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Transit Signal Priority
Systems Application and Technology Investigation

FINAL REPORT
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Submitted by

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16. Abstract

This report describes the process and results of research to develop an evaluation process that will assist NJ Transit in quickly determining which intersections are good candidates for Transit Signal Priority (TSP). This evaluation process is applicable for passive and active TSP and could be applied to a variety of roadways, including urban arterials, state routes and county roads.

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INTRODUCTION

In New Jersey, priorities and capital investment strategies are focusing on improving bus service, including express and Bus Rapid Transit (BRT) in key corridors. One key technological component of these investment strategies is Transit Signal Priority (TSP). The New Jersey Department of Transportation, Bureau of Research, in cooperation for New Jersey Transit (NJ Transit) engaged Cambridge Systematics, Inc., (CS) to develop an approach that quickly and cost-effectively determines where TSP is appropriate and could make the most impact on improving operations and, therefore, service.

The objective of this research is to develop an evaluation process that will assist NJ Transit in quickly determining which intersections are good candidates for TSP. This evaluation process is applicable for passive and active TSP and could be applied to a variety of roadways, including urban arterials, state routes, and county roads.

The research was conducted in five main tasks over a four-month period. Task 1 included a high-level survey of TSP implementations across North America to identify any intersection-level screening criteria either that were used during deployment or that could be recommended based on experience. Task 2 included the development and refinement of an intersection screening procedure based on experience elsewhere and applicable to New Jersey. Task 3 included the application of the screening procedure to three example corridors identified by NJ Transit. Task 4 included documentation of the research in this report. Task 5 included presentations to various stakeholders.

The appendices include final presentation handouts from two main progress meetings with stakeholders conducted during the study.

TECHNOLOGY REVIEW

Transit Signal Priority is an operational strategy that can allocate additional green time to help transit vehicles (e.g., buses or streetcars) through traffic signal-controlled intersections. Objectives of TSP include improved schedule adherence and/or reduced running times while minimizing impacts to normal traffic operations. TSP is made up of four components, including:

1. A detection system that lets the TSP system know when a vehicle is requesting priority and its location relative to the intersection.
2. A priority request generator that alerts the traffic control system that the vehicle would like to receive priority.
3. A traffic signal controller that processes the request and decides whether and how to grant priority based on strategies typically programmed in software.
4. Software that manages the system, collects data, and generates reports.[1]

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[1] Intelligent Transportation Society of America (ITS America). *Transit Signal Priority (TSP): A Planning*

Cambridge Systematics reviewed the literature on TSP to identify any intersection screening strategies that may be relevant in New Jersey. The literature review identified few criteria that could be used to develop an evaluation process that will assist NJ Transit in quickly determining which intersections are good candidates for TSP.

With little information available in the literature, Cambridge Systematics also surveyed seven transit agencies across North America that have deployed TSP about how they determined which intersections or corridors were good candidates for TSP.

Survey Approach

Seven agencies with established TSP systems were contacted and/or researched to develop a thorough understanding of the detailed components that have gone into their TSP decision process, including: corridor and intersection eligibility, initial screening criteria, use of microsimulation traffic operations modeling (if any), implementation status, performance measures, and recommendations for agencies considering TSP.

The agencies were selected to provide a representative cross section of TSP approaches, including:

- **Centralized versus Distributed Signal Control –** Different system architectures for managing the processing of signal priority requests.

- **Scale –** Different degrees of implementation, from a single priority route to large portions of the transit system.

- **Analysis Approach –** Different methodologies for evaluating feasibility and benefits, including microsimulation.

- **Geographic Distribution –** Different physical, climate, and political conditions across North America.

- **Implementation Experience –** Different levels of operating experience, from relatively recent implementation to programs that have developed over nearly 20 years.

As shown in Figure 1, selected agencies included:

1. Vancouver – South Coast British Columbia Transportation Authority (TransLink).

2. Portland – Tri-County Metropolitan Transportation District of Oregon (Tri-Met).

3. Oakland – Alameda-Contra Costa Transit District (AC Transit).

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and Implementation Handbook. May 2005. Available at www.itsa.org/itsa/files/pdf/TSPHandbook2005.pdf.

4. Los Angeles – Los Angeles County Metropolitan Transportation Authority (LACMTA).

5. Chicago – Regional Transportation Authority (RTA), Chicago Transit Authority (CTA), Pace Suburban Bus Service (Pace).

6. Toronto – Toronto Transit Commission (TTC).

7. New York City – New York City Metropolitan Transportation Authority (NYCMTA).

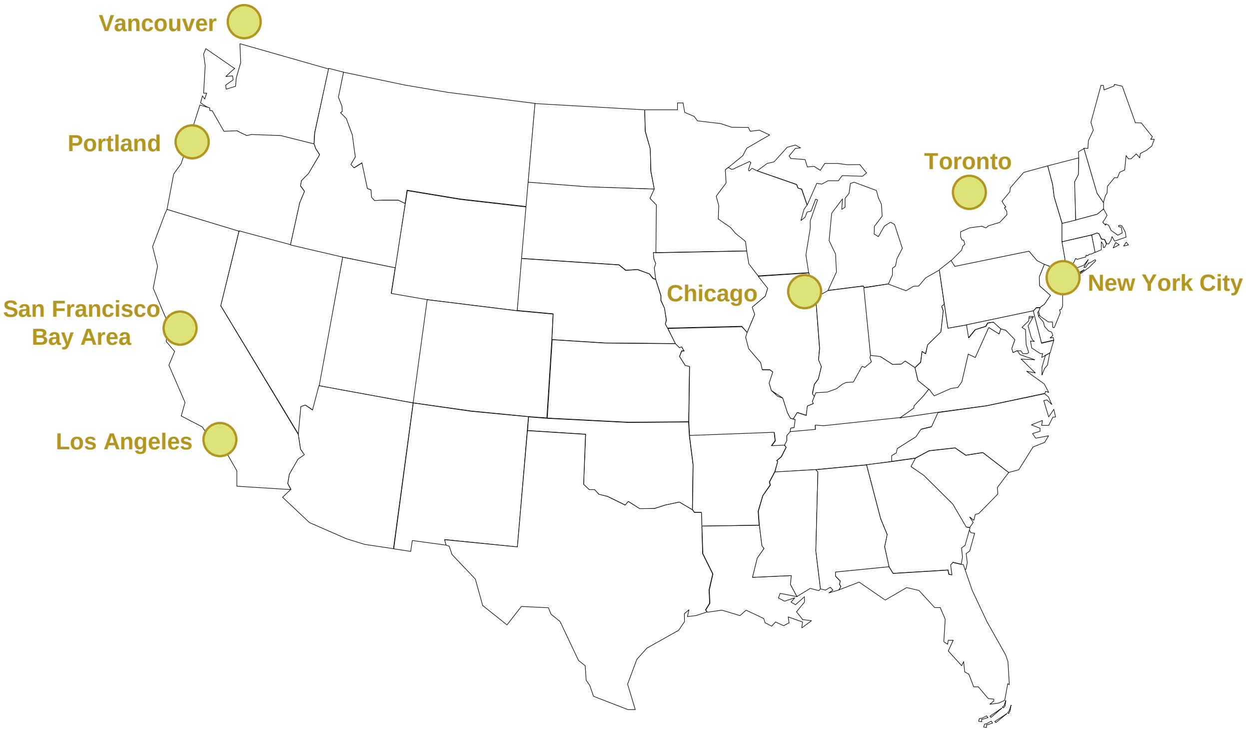


Figure 1. TSP Implementers Contacted

After identifying a knowledgeable contact in each region, Cambridge Systematics sent a list of questions for review in advance of a telephone interview. Questions included:

1. How were TSP intersections selected?

   a) Were they selected as part of a corridor search process (all intersections in a selected corridor), part of an intersection search process (certain intersections in a selected corridor), or a two-stage screening (select corridors first, then select intersections within each corridor)? Please describe specific selection criteria that were considered.

   b) If you have developed multiple corridors, have you refined your process since the initial deployments?

2. Was any screening done using high-level criteria (before detailed microsimulation)? If so, what criteria were used?

3. Was microsimulation used? What performance measures were evaluated? Did it confirm or contradict any high-level screening results?

4. Which signal control strategies do you use, and how did you choose them (e.g., passive/active, centralized/decentralized, etc.)?

5. What is the implementation status? Please describe any specific implementation barriers and/or keys to success, including technical issues.

6. What type of agency coordination has been involved in your TSP process?

7. Have any before-after studies been conducted? What do they suggest about the effectiveness of the initial screening?

8. Are there any screening criteria that you would recommend we use?

9. Are there any other systems utilizing TSP that you recommend we consider?

Implementation Overviews

Vancouver – TransLink

Interviewee: Hansel Wang, P.Eng. Program Manager, Transportation Engineering, Road and Infrastructure Planning

Date: 3 October 2008

Vancouver TransLink implemented a TSP system on the 98 B-line BRT corridor in 2001, which runs in an arterial corridor between downtown Vancouver and suburban Richmond. Some of the route is in a median busway, where passive TSP (timing signals to match typical transit operating speeds) is used. The rest operates in mixed traffic with active TSP.

The intent of the TSP system was to reduce travel time and increase schedule reliability. TSP is used at every intersection except for several intersections with significant transit service on the cross street (which are also those with the highest traffic volumes). Although microsimulation was used to evaluate operational impacts, the technique was not used for intersection screening because intersections were selected by policy.

TSP is deployed at about 40 intersections in the corridor. Signals were first coordinated and timing was optimized. Then TSP strategies including green extension (longer main street green phase) and red time truncation (shorter cross street green phase to provide "early green" on the main street) were implemented using infrared (optical) detection technology. Occasionally, a phase insertion strategy was used when the bus route makes a left turn.

TransLink is considering TSP for other high-frequency transit corridors. Future applications may use WiFi detection technology and newer signal controllers with the ability to log when a bus cleared the intersection during a priority interval. The current system is able to record when TSP requests are made and when requests were granted, but it is difficult to determine when grants are actually used.

A Before and After Study determined that travel-time savings, better on-time performance, and improved service quality resulted from TSP.

Portland – TriMet

Interviewee: Jon Lutterman, Project Manager, ITS Vehicle Systems

Date: 1 October 2008

Portland TriMet began exploring TSP technology in the 1990s and has deployed the technology at approximately 350 intersections along "Frequent Service Corridors," which are defined as corridors with bus service every 15 minutes or less throughout most of the day. Every major intersection in a corridor is typically equipped with TSP, except for some low-volume, two-lane cross streets with actuated signals. The rationale for excluding these intersections is that their green time is allocated only on demand and they contribute relatively little main street delay. The system uses red truncation and green extension strategies with infrared detection technology.

TriMet uses automatic vehicle location (AVL) system data to analyze the variability of bus travel times through intersections. In addition to the priority corridors, TriMet also has deployed TSP at isolated "hotspot" intersections that have been identified by bus operators as problem areas due to recurring traffic congestion, inefficient signal timing, or other reasons.

The agency's TSP philosophy involves the concepts of managing overall bus route travel-time variability and weighing person delay instead of vehicle delay. Even if a bus is empty near the beginning of a route, it is important to avoid the "snowball effect" of accumulating delay by keeping buses on schedule and maintaining reliability for downstream passengers. Intersection throughput is considered to be increased by enabling TSP rather than disabling it and retarding buses. A formula to assign values to passenger waiting, which measures the benefit to downstream riders was developed to measure effectiveness.

TriMet uses an aggressive schedule adherence threshold of zero seconds late for granting bus priority. If a vehicle is not early, then TSP requests are made at each intersection. The agency has found that TSP reduces running time variability, with a minimal reduction in running time. The improvement in schedule adherence can lead to substantial reductions in recovery time at the end of a route. In some cases, shorter recovery times can lead to reduced fleet requirements for a route.

The technology has been most useful at bus stops located on the far side of the intersection. At near-side stops, TSP has been less effective, resulting in some cases in overall increases in person delay as TSP is granted (delaying cross street traffic) but not used (because the bus does not clear the intersection during the priority interval due to long passenger boarding/alighting times). In a few locations, queue jump lanes are implemented with a right turn arrow to flush the right turn lane when a TSP request is received.

The need to design complete data logging into the system was mentioned as a lesson learned. While the agency can track priority requests and overall outcomes, such as travel-time reliability, there is no real-time capability to monitor TSP operations at the intersection level.

Bay Area – AC Transit

Interviewee: Jon Twichel, Transportation Planning Manager

Date: 20 October 2008

AC Transit has implemented TSP as part of two arterial BRT corridors that operate in mixed traffic. Each corridor is more than 10 miles long and contains at least 75 intersections. The agency-funded traffic signal controller upgrades and interconnections throughout each corridor. This strategy was effective in gaining support from local agencies with jurisdiction over the traffic signals. With the new controllers, signal timing plans were optimized and signals were coordinated, often creating significant benefits to traffic. The agency's primary interest in TSP was reducing running time ("making the Rapid really rapid"), although it was suggested that new signal timing improved speeds more than TSP. Stakeholders also gained emergency vehicle preemption (EVP) capability.

System simplicity was a major design theme. TSP strategies included green extension (up to about 10 percent of the cycle length) and red truncation (to pedestrian clearance minimums). Infrared detection is used. TSP was implemented at every intersection. The agency used long cycle recovery periods (the time after a TSP request is granted before the signal controller makes another opportunity available) to help maintain consistent headways without the need for AVL. Instead of requesting priority only when a bus is running late, AC Transit's BRT vehicles constantly emit requests, but signal controllers grant priority only about once per headway. This is accomplished by setting cycle recovery times to nearly the headway between BRT vehicles (10-minute recovery periods are used with 12-minute headways). When a bus is following another bus too closely (less than 10 minutes apart), it does not receive priority and tends to fall back. When a bus is running late, it receives priority and tends to catch up.

AC Transit has found TSP to provide the greatest benefit at the "medium" intersections. At the most heavily congested intersections, traffic queues frequently prevent buses from traveling from the detection point to the intersection in a predictable length of time, thus causing the priority interval to go unused by the bus. At the intersections with the lowest traffic volumes, actuated signals provided relatively little green time to the cross street, resulting in little transit vehicle delay to be reduced by TSP.

Los Angeles – LACMTA

Interviewee: Chun Wong, P.E., Transportation Engineer

Date: 15 October 2008

The City of Los Angeles initially established a centralized traffic control system in preparation for the 1984 Summer Olympics. TSP functionality was added to the system as a software upgrade for the MetroRapid arterial BRT system, which operates primarily in mixed traffic. Transit vehicles are located using transponders on the underside of vehicles and loop detectors in the pavement, which also provide traffic management data to the centralized signal control system. As the MetroRapid system has grown, the TSP system also has expanded throughout Los Angeles, now involving 26 corridors, 1,000 intersections (about 25 percent of the total intersections in the city), and more than 900 buses.

The system manages headways to maintain consistent spacing between buses by granting priority based on bus location relative to each other. The system also maintains an extensive event-log database, which assists in monitoring system performance and detecting hardware problems (e.g., loop failures).

The centralized system works well in Los Angeles, which already has the required infrastructure, but consensus building has been necessary to deploy TSP in surrounding cities. LACMTA currently is testing a distributed system to provide TSP functionality beyond the centralized traffic management area. WiFi detection is being tested in a MetroRapid corridor that runs through an adjacent municipality.

Chicago – RTA, CTA, Pace

Interviewee: Jeff Busby, Manager, Strategic Planning

Date: 20 October 2008

Chicago transit agencies have been exploring TSP since the mid-1990s, but relatively little has been implemented. The Cermak Road pilot program was an early national deployment, but is no longer in operation. The RTA completed a seminal TSP Location Study in 2004 that used extensive modeling and simulation to screen corridors and identify operational strategies. Until recently, implementation has been focused on two relatively short test corridors.

The CTA is now implementing an extensive BRT program that includes TSP as an element to reduce running time variation and recovery times. In the highest frequency bus corridors (approaching one bus per signal cycle), passive TSP will be used. In other corridors, AVL-based conditional priority will be used. An early phase includes expanding a 10-intersection test segment to include more intersections and an upgraded TSP architecture with conditional priority. Intersection selection criteria include controller capability (segments with TSP-capable controllers will be preferred), stop location (far-side bus stops will be preferred), intersection characteristics (high-volume intersections with long cycle times or complex phasing will be preferred over low-volume cross streets or driveways), and crossing transit service (TSP may be avoided where conflicts with trunk bus routes would occur).

Toronto – TTC

Interviewee: Jim Sinikas, Transportation Engineer, Service Planning Department

Date: 29 October 2008

The TTC began a TSP program in 1989. To date, 338 intersections on 8 streetcar routes and 4 bus routes are equipped with TSP. TTC generally implements TSP along an entire route. In addition, the agency implements TSP at individual intersections where transit vehicles experience lengthy and highly variable delays, such as in making left turns. All new signals installed on priority-equipped routes or to provide access new developments are equipped with TSP as part of the installation. TTC also obtains funding from developers to implement TSP around new developments to mitigate transit delays associated with site-generated traffic.

