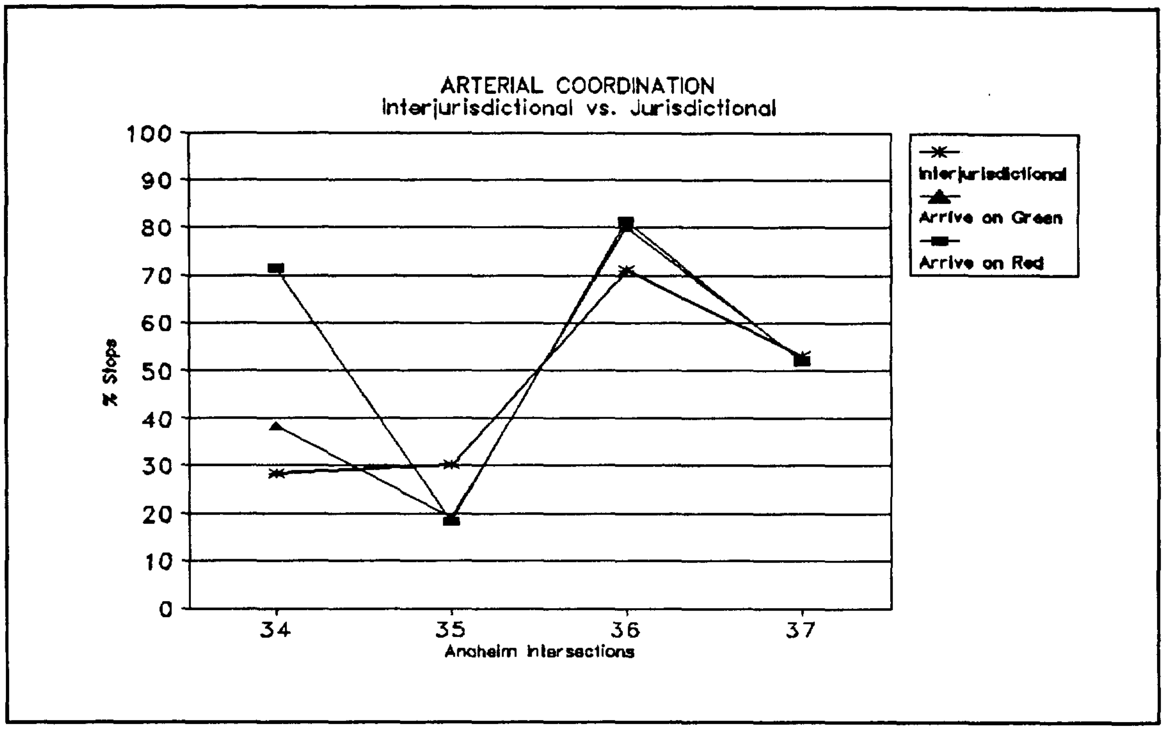

Figure A-10. Percent Stops: Intersections 34-37

Table A-8. System Stops: Interjurisdictional vs Jurisdictional Red Arrivals

Arrival Type	Mean	Standard Deviation	t-Score	2-Tail Probability
Interjurisdictional	198,725	169,796		
Jurisdictional:				
Arrival on Red	224,757	170,279	-3.15	0.003

(1) Vehicles arrive at subsystem borders in platoons on the green interval.
(2) Vehicles arrive in platoons on the red (suboptimal) interval.

Systemwide performance measures were generated for these alternatives (Table A-10).

A5.2 Analysis

Again, assuming that jurisdictions operate uncoordinated under the worst case conditions, interjurisdictional coordination along Katella Avenue will increase average delay per vehicle by 0.14 seconds and reduce the percent of cars stopping from 52 to 51 percent. This represents a one percent increase and three percent decrease, respectively. A paired t-test of these performance measures indicates that, at a five percent significance level, coordination between control systems on Katella Avenue will not produce better results than allowing the systems to operate independently (Tables A-11 and A-12). The probability that delays generated by the two coordination strategies are not significantly different is seventy one percent (Table A-11). The probability that stops generated by the two strategies are not significantly different is thirteen percent (Table A-12).

Table A-9. Katella Avenue: Master Controller Subsystems

Subsystem	Intersections	Controller	Jurisdictions
1	1-17	Traconex Closed-Loop	Los Alamitos, Cypress, Stanton, Caltrans
2	18	Type 170	Caltrans
3	19-40	UTCS	Anaheim, Garden Grove, Stanton, Caltrans

Table A-10. System Performance: Interjurisdictional vs Controller Subsystems

Arrival Type	Total Time (hrs)	Total Delay (hrs)	Avg Delay (secs)	No. of Stops	% Stops
Interjurisdictional	1863	1087	24.94	79,490	50.67
Controller Subsystems:					
On Green	1840	1064	24.42	80,593	51.37
On Red	1857	1081	24.80	81,631	52.03

Table A-11. System Delay: Interjurisdictional vs Controller Subsystems

Coordination Type	Mean	Standard Deviation	t-Score	2-Tail Probability
Interjurisdictional	27.17	29.54		
Controller Subsystems:				
Arrival on Red	27.02	29.56	0.37	0.714

Table A-12. System Stops: Interjurisdictional vs Controller Subsystems

Coordination Type	Mean	Standard Deviation	t-Score	2-Tail Probability
Interjurisdictional	198,725	169,796		
Controller Subsystems:				
Arrival on Red	204,078	172,060	-1.54	0.133

A6. COORDINATION BY TRAFFIC FLOW

The final coordination strategy attempted to determine if the system could operate more efficiently as a series of independent subgroups than as one continuous system. It was hypothesized that subsystems would operate most efficiently where vehicle through flows are continuous and less efficiently where high turn flows exist. The subsystem design could then take advantage of varying cycle lengths from one subsystem to another and lose little in the way of arterial progression.

A6.1 Methodology

To identify subsystems, arterial through movements were extracted from the turn count data for Katella Avenue. Areas where the through movements differed greatly between adjacent intersections (indicating that a significant number of vehicles entered or exited the arterial) were highlighted. Subsystems were defined where these differences occurred in both the eastbound and westbound directions. Five subsystems resulted: Intersections 1-5, 6-11, 12-14, 15-34, and 35-40. The border intersections and percent changes in volumes are presented in Table A-13. The performance measures were summed for arrivals on the green interval and on the red (suboptimal) interval at the subsystem borders. These were compared with performance measures for the interjurisdictionally coordinated system (Table A-14).

A6.2 Analysis

The subsystem design was not successful in providing a more efficient operation than interjurisdictional coordination. Interjurisdictional coordination produced an average delay which was 0.33 seconds (or 1.3 percent) lower than the subsystem design, and percent stops were decreased from 54 to 51 percent (or 7 percent). However, a paired t-test analysis indicated there was no significant difference between the two coordination strategies. Assuming vehicles arrived at subsystem borders under the worst case scenario, the probability that delay was not significantly different than that generated by the interjurisdictional system was ninety-four percent and the probability that stops generated by the two systems were not significantly different was sixty-one percent (Tables A-15 and A-16).

