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CHAPEL HILL – CARRBORO

SIGNAL SYSTEM

FINAL TRANSIT SIGNAL PRIORITY ASSESSMENT

TECHNICAL MEMORANDUM

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1. Purpose

The purpose of this memorandum is to provide background information and planning level cost assessment for adding Transit Signal Priority (TSP) capability to the currently under design Chapel Hill-Carrboro signal system. The memorandum explores several alternatives ranging from a demonstration deployment on one arterial to a full city-wide implementation of TSP. The memorandum also considers various upgrade paths to add TSP to the new system in the future. The costs of the various alternatives provided in this memorandum are "order of magnitude" in precision and are focused on supporting a comparative analysis. At such time a TSP system is programmed for implementation, a more comprehensive analysis should be engaged.

2. Transit Signal Priority

Transit Signal Priority (TSP) is an operational strategy that facilitates the movement of transit vehicles through traffic-signal controlled intersections. Objectives of TSP include improved schedule adherence and improved transit travel time efficiency while minimizing impacts to normal traffic operations. Like most endeavors, Transit Signal Priority has exhibited benefits for many operators, but others have not been able to realize those benefits. Also, TSP has significant cost considerations beyond software. These issues are discussed below.

2.1 Positive Impacts

In some cases, TSP has been shown to be a cost-effective method to enhance regional mobility by improving transit operations speed and schedule adherence, thereby increasing the attractiveness and reliability of the transit mode. Several examples (*Transit Signal Priority (TSP): A Planning and Implementation Handbook*; May 2005) of successful TSP implementations include:

- In Tacoma, Washington, the combination of TSP and signal optimization reduced transit signal delay about 40% in two corridors.

- Portland, Oregon was able to avoid adding one more bus by using TSP to reduce route travel time and improve schedule adherence. As a result, the agency experienced a 10% improvement in travel time and up to a 19% reduction in travel time variability. Due to this increased reliability, the transit property was able to reduce scheduled recovery time.

- In Chicago, buses realized an average of 15% reduction (three minutes) in running time. Actual running time reductions varied from 7% to 20% depending on the time of day. With the implementation of TSP and through more efficient run cutting, Chicago was able to realize a savings of one weekday bus while maintaining the same frequency of service.

Of course, not every system has been able to produce results as favorable as these. The location of bus stops, the underlying signal coordination, traffic flow along the route, the frequency of priority requests, and the number of signals are a few of the factors that will influence the success of a system. Some of the potentially negative impacts are discussed below.

2.2 Costs

TSP benefits typically come to agencies after significant investment. This investment is manifested in two forms: initial planning, design, and implementation costs; and operations and maintenance costs. Major elements of these costs are noted below.

2.2.1 Initial Costs

A significant portion of the initial costs are the costs related to the planning and design of the TSP. Specifically, three documents will be required for implementation: a detailed TSP Concept of Operations (ConOps); a transit/signal operations study; and the PS& E documents themselves.

The Concept of Operations (ConOps) is a user-oriented document that describes the characteristics of the TSP system or from the viewpoint of the individuals and organizations (Stakeholders) who will use the system in their daily work activities and who will operate and interact directly with the system. The ConOps provides an analysis that bridges the gap between the users' operational needs and visions and the System Developer's technical specifications, without becoming bogged down in detailed technical issues.

It is recommended that the TSP effort follow the Systems Engineering process as depicted on the "Vee" diagram shown **Figure 1**. Notice that the ConOps provides the foundation for all of the following development effort. The ConOps also documents a system's characteristics and the users' operational needs in a manner that can be confirmed by the user without requiring any technical knowledge beyond that required to perform normal job functions. The cost of the ConOps for TSP in Chapel Hill-Carrboro is expected to be in the range of $20,000 to $30,000.

The Transit/Signal Operations Study will review transit routes, bus stop locations, and estimate priority-request frequencies. An overall map of the transit system is shown on **Figure 2**. This information will prove invaluable in identifying locations where TSP can be employed successfully. This effort will require approximately 4 person-hours per intersection. Of particular concern in this analysis is the line-of-sight between the vehicle requesting priority and the receiver. Vegetation is frequently an issue that constrains the range of the equipment. If 40 intersections were to be studied, the cost would be in the range of $15,000 to $25,000.