The agency believes that virtually all intersections are good candidates for signal priority, although some physical modifications may be required at intersections of major arterial roads and at intersections with near-side stops having lengthy and highly variable passenger boarding/alighting times (dwell times). As most bus and streetcar stops are located on the near side of intersections, TTC is unique among selected agencies in its extensive deployment of TSP without relocating bus stops to the far side. To accommodate variability in dwell times, Toronto allows remarkably long green extensions of up to 30 seconds. At major transfer points or other locations where dwell time variability makes even long green extensions less effective, TTC has begun to relocate stops to far-side bus bays and/or to construct queue jump lanes (long exclusive right turn lanes, buses excepted) that allow buses to bypass traffic queues during the peak periods.

Traffic simulation was conducted early in the program to optimize TSP strategies. Delay was the primary performance measure, with evaluation based on random vehicle arrivals at a single intersection and the overall reallocation of green time. Before/After speed and delay surveys were conducted on the routes that were initially equipped. The surveys confirmed the benefits that were predicted by the simulations. With its large base of empirical experience, the agency now rarely uses microsimulation – typically only at unique and complex intersections or corridors, and primarily to develop the most effective algorithms.

TTC uses a range of TSP strategies, including green extension (extending main street green phases by up to 30 seconds at most intersections and left turn phases by up to 16 seconds), early green (by truncating the cross street green to its pedestrian minimum), phase insertions (inserting and extending a protected left turn phase that is only callable by transit vehicles), and special transit phases (to allow transit vehicles to make turns that general traffic is not permitted to make).

Based on the number of priority-equipped intersections and the long history of implementation, TSP is now an accepted practice. Changes in traffic engineering staff at sister agencies have led to some differences of opinion on which intersections were unacceptable for implementation of priority and TSP expansion was halted for a period of several years.

Routes are selected based on the payback time. In the past, TTC reduced fleet assignments to reflect the benefits achieved by TSP as the improvement in speed allowed the agency to provide the same frequency of service with fewer vehicles. Current practice is to not remove the vehicles and simply allow the frequency of service to improve. Therefore, the ranking of routes for implementation of signal priority was based on a combination of service frequency and number of signalized intersections that a route traveled through. Based on experience, TTC assumes an average travel-time savings of eight seconds in the peak period and six seconds off-peak for each TSP-equipped intersection encountered during a trip. Similar benefits are assumed for all routes, including those with the greatest service frequency (e.g., those with one- to two-minute headways).

New York City – NYCMTA

Interviewee: Ted Orosz, Project Director, Select Bus Service

Date: 29 October 2008

In 2007, New York City MTA implemented TSP in coordination with the Select Bus Service (SBS) BRT route on Victory Boulevard on Staten Island, which serves peak direction demand for the Staten Island Ferry. The service operates in curbside bus lanes. TSP was implemented to improve reliability and reduce travel time. The MTA upgraded signals at 14 intersections with Type 2070 controllers and infrared detection, equipped every bus on Staten Island with emitters, and moved stops to the far side of intersections. TSP strategies include green extension and red truncation. There is no recovery cycle, conditional priority, or AVL system.

In mid-2008, Fordham Road was upgraded for TSP service. MTA replaced all 25 signal controllers in the corridor and enabled TSP at 20 intersections. Intersections with especially high pedestrian volumes or high cross street traffic volumes were avoided. Microsimulation was used for both corridors.

The agency expressed a desire for better logging capabilities to determine how often TSP actually provides a benefit to transit vehicles.

Key Findings

This section summarizes some implementation considerations that were observed in the literature review and agency interviews, including design principles, approaches to gaining the support of the traffic engineering community, and potential screening criteria.

Design Principles

While the agencies surveyed represent a wide range of TSP philosophies and strategies, some themes emerged that were common to at least a majority of agencies in each case. These key findings help to establish some design parameters for the New Jersey evaluation process.

- **TSP is Best for Schedule Reliability –** While some agencies reported using TSP to reduce transit travel times (e.g., AC Transit, TTC), the majority of agencies have used TSP primarily to improve schedule adherence. In many cases, there has been a side benefit of travel-time savings. At LACMTA and AC Transit, TSP has been used to maintain consistent headways between vehicles, rather than consistent arrival times at timepoints.

- **AVL-Based Conditional Priority –** To achieve improvements in schedule adherence, many TSP systems have included conditional priority functionality in which the vehicle requests priority only if it is running behind schedule. The most common approach is to integrate the on-vehicle priority request hardware (e.g., infrared emitter, transponder, or WiFi device) with an on-board automatic vehicle location (AVL) system using global positioning system (GPS) technology. The vehicle computes its schedule adherence and requests priority when lateness exceeds a defined threshold. Tri-Met has successfully used a low threshold (zero seconds or “not early”) to reduce delays before they accumulate into significant schedule reliability problems down the line.

  As an alternative to AVL, AC Transit is notable in its use of long TSP cycle recovery times that approach a full priority route headway to effectively maintain even spacing between vehicles.

- **TSP Works Best with Far-Side Stops –** Most agencies typically relocate near-side stops to the far side to improve the performance of TSP. Far-side stops allow for more predictable bus travel times between the upstream priority request detection point and the intersection, thus increasing the probability that the transit vehicle will clear the intersection during a priority phase if it is granted. TTC is a notable exception in its extensive use of TSP with near-side stops. However, longer green time manipulations are needed to compensate for variability in dwell times at the stop.

- **TSP Operations Should Be Invisible –** Early experience with TSP systems suggested increased accident rates or other disbenefits from priority phase confirmation systems (e.g., indications to bus drivers that the signal will stay green, as in some emergency vehicle preemption systems) or bus driver-activated priority requests (e.g., dashboard switches for use when running late). There also were motorist objections to aggressive priority strategies (e.g., phase skipping). As a result, most agencies have implemented TSP as transparent, automatic systems in which there is no bus driver involvement or knowledge of TSP status. Likewise, most agencies have minimized use of phase skipping, phase insertion, or other relatively disruptive TSP strategies that can be apparent to motorists.

- **Green Extension and Red Truncation –** The most common TSP strategies allocate additional green time at the beginning or end of a main street green phase by truncating the cross street green phase early or extending the main street green phase. In most cases, these interventions are limited to about 10 percent of a signal cycle, although TTC is noteworthy in its use of manipulations of up to 30 seconds to accommodate near-side stops.

- **Queue Jump Where Feasible and Appropriate –** Queue jump lanes are generally right turn lanes that extend beyond the typical traffic queue at an intersection and are typically combined with priority transit phases (e.g., a green light for buses a few seconds before other traffic) or merge areas beyond the intersection to allow buses back into the traffic stream. Some agencies have used queue jump lanes to allow buses to overtake other vehicles at intersections and reduce travel-time variability between the detection point and the intersection, sometimes in combination with near-side stops. However, the need to acquire right-of-way or to reduce on-street parking has limited their application.

- **Distributed Architecture Offers More Flexibility across Jurisdictions –** Most TSP system architectures have involved processing of TSP requests at or near the intersection. Communications between vehicles and signal controllers are typically managed within the intersection signal cabinet or at one master signal in an interconnected corridor. This distributed approach allows for some variation in the type of vehicle detection, TSP processing, and signal controller equipment throughout a system. Variation provides flexibility in implementation sequence or phasing over time and across jurisdictions.

- **TSP Detection Technology is a Minor Consideration –** Vehicle-to-roadside communications technology is one of the most visible parts of the TSP system architecture, and has frequently received substantial attention in system design. Early TSP systems commonly used infrared (optical) emitters on vehicles with roadside receivers, transponders on the bottom of vehicles with loop detectors in the pavement, or radio frequency-based signpost systems along the route. Many agencies are now experimenting with or transitioning to detection systems based on a network of WiFi-based wireless cards and access points on vehicles and along the route. The WiFi-based system promises lower maintenance, higher reliability, more detailed vehicle-to-roadside communications, and freedom from geometric constraints. Since there are a number of proven and relatively interchangeable technologies available for vehicle-to-roadside communications, as well as continued evolution of the state of the art, detection technology is considered to be a relatively minor implementation consideration.

- **Successful Coordination with the Traffic Engineering Community** – Achieving buy-in from the traffic engineering community was accomplished through a variety of mechanisms. Perhaps the most universally successful approach heard during the survey, was some form of quantitative analysis conducted by the transit authority. Portland conducted a study which quantified person delay versus vehicle delay to encourage participating with the DOT. Other systems such as CTA conducted microsimulation analyses to demonstrate the impacts of TSP along key corridors. It was reported that these analyses dramatically helped allay the fears that some of the traffic engineering community had for the projects. Other transit authorities simply actively negotiated with the relevant traffic engineers on a cycle recovery time as a way to ensure the engineering office felt ownership in the project and process. A final key finding was that even if a jurisdiction does not participate, TSP is still worth doing. In Los Angeles, MTA did not implement TSP at signals in the Beverley Hills community in their first deployment of the MetroRapid BRT system. Even though this community was not included, significant reliability gains were achieved with TSP.

Potential Selection Criteria

The technology review identified a number of potential selection criteria for consideration in the development of an evaluation process that will assist NJ Transit in quickly determining which intersections are good candidates for TSP. Selection criteria were observed that are applicable at an intersection level and at a corridor level.

Potential intersection-level selection criteria include:

- **Schedule Reliability** – Intersections that are major contributors to schedule adherence problems would be better candidates for TSP.

- **Far-Side Stop** – Intersections where a far-side stop is in place or is feasible would be better candidates for TSP.

- **Actuated Signal** – Low-volume cross streets that receive relatively little green time (as indicated by an actuated phase in contrast to a pre-timed phase) would be worse candidates for TSP, since transit vehicles on the main street likely encounter few delays at the intersection and the investment in the TSP equipment would produce relatively little benefit.

- **Type of Controller** – Intersections that already have TSP-compatible signal controllers (e.g., Type 170, Type 2070, NEMA TS2) would be better candidates for TSP.

- **Emergency Vehicle Preemption** – Intersections that already have emergency vehicle preemption (EVP) systems would be better candidates for TSP because there is already likely to be compatible detection equipment in place, as well as compatible or upgradeable priority request generators and signal controllers in the cabinet.

- **Jurisdiction Support** – Intersections in communities where the stakeholders (e.g., traffic engineers, police, and/or fire departments) support transit priority would be better candidates for TSP.

- **Intersection Complexity** – Intersections with four or fewer approach legs would be better candidates for TSP because there are likely fewer conflicting movements and longer phases from which to borrow green time for transit vehicles.

Potential corridor-level selection criteria include:

- **Schedule Reliability** – Corridors with the greatest schedule adherence problems would be better candidates for TSP.

- **Ridership** – Corridors with the highest ridership would be better candidates for TSP because the benefits would accrue to more transit users.

- **Traffic Congestion** – Corridors with extreme traffic congestion may be worse candidates for TSP, because saturated flow conditions can contribute to long and unpredictable travel times between the detection point and the intersection, thus reducing the probability that a bus can make use of a priority phase if granted. Also, congested corridors frequently have at least some high-volume cross streets at which reallocating green time can lead to significant increases in motorist delay.

- **Service Frequency** – Corridors with very frequent transit service (e.g., buses every two to three minutes or less) may be worse candidates for active TSP strategies, because frequent priority requests may not be served due to cycle recovery policies. Likewise, when buses follow closely, TSP systems may not be able to distinguish between on-time and late vehicles and grant priority to more than one vehicle per cycle. Passive TSP strategies, such as timing the signals at the average speed of buses (including stops), can be more effective.

- **Transit Potential** – Corridors with a high potential for increased ridership (based on unmet demand, market research findings, planned development, or other considerations) would be better candidates for TSP, particularly when it is combined with other BRT features.

- **Intersection Spacing** – Corridors with closely spaced intersections (e.g., signals every two blocks or less) may be worse candidates for TSP. When distances between intersections get too short, even far-side bus stops can effectively function as near-side bus stops in relation to the next intersection.

- **Pedestrian Volume** – Corridors with high pedestrian volumes may be worse candidates for TSP because pedestrian clearance intervals may leave relatively little green time available for manipulation.

Many of the agencies that had evaluated TSP using microsimulation analysis sought to maximize corridor-wide TSP benefits, rather than individual intersection benefits. For example, while the decisions to include individual intersections were based on intersection-specific criteria (such as change in person-delay), there also was some consideration of overall benefits (such as whether schedule reliability would be improved sufficiently to reduce vehicle requirements or improve service frequency on the priority route). In practice, this could mean including some marginal intersections that may have been initially screened out in order to achieve a corridor-wide performance target.

EVALUATION PROCESS

The study team developed the evaluation process in a two-step process. Preliminary intersection selection criteria were developed based on the findings of the technology review and presented at the first Progress Meeting in October 2008. Based on comments received at the meeting, the criteria were refined and a draft scoring approach was developed and presented at the second Progress Meeting in November 2008.

Preliminary Selection Criteria

Preliminary TSP intersection selection criteria were developed based on the potential screening criteria observed in the literature and in the agency surveys discussed in section 2. As shown in Table 1, selection criteria were grouped into four main categories.

Table 1. Preliminary Intersection Selection Criteria

Criterion	Intersection Measure	Intersection Priority Effect
Reliability		
Hotspot	Is intersection identified by driver input or objective data as significant source of travel-time variance?	↑
Potential for Improvement	Could TSP significantly reduce transit travel-time variation through the intersection?	↑
Geometry		
Far-Side Bus Stop	Are existing bus stops along the priority corridor located on the far side of the intersection? Is relocation of bus stops to the far side physically and politically feasible?	↑ ↑
Queue Jump	Is there an existing queue jump lane along the priority corridor at the intersection? Is a queue jump lane physically and politically feasible?	↑ ↑
Intersection Complexity	Does the intersection have more than four approach legs?	↑
Technology		
Signal Controller	Is the existing signal controller a Type 170, Type 2070, NEMA TS2, or other TSP-compatible model?	↑
Emergency Vehicle Preemption	Is there an existing optical emergency vehicle preemption system that is upgradeable to TSP?	↑
Conflicts		
Actuated Signal	Does the intersection cross street have and actuated signal and less than 10% to 20% of the green time?	↓
Crossing Transit Route	Does the cross street have transit routes with combined headway less than twice that of the priority corridor?	↓
Jurisdiction Support	Does local traffic agency support the TSP program?	↑

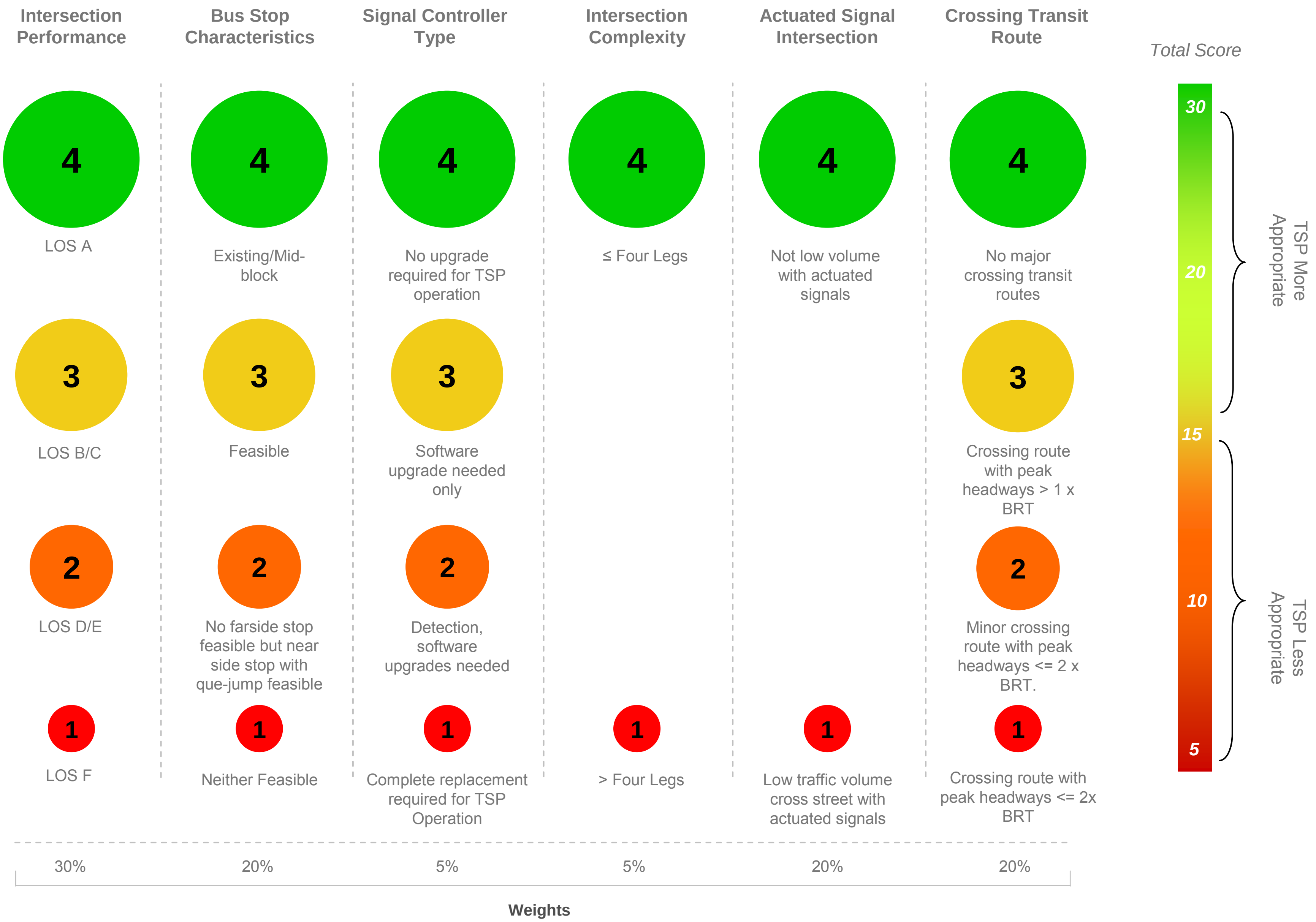
Based on discussions with NJ Transit about existing conditions in New Jersey and potential data availability, several preliminary selection criteria were eliminated from further consideration, including:

- **Potential for Improvement –** No objective methodology or existing data source was identified to evaluate this criterion.
- **Emergency Vehicle Preemption –** Because there are few, if any, EVP systems operating in New Jersey, this criterion was judged not to distinguish intersections or corridors.
- **Jurisdiction Support –** It was decided to identify TSP intersections in a corridor based on objective criteria first, then to build support for the program with jurisdictions prior to implementation. As a result, this criterion was not needed for screening.