Table A-13. Changes in Through Volumes Between Intersections

Intersections	East Bound Change (%)	West Bound Change (%)
5-6	84	-36
11-12	-54	93
14-1	-34	-45
34-35	-28	46

Table A-14. System Performance: Interjurisdictional vs Volume Specified Subsystems

Arrival Type	Total Time (hrs)	Total Delay (hrs)	Avg Delay (secs)	Number of Stops	Stops (%)
Jurisdictional	1863	1087	24.94	79,490	50.67
Volume Specified:					
On Green	1843	1067	24.47	80,814	51.51
On Red	1877	1101	25.27	85,122	54.26

Table A-15. System Delay: Interjurisdictional vs Volume-Specified Subsystems

Coordination Type	Mean	Standard Deviation	t-Score	2-Tail Probability
Interjurisdictional	27.17	29.54		
Volume Specified:				
Arrival on Red	27.53	29.44	-0.77	0.944

Table A-16. System Stops: Interjurisdictional vs Volume-Specified Subsystems

Coordination Type	Mean	Standard Deviation	t-Score	2-Tail Probability
Interjurisdictional	198,725	169,796		
Volume Specified:				
Arrival on Red	212,804	167,577	-0.51	0.610

A7. SUMMARY

The interjurisdictional coordination of Katella Avenue was offered as an alternative to three alternate coordination strategies. These strategies were:

(1) Coordination within jurisdictions only,
(2) Coordination within controller subsystems, and
(3) Coordination within subsystems as specified by through volumes.

Jurisdictional coordination of the arterial resulted in 15 independently coordinated subsystems representing the forty-intersection arterial. Coordination within controller systems resulted in three subsystems, and coordination as specified by arterial through volumes resulted in five subsystems.

The interjurisdictionally coordinated system operated under one cycle length determined to be optimal for the entire forty intersection system. An optimal cycle length was individually determined for, and utilized by, each subsystem of the alternate coordination strategy systems. For the purposes of this study, it was assumed that vehicles would arrive suboptimally (in platoons on the red interval) at subsystem borders.

System performance was measured in terms of stops and delay as calculated by TRANSYT-7F. Interjurisdictional coordination significantly improved system performance in one of the three alternate coordination strategy cases: Interjurisdictional versus jurisdictional coordination. The effect of interjurisdictional coordination was insignificant when compared to arterial performance under both controller subdivided and through volume subdivided conditions. Because the jurisdictional coordination strategy resulted in a greater number of subsystems than did the other alternate coordination strategies (15 vs. 3 and 5), these results suggest that an arterial system may be able to sustain a certain percentage of system breaks versus number of intersections or arterial length without incurring a measurable degradation in performance.

CITY OF ANAHEIM, CALIFORNIA

Public Works - Engineering Department

May 22, 1991

KATELLA AVENUE SIGNAL COORDINATION PROJECT

MEMORANDUM OF UNDERSTANDING

This document will serve as a "Memorandum of Understanding" between the City of Anaheim, the City of Garden Grove, the City of Stanton, the City of Cypress, the City of Los Alamitos, the Orange County/EMA, and California Department of Transportation (Caltrans) relating to the Katella Avenue Signal Coordination Project.

The Problem

Considerable traffic congestion exists along the Katella Avenue corridor between Interstate 605 and Douglass Road (The Corridor), and ANAHEIM, GARDEN GROVE, STANTON, CYPRESS, LOS ALAMITOS, COUNTY OF ORANGE, and STATE OF CALIFORNIA all have jurisdiction over portions of the Corridor.

The need for coordination is in response to the Orange County Transportation Commission's solicitation of traffic signal coordination projects which include the following features: Katella Avenue as a designated Superstreet, Coordination with 5 City agencies, Coordination with Caltrans, Demonstration of WWV (a universal time broadcast radio station) time reference device as a countywide non-propriety coordination unit, Demonstration of traffic signal coordination between a UTCS (Urban Traffic Control System) and TRACONEX (closed-loop system manufacturer) master signal systems, and Documentation and evaluation by University of California, Irvine of this traffic signal coordination project as part of an FHWA Demonstration
Project.

The Solution

ANAHEIM, GARDEN GROVE, STANTON, CYPRESS, LOS ALAMITOS, COUNTY and CALTRANS will mutually establish traffic signal timings for the traffic signal locations listed in Exhibit A.

ANAHEIM, GARDEN GROVE, STANTON and COUNTY will implement the interconnected and coordinated UTCS traffic signal system utilizing WWV and operated through the master computer of ANAHEIM. ANAHEIM will be responsible for operating and maintaining the timings for the UTCS system.

LOS ALAMITOS, CYPRESS and STANTON will implement the interconnected and coordinated Traconex Closed-loop traffic signal system utilizing WWV and operated through the master controller of Los Alamitos. Los Alamitos will be responsible for operating and maintaining the timings for the Closed-loop system.

CALTRANS will implement a coordinated signal system plan at the intersection of Katella Avenue and Beach Boulevard utilizing WWV and operated through their PC-Quicknet system.

The operational characteristics of the system will be reviewed regularly, at a minimum of every (3) months, in order that proposals for needed modification to the system may be made at those times. The agencies will establish a Coordinating Committee comprised of the Traffic Engineer (or designee of the Traffic Engineer) from each agency.

No agency will modify the signal timing without written notification to and approval by all the other agencies unless required to do so under emergency or other exigent circumstances.

The REPRESENTATIVE of each agency will be responsible for notifying all other agencies as soon as possible, but no later than the first working day following a system failure, emergency repair, or power failure affecting the interconnected system. The committee member(s) of ANAHEIM, GARDEN GROVE, STANTON, CYPRESS, LOS ALAMITOS, COUNTY and CALTRANS will also give advance notice of at least two (2) working days prior to any shutdown of the master controller affecting the interconnect system.

The committee will prepare a summary report of its meetings, system activity and future needs at the end of each calendar year.

Upon completion of the interconnected traffic signal system and designated signal timing, the maintenance of the system hardware components will become the responsibility of each agency for these traffic signal locations within its jurisdiction, including the maintenance of the communication equipment from the drop at the interconnect trunkline to individual intersection controllers.

Any signal timing disagreements between agencies related to the operational aspects of the Corridor will be submitted to:

> Three (3) arbitrators mutually agreed upon by each agency, none of the three to be employees, representatives or agents for either of the parties to this Agreement. Any decision by the majority of said arbitrators shall be final and binding.

All agencies must mutually agree to the three individual arbitrators comprising the arbitration committee. Any decision by the majority of said arbitrator shall be final and binding.

In short, each agency recognizes the need to carry out the signal timing plans for a fair period of time to properly evaluate the project.