The cost of the PS & E would also have to be considered. The cost of the plans would be rather low because “as-built” plans will be available as a result of the signal project. The specifications, however, will require a significant amount of work. The cost of preparing the PS&E documents for the TSP system is estimated to be in the range of $35,000 to $45,000

The final initial cost to be considered is the cost of developing the controller parameters that are used for the priority operation. This cost is considered to be equal to the cost of developing the signal plans themselves. For 40 intersections, this cost is estimated to be in the range of $80,000 to $120,000.

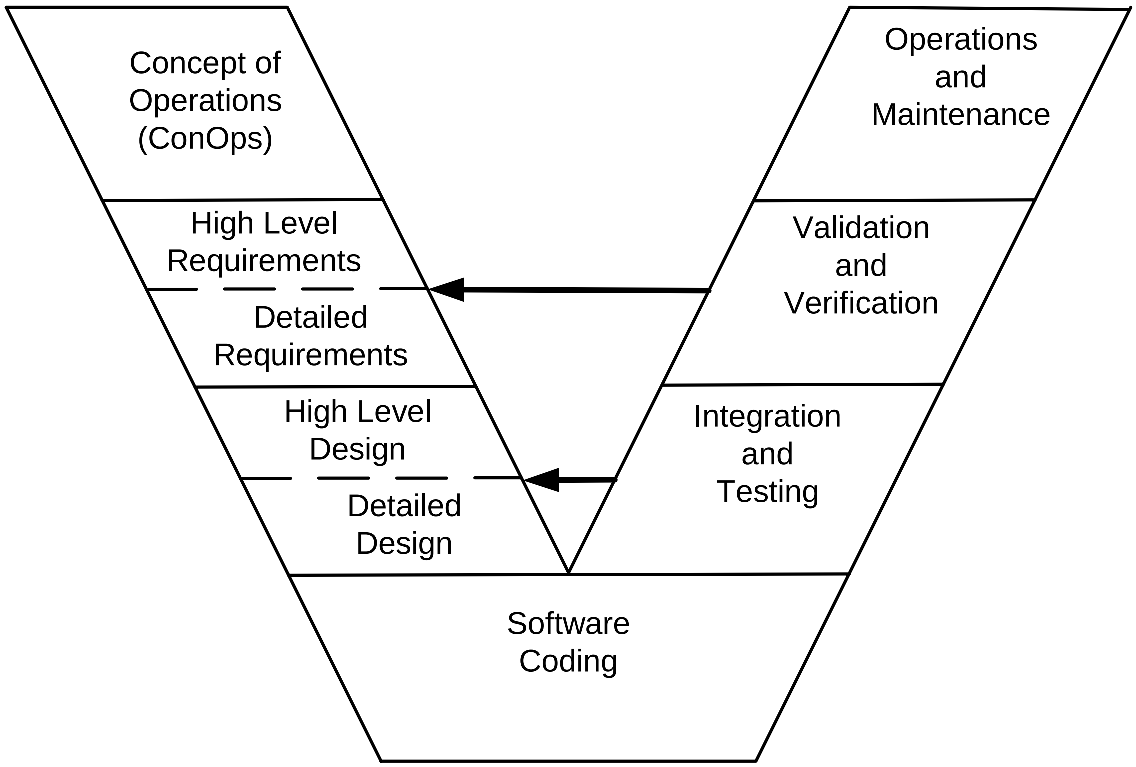

Figure 1. Systems Engineering Vee Diagram

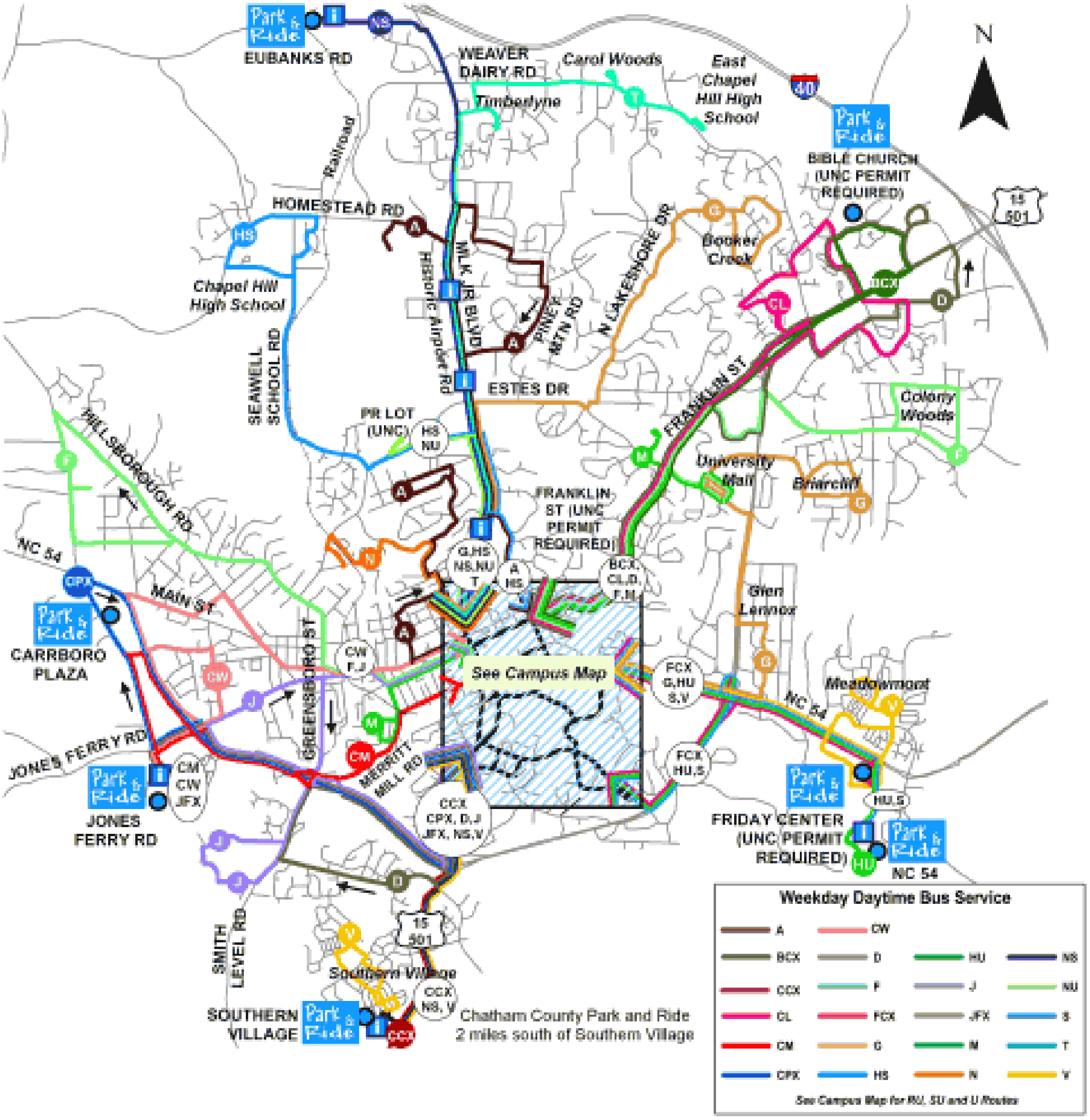

Figure 2. Chapel Hill Transit Routes

2.2.2 Operations and Maintenance Costs

With one exception, the operations and maintenance costs are estimated to be minimal and may be considered to be similar to the operations and maintenance costs of the traffic signal system. The annual hardware maintenance costs are estimated to be 10 percent of the equipment cost. The exception is the cost of the maintaining the controller parameters for the priority operation. Signal timing plans typically operate for three or four years before the traffic demands change enough to require a significant upgrade. Whenever the signal timing plans are revised, the transit priority parameters will have to be revised as well. A complete retiming would cost as much as the original implementation costs ($80,000 to $120,000).