Intersection Scoring Approach

Based on the input from NJ Transit, the preliminary selection criteria were refined into a weighted scoring framework in which individual intersections can be evaluated and ranked in the context of an entire corridor. Likewise, overall corridor scores potentially can be compared with those of other corridors to support resource allocation decisions. The scoring approach is illustrated in Figure 2.

The scoring approach deviates from the "decision tree" originally envisioned in the study scope of work. Whereas the decision tree may have applied a threshold to determine whether an intersection was a candidate for signal priority, the scoring approach reflects a more fluid spectrum of feasibility in which intersections in a corridor are prioritized based on their TSP suitability. Any number of intersections from none to all may be selected depending on available resources, phasing considerations, program objectives, and other factors.



Score	Intersection Performance	Bus Stop Characteristics	Signal Controller Type	Intersection Complexity	Actuated Signal Intersection	Crossing Transit Route
4	LOS A	Existing/Mid-block	No upgrade required for TSP operation	≤ Four Legs	Not low volume with actuated signals	No major crossing transit routes
3	LOS B/C	Feasible	Software upgrade needed only			Crossing route with peak headways > 1 x BRT
2	LOS D/E	No farside stop feasible but near side stop with que-jump feasible	Detection, software upgrades needed			Minor crossing route with peak headways <= 2 x BRT.
1	LOS F	Neither Feasible	Complete replacement required for TSP Operation	> Four Legs	Low traffic volume cross street with actuated signals	Crossing route with peak headways <= 2x BRT
Weights	30%	20%	5%	5%	20%	20%

Figure 2. Intersection Evaluation Scoring Approach

The intersection evaluation scoring approach assigns scores of 1 (lowest TSP suitability) to 4 (highest TSP suitability) to each of six criteria. Table 2 shows the specific considerations used to assign scores under each criterion. Criteria include:

- **Intersection Performance –** Traffic level of service (LOS).
- **Bus Stop Characteristics –** Far-side stop or queue jump lane.
- **Signal Controller Type –** TSP-compatible signal controller.
- **Intersection Complexity –** Number of intersection approaches.
- **Actuated Signal Intersection –** Cross-street signal actuation.
- **Crossing Transit Route –** Service frequency on cross street.

Each screening criterion also is assigned a weight factor to produce an overall intersection score of 1 to 4. TSP is considered to be more appropriate at intersections with a score near 4 than at those with a score near 1.

The weighting criteria were assigned based on the relative importance of each consideration to overall TSP cost-effectiveness, as indicated by observations from the technology review. Reflecting the importance placed by many agencies on traffic level of service in their microsimulation evaluations, intersection performance was assigned a weight of 30 percent. The frequent mention of cross-street traffic volumes as a TSP consideration (both at the high end as indicated by the presence of crossing transit routes and at the low end as indicated by actuated signals) was reflected in a next highest weight of 20 percent. Based on the widespread preference for far-side stops (or at least queue jump lanes to improve the compatibility of near-side stops with TSP), considerations of bus stop characteristics, including far-side stop locations and queue jump lanes, also were assigned a weight of 20 percent. Considerations that could be relatively easily managed during implementation, including intersection complexity and the TSP compatibility of the signal controller, were assigned the least weight of 5 percent.

Depending on the applications, the scoring approach can be used in two ways:

1. **Intersection Score –** The weight factors and criterion scores are applied to develop an overall intersection score from 1 to 4, which can be compared with those of other intersections to rank intersections within a corridor, such as to identify which intersections should receive TSP treatment first.

2. **Corridor Score –** The average intersection score of a corridor can be computed to develop an overall corridor score from 1 to 4, which can be compared with other potential priority corridors, such as to identify the relative merits of TSP investment in various corridors under consideration.

Table 2. Intersection Scoring Criteria

Criterion	**Score** **1**	**2**	**3**	**4**
Intersection Performance	LOS F	LOS D/E	LOS B/C	LOS A
Bus Stop Location	Existing near-side stop AND no far-side relocation feasible AND no queue jump lane feasible	Existing near-side stop AND queue jump lane feasible	Existing near-side stop AND far-side relocation feasible	Existing far-side stop OR mid-block stop more than 300 feet from intersection OR no stop
Signal Controller Type	Traffic signal controller upgrade needed for TSP operation	Detection hardware needed AND software upgrade needed for TSP operation	Software upgrade only needed for TSP operation	No upgrade required for TSP operation
Intersection Complexity	More than four approach legs	N/A	N/A	Four or fewer approach legs
Actuated Signal Intersection	Cross street has low traffic volume AND signal phases are actuated	N/A	N/A	Cross street does NOT have low traffic volumes AND actuated signal phases
Crossing Transit Route	Crossing routes with peak headways less than or equal to 1x priority route headway	Crossing routes with peak headways less than or equal to 2x priority route headway	Crossing routes with peak headways more than 2x priority route headway	No major crossing routes

CASE STUDIES

Three representative corridors were identified by NJ Transit as test cases for applying the evaluation process. Because the scoring approach evaluates intersections in the context of an overall corridor, it was decided to evaluate multiple intersections in three corridors.

The corridors are listed in Table 3 and displayed in Figure 3. The case study corridors represent a range of operating conditions, including a street in a dense urban environment in Jersey City (John F. Kennedy Boulevard near Journal Square), urban arterials in moderate density environments (John F. Kennedy Boulevard near Bayonne and Springfield Avenue in Irvington), and a major state highway in an automobile-oriented suburban area in Old Bridge (State Route 18).

Table 3. Corridor Case Studies

	Name	Priority Street	Endpoints	County
1.	JFK South	John F. Kennedy Boulevard	Journal Square to Bayonne City Line	Hudson County
2.	Route 18	State Route 18	New Jersey Turnpike to Garden State Parkway	Middlesex County
3.	Springfield	Springfield Avenue	Market Street to 43rd Street	Essex County

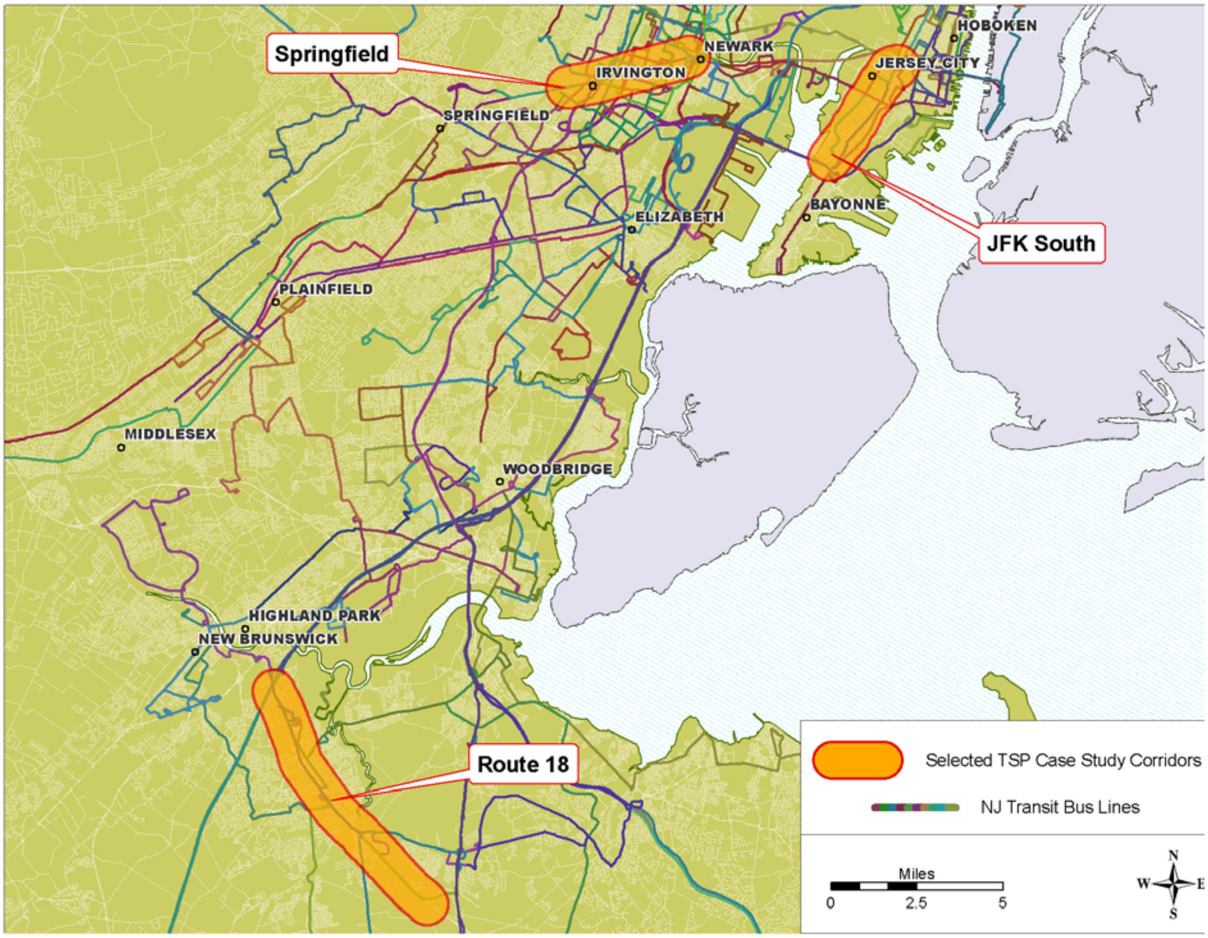


Figure 3. Corridor Case Study Overview

The three corridors were evaluated using available data sources, including bus route alignments, bus schedules, and bus stop location information from NJ Transit, as well as satellite imagery, aerial photography, and related geographic information system (GIS) data from Google Maps and other on-line sources. Because detailed information on traffic LOS and signal control equipment were not available, Cambridge Systematics made assumptions to populate the scoring database with representative data. As the objective of this exercise was to prove the concept of the scoring approach, it is recognized that intersection scores and overall results could change if more complete input data were used. Data sources used for these test cases include:

- **Intersection Performance –** Intersections that appeared from satellite imagery to have relatively high-density surrounding land uses (floor area ratios exceeding 2.0), major streets (more than two lanes in each direction or traffic queues longer than a few vehicles), or complex geometry (more than four approach legs) were assumed to have poor LOS and were assigned a score of 2. Intersections with a major arterial cross street (more than two lanes in each direction or part of a one-way couple of two or more lane streets) were assumed to have moderate LOS and were assigned a score of 3. Intersections with relatively minor cross streets were assumed to have good LOS and were assigned a score of 4.

- **Bus Stop Characteristics –** Scores are an average of stops in each direction (e.g., northbound and southbound) where applicable. At intersections with a near-side stop (based on NJ Transit's bus stop location inventory), the physical feasibility of relocating the stop to the far side or introducing a queue jump lane was explored using satellite imagery and aerial photography. Physical feasibility was judged based on the apparent availability of space. The need to reduce or relocate on-street parking or make minor adjustments to lane width or curb location were not considered to make a location infeasible in this screening analysis, although more detailed examination or the emergence of local objections could result in different outcomes during implementation.

  Intersections at which a near-side stop could be neither relocated to the far side neither nor supplemented with a queue jump lane were assigned a score of 1. Intersections at which a near-side stop could not be relocated, but some travel-time variation could potentially be reduced with a queue jump lane, were assigned a score of 2. Intersections at which a near-side stop could be relocated to the far side were assigned a score of 3. All other intersections, including those without a stop or with an existing far-side stop, were assigned a score of 4.

  This screening analysis evaluated bus stop characteristics at every signalized intersection. In practice, priority routes may operate with limited stops, requiring scoring only at intersections with priority route bus stops. The result could be higher scores at some intermediate intersections with existing near-side stops. (This assumes that local routes will either continue to serve existing stops without TSP capability or will be replaced by priority routes.)

- **Signal Controller Type –** Because no data was available on existing signal controller equipment for this test exercise, it was assumed that signal controllers at each intersection would need to be replaced. Each intersection was assigned a score of 1. If more detailed data became available, this criterion could reflect more variation between intersections.

- **Intersection Complexity –** Using satellite imagery and aerial photographs, the number of intersection approach legs was determined. Intersections with more than four approach legs were assigned a score of 1. All other intersections were assigned a score of 4.

- **Actuated Signal Intersection –** Intersections with cross streets that appeared from satellite images and aerial photographs to have especially low traffic volumes (as indicated by narrow lane width, lack of traffic queues, and/or limited connections to other streets) were assumed to have actuated signals with relatively little main street green time and were assigned a score of 1. All other intersections were assigned a score of 4.

  In the urban corridors (JFK South and Springfield), low-volume cross streets with actuated signals were assumed to occur at fewer than five percent of signalized intersections. In the suburban corridor (Route 18), nearly half of the intersections were judged to be neighborhood access roads or shopping center entrances with low-volume actuated intersections.

- **Crossing Transit Route –** The number of buses operating during the weekday morning peak period (about 7:00 a.m. to 9:00 a.m.) on each route crossing the priority corridor was derived from NJ Transit GIS route maps and bus schedules. Scores were assigned by summing the number of buses per hour on the crossing route(s) and comparing to the priority route service frequency (assumed to be four buses per hour in each direction or 15-minute headways). Intersections carrying four or more buses per hour were judged to have relatively high potential for conflicts between priority route TSP manipulations and crossing transit service and were assigned a score of 1. Intersections with two to four buses per hour were assigned a score of 2. Intersections with less than two buses per hour were assigned a score of 3. Intersections with no crossing transit service were assigned a score of 4.

Intersection scores are computed for each intersection and presented in tabular form and map form. The tables show intersections in descending order, with the most TSP-appropriate intersections near the top.

JFK South

The John F. Kennedy Boulevard priority route corridor runs along an urban arterial from Journal Square in downtown Jersey City south through a moderate density residential and commercial corridor to Pamrapo Avenue near the Bayonne city limit. The corridor is 3.4 miles long and has 52 signalized intersections. Major cross streets include Montgomery Street, Communipaw Avenue, Claremont Avenue, Grant Avenue, and Danforth Avenue in Jersey City.

Scoring results are shown in Table 4 and Figure 4.