This Memorandum of Understanding sets forth suggested operating procedures and policies and is intended solely as an operating guide for the staffs of the public agencies specified in this memorandum (hereinafter the 'parties'). This memorandum is not a binding agreement upon the parties, their respective officers, agents and employees, or the signatories hereto. Failure in any instance to comply with these operating procedures and policies shall not be deemed a breach of contract, or evidence of negligence, or otherwise actionable in contract, tort or otherwise by any parties, or their respective officers, agents or employees, or by any third parties whomsoever or whatsoever).

The following agency department heads will agree in good faith to perform the afore-mentioned.

CITY OF ANAHEIM
DIRECTOR OF PUBLIC WORKS

DATE 6·17·91

CITY OF GARDEN GROVE
CITY ENGINEER

DATE

CITY OF STANTON
DIRECTOR OF PUBLIC WORKS

DATE 7/22/91

CITY OF CYPRESS
DIRECTOR OF PUBLIC WORKS

DATE 8-9-91

CITY OF LOS ALAMITOS
CITY ENGINEER

DATE 8/13/91

ORANGE COUNTY/EMA
TRANSPORTATION FUNCTION DIRECTOR

8/18/91
DATE

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DEPUTY DISTRICT DIRECTOR

DATE

"EXHIBIT A"

Katella Signal Coordination Project
Intersections by Agency

Caltrans

1) I-605
2) I-5
3) SR-57 (S/B)
4) SR-57 (N/B)
5) Beach

SubTotal = 5

Los Alamitos

1) City Hall
2) Walnut
3) Los Alamitos
4) Bloomfield
5) Noel
6) Lexington
7) Winners

SubTotal = 7

Cypress

1) Siboney
2) Walker
3) Douglas
4) Hope
5) Valley View
6) Holder
7) Meridian

SubTotal = 7

Stanton

1) Knott
2) Western
3) Magnolia(UTCS)

SubTotal = 3

Garden Grove

1) Dale
2) Gilbert

SubTotal = 2

Anaheim

1) Brookhurst
2) Nutwood
3) Euclid
4) Ninth
5) Walnut
6) West
7) Convention Center
8) Harbor
9) Clementine
10) Haster
11) Katella Way
12) Claudina Way
13) Lewis
14) State College
15) Howell
16) Douglass

SubTotal = 16

Total Number of Intersections = 40

The list of intersections for Los Alamitos, Cypress and Stanton are all part of the Traconex Closed-loop portion of the project except for Magnolia. The list of intersections for Garden Grove and Anaheim as well as Magnolia are all part of the UTCS portion of the project.

A G R E E M E N T

THIS AGREEMENT, dated for purposes of identification only this day of , is made and entered into by and between the

CITY OF ANAHEIM, a municipal corporation,
hereinafter referred to as "ANAHEIM,"

A
N
D

CITY OF GARDEN GROVE, a municipal corporation,
hereinafter referred to as "GARDEN GROVE,"

A
N
D

CITY OF STANTON, a municipal corporation,
hereinafter referred to as "STANTON,"

A
N
D

COUNTY OF ORANGE, acting by and through its
Department of Transportation,
hereinafter referred to as "COUNTY."

W I T N E S S E T H:

WHEREAS, considerable traffic congestion exists along the Katella Avenue corridor between Dale Avenue and Douglass Road (The Corridor); and

WHEREAS, ANAHEIM, GARDEN GROVE, STANTON and COUNTY all have jurisdiction over portions of the Corridor; and

WHEREAS, the traffic signal locations listed in "Exhibit A" are within the corporate boundaries of ANAHEIM, GARDEN GROVE, STANTON and COUNTY; and

WHEREAS, ANAHEIM, GARDEN GROVE, STANTON and COUNTY share jurisdiction or hold jurisdiction exclusively as indicated in Exhibit A; and

WHEREAS, the Comprehensive Signal Coordination Plan for Orange County and other engineering studies indicate that an interconnected and coordinated traffic signal system would be mutually beneficial to the cities and would improve traffic safety and flow; and

WHEREAS, ANAHEIM, GARDEN GROVE, STANTON and COUNTY are willing to cooperate with each other in the coordination of traffic signals and in the maintenance of traffic signal and hardwire interconnect systems; and

WHEREAS, ANAHEIM, GARDEN GROVE, STANTON and COUNTY wish to define the responsibilities of each party.

NOW, THEREFORE, in consideration of the mutual covenants and agreements contained herein, and for good and valuable consideration, the receipt of which is hereby acknowledged, IT IS AGREED by the parties hereto as follows:

I. Signal Operations:

In order to implement an interconnected and coordinated UTCS traffic signal system, all traffic signal locations listed in Exhibit "A" will be operated by the master computer of ANAHEIM.

II. Signal Timing:

ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall mutually establish traffic signal timings for the traffic signal locations listed in Exhibit A for the UTCS System. The timings shall be established and agreed upon in writing by the Traffic Engineer for each party or the Traffic Engineer's designee. ANAHEIM shall be responsible for operating the UTCS master signal system and maintaining these timings for the UTCS system. Neither party shall modify the signal timing without written notification to and approval by the other agencies unless required to do so under emergency or other exigent circumstances.

III. Maintenance:

Upon completion of the interconnected traffic signal system and designated signal timing, ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall maintain the traffic signals as designated in Exhibit "A". ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall each maintain the street, curb, gutter, sidewalk, signs, stripings, markings and other facilities at the signalized intersections within their respective boundaries.

IV. ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall mutually establish traffic signal timings for the traffic signal locations listed in Exhibit A for the UTCS System. The timings shall be established and agreed upon in writing by the Traffic Engineer for each party or the Traffic Engineer's designee.

ANAHEIM shall be responsible for operating the UTCS master signal system and maintaining these timings for the UTCS system. Neither party shall modify the signal timing without written notification to and approval by the other agencies unless required to do so under emergency or other exigent circumstances.

V. Upon completion of the interconnected traffic signal system and designated signal timing, the maintenance of the system shall become the responsibility of each agency for these traffic signal locations within its jurisdiction, including the maintenance of the communication equipment from the drop at the interconnect trunkline to individual intersection controllers.

VI. Each agency acknowledges that, in order for the interconnected system to operate optimally, it is necessary that the operational characteristics of the system be reviewed regularly, at a minimum of every (3) months, in order that proposals for needed modification to the system may be made at those times. The agencies shall establish a Coordinating Committee comprised of the Traffic Engineer (or designee of the Traffic Engineer) from each agency. Each agency may change its designated representative at any time.

The REPRESENTATIVE of each agency shall be responsible for notifying all other agencies as soon as possible, but no later than the first working day following a system failure, emergency repair, or power failure affecting the interconnected system. The committee member(s) of ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall also give advance notice of at least two (2) working days prior to any shutdown of the master controller affecting the interconnect system.

The committee shall prepare a summary report of its meetings, system activity and future needs at the end of each calendar year. The report shall be completed by a date mutually acceptable by all agencies. Each agency shall keep open book records of PROJECT which shall be available for inspection by any agency, at any reasonable time, during regular business hours.