2.3 TSP Impact Summary

An initial concern in a TSP project is identifying the problem (such as buses experiencing delay at traffic signals) to be solved by the system. This effort will enable the developers to focus on the issues. One of the most important elements in this planning process is early identification and involvement of stakeholders who can provide support and/or create road-blocks. During the planning process the stakeholders must identify project goals and create a Concept of Operations (ConOps) which will help all partners understand and agree on what TSP will be able to do and how it should function. Such considerations are beyond the scope of this effort.

3. Chapel Hill-Carrboro Transit System

There are approximately 120 signalized intersections in the study area. The Chapel Hill Transit system operates 31 fixed routes that provide coverage throughout the community during the week. Chapel Hill Transit currently has approximately 100 buses. Service is provided to eight Park and Ride Lots. There are eight routes that operate on Saturdays, and two routes that operate on Sundays. The basic hours of operation are from 6:00 am to 7:30 pm. Evening service is provided on seven routes.

4. Transit Signal Priority (TSP) Systems

There are three systems that must be interfaced to have a fully functional Transit Signal Priority (TSP) system: the bus management system, the priority call system, and the traffic control system. Each of these systems is described below.

4.1 Bus Management

In Chapel Hill-Carrboro, NextBus is the bus management system. NextBus uses satellite technology and advanced computer modeling to track vehicles on their routes. Each vehicle is fitted with a satellite tracking system. By knowing the actual position of the buses, their intended stops, and the typical traffic patterns, NextBus can estimate vehicle arrivals with a high degree of accuracy. These estimates are updated constantly. The predictions are then made available on the World Wide Web and to wireless devices including signs at bus stops and businesses, internet capable cell phones, and other personal digital assistants (PDAs).

NextBus Information Systems uses commercial off-the-shelf (COTS) technology, public data networks, and the Internet. Bus position tracking is accomplished through the use of Global Position System (GPS) receivers. Data communication is provided through the use of Cellular Digital Packet Data (CDPD), a public data network. GPS provides the basic location (latitude and longitude) of the vehicle. CDPD transmits the location, vehicle ID, current route assignment and other data to the tracking system.

Of importance to TSP, is that the knowledge of whether the bus is early, on-time, or late is known by the NextBus system. This information can be interfaced with the TSP system to determine whether a bus should be provided signal priority or not. This is important since there have been several research studies that have shown that TSP can actually degrade transit service when priority is provided to buses that are early and can degrade overall traffic operations when priority is provided to vehicles that are on-time or ahead of schedule.

The management of NextBus noted that to date they have not interfaced with a TSP system, but they indicated a willingness to work with other vendors to provide the bus status (ahead, on-time, or behind schedule). This functionality is essential for a fully capable TSP. The cost of this interface is unknown at this time but is estimated to be in the $50,000 to $150,000 range. This value can be used for the preliminary comparison of alternatives. The actual cost will depend on how it is implemented and which system is interfaced with NextBus.

It is possible, however, to have an operational TSP system without interfacing with the NextBus system. There are numerous options to provide the schedule status of a transit vehicle to a TSP system.

4.2 Priority Call System

Global Traffic Technologies provides a priority call system, Opticom. Opticom is in common use throughout the United States. There are two versions of this product; one uses GPS and the other uses Infrared.

The Opticom GPS system uses the GPS position to calculate vehicle speed, heading, longitude, and latitude information. The Opticom GPS system intersection equipment is programmed with an approach map to define corridors for bus priority routes. As the oncoming vehicle enters the intersection's radio range (up to 2,500 feet), the vehicle sends speed, heading and position information to the intersection. This information is updated every second. The signal from the vehicle also transmits vehicle, class and agency ID information, as well as turn signal status. The Opticom GPS system intersection equipment sends the priority request to the Opticom GPS Phase Selector in the controller cabinet, which requests green-light priority through normal controller functions. The system recognizes the activated turn signal and relays the priority call forward to the next appropriate intersection on the route.

The Opticom Infrared system uses detectors installed at the intersection, emitters installed on buses, and Phase Selectors installed in the controller cabinet. An Opticom emitter mounted on the bus activates the system by broadcasting a secure, encoded priority request to the intersection. An Opticom detector at the intersection on the approach receives the infrared transmission and relays the request to the Phase Selector. The Opticom Phase Selector validates the request and provides input to the traffic controller, which then provides a green light through normal operations.