Table 4. JFK South Scoring Results

Cross Street	Intersection Performance	Stop Location	Controller Type	Intersection Complexity	Actuated Signal	Cross Route	Score	Rank
Highland Avenue	4	4	1	4	4	4	3.85	1
Glenwood Avenue	4	4	1	4	4	4	3.85	1
Fairmount Avenue	4	4	1	4	4	4	3.85	1
Fairview Avenue	4	4	1	4	4	4	3.85	1
Jewett Avenue	4	4	1	4	4	4	3.85	1
Lincoln Park	4	4	1	4	4	4	3.85	1
Bentley Avenue	4	4	1	4	4	4	3.85	1
Harrison Avenue	4	4	1	4	4	4	3.85	1
Lexington Avenue	4	4	1	4	4	4	3.85	1
Clendenny Avenue	4	4	1	4	4	4	3.85	1
Union Street	4	4	1	4	4	4	3.85	1
Boyd Avenue	4	4	1	4	4	4	3.85	1
Virginia Avenue	4	4	1	4	4	4	3.85	1
Orient Avenue	4	4	1	4	4	4	3.85	1
Culver Avenue	4	4	1	4	4	4	3.85	1
Stegman Parkway	4	4	1	4	4	4	3.85	1
Stegman Street	4	4	1	4	4	4	3.85	1
Fulton Avenue	4	4	1	4	4	4	3.85	1
Woodlawn Street	4	4	1	4	4	4	3.85	1
Fowler Avenue	4	4	1	4	4	4	3.85	1
Cator Avenue	4	4	1	4	4	4	3.85	1
Greenville Avenue	4	4	1	4	4	4	3.85	1
Lembeck Avenue	4	4	1	4	4	4	3.85	1
Bartholdi Avenue	4	4	1	4	4	4	3.85	1
Neptune Avenue	4	4	1	4	4	4	3.85	1
Gates Avenue	4	4	1	4	4	4	3.85	1

Table 4. JFK South Scoring Results (continued)

Cross Street	Intersection Performance	Stop Location	Controller Type	Intersection Complexity	Actuated Signal	Cross Route	Score	Rank
Duncan Avenue	4	3.5	1	4	4	4	3.75	27
Gifford Avenue	4	3.5	1	4	4	4	3.75	27
Clinton Avenue	4	3.5	1	4	4	4	3.75	27
Ege Avenue	4	3.5	1	4	4	4	3.75	27
Broadman Parkway	4	3.5	1	4	4	4	3.75	27
Audubon Avenue	4	3.5	1	4	4	4	3.75	27
McAdoo Avenue	4	3.5	1	4	4	4	3.75	27
Pamrapo Avenue	4	3.5	1	4	4	4	3.75	27
Stuyvesant Avenue	4	3	1	4	4	4	3.65	35
Kensington Avenue	4	3	1	4	4	4	3.65	35
Van Houten Avenue	4	3	1	4	4	4	3.65	35
Dwight Street	4	3	1	4	4	4	3.65	35
Van Nostrand Avenue	4	3	1	4	4	4	3.65	35
Stevens Avenue	4	3	1	4	4	4	3.65	35
Wade Street	4	3	1	4	4	4	3.65	35
Grant Avenue	3	4	1	4	4	4	3.55	42
Danforth Avenue	3	4	1	4	4	4	3.55	42
Claremont Avenue	3	3.5	1	4	4	4	3.45	44
Journal Square	2	4	1	4	4	4	3.25	45
Bond Street	4	4	1	4	1	4	3.25	45
Seaview Avenue	4	4	1	4	4	1	3.25	45
Communipaw Avenue	3	4	1	4	4	2	3.15	49
Morton Place	4	3.5	1	4	1	4	3.15	48
Tonnele Avenue	2	4	1	1	4	4	3.1	50
Montgomery Street	3	3	1	4	4	1	2.75	51
Sip Avenue	2	3.5	1	1	4	1	2.4	52

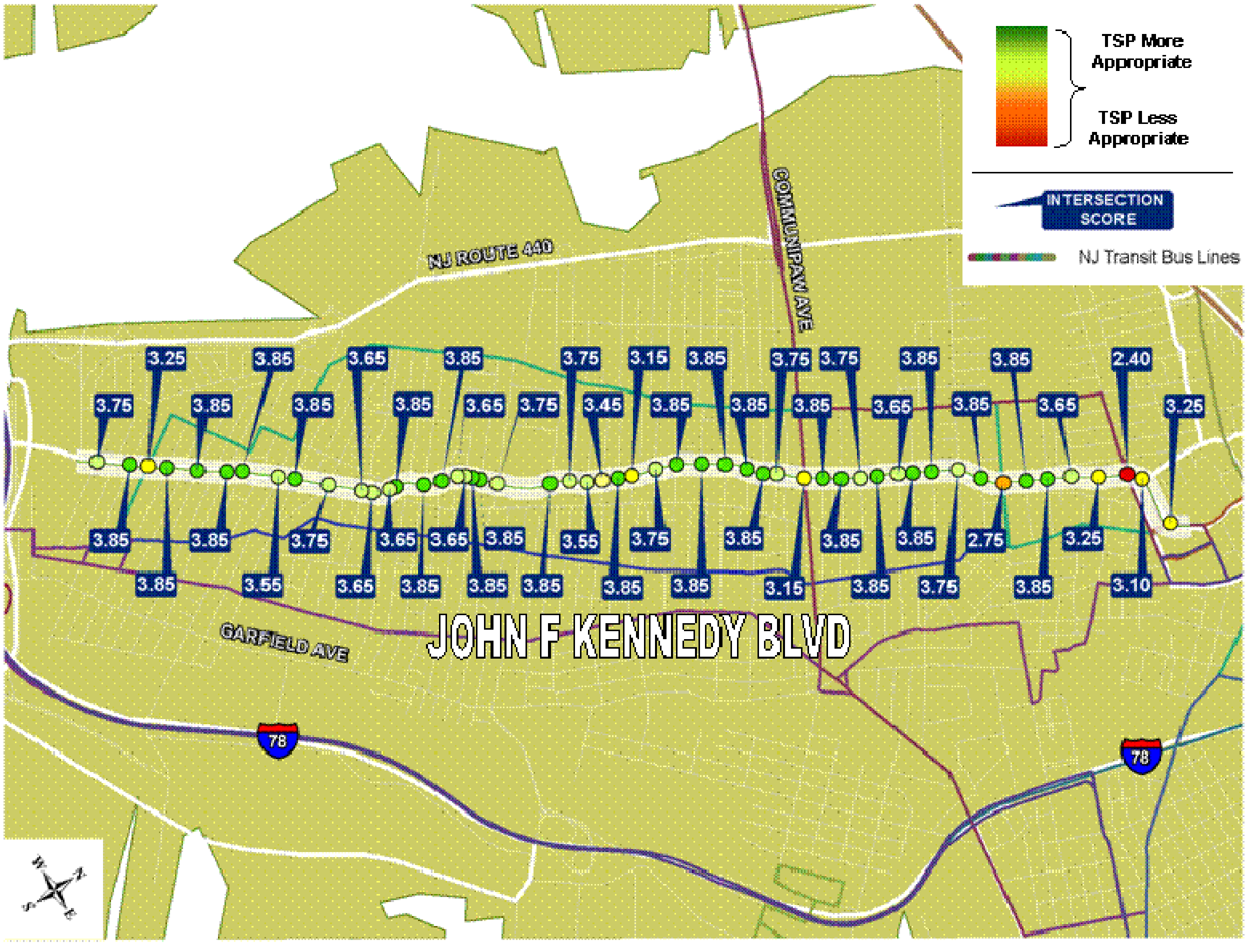


Figure 4. John F. Kennedy Boulevard

Route 18

State Route 18 is a major highway with a combination of at-grade intersections and grade-separated interchanges in a suburban setting. Signalized intersections are approximately evenly distributed between major arterials and minor entrances to adjacent development, such as residential subdivisions, shopping centers, and office parks. The signalized portion of the corridor is 7.5 miles long and has 13 signalized intersections. Major cross streets include Old Bridge Turnpike and Tices Lane in East Brunswick, and Ferry Road in Old Bridge.

Scoring results are shown in Table 5 and Figure 5.

Table 5. Route 18 Scoring Results

Cross Street	Intersection Performance	Stop Location	Controller Type	Intersection Complexity	Actuated Signal	Cross Route	Score	Rank
West Ferris Street	4	3	2	4	4	4	3.7	1
Arthur Street	4	3	2	4	4	4	3.7	1
Hillsdale Road	4	3	2	4	4	4	3.7	1
Race Track Road	4	3.5	2	4	4	3	3.6	4
Ferry Road	3	4	2	4	4	4	3.6	5
Eggers Street	4	4	2	4	1	4	3.3	6
Cindy Way	4	4	2	4	1	3	3.1	7
Maple Street	4	3	2	4	1	4	3.1	7
Southwood Drive	4	3.5	2	4	1	3	3	9
Old Bridge Turnpike	3	3.5	2	4	4	1	2.9	10
Shopping Center Entrance	4	4	2	4	1	2	2.9	10
Rues Lane	4	4	2	4	1	2	2.9	10
Tices Lane	3	2.5	2	4	4	1	2.7	13

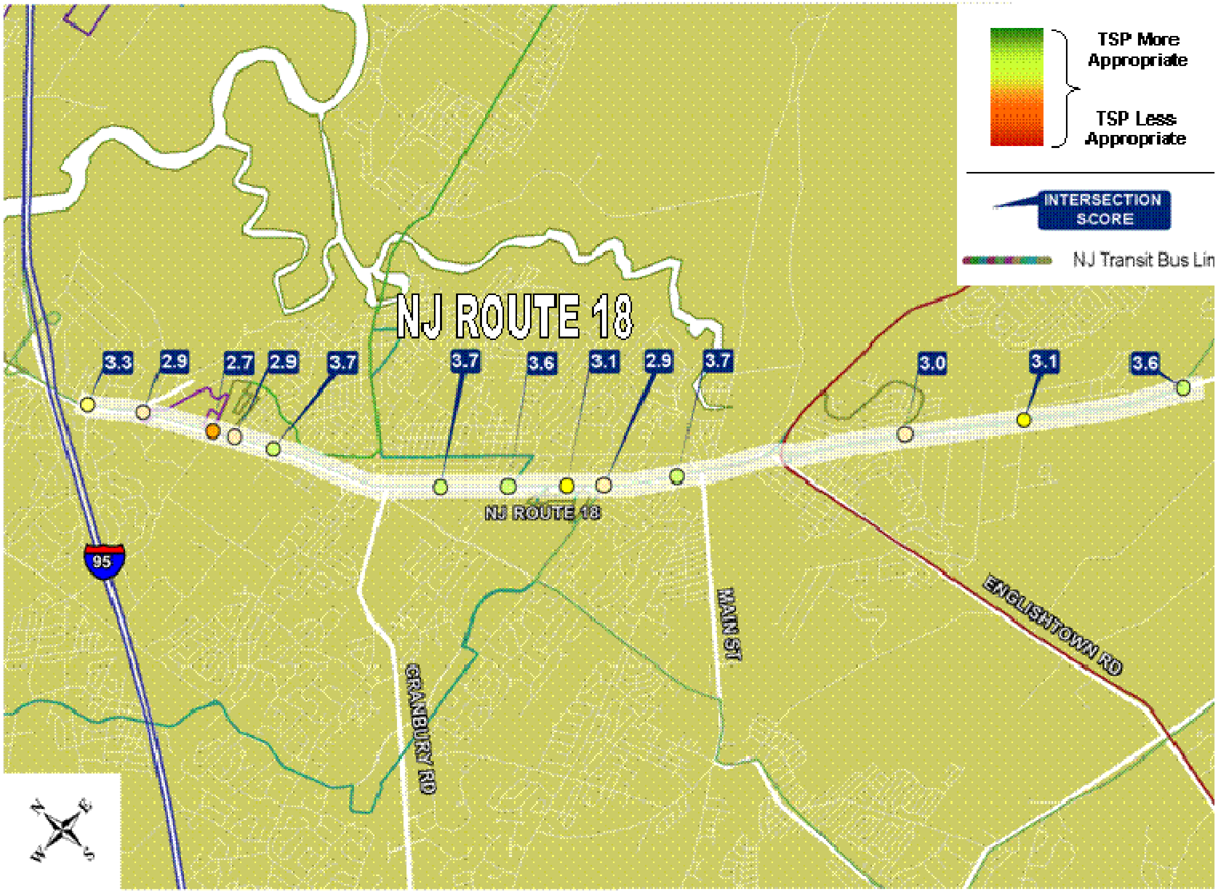


Figure 5. New Jersey State Route 18

Springfield

Springfield Avenue is an urban arterial through moderate density residential and commercial areas in Newark and Irvington. The corridor includes the Irvington Terminal transit facility. Many signalized intersections are closely spaced through residential neighborhoods at one-way couples. The signalized portion of the corridor is 3.6 miles long and has 31 signalized intersections. Major cross streets include Martin Luther King Boulevard, South Orange Avenue, Jones Street, Hayes Street, Morris Avenue, Bergen Street, South 10th Street, and South 14th Street in Newark, and Grove Street, Washington Avenue, Myrtle Avenue, Clinton Avenue, Stuyvesant Avenue, Lyons Avenue, and Stanford Avenue in Irvington.

Scoring results are shown in Table 6 and Figure 6.

Table 6. Springfield Scoring Results

Cross Street	Intersection Performance	Stop Location	Controller Type	Intersection Complexity	Actuated Signal	Cross Route	Score	Rank
Charlton Street	4	4	1	4	4	4	3.85	1
Prince Street	4	3.5	1	4	4	4	3.75	2
South 11th Street	4	3.5	1	4	4	4	3.75	2
South 20th Street	4	3.5	1	4	4	4	3.75	2
Ellis Avenue	4	3.5	1	4	4	4	3.75	2
Florence Avenue	4	3.5	1	4	4	4	3.75	2
Headley Terrace	4	3.5	1	4	4	4	3.75	2
Fairmount Avenue	4	3	1	4	4	4	3.65	8
South 21st Street	4	3	1	4	4	4	3.65	8
Civic Square	4	3	1	4	4	4	3.65	8
South Orange Avenue	3	4	1	4	4	4	3.55	11
Lyons Avenue	3	3.5	1	4	4	4	3.45	12
Hayes Street	3	4	1	1	4	4	3.4	13
South 12th Street	4	3.5	1	1	4	3	3.4	14
Bergen Street	3	3.5	1	2	4	4	3.35	15
South 18th Street	4	3.5	1	4	4	2	3.35	16
Sanford Avenue	3	3	1	4	4	4	3.35	17
South 14th Street	3	3.5	1	1	4	4	3.3	18
Martin Luther King Boulevard	3	3	1	4	4	3	3.15	20
Jacob Street	4	3.5	1	4	4	1	3.15	19
Maple Avenue	4	3	1	4	4	1	3.05	21
New Street	4	3	1	4	4	1	3.05	21
Grove Street	3	3.5	1	4	4	1	2.85	23
Stuyvesant Avenue	3	3	1	4	4	1	2.75	24
Jones Street	3	3.5	1	1	4	1	2.7	25

Table 6. Springfield Scoring Results (continued)

Cross Street	Intersection Performance	Stop Location	Controller Type	Intersection Complexity	Actuated Signal	Cross Route	Score	Rank
Morris Avenue	3	3.5	1	1	4	1	2.7	25
South 10th Street	3	3.5	1	1	4	1	2.7	25
Sharon Avenue	4	4	1	4	1	1	2.65	28
Washington Avenue	3	3	1	1	4	1	2.6	29
Myrtle Avenue	3	3	1	1	4	1	2.6	29
Clinton Avenue	3	3	1	1	4	1	2.6	29

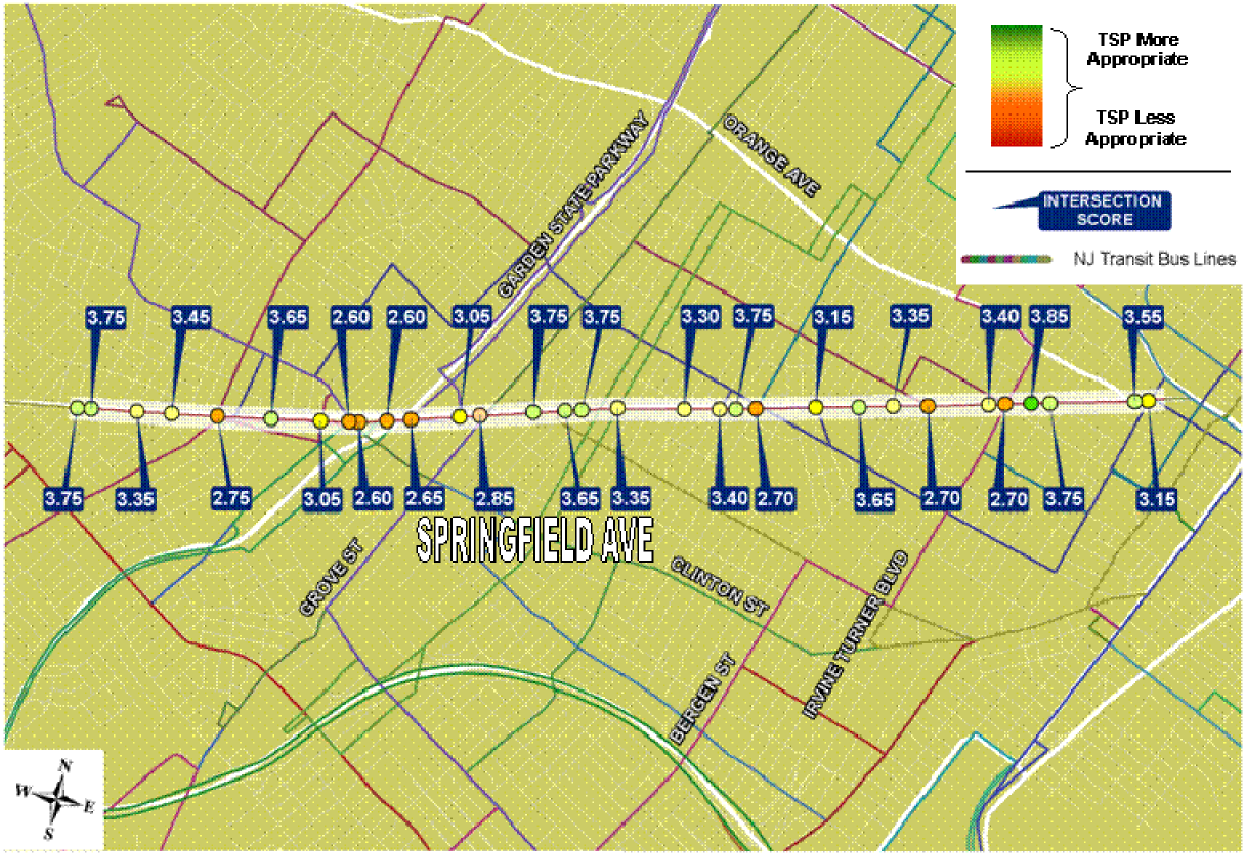


Figure 6. Springfield Avenue

Application Recommendations

The preceding methodology provides NJ Transit with a powerful sketch planning tool that can be utilized in a variety of ways as they continue to expand BRT-like service throughout their system. First, NJ Transit should apply this scoring approach to all of the corridors which have been identified for either BRT or BRT-“like” service. The results of that exercise would assist NJ Transit in setting priorities for those corridors, as well as getting an early look at some of the cost implications of TSP applications by corridor.