VII. It is mutually understood and agreed by each agency that neither ANAHEIM nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by GARDEN GROVE, STANTON or COUNTY under or in connection with any work, authority or jurisdiction delegated to GARDEN GROVE, STANTON and COUNTY under this Agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, GARDEN GROVE, STANTON and COUNTY shall fully indemnify, defend and hold harmless ANAHEIM from any liability imposed for injury (as defined by government Code Section 810.8), occurring by reason of anything done or omitted to be done by GARDEN GROVE, STANTON or COUNTY, under or in connection with, any work, authority or jurisdiction delegated to GARDEN GROVE, STANTON and COUNTY under this Agreement.

Neither GARDEN GROVE nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by ANAHEIM, STANTON or COUNTY, under or in connection with any work, authority or jurisdiction delegated to ANAHEIM, STANTON and COUNTY under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, ANAHEIM, STANTON and COUNTY shall fully indemnify, defend and hold harmless GARDEN GROVE from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by ANAHEIM, STANTON and COUNTY under or in connection with any work, authority, or jurisdiction delegated to ANAHEIM, STANTON or COUNTY under this Agreement.

Neither STANTON nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by ANAHEIM, GARDEN GROVE or COUNTY, under or in connection with any work, authority or jurisdiction delegated to ANAHEIM, GARDEN GROVE and COUNTY under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, ANAHEIM, GARDEN GROVE and COUNTY shall fully indemnify, defend and hold harmless STANTON from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by ANAHEIM, GARDEN GROVE and COUNTY under or in connection with any work, authority, or jurisdiction delegated to ANAHEIM, GARDEN GROVE or COUNTY under this Agreement.

Neither COUNTY nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by ANAHEIM, GARDEN GROVE or STANTON, under or in connection with any work, authority or jurisdiction delegated to ANAHEIM, GARDEN GROVE and STANTON under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, ANAHEIM, GARDEN GROVE and STANTON shall fully indemnify, defend and hold harmless COUNTY from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by ANAHEIM, GARDEN GROVE and STANTON under or in connection with any work, authority, or jurisdiction delegated to ANAHEIM, GARDEN GROVE or STANTON under this Agreement.

VIII. This Agreement supersedes any and all other agreements, either oral or written, between the agencies with respect to the subject matter herein. Each agency to this Agreement acknowledges that no representation by any agency which is not embodied herein, nor any other agreement, statement, or promise not contained in this Agreement shall be valid and binding. Modification of this Agreement shall be effective only if it is in writing signed by all parties to this Agreement.

IX. This Agreement shall be governed and construed in accordance with the laws of the State of California.

X. This Agreement shall remain in effect for one year as of the effective date of this Agreement with automatic renewals each year unless terminated by any agency. Any agency may terminate this Agreement at any time upon giving sixty (60) days written notice of termination to all other agencies.

XI. The invalidity in whole or in part of any provision of this Agreement shall not void or affect the validity of any other provision of this Agreement.

XII. This AGREEMENT may be executed in multiple originals with each fully executed original having full force and effect as an original copy hereof.

XIII. The effective date of this Agreement shall be the latest date of execution hereinafter set forth opposite the names of the signators hereto. In the event an agency fails to set forth a date of execution opposite the name(s) of their signator(s), that agency hereby authorizes ANAHEIM, by and through its representative, to insert the date of execution by that agency's signatories as the date said Agreement, as executed by that agency, is received by ANAHEIM.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed on the dates hereinafter respectively set forth.

CITY OF ANAHEIM,
a municipal corporation

By______________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By______________________

Date______________________

CITY OF GARDEN GROVE,
a municipal corporation

By______________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By______________________

Date______________________

CITY OF STANTON,
a municipal corporation

By______________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By______________________

Date______________________

COUNTY OF ORANGE, acting by and through its Department of Transportation

By______________________
CHAIRMAN OF THE BOARD OF SUPERVISORS

ATTEST:

____
COUNTY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE COUNTY ATTORNEY

By______________________

Date______________________

A G R E E M E N T

THIS AGREEMENT, dated for purposes of identification only this   day of   , is made and entered into by and between the

CITY OF ANAHEIM, a municipal corporation,
hereinafter referred to as "ANAHEIM,"

A
N
D

CITY OF GARDEN GROVE, a municipal corporation,
hereinafter referred to as "GARDEN GROVE,"

A
N
D

CITY OF STANTON, a municipal corporation,
hereinafter referred to as "STANTON,"

W I T N E S S E T H:

WHEREAS, considerable traffic congestion exists along the Katella Avenue corridor between Dale Avenue and Douglass Road (The Corridor); and

WHEREAS, ANAHEIM, GARDEN GROVE, and STANTON all have jurisdiction over portions of the Corridor; and

WHEREAS, the traffic signal locations listed in "Exhibit A" are within the corporate boundaries of ANAHEIM, GARDEN GROVE, and STANTON; and

WHEREAS, ANAHEIM, GARDEN GROVE, and STANTON share jurisdiction or hold jurisdiction exclusively as indicated in Exhibit A; and

WHEREAS, the Comprehensive Signal Coordination Plan for Orange County and other engineering studies indicate that an interconnected and coordinated traffic signal system would be mutually beneficial to the cities and would improve traffic safety and flow; and

WHEREAS, ANAHEIM, GARDEN GROVE, and STANTON are willing to cooperate with each other in the coordination of traffic signals and are willing to participate in the construction and engineering cost of traffic signal coordination; and

WHEREAS, ANAHEIM shall be and is hereby designated as PROJECT MANAGER;

WHEREAS, ANAHEIM, GARDEN GROVE, and STANTON wish to define the responsibilities of each party and specify the share of the costs that are to be borne by each agency following completion of PROJECT.

NOW, THEREFORE, in consideration of the mutual covenants and agreements contained herein, and for good and valuable consideration, the receipt of which is hereby acknowledged, IT IS AGREED by the parties hereto as follows:

I. ANAHEIM shall:

A. Be and is hereby designated as the "lead Agency" for the project pursuant to the Guidelines for Implementation of the California Environmental Quality Act of 1970 as amended.

B. Act as PROJECT MANAGER for the Beach Blvd. to SR-57 portion of the project and coordination between the UTCS and TRACONEX master signal systems, and Contracting and Construction Agent for the UTCS system to do and perform all acts necessary or required in order to design and construct the PROJECT in accordance with the plans and specifications, including material control, inspection of the construction work, and to execute and deliver all documents required in connection with the construction and completion of said PROJECT, including a Certificate of Cost and a Certificate of Compliance of PROJECT.

C. Provide GARDEN GROVE, STANTON, COUNTY and STATE with approved plans, specifications and upon award, executed copies of PROJECT contract documents.

E. Implement the interconnected and coordinated UTCS traffic signal system by operating through the master computer of ANAHEIM.

F. Be responsible for any agreements and/or coordination with other agencies regarding equipment, design, construction, maintenance, operation and expenses, that are necessary for the completion and acceptance of PROJECT.