The approximate costs of these system elements are as follows:

Table 1. Priority Call System Costs

On-bus GPS transmitter	$3,000
Intersection GPS hardware	$10,000
On-bus Infrared transmitter	$1,500
Intersection Infrared hardware	$4,000

There are other vendors that supply bus emitters and detectors. Reno A & E provides a system that uses coded transmitters that are installed on the buses and two antenna loop coils installed in the roadway at the intersection. The installed cost of the receiver is estimated to be approximately $2,000 per controller and the emitters cost approximately $750 per vehicle. These costs are approximately one half the cost of the Opticom Infrared alternative. The design of the TSP system will have to consider these and other alternatives to arrive at a cost-effective solution. For the purposes of this assessment, it is assumed that the Opticom Infrared approach will be used since this is a common option used in the United States and is a mature technology.

Obviously, the cost of this hardware depends on the technology selected, the number of intersections instrumented and the number of buses which are outfitted with transmitters. This assessment considers three scenarios: a demonstrations deployment, a major routes deployment, and a city-wide deployment.

4.2.1 Demonstration Deployment

The demonstration deployment assumes that TSP will be installed on one major arterial at ten signalized intersections. It also assumes that ten buses will be instrumented with emitters. The purpose of the demonstration system is to deploy a meaningful TSP system at the lowest feasible cost to be able to demonstrate its effectiveness in the Chapel Hill-Carrboro environment.

4.2.2 Major Route Deployment

The purpose of the major routes deployment is to define a TSP system that covers the major transit routes in Chapel Hill-Carrboro. This configuration assumes that 40 signalized intersections will be instrumented and that 40 buses will be instrumented with priority emitters. There are 80 intersections that will not be outfitted with TSP. This alternative represents a median between the minimum demonstration system and the city-wide system.

4.2.3 City-wide Deployment

The final alternative is the city-wide deployment. In this configuration it is assumed that 80 signalized intersections are instrumented for TSP and that 100 buses (the entire fleet) are equipped with emitters. This deployment assumes there are 40 signalized intersections that do not service bus routes.

4.3 Traffic Control Systems

The traffic control system upgrade and expansion is currently under design. There are approximately 120 intersections in the system and of these; approximately 110 are on state routes and ten serve Town streets only. This is significant because NCDOT has a statewide software license that will provide local controller software at no cost to the project at locations on state roads if the project elects to use the Econolite OASIS software at these locations. The project will have to buy OASIS for only the ten Town intersections. If the project were to use another local controller software package, then the project would have to procure a license for all 120 controllers.

At issue is how to provide for TSP either when the system is initially deployed or as an element that can be added at a future date. There are several systems that are logical candidates for Chapel Hill – Carrboro. These include traffic control systems from companies like Econolite, Siemens, and Naztec. Regardless of the supplier, each system will operate with the same hardware infrastructure and communications plant. The local controller will be a Type 2070L. Each of these systems has two distinct software components; the local controller software and the central system software. The local controller software controls the signal displays at the intersection. The central software provides an overarching control of the system. The controller and central software should not be mixed and matched with products from different vendors. Controller TSP software from one vendor should be used with the central software from the same vendor if a commercial off the shelf (COTS) deployment is desired.

For the purpose of this preliminary cost assessment, prices were obtained from two vendors, Econolite and Naztec. The intent was to be able to use the process from one as a credibility check on the other. There are other TSP suppliers, if a decision is made to make a competitive procurement of TSP these other vendors may chose to pursue the project. The following is a description of the Econolite and Naztec offerings.

4.3.1 Econolite

Econolite offers two local controller software packages that are of interest to this project, OASIS and ASC/3-2070. The OASIS software was designed to meet the North Carolina DOT requirements for the Type-2070 Controller. The OASIS software facilitates and expedites the movement of pedestrian and vehicle traffic. OASIS was developed in ANSI C to maintain compliance with the OS-9 operating system. It is designed to operate under PYRAMIDS, a central system software application that supports real-time intersection information displays as well as other advanced traffic management operations, such as database management, log reporting, and event scheduling. Many of the advanced features incorporated in OASIS take full advantage of the higher performance processor and significantly increased memory that 2070 controllers provide. NCDOT has a license to use OASIS on any state road. Therefore, there is no additional cost associated with the use of OASIS in the project at approximately 110 controllers. Unfortunately, OASIS and PYRAMIDS do not support TSP.