Additionally, NJ Transit could consider applying this approach across all the corridors across the entire NJ Transit system. By applying the scoring process on all corridors, a complete statewide perspective would be generated. Having this information already compiled would help facilitate new corridors for BRT consideration.

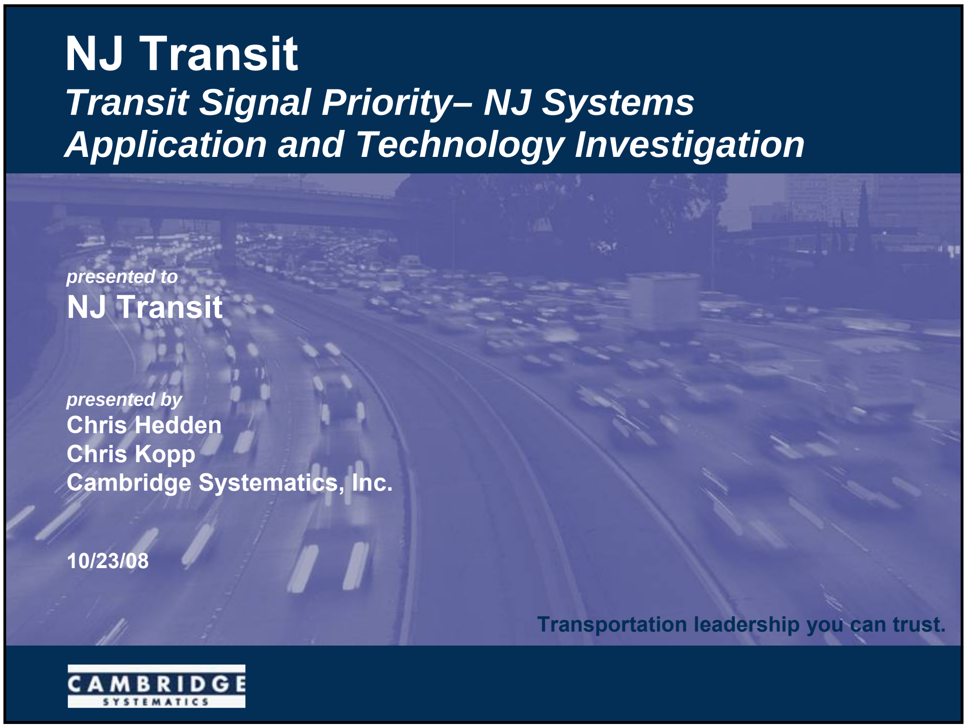
Finally, the study team recommends that NJ Transit consider institutionalizing this scoring approach by recreating it within a secure web environment. By putting this process within a web environment, NJ Transit planners could easily conduct their own sensitivity analyses on certain corridors and see the impacts of their changes both in a tabular, as well as a GIS environment in real time. The site could be designed to not only create on-screen results but also provide the capability to export to spreadsheets and GIS for presentations and further analyses. Furthermore, NJ Transit could share this site with interested local jurisdictions and traffic engineers. By providing them direct access to the information by which NJ Transit is making decisions, it would further bring the traffic engineering community into the process and encourage acceptance and buy-in. It is the logical next step to this project, to create a tool within a secure NJ Transit web site which would be the repository for all the results, of all the studied corridors.

Appendix A

Progress Meeting

October 23, 2008

Handouts include minor updates to the material presented at the meeting based on subsequent work, additional refinements, and responses to stakeholder comments.



NJ Transit

Transit Signal Priority– NJ Systems Application and Technology Investigation

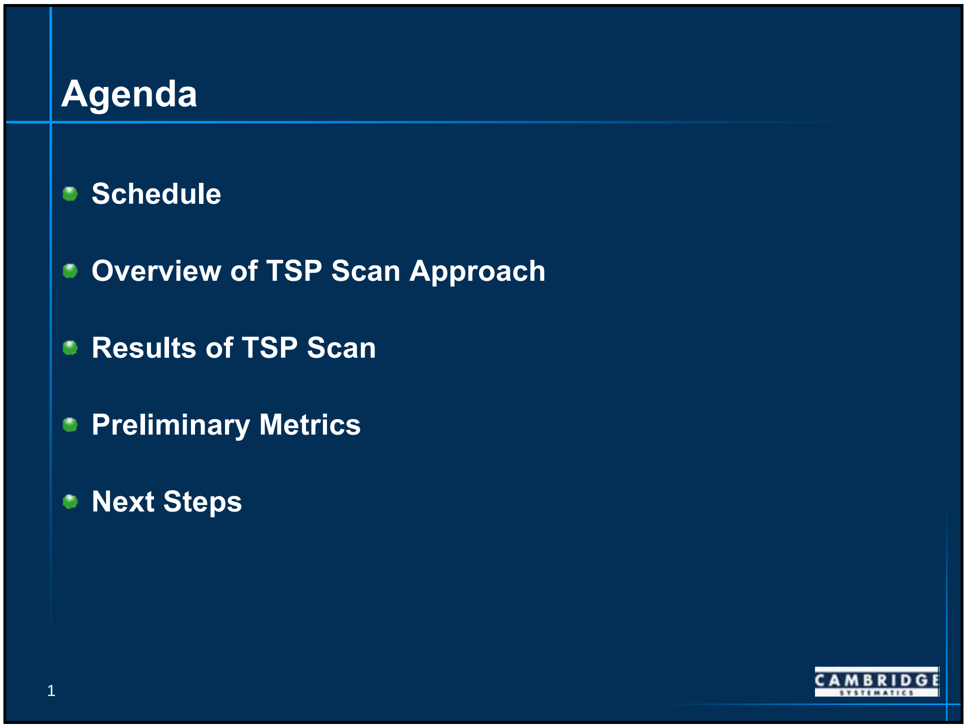
presented to
NJ Transit

presented by
Chris Hedden
Chris Kopp
Cambridge Systematics, Inc.

10/23/08

Transportation leadership you can trust.

CAMBRIDGE SYSTEMATICS



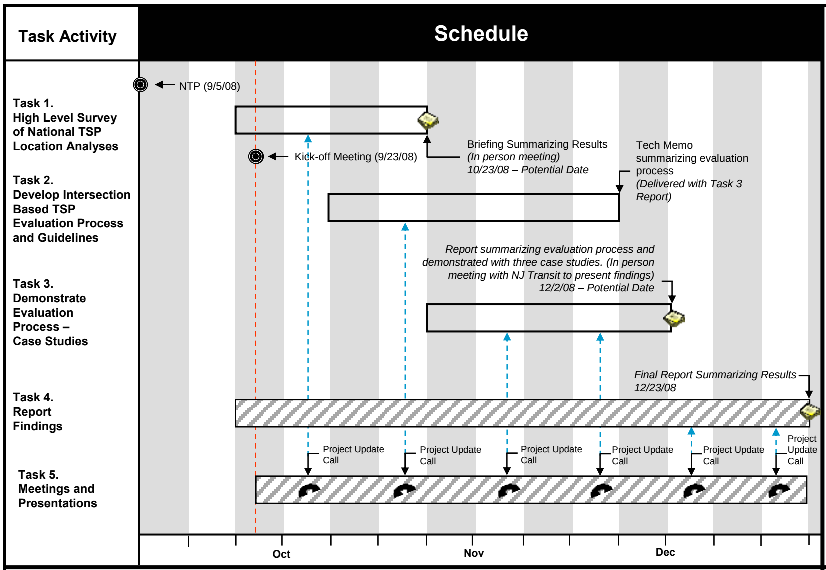
Agenda

- Schedule
- Overview of TSP Scan Approach
- Results of TSP Scan
- Preliminary Metrics
- Next Steps

CAMBRIDGE SYSTEMATICS

Task Activity

Schedule



Task 1.
High Level Survey of National TSP Location Analyses

Task 2.
Develop Intersection Based TSP Evaluation Process and Guidelines

Task 3.
Demonstrate Evaluation Process – Case Studies

Task 4.
Report Findings

Task 5.
Meetings and Presentations

NTP (9/5/08)

Kick-off Meeting (9/23/08)

Briefing Summarizing Results
(In person meeting)
10/23/08 – Potential Date

Tech Memo summarizing evaluation process
(Delivered with Task 3 Report)

Report summarizing evaluation process and demonstrated with three case studies. (In person meeting with NJ Transit to present findings)
12/2/08 – Potential Date

Final Report Summarizing Results
12/23/08

Project Update Call

Project Update Call

Project Update Call

Project Update Call

Project Update Call

Project Update Call

Key Early Activities

Dates for In Person Meetings:
- *Task 1 Briefing: 10/23/08*
- *Task 2 and 3 Briefing: 12/2/08*

Potential Dates for Bi-Weekly Coordination Calls: 10 a.m.
- *10/10*
- *10/24*
- *11/7*
- *11/21*
- *12/5*
- *12/19*

NJ Transit - Transit Signal Priority– NJ
Systems Application and Technology Investigation

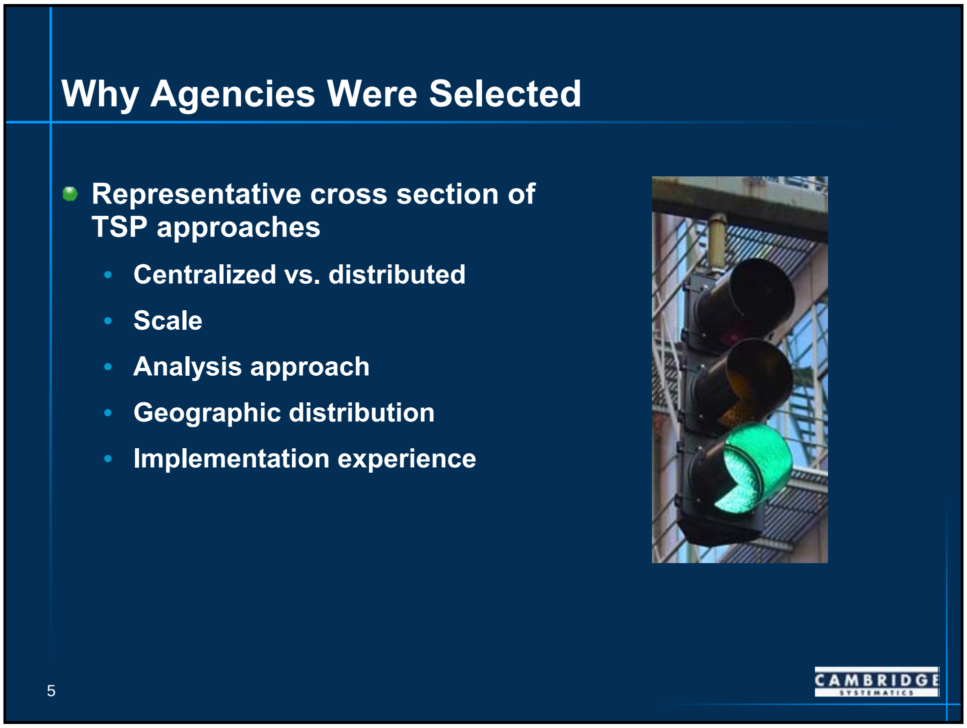
Kick-Off Meeting

Task Goals

- Research active/current TSP deployments
  - Identify screening criteria
  - Lessons learned
- Determine what is applicable to NJ Transit
- Use best elements in developing NJ selection process

Transit Agencies Interviewed

- Portland - TriMet
- Vancouver - Translink
- Los Angeles – LACMTA
- Chicago – RTA, CTA, Pace
- Oakland – AC Transit
- Toronto – Go Transit *(pending)*
- New York City - NYCMTA *(pending)*



Why Agencies Were Selected

- Representative cross section of TSP approaches
  - Centralized vs. distributed
  - Scale
  - Analysis approach
  - Geographic distribution
  - Implementation experience

Interview Topics

- Intersection selection
- Screening criteria utilized
- Analysis tools
- TSP strategies
- Program status
- Agency coordination issues
- Before/after Studies
- Lessons learned

Memorandum

TO:

FROM:

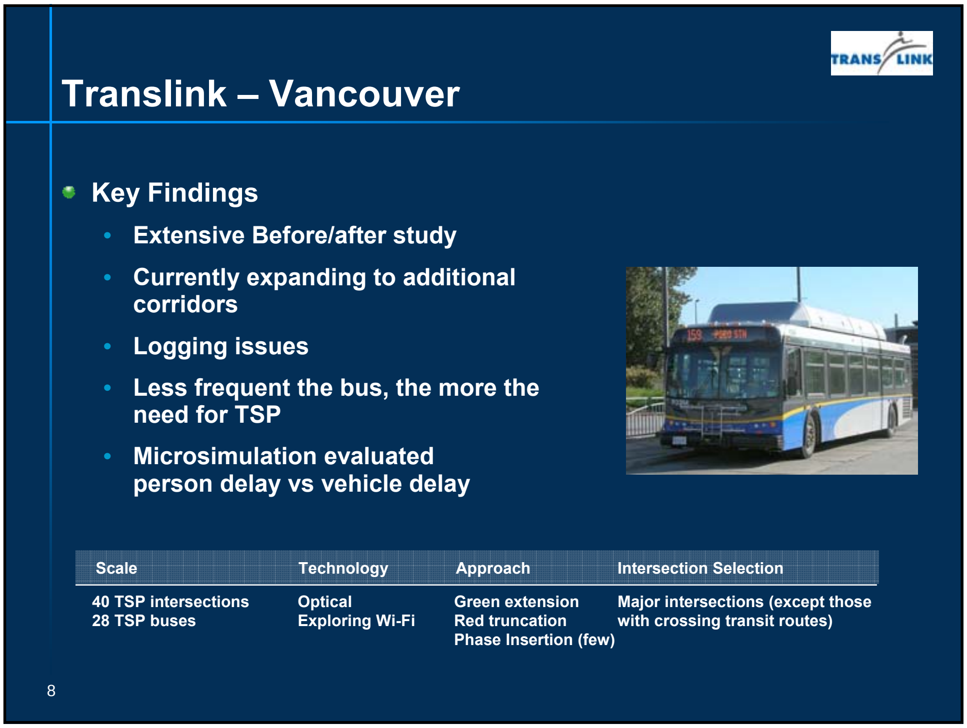
DATE:

RE:

TriMet – Portland

- Key Findings
  - Give priority to all late buses
  - Moved to far-side stops where feasible
  - Avoided actuated minor cross street intersections
  - Relatively little signal optimization needed
  - Driver contest to identify hotspots
  - Build off of emergency vehicle preemption
  - Event logging issues

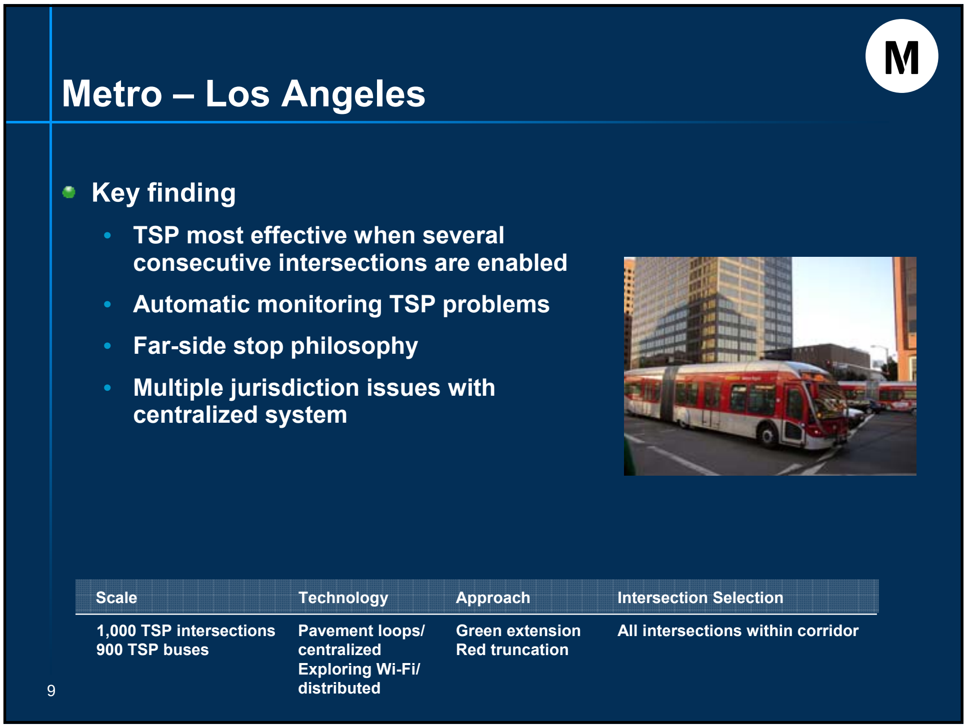
Scale	Technology	Approach	Intersection Selection
350 TSP intersections 650 TSP buses	Optical	Green extension Red truncation	Major intersections in high frequency corridors