II. GARDEN GROVE shall:

A. Review and approve PROJECT plans and specifications.

B. At all times during the progress of the PROJECT have access to the work for the purpose of inspection thereof and should GARDEN GROVE deem any remedial measures to be necessary, GARDEN GROVE shall so notify ANAHEIM thereof.

C. Reimburse ANAHEIM for the GARDEN GROVE proportionate share for the project construction and signal retiming costs as estimated by the ANAHEIM cost estimate prepared on May 1, 1989. Said proportionate share is estimated to be

$34,575.00;

III. STANTON shall:

A. Review and approve PROJECT plans and specifications.

B. At all times during the progress of the PROJECT have access to the work for the purpose of inspection thereof and should STANTON deem any remedial measures to be necessary, STANTON shall so notify ANAHEIM thereof.

C. Reimburse ANAHEIM for the STANTON proportionate share for the project construction and signal retiming costs as estimated by the ANAHEIM cost estimate prepared on May 1, 1989. Said proportionate share is estimated to be $13,756.00;

VII. ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall mutually establish traffic signal timings for the traffic signal locations listed in Exhibit A for the UTCS System. The timings shall be established and agreed upon in writing by the Traffic Engineer for each party or the Traffic Engineer's designee. ANAHEIM shall be responsible for operating the UTCS master signal system and maintaining these timings for the UTCS system. Neither party shall modify the signal timing without written notification to and approval by the other agencies unless required to do so under emergency or other exigent circumstances.

VIII. Upon completion of the interconnected traffic signal system and designated signal timing, the maintenance of the system shall become the responsibility of each agency for these traffic signal locations within its jurisdiction, including the maintenance of the communication equipment from the drop at the interconnect trunkline to individual intersection controllers.

IX. Each agency acknowledges that, in order for the interconnected system to operate optimally, it is necessary that the operational characteristics of the system be reviewed regularly, at a minimum of every (3) months, in order that proposals for needed modification to the system may be made at those times. The agencies shall establish a Coordinating Committee comprised of the Traffic Engineer (or designee of the Traffic Engineer) from each agency. Each agency may change its designated representative at any time.

The REPRESENTATIVE of each agency shall be responsible for notifying all other agencies as soon as possible, but no later than the first working day following a system failure, emergency repair, or power failure affecting the interconnected system. The committee member(s) of ANAHEIM, GARDEN GROVE, STANTON and COUNTY shall also give advance notice of at least two (2) working days prior to any shutdown of the master controller affecting the interconnect system.

The committee shall prepare a summary report of its meetings, system activity and future needs at the end of each calendar year. The report shall be completed by a date mutually acceptable by all agencies. Each agency shall keep open book records of PROJECT which shall be available for inspection by any agency, at any reasonable time, during regular business hours.

XI. It is mutually understood and agreed by each agency that neither ANAHEIM nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by GARDEN GROVE, or STANTON under or in connection with any work, authority or jurisdiction delegated to GARDEN GROVE and STANTON under this Agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, GARDEN GROVE and STANTON shall fully indemnify, defend and hold harmless ANAHEIM from any liability imposed for injury (as defined by government Code Section 810.8), occurring by reason of anything done or omitted to be done by GARDEN GROVE or STANTON, under or in connection with, any work, authority or jurisdiction delegated to GARDEN GROVE and STANTON under this Agreement.

Neither GARDEN GROVE nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by ANAHEIM or STANTON, under or in connection with any work, authority or jurisdiction delegated to ANAHEIM and STANTON under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, ANAHEIM and STANTON shall fully indemnify, defend and hold harmless GARDEN GROVE from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by ANAHEIM and STANTON under or in connection with any work, authority, or jurisdiction delegated to ANAHEIM or STANTON under this Agreement.

Neither STANTON nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by ANAHEIM or

GARDEN GROVE, under or in connection with any work, authority or jurisdiction delegated to ANAHEIM and GARDEN GROVE under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, ANAHEIM and GARDEN GROVE shall fully indemnify, defend and hold harmless STANTON from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by ANAHEIM and GARDEN GROVE under or in connection with any work, authority, or jurisdiction delegated to ANAHEIM or GARDEN GROVE under this Agreement.

XII. This Agreement supersedes any and all other agreements, either oral or written, between the agencies with respect to the subject matter herein. Each agency to this Agreement acknowledges that no representation by any agency which is not embodied herein, nor any other agreement, statement, or promise not contained in this Agreement shall be valid and binding. Modification of this Agreement shall be effective only if it is in writing signed by all parties to this Agreement.

XIII. This Agreement shall be governed and construed in accordance with the laws of the State of California.

XIV. This Agreement shall remain in effect for one year as of the effective date of this Agreement with automatic renewals each year unless terminated by any agency. Any agency may terminate this Agreement at any time upon giving sixty (60) days written notice of termination to all other agencies.

XV. The invalidity in whole or in part of any provision of this Agreement shall not void or affect the validity of any other provision of this Agreement.

XVI. This AGREEMENT may be executed in multiple originals with each fully executed original having full force and effect as an original copy hereof.

XVII. The effective date of this Agreement shall be the latest date of execution hereinafter set forth opposite the names of the signators hereto. In the event an agency fails to set forth a date of execution opposite the name(s) of their signator(s), that agency hereby authorizes ANAHEIM, by and through its representative, to insert the date of execution by that agency's signatories as the date said Agreement, as executed by that agency, is received by ANAHEIM.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed on the dates hereinafter respectively set forth.

CITY OF ANAHEIM,
a municipal corporation

By______________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

CITY OF GARDEN GROVE,
a municipal corporation

By______________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By____________________________

Date__________________________

CITY OF STANTON,
a municipal corporation

By____________________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By____________________________

Date__________________________

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By____________________________

Date__________________________

COOPERATIVE AGREEMENT

12-ORA-605-1.42 at Katella Avenue
12-ORA-039-10.66 at Katella Avenue
12-ORA-005-36.37 at Katella Avenue
12-ORA-057-12.56 at Katella Avenue
12383 914145
District Agreement No. 12-122

THIS AGREEMENT, ENTERED INTO ON ________________, is between the STATE OF CALIFORNIA, acting by and through its Department of Transportation, referred to herein as STATE, and

CITY OF ANAHEIM,
A body politic and a municipal corporation of the State of California, referred to herein as "ANAHEIM"

RECITALS

(1) STATE and ANAHEIM pursuant to Streets and Highways Code Section 130, are authorized to enter into a cooperative agreement for improvements to State highways within ANAHEIM,

(2) Considerable traffic congestion exists along the Katella Avenue corridor (The Corridor) between Interstate 605 and State Route 57,

(3) ANAHEIM, STATE, the CITY OF GARDEN GROVE, a municipal corporation, hereinafter designated as "GARDEN GROVE," the CITY OF STANTON, a municipal corporation, hereinafter designated as "STANTON," the CITY OF CYPRESS, a municipal corporation, hereinafter designated as "CYPRESS," the CITY OF LOS ALAMITOS, a municipal corporation, hereinafter designated as "LOS ALAMITOS," and the COUNTY OF ORANGE, acting by and through its Department of Transportation, hereinafter designated as "COUNTY" all have jurisdiction over portions of the Corridor,