In telephone discussions with Econolite, it was learned that Econolite has no plans to add TSP into OASIS and PYRAMIDS. However, Econolite is developing a TSP package using the ASC/3-2070 software platform and is willing to provide this software package, when equipped with TSP, to NCDOT at no additional cost other than the cost of the TSP module, which is estimated to be approximately $300 per intersection. The ASC/3-2070 with TSP will operate with a new central software package that will support both the ASC/3-2070 and OASIS. This new system is currently being developed for Colorado Springs, CO and other Econolite customers and is expected to be fully developed, tested, and deployed early this summer (2008).

4.3.2 Naztec

Naztec also provides a very capable traffic control system that incorporates TSP. The local Naztec software is called Apogee and the central system software is called ATMS-NOW. Naztec sells Apogee for approximately $600 per intersection and ATMS-NOW for approximately $100,000. In small quantities, say less than 50, Naztec sells TSP for $1760 per intersection. For a city-wide license, Naztec would charge $175,000 for TSP.

5. Cost Assessment

A cost estimate is provided for three levels of implementation of TSP: a ten intersection-ten bus demonstration system, a 40 intersection-40 bus system, and a city-wide system. These costs are estimated using cost data provided by the following vendors: Global Traffic Technologies (Opticom), Naztec and Econolite. In each case, the local intersection, central computer, and communications infrastructure are identical regardless of the software and therefore are not considered in this analysis. The cost estimate includes the costs related to installing software for 120 local controllers and the supporting central system. The cost of all hardware directly related to TSP is included in each estimate.

It should be noted that there is no cost associated with local controller software that use the Econolite system and does not have TSP. This is because this software will be provided by NCDOT at no cost to the project, or if provided as promised, Econolite will provide the ASC/3-2070 software at no cost on State roads where TSP will be implemented. Although PYRAMIDS does not support TSP, a new system currently under development in Colorado Springs supports both ASC/3-2070 (with and without TSP) and OASIS. This would allow the City to use ASC/3-2070 at TSP locations and OASIS at other locations if desired.

The software costs for 120 local controllers are included for the Naztec alternative because the local controller software will be necessary to maintain compatibility with the central software for the system.

5.1 Baseline System

This system does not support TSP but is provided for comparison purposes. There are two cost components provided for this alternative; the central software and the local intersection software. All other hardware costs would be the same regardless of the software selected.

The Econolite alternative using PYRAMIDS and OASIS does not offer a direct path to add TSP in the future. This base system is estimated to cost $130,000. It is possible, however, to replace PYRAMIDS and OASIS with the Econolite “New System” and ASC/3-2070 controller software and add TSP in the future. This is the second Econolite alternative shown below and is estimated to cost a slightly higher $155,000. It is also possible to procure a Naztec system which can be upgraded to TSP in the future. This alternative is shown as the Naztec-ATMS-NOW solution and is estimated at $170,000.

Table 2. Baseline System Costs for Econolite (Pyramids)

Central Software – PYRAMIDS	$125,000
Local Software – OASIS (City- 10 * $500)	$5,000
Local Software – OASIS (State- 110 * $0)	$0
Total	**$130,000**

Table 3. Baseline System Costs for Econolite (New System)

Central Software – New System	$150,000
Local Software – ASC/3-2070 (City- 10 * $500)	$5,000
Local Software – OASIS (State- 110 * $0)	$0
Total	**$155,000**

Table 4. Baseline System Costs for Naztec (ATMS.NOW)

Central Software – ATMS.NOW)	$100,000
Local Software – Apogee (120 * $600)	$72,000
Total	**$172,000**

Each of these baseline alternatives offers an upgrade path. The PYRAMIDS/OASIS solution would require the cost associated with upgrading from PYRAMIDS to the new Econolite central system software. The cost of this upgrade has not been determined by Econolite at this point. It is reasonable, however, to assume that the upgrade would cost less than the $150,000 that an initial purchase would cost. The cost of an upgrade from this alternative would be the cost of the TSP elements plus the cost of controller upgrades plus the cost of central software (less than $150,000).