Translink – Vancouver

- Key Findings
  - Extensive Before/after study
  - Currently expanding to additional corridors
  - Logging issues
  - Less frequent the bus, the more the need for TSP
  - Microsimulation evaluated person delay vs vehicle delay

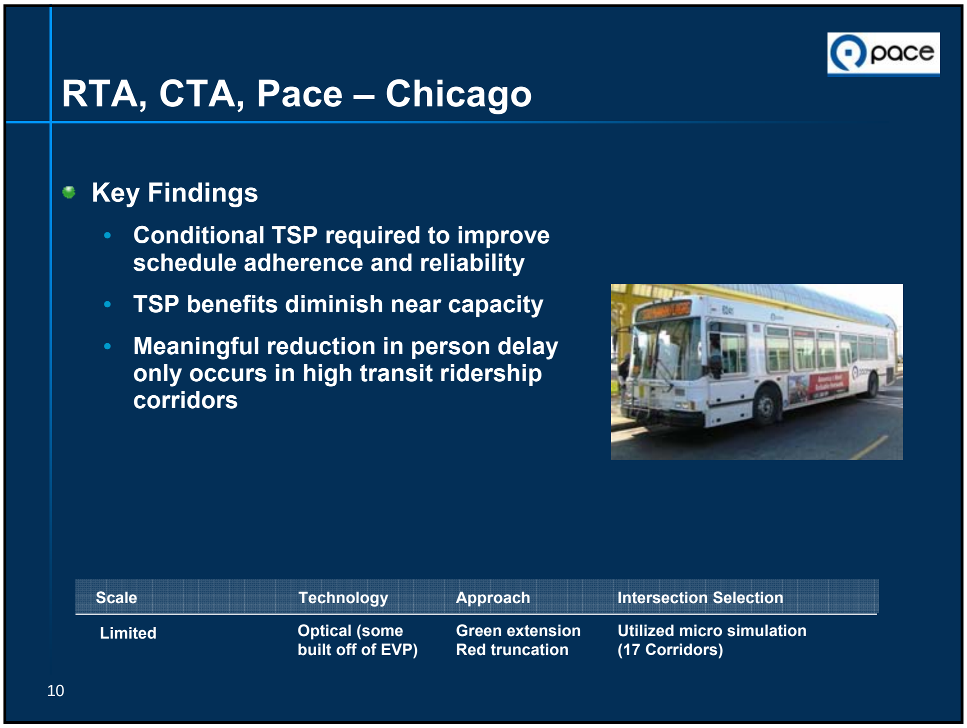
Scale	Technology	Approach	Intersection Selection
40 TSP intersections 28 TSP buses	Optical Exploring Wi-Fi	Green extension Red truncation Phase Insertion (few)	Major intersections (except those with crossing transit routes)



Metro – Los Angeles

- Key finding
  - TSP most effective when several consecutive intersections are enabled
  - Automatic monitoring TSP problems
  - Far-side stop philosophy
  - Multiple jurisdiction issues with centralized system

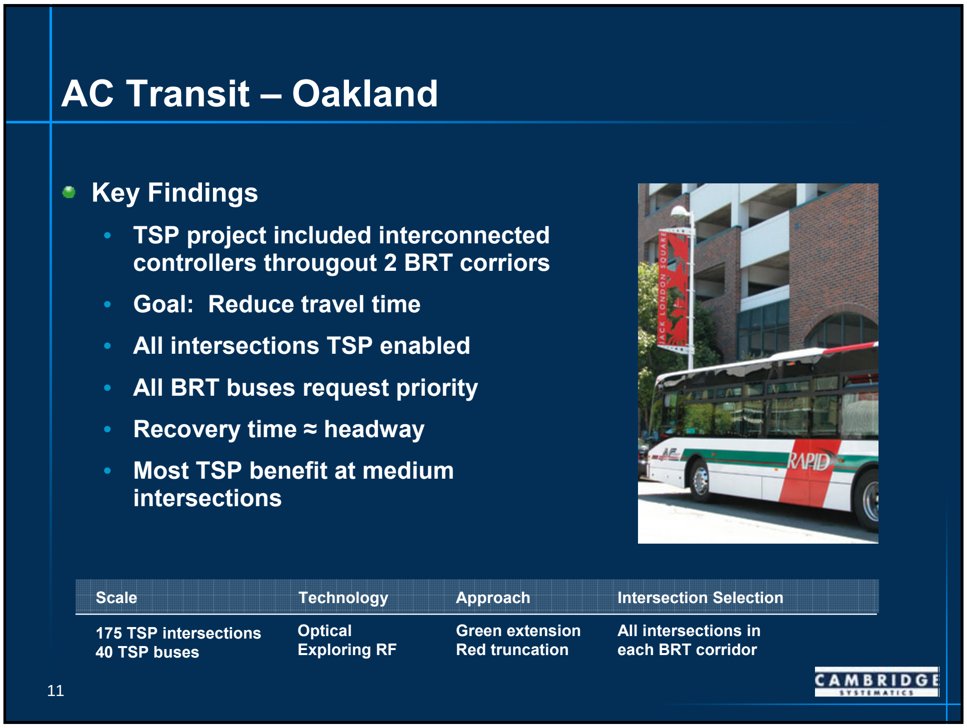
Scale	Technology	Approach	Intersection Selection
1,000 TSP intersections 900 TSP buses	Pavement loops/ centralized Exploring Wi-Fi/ distributed	Green extension Red truncation	All intersections within corridor



RTA, CTA, Pace – Chicago

- Key Findings
  - Conditional TSP required to improve schedule adherence and reliability
  - TSP benefits diminish near capacity
  - Meaningful reduction in person delay only occurs in high transit ridership corridors

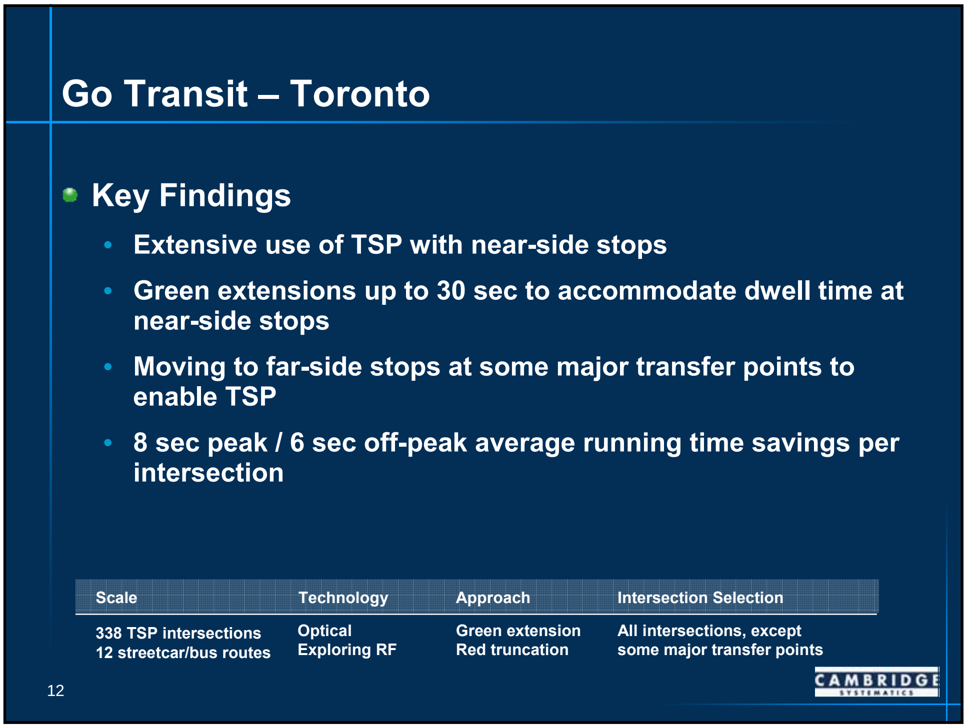
Scale	Technology	Approach	Intersection Selection
Limited	Optical (some built off of EVP)	Green extension Red truncation	Utilized micro simulation (17 Corridors)



AC Transit – Oakland

- Key Findings
  - TSP project included interconnected controllers througout 2 BRT corriors
  - Goal: Reduce travel time
  - All intersections TSP enabled
  - All BRT buses request priority
  - Recovery time ≈ headway
  - Most TSP benefit at medium intersections

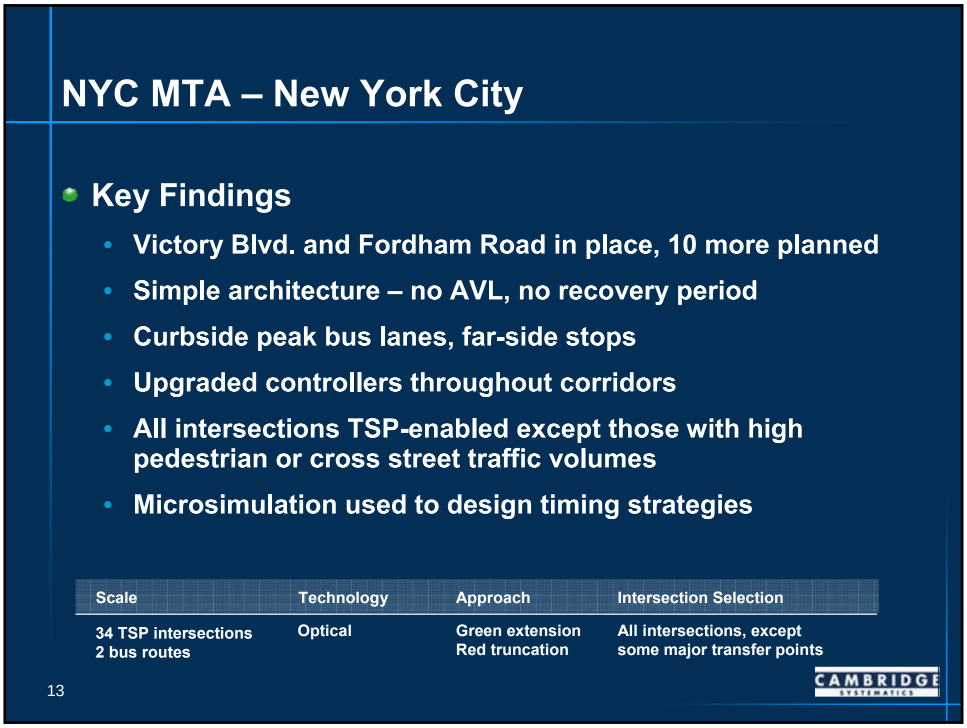
Scale	Technology	Approach	Intersection Selection
175 TSP intersections 40 TSP buses	Optical Exploring RF	Green extension Red truncation	All intersections in each BRT corridor



Go Transit – Toronto

- Key Findings
  - Extensive use of TSP with near-side stops
  - Green extensions up to 30 sec to accommodate dwell time at near-side stops
  - Moving to far-side stops at some major transfer points to enable TSP
  - 8 sec peak / 6 sec off-peak average running time savings per intersection

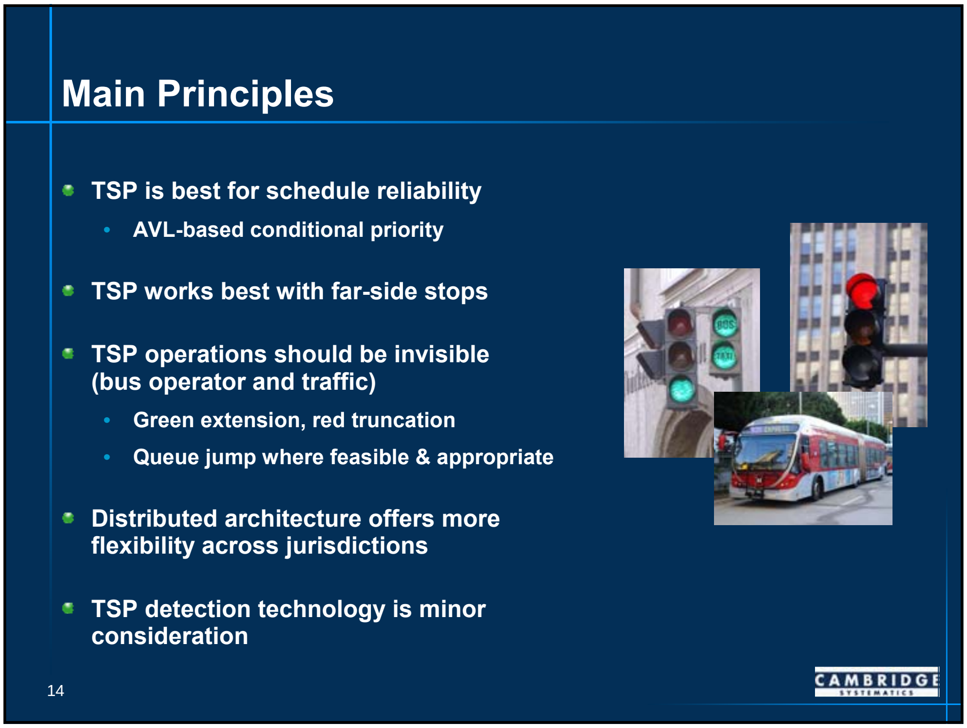
Scale	Technology	Approach	Intersection Selection
338 TSP intersections 12 streetcar/bus routes	Optical Exploring RF	Green extension Red truncation	All intersections, except some major transfer points



NYC MTA – New York City

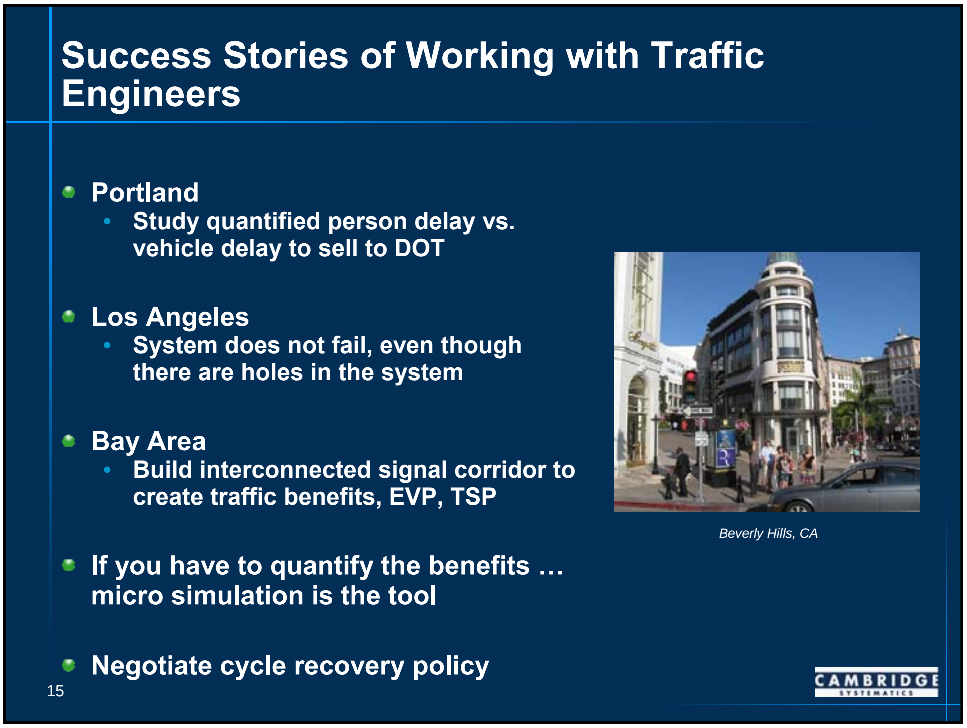
- Key Findings
  - Victory Blvd. and Fordham Road in place, 10 more planned
  - Simple architecture – no AVL, no recovery period
  - Curbside peak bus lanes, far-side stops
  - Upgraded controllers throughout corridors
  - All intersections TSP-enabled except those with high pedestrian or cross street traffic volumes
  - Microsimulation used to design timing strategies

Scale	Technology	Approach	Intersection Selection
34 TSP intersections 2 bus routes	Optical	Green extension Red truncation	All intersections, except some major transfer points