(4) The traffic signal locations listed in "Exhibit A" are within the corporate boundaries of ANAHEIM, CYPRESS, GARDEN GROVE, LOS ALAMITOS, STANTON, COUNTY AND STATE,

(5) ANAHEIM, CYPRESS, GARDEN GROVE, LOS ALAMITOS, STANTON, COUNTY AND STATE share jurisdiction or hold jurisdiction exclusively as indicated in Exhibit A,

(6) The Comprehensive Signal Coordination Plan for Orange County and other engineering studies indicate that an interconnected and coordinated traffic signal system would be mutually beneficial to the cities and would improve traffic safety and flow,

(7) The estimated construction and engineering cost for traffic signal coordination is two million one hundred sixty-

four thousand six hundred ninety dollars ($2,164,690.00),

(8) ANAHEIM and STATE are willing to cooperate with each other in the coordination of traffic signals and are willing to participate in the construction and engineering cost of traffic signal coordination, said work shall hereinafter be referred to as "PROJECT",

(9) ANAHEIM and STATE wish to define the responsibilities of each party and specify the share of the costs that are to be borne by each agency following completion of PROJECT.

NOW, THEREFORE, in consideration of the mutual covenants and agreements contained herein, IT IS AGREED by the parties hereto as follows:

SECTION I

ANAHEIM AGREES:

(1) To be and is hereby designated as the "Lead Agency" for PROJECT pursuant to the Guidelines for Implementation of the California Environmental Quality Act of 1970 as amended.

(2) To act as PROJECT MANAGER for the Beach Blvd. to State Route 57 portion of PROJECT and to ensure coordination between the UTCS, QuicNet and TRACONEX master signal systems, and Contracting and Construction Agent for the UTCS system, and to do and perform all acts necessary or required in order to design and construct PROJECT in accordance with the plans and specifications, including material control, inspection of the construction work, and to execute and deliver all documents required in connection with the construction and completion of said PROJECT, including a Certificate of Cost and a Certificate of Compliance of PROJECT.

(3) To provide GARDEN GROVE, STANTON, CYPRESS, LOS ALAMITOS, COUNTY and STATE with approved plans, specifications and upon award, executed copies of PROJECT contract documents.

(4) To implement the interconnected and coordinated UTCS traffic signal system by operating through the master computer of ANAHEIM.

(5) To be responsible for any agreements and/or coordination with other agencies regarding equipment, design, construction, maintenance, operation and expenses, that are necessary for the completion and acceptance of PROJECT.

(6) To pay any amount for construction of PROJECT in

excess of STATE's contribution of twenty seven thousand three hundred twenty five dollars ($27,325.00).

(7) PROJECT will be designed and implemented to the satisfaction of and subject to the approval of STATE.

(8) Should PROJECT call for any subsurface construction work to be performed within the STATE's right of way, to identify and locate all affected high and low risk underground facilities and protect or otherwise provide for such facilities, all in accordance with STATE's "Manual on High and Low Risk Underground Facilities within Highway Rights of Way". Cost of locating, identifying, and protecting shall be borne by ANAHEIM. ANAHEIM hereby acknowledges the receipt of STATE's "Manual on High and Low Risk" and agrees to construct any portions of the system within the STATE's right of way in accordance with such Manual.

(9) To apply for any necessary encroachment permits for work within the State Highway Right of Way, in accordance with State's standard permit procedures. STATE agrees to waive any required permit fees.

(10) Within ninety (90) days after completion of the PROJECT to furnish STATE with final accounting of cost to construct PROJECT and to return any unused funds from the deposit account to STATE.

(11) To retain or cause to be retained for audit for STATE or other government auditors for a period of three (3) years from date of final payment all records and accounts relating to construction of PROJECT.

SECTION II

STATE AGREES:

(1) To deposit with ANAHEIM, within twenty-five (25) days of receipt of billing therefor (which billing may be forwarded immediately following ANAHEIM's bid advertising date of a construction contract for PROJECT) the amount of twenty seven thousand three hundred twenty five dollars ($27,325.00), which figure represents STATE's share of the PROJECT engineering costs. STATE's total obligation for PROJECT shall not exceed twenty seven thousand three hundred twenty five dollars ($27,325.00).

(2) To review and approve PROJECT plans and specifications.

SECTION III

IT IS MUTUALLY AGREED AS FOLLOWS:

(1) All obligations of STATE under the terms of this Agreement are subject to the appropriation of resources by the Legislature and the allocation of resources by the California Transportation Commission.

(2) Should ANAHEIM award a contract for PROJECT prior to the allocation of resources by the California Transportation Commission, there is no guarantee of STATE's participation and ANAHEIM shall assume all risks thereof.

(3) Should any portion of PROJECT be financed with Federal funds or STATE gas tax funds, all applicable laws, regulations and policies relating to the use of such funds shall apply notwithstanding other provisions of this Agreement.

(4) Construction by ANAHEIM of improvements referred to herein which lie within STATE rights of way or affect STATE facilities, shall not be commenced until ANAHEIM's original contract plans involving such work, have been reviewed and approved by signature of STATE's District Director of District 12, or his delegated agent, and until an Encroachment Permit authorizing such work has been issued by STATE therefor. Receipt by ANAHEIM of contract plans signed by STATE shall constitute STATE's acceptance of and official approval of said plans.

(5) ANAHEIM will obtain the aforesaid Encroachment Permit through the office of STATE's District 12 Permit Engineer and that ANAHEIM's application therefor shall be accompanied by reproducible tracings of aforesaid STATE approved contract

plans. Receipt thereafter by ANAHEIM of the approved Encroachment Permit shall constitute ANAHEIM's authorization from STATE to proceed with work which lies within STATE rights of way or which affects STATE facilities, pursuant to work covered by this Agreement. ANAHEIM's authorization to proceed with said work shall, however, be contingent upon ANAHEIM's compliance with all provisions set forth in said Encroachment Permit.

(6) ANAHEIM's contractor will also be required to obtain an Encroachment Permit from STATE prior to commencing any work which lies within STATE rights of way or which affects STATE facilities. The application for said Encroachment Permit shall be made through the office of STATE's District Permit Engineer (and shall include a Surety Bond).

(7) If existing public and/or private utilities conflict with the construction of the PROJECT, ANAHEIM will make all necessary arrangements with the owners of such utilities for their protection, relocation or removal. ANAHEIM will inspect the protection, relocation, or removal.

(8) The cost of any engineering or maintenance referred to herein shall include all direct and indirect costs (functional and administrative overhead assessment) attributable to such work, applied in accordance with STATE's standard accounting procedures.