The other two baseline alternatives allow a direct upgrade to TSP without losing any of the initial investment. The disadvantage of the Econolite (New System) alternative is that the system operations will be complicated slightly by the necessity of operating with two different controller software packages, OASIS and ACS/3-2070. The cost of this option is estimated to be $25,000 higher than the PYRAMIDS option. Also, the new Econolite central software will have a more limited track record, adding risk to the project.

The Naztec option offers a direct upgrade path, but the cost is estimated at $172,000 reflecting the cost of buying controller software for all 120 intersections.

5.2 Demonstration System

This system would install TSP capability at ten intersections and equip ten buses with priority transmitters. This alternative assumes that the Econolite alternative uses the "New System" since the PYRAMIDS alternative does not support TSP. The TSP hardware is based on the Opticom infrared system. It is assumed that the 10 intersections are on the state system and therefore there is no additional controller software cost other than the cost for TSP.

Table 5. Demonstration System Costs for Econolite

NextBus – Central system software interface	$100,000
Opticom Infrared bus transmitters (10* 1,500)	$15,000
Opticom local Infrared TSP hardware (10*4,000)	$40,000
Local controller TSP software (10 * 300)	$3,000
TOTAL	**$158,000**

Table 6. Demonstration System Costs for Naztec

NextBus – Central system software interface	$100,000
Opticom Infrared bus transmitters (10* 1,500)	$15,000
Opticom local Infrared TSP hardware (10*4,000)	$40,000
Local controller TSP software (10 * 2000)	$20,000
TOTAL	**$175,000**

5.3 40 Intersection-40 Bus System

This alternative would install TSP capability at 40 intersections and equip 40 buses with priority transmitters. This alternative provides for TSP operation on the transit routes that would achieve the highest benefit. With this alternative, it is assumed that all of the routes are on the State system. Because this is a more intensive implementation of TSP, it is assumed that the priority call hardware would use the infrared technology rather than the more expensive GPS technology.

Table 7. Forty Intersection System Costs for Econolite

NextBus – Central system software interface	$100,000
Bus Transmitters (40 * 1,500)	$60,000
Local controller TSP hardware (40 * 4,000)	$160,000
Local controller TSP software (40 * 300)	$12,000
TOTAL	**$332,000**

Table 8. Forty Intersection System Costs for Naztec

NextBus – Central system software interface	$100,000
Bus Transmitters (40* 1,500)	$60,000
Local controller TSP hardware (40 *4,000)	$160,000
Local controller TSP software (40 * 1750)	$70,000
TOTAL	**$390,000**

5.4 City-wide TSP system

This alternative provides every intersection that has a bus route (assumed to be 80 intersections) with a TSP enabled controller and equips every bus in the system with a transmitter so that any bus can be used on any route and achieve priority treatment.

Table 9. Citywide System Costs for Econolite-Opticom

NextBus – Central system software interface	$100,000
Bus Transmitters (100* 1,500)	$150,000
Local controller TSP hardware (80*4,000)	$320,000
Local controller TSP software (80 * 300)	$24,000
TOTAL	**$594,000**

Table 10. Citywide System Costs for Naztec-Opticom

NextBus – Central system software interface	$100,000
Bus Transmitters (100* 1,500)	$150,000
Local controller TSP hardware (80*4,000)	$320,000
Local controller TSP software (80 * 1750)	$140,000
TOTAL	**$710,000**

In each of these scenarios, the Opticom local controller TSP hardware represents the costliest factor. This is because of the cost of the "Phase-Selector". This device is essential at the ten intersection-ten bus level since it allows the implementation of the system using only COTS software and hardware. At the next level, however, it may be possible to eliminate this device and replace it with a receiver that sends a priority call to the controller. This capability is estimated to cost $2,000 per intersection or $80,000 for the 40 intersection system and $160,000 for the city-wide system.