Main Principles

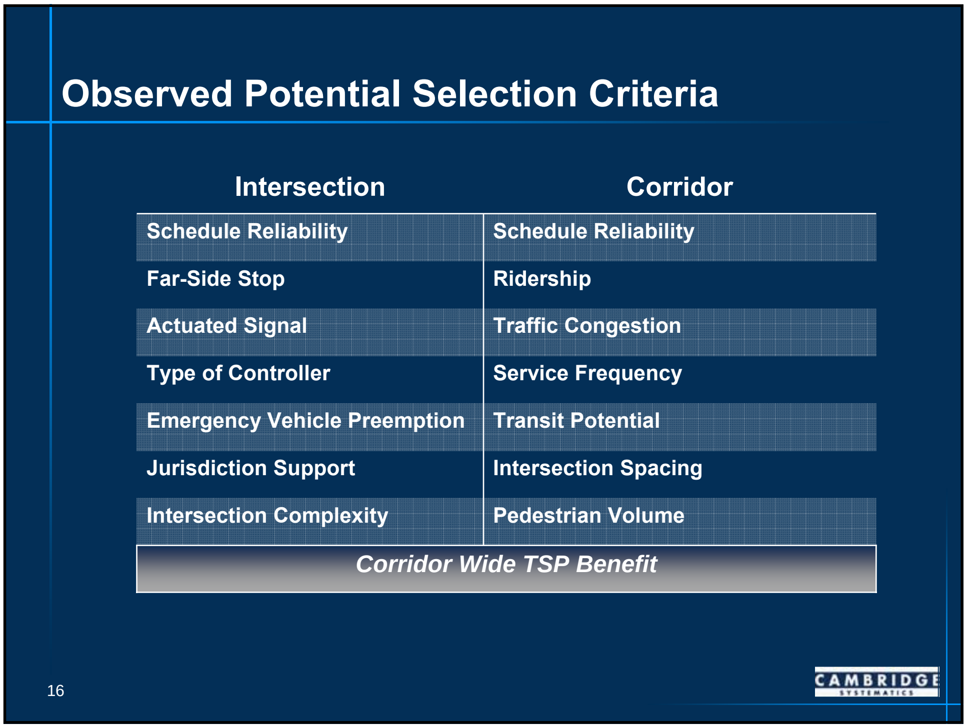
- TSP is best for schedule reliability
  - AVL-based conditional priority
- TSP works best with far-side stops
- TSP operations should be invisible (bus operator and traffic)
  - Green extension, red truncation
  - Queue jump where feasible & appropriate
- Distributed architecture offers more flexibility across jurisdictions
- TSP detection technology is minor consideration



Success Stories of Working with Traffic Engineers

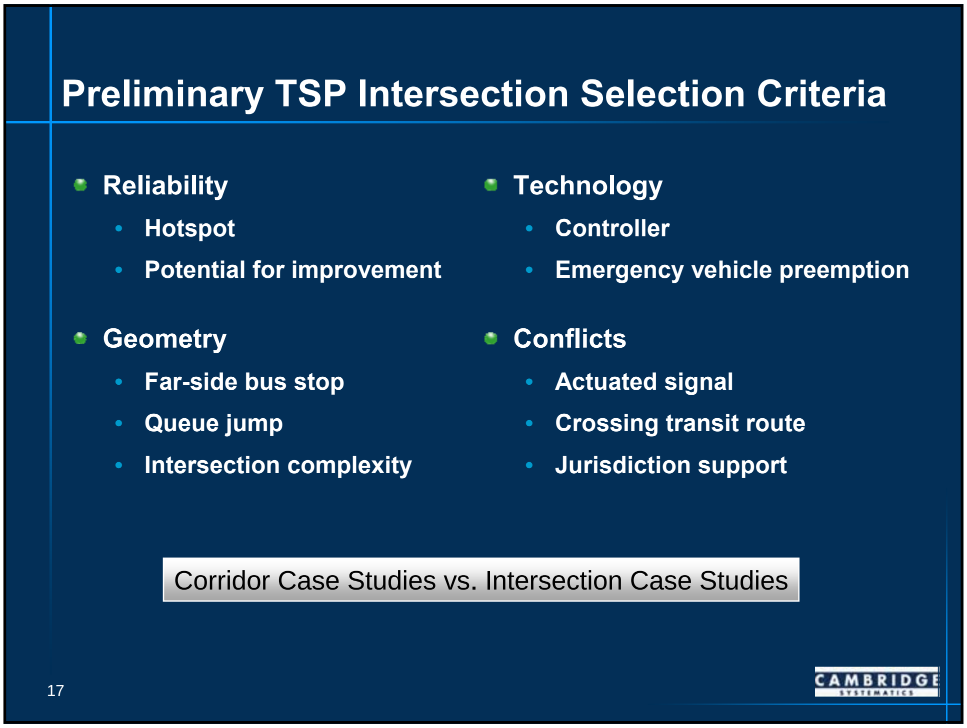
- Portland
  - Study quantified person delay vs. vehicle delay to sell to DOT
- Los Angeles
  - System does not fail, even though there are holes in the system
- Bay Area
  - Build interconnected signal corridor to create traffic benefits, EVP, TSP
- If you have to quantify the benefits … micro simulation is the tool
- Negotiate cycle recovery policy

Beverly Hills, CA



Observed Potential Selection Criteria

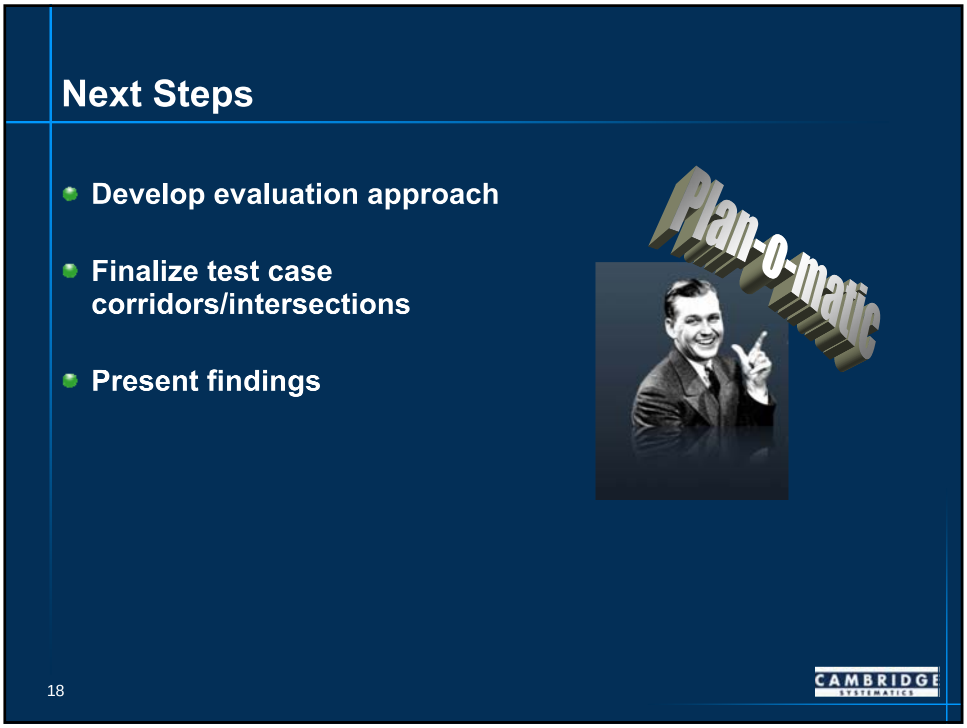
Intersection	Corridor
Schedule Reliability	Schedule Reliability
Far-Side Stop	Ridership
Actuated Signal	Traffic Congestion
Type of Controller	Service Frequency
Emergency Vehicle Preemption	Transit Potential
Jurisdiction Support	Intersection Spacing
Intersection Complexity	Pedestrian Volume
Corridor Wide TSP Benefit	



Preliminary TSP Intersection Selection Criteria

- Reliability
  - Hotspot
  - Potential for improvement
- Geometry
  - Far-side bus stop
  - Queue jump
  - Intersection complexity
- Technology
  - Controller
  - Emergency vehicle preemption
- Conflicts
  - Actuated signal
  - Crossing transit route
  - Jurisdiction support

Corridor Case Studies vs. Intersection Case Studies



Next Steps

- Develop evaluation approach
- Finalize test case corridors/intersections
- Present findings

Appendix B

Progress Meeting

November 18, 2008

Handouts include minor updates to the material presented at the meeting based on subsequent work, additional refinements, and responses to stakeholder comments.

NJ Transit

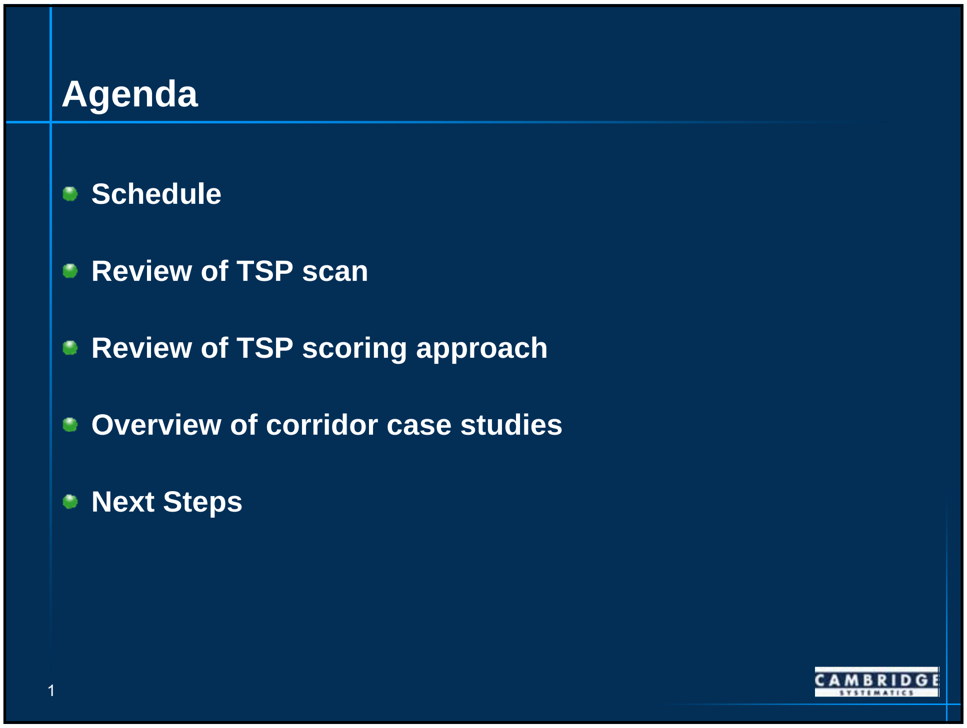
Transit Signal Priority– NJ Systems Application and Technology Investigation

presented to
NJ Transit

presented by
Chris Kopp
Cambridge Systematics, Inc.

11/20/08

Transportation leadership you can trust.



Agenda

- Schedule
- Review of TSP scan
- Review of TSP scoring approach
- Overview of corridor case studies
- Next Steps

Task Activity

Schedule

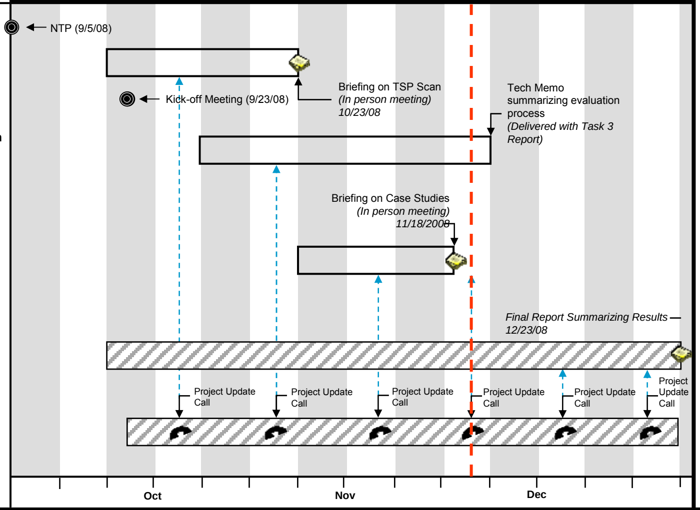
Task 1. **High Level Survey of National TSP Location Analyses**

Task 2. **Develop Intersection Based TSP Evaluation Process and Guidelines**

Task 3. **Demonstrate Evaluation Process – Case Studies**

Task 4. **Report Findings**

Task 5. **Meetings and Presentations**



NJ Transit - Transit Signal Priority– NJ Systems Application and Technology Investigation

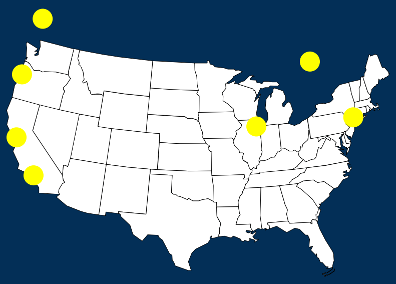
Corridor Test Case Meeting

TSP Scan Goals

- Research active/current TSP deployments
  - Identify screening criteria
  - Lessons learned
- Determine what is applicable to NJ Transit
- Use best elements in developing NJ selection process

Transit Agencies Interviewed

- Portland - TriMet
- Vancouver - Translink
- Los Angeles – LACMTA
- Chicago – RTA, CTA, Pace
- Oakland – AC Transit
- Toronto – TTC
- New York City - NYCMTA



Why Agencies Were Selected

- Representative cross section of TSP approaches
  - Centralized vs. distributed
  - Scale
  - Analysis approach
  - Geographic distribution
  - Implementation experience

Interview Topics

- Intersection selection
- Screening criteria utilized
- Analysis tools
- TSP strategies
- Program status
- Agency coordination issues
- Before/after Studies
- Lessons learned

Memorandum

Main Principles

- TSP is best for schedule reliability
  - AVL-based conditional priority
- TSP works best with far-side stops
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  - Queue jump where feasible & appropriate
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Beverly Hills, CA

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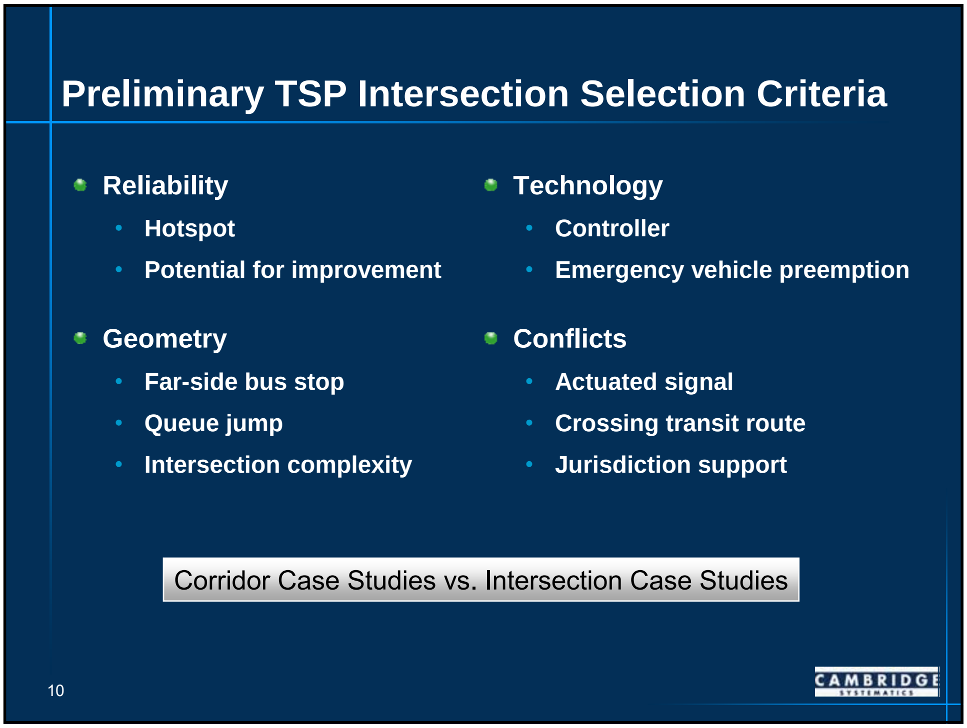
Jurisdiction Support	Intersection Spacing
Intersection Complexity	Pedestrian Volume
Corridor Wide TSP Benefit	