(9) At all times during the progress of PROJECT, STATE shall have access to the work for the purpose of inspection thereof and should STATE deem any remedial measures to be necessary, STATE shall so notify ANAHEIM thereof.

(10) Upon completion, the maintenance and operation cost of said traffic signals within its jurisdiction shall become the responsibility of each agency.

(11) ANAHEIM and STATE shall mutually establish traffic signal timings for the traffic signal locations listed in Exhibit A for the UTCS System. The timings shall be established and agreed upon in writing by the Traffic Engineer of each party or the Traffic Engineer's designee. ANAHEIM shall be responsible for operating the UTCS master signal system and maintaining these timings for the UTCS system. Neither party shall modify the signal timing without written notification to and approval by the other party unless required to do so under emergency or other exigent circumstances.

(12) Upon completion of the interconnected traffic signal system and designated signal timing, the maintenance of the system shall become the responsibility of each party for these traffic signal locations within its jurisdiction, including the maintenance of the communication equipment from the drop at the interconnect trunkline to individual intersection controllers.

(13) Each party acknowledges that, in order for the interconnected system to operate optimally, it is necessary that the operational characteristics of the system be reviewed regularly, at a minimum of every (3) months, in order that proposals for needed modification to the system may be made at those times. The parties shall establish a Coordinating Committee comprised of the Traffic Engineer (or designee of the Traffic Engineer) from each agency. Each party may change its designated representative at any time.

The REPRESENTATIVE of each party shall be responsible for notifying the other party as soon as possible, but no later than the first working day following a system failure, emergency repair, or power failure affecting the interconnected system. The Committee member(s) of ANAHEIM and STATE shall also give advance notice of at least two (2) working days prior to any shutdown of the master controller affecting the interconnect system.

(14) If, upon opening bids, it is found that the cost will exceed the estimate, ANAHEIM and STATE shall endeavor to agree upon an alternative course of action. If, after 30 days, an alternative course of action is not agreed upon, this Agreement shall be deemed to be terminated by mutual consent.

(15) Neither ANAHEIM nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by STATE in connection with any work, authority or jurisdiction delegated to STATE under this Agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, STATE shall fully indemnify, defend and hold harmless ANAHEIM from any liability imposed for injury (as defined by government Code Section 810.8), occurring by reason of anything done or omitted to be done by STATE, in connection with, any work, authority or jurisdiction delegated to STATE under this Agreement.

(16) Neither STATE nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by ANAHEIM, in connection with any work, authority or jurisdiction delegated

to ANAHEIM under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, ANAHEIM shall fully indemnify, defend and hold harmless STATE from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by ANAHEIM, in connection with any work, authority, or jurisdiction delegated to ANAHEIM under this Agreement.

(17) This Agreement supersedes any and all other agreements, either oral or written, between the agencies with respect to the subject matter herein. Each party to this Agreement acknowledges that no representation which is not embodied herein, nor any other agreement, statement, or promise not contained in this Agreement shall be valid and binding. Modification of this Agreement shall be effective only if it is in writing and signed by ANAHEIM and STATE.

(18) This Agreement shall be governed and construed in accordance with the laws of the State of California.

(19) This Agreement shall terminate upon completion and acceptance of the PROJECT construction contract by STATE or on _____________, whichever is earlier in time; however, the ownership and maintenance clauses shall remain in effect until terminated, in writing, by mutual agreement.

(20) The invalidity in whole or in part of any provision of this Agreement shall not void or affect the validity of any other provision of this Agreement.

(21) The effective date of this Agreement shall be the latest date of execution hereinafter set forth opposite the names of the signators hereto. In the event STATE fails to set

forth a date of execution opposite the name of their signator, STATE hereby authorizes ANAHEIM, by and through its representative, to insert the date of execution by STATE signator(s) as the date said Agreement, as executed by STATE, is received by ANAHEIM.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed on the dates hereinafter respectively set forth.

STATE of CALIFORNIA
Department of Transportation

By: ______________________
James W. Van Loben Sels
Director of Transportation

By: ______________________
Chief Deputy District Director
District 12

DATE OF EXECUTION:

____
APPROVED AS TO FORM AND PROCEDURE

By: ______________________
Attorney
Department of Transportation

APPROVED AS TO FUNDS AND PROCEDURE

____
District Accounting Officer

CITY OF ANAHEIM
A municpal corporation

By______________________
MAYOR

ATTEST: ______________________
City Clerk

DATE OF EXECUTION:

____
APPROVED AS TO FORM

JACK L. WHITE, CITY ATTORNEY

By: ______________________
Deputy Attorney

Date: ______________________

A G R E E M E N T

THIS AGREEMENT, dated for purposes of identification only this day of , is made and entered into by and between the

CITY OF LOS ALAMITOS, a municipal corporation, hereinafter referred to as "LOS ALAMITOS,"

A
N
D

CITY OF CYPRESS, a municipal corporation, hereinafter referred to as "CYPRESS,"

A
N
D

CITY OF STANTON, a municipal corporation, hereinafter referred to as "STANTON,"

W I T N E S S E T H:

WHEREAS, considerable traffic congestion exists along the Katella Avenue corridor between Dale Avenue and Douglass Road (The Corridor); and

WHEREAS, LOS ALAMITOS, CYPRESS and STANTON all have jurisdiction over portions of the Corridor; and

WHEREAS, the traffic signal locations listed in "Exhibit A" are within the corporate boundaries of LOS ALAMITOS, CYPRESS and STANTON; and

WHEREAS, LOS ALAMITOS, CYPRESS AND STANTON all share jurisdiction or hold jurisdiction exclusively as indicated in Exhibit A; and

WHEREAS, the Comprehensive Signal Coordination Plan for Orange County and other engineering studies indicate that an interconnected and coordinated traffic signal system would be mutually beneficial to the cities and would improve traffic safety and flow; and

WHEREAS, LOS ALAMITOS, CYPRESS and STANTON are all willing to cooperate with each other in the coordination of traffic signals and in the maintenance of traffic signal and hardwire interconnect systems; and

WHEREAS, LOS ALAMITOS, CYPRESS and STANTON wish to define the responsibilities of each party.

NOW, THEREFORE, in consideration of the mutual covenants and agreements contained herein, and for good and valuable consideration, the receipt of which is hereby acknowledged, IT IS AGREED by the parties hereto as follows:

I. Signal Operations:

In order to implement an interconnected and coordinated Tectronix traffic signal system, all traffic signal locations listed in Exhibit "A" will be operated by the master computer of LOS ALAMITOS.

II. Signal Timing:

LOS ALAMITOS, CYPRESS and STANTON shall mutually establish traffic signal timings for the traffic signal locations listed in Exhibit A for the Tectronix System. The timings shall be established and agreed upon in writing by the Traffic Engineer for each party or the Traffic Engineer's designee. LOS ALAMITOS shall be responsible for operating the Tectronix master signal system and maintaining these timings for the Tectronix system. Neither party shall modify the signal timing without written notification to and approval by the other agencies unless required to do so under emergency or other exigent circumstances.