6. Other TSP Costs

The implementation of any TSP system will require a significant amount of work to calculate, install, and validate the controller parameters that are necessary to operate the priority system. This work is estimated to be equal to or greater than the time required to generate the traffic signal plans for each intersection exclusive of TSP.

TSP can be expected to provide an overall decrease in traffic signal delays for transit vehicles in the order of 10 to 15 percent. However, these improvements may not be achieved at every location. At locations that have near side bus stops, research has shown that TSP can actually degrade transit operation and increase the operational delays. This is because the dwell times at each bus stop are unpredictable. The bus will frequently require more time to service passengers than is available in the priority window and will not be able to use the priority green. To determine where TSP can be used effectively, a stop by stop inventory of every bus route under consideration for signal priority must be performed. This analysis should investigate all measures that can be used to determine if near-side bus stops can be relocated. This analysis must be conducted by persons who are experienced with transit operations and with persons who are experienced with traffic signal operations.

One final category of costs must be noted, the design and integration costs. For most Intelligent Transportation System type contracts, the design and integration costs range in the ten to twenty percent of the construction costs. Because of the complexity of this project, it is reasonable to expect that the design and integration costs to be at the high end of this range.

7. Assessment

In summary, this analysis is intended to provide an "order of magnitude" assessment of the cost of TSP. This assessment compared two possible solutions to provide for TSP; one based on using the Econolite system and the other using the Naztec system. The cost to the project for system and controller software without the possibility of upgrading to TSP in the future is approximately $130,000. This alternative would use PYRAMIDS for the central software and OASIS for the controller software.

To provide an upgrade path for TSP with Econolite, new system software must be used. This software currently under development and will operate with both OASIS which does not support TSP, and with ASC/3-2070 which does support TSP. The cost of this alternative is $155,000 --

$25,000 more than the Econolite alternative that does not support TSP. The cost of the Naztec system which does support TSP is $172,000 -- $17,000 higher than the Econolite system with TSP expansion possibilities.

Three different levels of TSP were considered, a 10 location implementation, a 40 location implementation and a city-wide implementation. The additional costs associated with each level of expansion are shown in the tables below.

Table 11. Summary of Econolite TSP Implementation Costs

Type	Concept of Operations	Operational Analysis	PS&E Development	Timing and Parameter Development	TSP Construction	Total Cost	Annual Maintenance Cost
10 – Location	$25,000	$5,000	$45,000	$20,000	$158,000	**$253,000**	$16,000
40 – Location	$25,000	$15,000	$60,000	$80,000	$332,000	**$512,000**	$34,000
City-wide	$25,000	$25,000	$120,000	$240,000	$594,000	**$1,004,000**	$60,000

Table 12. Summary of Naztec TSP Implementation Costs

Type	Concept of Operations	Operational Analysis	PS&E Development	Timing and Parameter Development	TSP Construction	Total Cost	Annual Maintenance Cost
10 – Location	$25,000	$5,000	$45,000	$20,000	$175,000	**$270,000**	$18,000
40 – Location	$25,000	$15,000	$60,000	$80,000	$390,000	**$570,000**	$39,000
City-wide	$25,000	$25,000	$120,000	$240,000	$710,000	**$1,120,000**	$71,000

To summarize, an additional investment of $25,000 would provide the City with an upgrade path to TSP using the Econolite system. It should be noted that this alternative assumes that the new system software will be acceptable to the City and State and that it will provide all of the functionality of PYRAMIDS. For an additional $42,000, the City can acquire ATMS-NOW from Naztec. This alternative provides a clear upgrade path with no software development risk. This avenue, however, comes with a significant cost of $1,750 per intersection for TSP. This also moves the Town from the statewide local software standard.

In addition to these capital costs, it will be necessary to budget for a modest increase in maintenance costs. This is estimated to be ten percent of the cost show in the above summary cost tables. Some of this cost will be required to procure hardware. However, most of this cost is expected to be used for updating the TSP controller parameters as transit routes are changes and new routes are added to the system.

Regardless of the level of implementation and which vendor appears to be more attractive, the first step in implementing TSP should be the preparation of a Concept of Operations report. This should be followed with a TSP operational design report that would identify the routes, the TSP phasing, timing, and intersections that could benefit from TSP.