Preliminary TSP Intersection Selection Criteria

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  - Potential for improvement
- Technology
  - Controller
  - Emergency vehicle preemption
- Geometry
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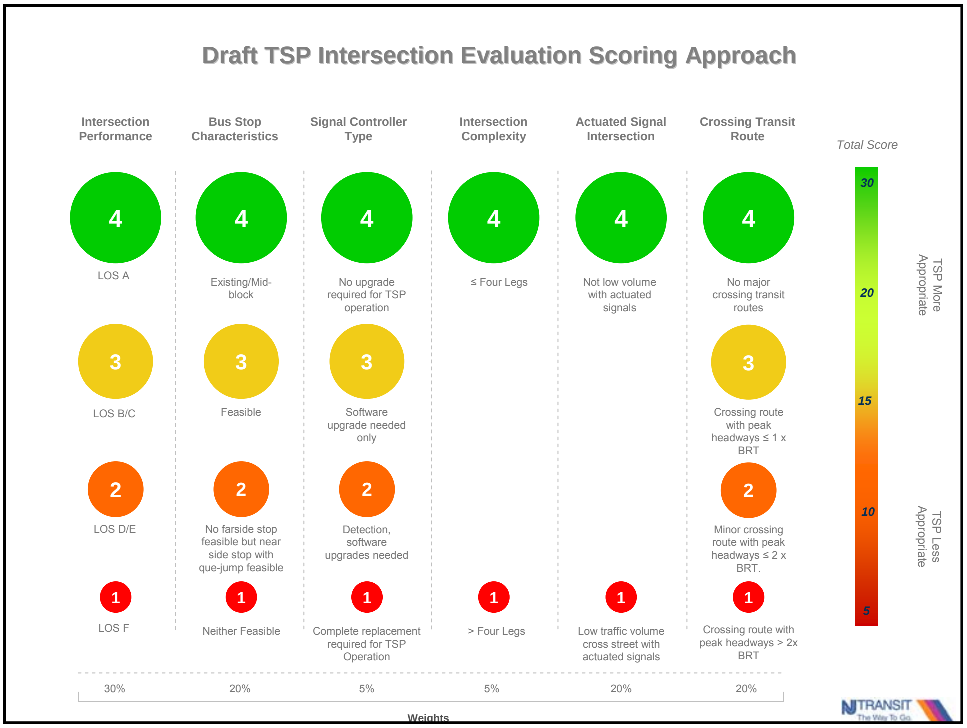
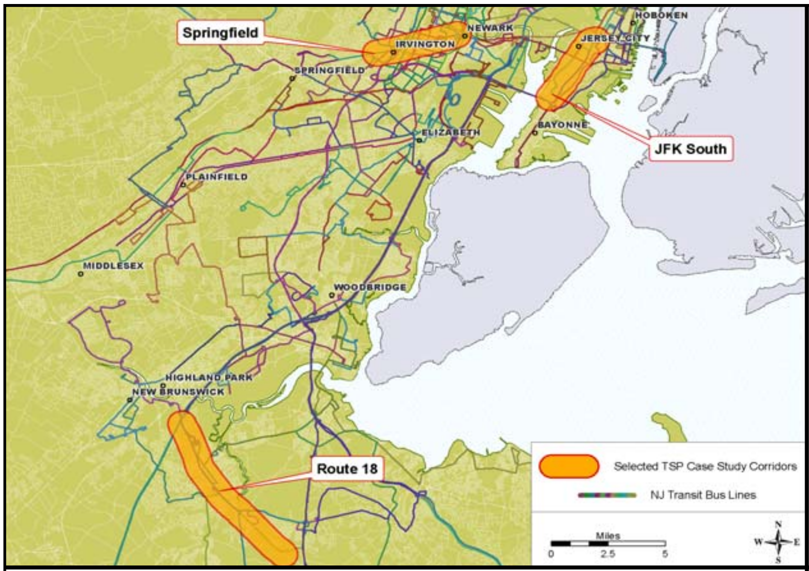
  - Queue jump
  - Intersection complexity
- Conflicts
  - Actuated signal
  - Crossing transit route
  - Jurisdiction support

Corridor Case Studies vs. Intersection Case Studies



Draft TSP Intersection Evaluation Scoring Approach

	Intersection Performance	Bus Stop Characteristics	Signal Controller Type	Intersection Complexity	Actuated Signal Intersection	Crossing Transit Route
4	LOS A	Existing/Mid-block	No upgrade required for TSP operation	≤ Four Legs	Not low volume with actuated signals	No major crossing transit routes
3	LOS B/C	Feasible	Software upgrade needed only			Crossing route with peak headways ≤ 1 x BRT
2	LOS D/E	No farside stop feasible but near side stop with que-jump feasible	Detection, software upgrades needed			Minor crossing route with peak headways ≤ 2 x BRT.
1	LOS F	Neither Feasible	Complete replacement required for TSP Operation	> Four Legs	Low traffic volume cross street with actuated signals	Crossing route with peak headways > 2x BRT
Weights	30%	20%	5%	5%	20%	20%



Corridors Case Studies

~~1. Route 18~~
Turnpike to GSP
Middlesex County

2. **JFK South**
Journal Square to
Bayonne City Line
Hudson County

3. **Springfield**
Market Street to
43rd Street
Essex County

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Corridor Case Studies

Corridor Characteristics

- ~~3.4 miles~~
- **52 intersections**

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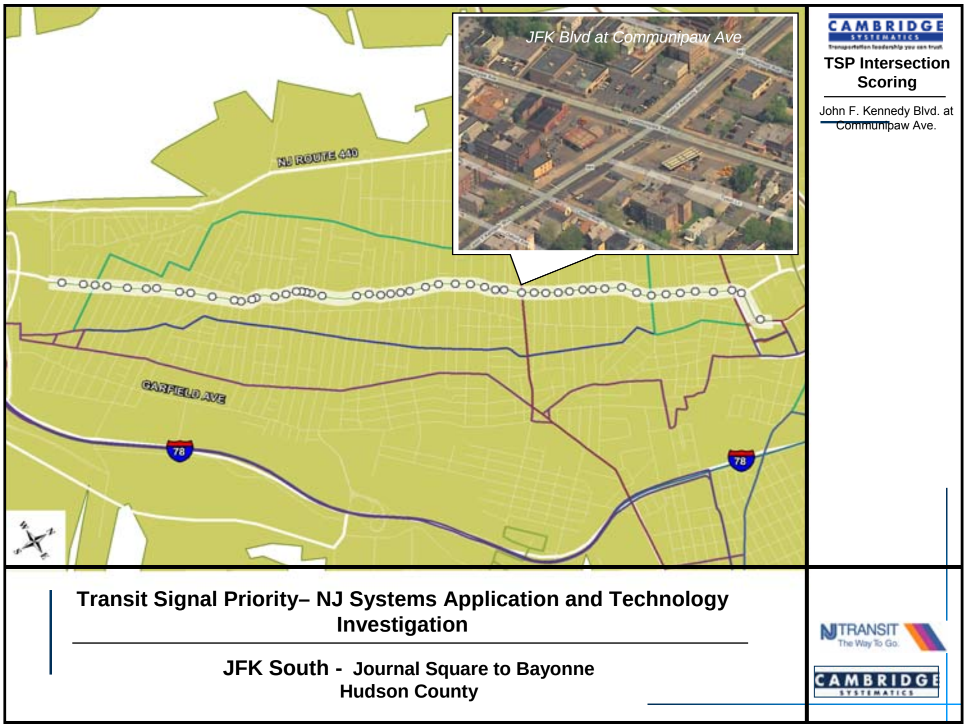
JFK South - Journal Square to Bayonne
Hudson County



TSP Intersection Scoring

John F. Kennedy Blvd. at Communipaw Ave.

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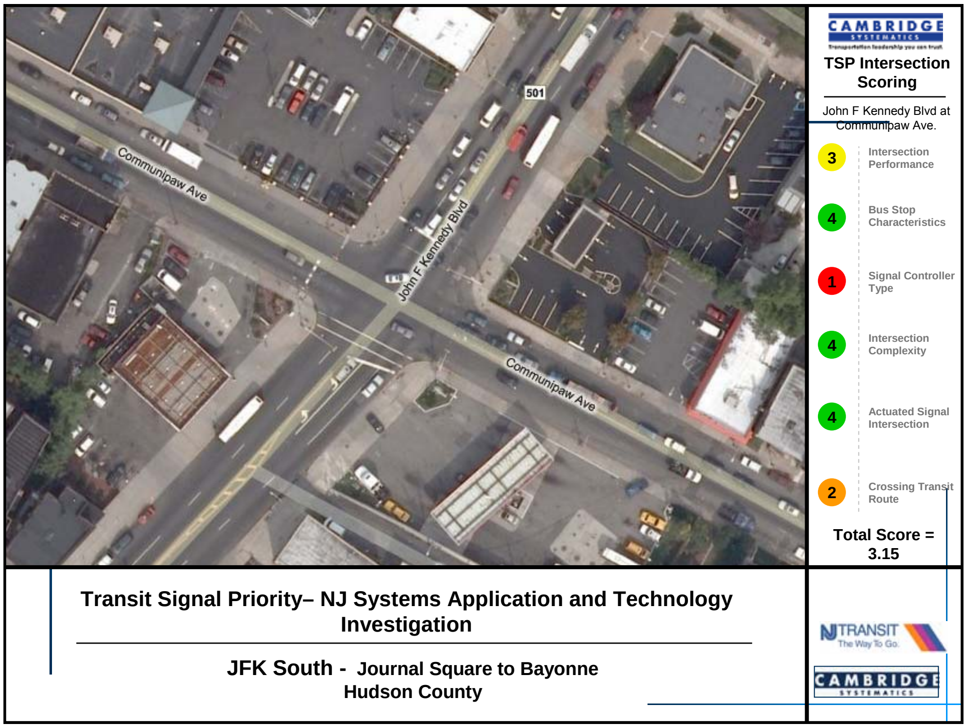
JFK South - Journal Square to Bayonne
Hudson County



TSP Intersection Scoring

John F Kennedy Blvd at Communipaw Ave.

3	Intersection Performance
4	Bus Stop Characteristics
1	Signal Controller Type
4	Intersection Complexity
4	Actuated Signal Intersection
2	Crossing Transit Route

Total Score = 3.15

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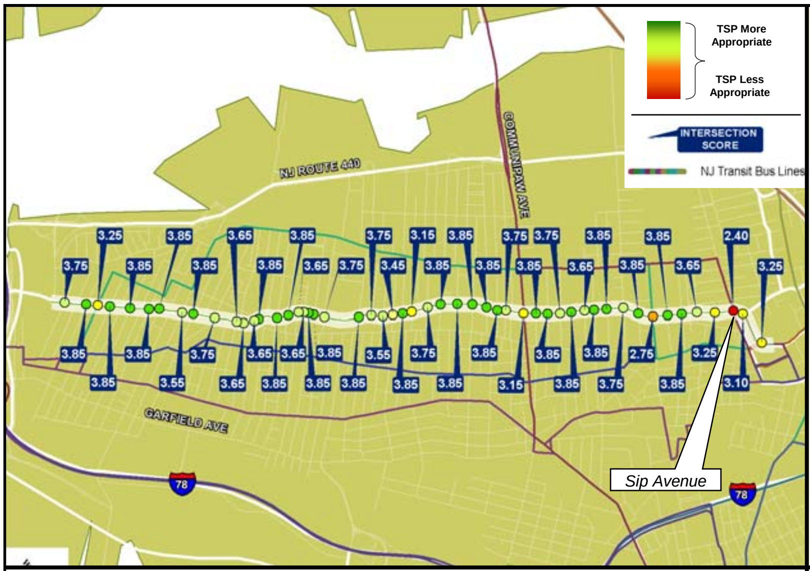
JFK South - Journal Square to Bayonne
Hudson County



Sip Avenue

TSP Intersection Scoring

Overall Scoring

98% = TSP More Appropriate

6% intersections have major crossing transit routes

- Average Intersection Score Along Corridor = **3.66**
- Assumed all controllers would need to be replaced

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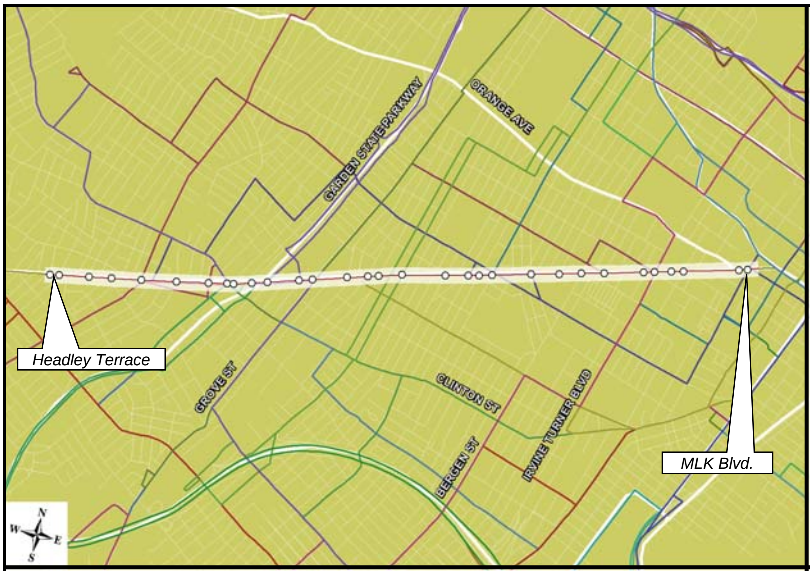
JFK South - Journal Square to Bayonne
Hudson County



Headley Terrace

MLK Blvd.

Corridor Characteristics

- **3.5 miles**
- **31 intersections**

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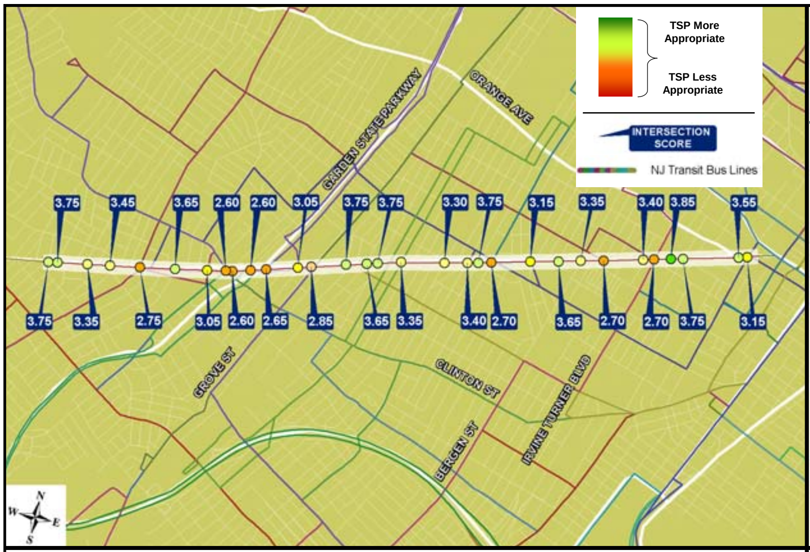
Springfield – Market Street to 43rd Street
Essex County



TSP Intersection Scoring

Overall Scoring

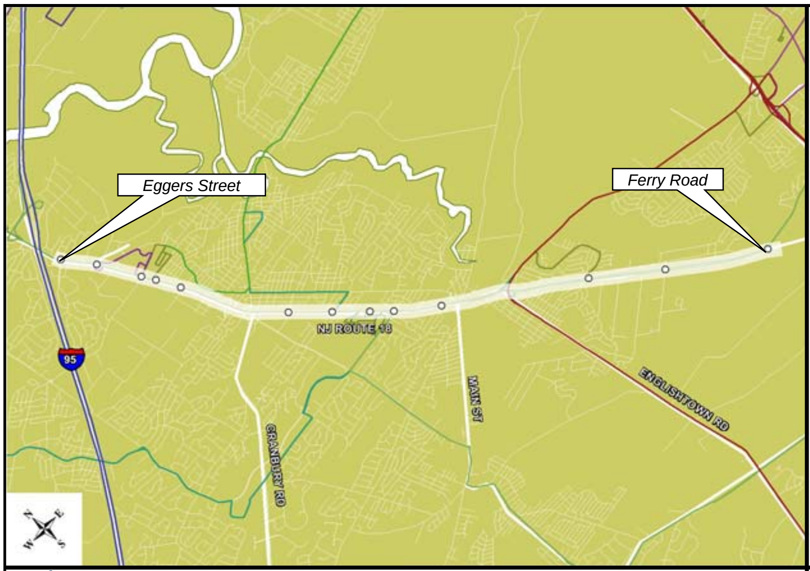
100% = TSP More Appropriate

39% intersections have major crossing transit routes

- Average Intersection Score Along Corridor = **3.26**
- Assumed all controllers would need to be replaced

Transit Signal Priority– NJ Systems Application and Technology Investigation

Springfield – Market Street to 43rd Street
Essex County

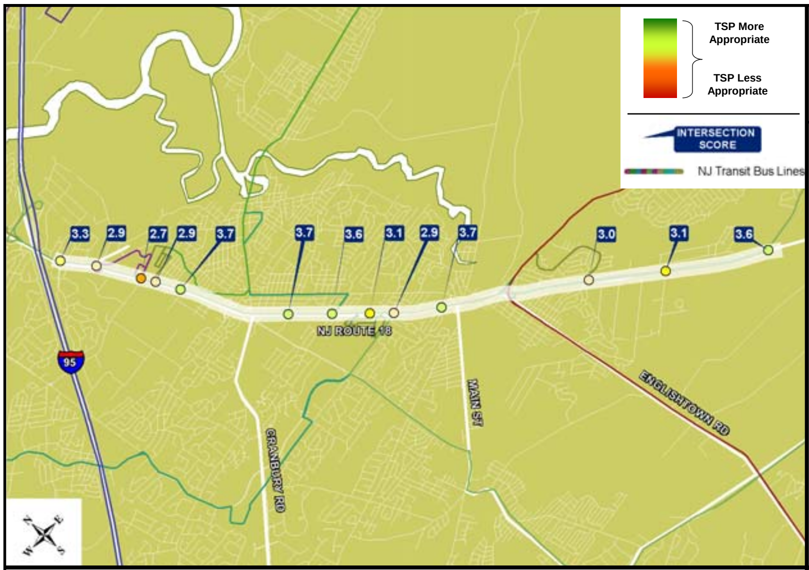


Corridor Characteristics

- **7.5 miles**
- **13 intersections**

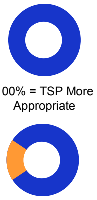
Transit Signal Priority– NJ Systems Application and Technology Investigation

Route 18 - Turnpike to GSP
Middlesex City



TSP Intersection Scoring

Overall Scoring



100% = TSP More Appropriate

15% intersections have major crossing transit routes

- Average Intersection Score Along Corridor = **3.25**
- Assumed all controllers would need to be replaced

Transit Signal Priority– NJ Systems Application and Technology Investigation

Route 18 - Turnpike to GSP
Middlesex City

Next Steps

- Finalize test case corridors based on comments from today's meeting
- Finalize in report
- Report due 12/31/08