III. Maintenance:

Upon completion of the interconnected traffic signal system and designated signal timing, LOS ALAMITOS, CYPRESS and STANTON shall maintain the traffic signals as designated in Exhibit "A". LOS ALAMITOS, CYPRESS and STANTON shall each maintain the street, curb, gutter, sidewalk, signs, stripings, markings and other facilities at the signalized intersections within their respective boundaries.

IV. LOS ALAMITOS, CYPRESS and STANTON shall mutually establish traffic signal timings for the traffic signal locations listed in Exhibit "A" for the Tectronix system. The timings shall be established and agreed upon in writing by the Traffic Engineer for each party or the Traffic Engineer's designee.

LOS ALAMITOS shall be responsible for operating the Tectronix master signal system and maintaining these timings for the Tectronix system. Neither party shall modify the signal timing without written notification to and approval by the other agencies unless required to do so under emergency or other exigent circumstances.

V. Upon completion of the interconnected traffic signal system and designated signal timing, the maintenance of the system shall become the responsibility of each agency for these traffic signal locations within its jurisdiction, including the maintenance of the communication equipment from the drop at the interconnect trunkline to individual intersection controllers.

VI. Each agency acknowledges that, in order for the interconnected system to operate optimally, it is necessary that the operational characteristics of the system be reviewed regularly, at a minimum of every three (3) months, in order that proposals for needed modification to the system may be made at those times. The agencies shall establish a Coordinating Committee comprised of the Traffic Engineer (or designee of the Traffic Engineer) from each agency. Each agency may change its designated representative at any time.

The REPRESENTATIVE of each agency shall be responsible for notifying all other agencies as soon as possible, but no later than the first working day following a system failure, emergency repair, or power failure affecting the interconnected system. The committee member(s) of LOS ALAMITOS, CYPRESS and STANTON shall also give advance notice of at least two (2) working days prior to any shutdown of the master controller affecting the interconnect system.

The committee shall prepare a summary report of its meetings, system activity and future needs at the end of each calendar year. The report shall be completed by a date mutually acceptable by all agencies. Each agency shall keep open book records of PROJECT which shall be available for inspection by any agency, at any reasonable time, during regular business hours.

VII. It is mutually understood and agreed by each agency that neither LOS ALAMITOS nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by CYPRESS and STANTON under or in connection with any work, authority or jurisdiction delegated to CYPRESS and STANTON under this Agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, CYPRESS and STANTON shall fully indemnify, defend and hold harmless LOS ALAMITOS from any liability imposed for injury (as defined by Government Code Section 810.8), occurring by reason of anything done or omitted to be done by CYPRESS and STANTON under or in connection with, any work, authority or jurisdiction delegated to CYPRESS and STANTON under this Agreement.

Neither CYPRESS nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by LOS ALAMITOS and STANTON under or in connection with any work, authority or jurisdiction delegated to LOS ALAMITOS and STANTON under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, LOS ALAMITOS and STANTON shall fully indemnify, defend and hold harmless CYPRESS from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by LOS ALAMITOS and STANTON under or in connection with any work, authority, or jurisdiction delegated to LOS ALAMITOS and STANTON under this Agreement.

Neither STANTON nor any officer or employee thereof shall be responsible for any damage or liability occurring by reason of anything done or omitted to be done by LOS ALAMITOS and CYPRESS under or in connection with any work, authority or jurisdiction delegated to LOS ALAMITOS and CYPRESS under this agreement. It is also understood and agreed that, pursuant to California Government Code Section 895.4, LOS ALAMITOS and CYPRESS shall fully indemnify, defend and hold harmless STANTON from any liability imposed for injury (as defined by Government Code Section 810.8) occurring by reason of anything done or omitted to be done by LOS ALAMITOS and CYPRESS under or in connection with any work, authority or jurisdiction delegated to LOS ALAMITOS and CYPRESS under this Agreement.

VIII. This Agreement supersedes any and all other agreements, either oral or written, between the agencies with respect to the subject matter herein. Each agency to this Agreement acknowledges that no representation by any agency which is not embodied herein, nor any other agreement, statement, or promise not contained in this Agreement shall be valid and binding. Modification of this Agreement shall be effective only if it is in writing signed by all parties to this Agreement.

IX. This Agreement shall be governed and construed in accordance with the laws of the State of California.

X. This Agreement shall remain in effect for one year as of the effective date of this Agreement with automatic renewals each year unless terminated by any agency. Any agency may terminate this Agreement at any time upon giving sixty (60) days written notice of termination to all other agencies.

XI. The invalidity in whole or in part of any provision of this Agreement shall not void or affect the validity of any other provision of this Agreement.

XII. This AGREEMENT may be executed in multiple originals with each fully executed original having full force and effect as an original copy hereof.

XIII. The effective date of this Agreement shall be the latest date of execution hereinafter set forth opposite the names of the signators hereto. In the event an agency fails to set forth a date of execution opposite the name(s) of their signator(s), that agency hereby authorizes LOS ALAMITOS, by and through its representative, to insert the date of execution by that agency's signatories as the date said Agreement, as executed by that agency, is received by LOS ALAMITOS.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed on the dates hereinafter respectively set forth.

CITY OF LOS ALAMITOS
a municipal corporation

By______________________
MAYOR

CITY OF CYPRESS,
a municipal corporation

By______________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By____________________________

Date__________________________

CITY OF STANTON,
a municipal corporation

By____________________________
MAYOR

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By____________________________

Date__________________________

ATTEST:

____
CITY CLERK

DATE OF EXECUTION:

____

APPROVED AS TO FORM:

OFFICE OF THE CITY ATTORNEY

By____________________________

Date__________________________

M E M O R A N D U M
KATELLA AVENUE SIGNAL COORDINATION PROJECT

Date: May 22, 1991

To: All Agencies **From:** James M. Paral

SUBJECT: KATELLA AVENUE SIGNAL COORDINATION - CITIZEN CALLS

In an effort to try and standardize the responses to the numerous telephone calls each agency may receive over the next few months, I am preparing this sample response of how the system will proceed.

"Thank-you very much for your telephone call. The City of ____________ is currently installing a new computerized multi-agency traffic signal system along Katella Avenue. This process is expected to take a couple of months which involves putting each traffic signal on-line with the computer, one intersection at a time. The project includes 40 intersections along Katella Avenue from the I-605 Freeway to I-57 Freeway involving five city agencies and Caltrans. The new system is designed to provide better coordination and progression on Katella Avenue across jurisdictional boundaries in Orange County. Currently there is no coordination between different jurisdiction's traffic signals, each jurisdiction works independently.

Your call will help us identify areas of concern, if you would take a few minutes to answer these following questions.

Name of Intersection ______________________________

Time of Day you noticed problem ______________________

Describe Problem Found ______________________________

____

____

Any Further Comments ______________________________

____

____

We apologize for the inconvenience and hope that in the near future you will be seeing traffic flowing smoothly along Katella Avenue.

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