Guidance For Identifying Corridor Conditions That Warrant Deploying Transit Signal Priority And Queue Jump

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***Abstract*— Nowadays, our streets and highways are growing in traffic congestion as large number of cars are entering the transportation system due to rise in population. The high volume of vehicles and numerous signalized intersection the traffic congestion is causing huge problems to schedule reliability. As transportation demand is increasing various road networks are facing increasing congestion. To mitigate the high-density congestion transit signal priority (TSP) and queue jumper are significant solution. Transit signal priority is providing solutions according to many variables, and it is pursuing several valuable objectives such as: reduced transit travel times, better schedule adherence, better transit efficiency, and increased road network efficiency by car mobility.**

Our objective is to compare and evaluate existing guidelines or form new guidelines for TSP and Queue jump. In addition, in this research, we study various findings from a series of gap filling research efforts of various guidelines strategies which are not in common use in the United States; a simulation platform will be used to study transit signal priority and their guidelines. The preliminary results show improvement in travel times in each directional of travel and various scenario that implemented some of the transit preferential treatments, when compared to base scenario.

Keywords—Transit Signal Priority; queue jump; traffic congestion; travel times

1. INTRODUCTION

In the recent years, the interest in sustainable transportation and surface transit systems is increasing. As the roadway congestion is growing the reliability of transit systems have been a concern. In order to improve the performance of these systems, implementation of TSP is one of the major technology which can mitigate the concerns of transit system. TSP is an operational method that facilitates the movement of transit vehicles through traffic-signal controlled intersections. The overall objective of implementation of TSP is to improve transit travel time, travel time reliability, and safety. The improvements in transit travel time and reliability at individual locations may sometime be relatively small, but, the aggregated benefits across the network or corridor can be substantial. Moreover, maintaining exceptional transit services in the long term can promote modal shifts from personal vehicles to transit. In addition, by applying TSP technology can potentially maintain ridership and revenue, mean while reducing the operating cost if also traffic operation is impacted.

The study's primary purpose is to develop a guidance for the transit agencies in identifying corridor conditions that warrant TSP and queue jump. The objective of the study is to:

Identify:
- Current state of traffic signal control and TSP systems used in Florida.
- Current state of TSP and queue jump systems used in the nation.

Recommend:
- Minimum operational characteristics and on-time performance indicators that would necessitate TSP along a corridor.
- Simulation modeling to coordinate implementation of TSP and Queue jump systems in proposed case studies.

Establish:
- Guidelines for TSP and queue jump implementations in Florida
- Tests of the developed guidance for three corridors around Florida.

This technical quarterly report is the first of three deliverables associated with the TSP and Queue Jump Study. It provides the foundational concepts needed to understand what TSP is and what it can offer specific to the context of a public transportation systems framework. Also, it discusses previous studies in the state and in the nation including policy issues and challenges to resolve when considering TSP and Queue jump.

2. LITERATURE REVIEW

Due to the constant growth of automobile traffic there are various negative impacts which include an increase in travel times and reduction in its reliability and punctuality, an increase in passenger's bus stop waiting times and bus crowding. Therefore, in this section the authors review a few major evaluation studies on TSP and Queue Jumpers. Transit priority at signalized intersections had been reviewed in the United States since the 1970s (1). In recent years, TSP had been broadly applied by transportation agencies in North America and these growing deployments of TSP across the nation require broad evaluation studies to assess their historical impact. A comprehensive number of studies had been attempted to assess TSP using either empirical, analytical or simulation tools.

Evaluations of Cases of Study of Transit Signal Priority around the United States

According to (2) they developed a model evaluating a bus priority strategy for a signalized intersection in a

978-1-5090-6484-7/17/$31.00 ©2017 IEEE

coordinated signal system in College Station, Texas. The model used the 1985 Highway Capacity Manual delay equation for signalized intersections and adapted the equation to calculate person-delay for cases with and without priority strategies. Priority is provided by early green and green extensions of the priority phase at regular intervals, coordinating with the estimated bus arrival interval. Five cases were identified:

1- No priority
2- Priority phases receive a minimum extension
3- Priority phases receive a maximum extension
4- Priority phases provide a minimum early start
5- Priority phases provide maximum early start

Priority strategy remunerations were established by measuring the delay for vehicles and buses on a cycle by cycle basis. A normal delay is calculated for a non-priority scenario to demonstrate that the model was contrasted with field assessment to test the reliability of the results. A site was chosen in College Station, TX, and the controller altered to accept manual inputs to simulate a bus approach. Around 10 sample priority cycles were obtained for case 3 and case 5. It was determined that the other evaluated cases would not be considered due to the little impact they had on the side street traffic.

Research completed by (4) is amongst the first TSP studies in the United States (3). This work assessed the initial Urban Traffic Control System - Bus Priority System (UTCS-BPS) in Washington, D.C, District of Columbia; using a microscopic simulation model, UTCS-1. The UTCS-1 model simulated a network with unconditional preemption for transit buses, applying early green and extended green logic; building the initial assessment. This assessed different scenarios by varying the headways of 1 transit route from 30 seconds to 4 minutes, therefore, moving the bus stops to represent far side or near side stops. The model used bus detection zones 210 feet upstream from the instrumented intersection to within 5 feet of the intersection (4). Any signal coordination in the network is maintained after the departure of all buses from the detection zone (4). The key findings from this report are summarized as follows:

- the mean bus travel times decreased from 22 percent to 32 percent,
- crossing street traffic travel time increased from 6 percent to 30 percent for far-side stops,
- crossing street traffic travel time increased from 9 percent to 66 percent for near-side stops and,
- The mean bus travel time was within 15 percent of the theoretical minimum travel time of the transit vehicle.

In San Diego, CA the high rate of trolleys brought extensive delays through the deployment of passive priority system. To improve the situation, an active priority system was planned to develop a better progression to the next station in the transportation network with savings in operating travel time throughout center city by as much as 2-3 minutes (5). (12) Investigated signal progression for light rail transit (LRT) located in downtown Baltimore, MD. The evaluated corridor was 2.4 miles long corridor along Howard Street. Based on TRANSYT-7F simulation, the study reconfirmed that fill priority LRT operations could be designed without significantly affecting cross street progression (12). In Chicago, IL, approximately 2-3 minutes saved on the travel time by a bus run, and the impact to traffic was minimal (13). The system examination also showed that the priority was provided to only 30% buses as 70% of the buses arriving during the normal green time. In addition, according to (6) research report mentioned that the modern technology facilitated the design, testing, and deployment of TSP strategies for transit buses. This research tries to assist in the evaluation of such strategies through presentation of an evaluation framework and plan that provides a systematic method to assess potential impacts.

A case of study developed in California included the study of 34 key study intersections in the Russel Boulevard corridor, California USA. The study, based in transit passenger delay, identified key intersections and corridors that degrade transit on-time performance due to high vehicle passenger delays. Using Bus GPS technology, researchers evaluated the detailed ranking of 34 study intersections and selected them for detailed VISSIM analysis (see Table 1). They utilized a combination of signal coordination, TSP, and operational improvement strategies to fully analyze these intersections using the VISSIM multi modal microsimulation analysis software for weekday AM and PM peak hour conditions.

The total delay was calculated by multiplying the number of transit vehicles passing through each intersection by the average delay at each intersection, and based on the detailed VISSIM microsimulation analysis were determined that by improving signal operations and coordination will benefit overall traffic flow and reduce stop and go conditions, therefore, the overall impact of transit signal priority on general traffic would be negligible. In addition, the vehicle emissions would be reduced and average travel speeds maintained with the implementation of “green extension” for approaching transit vehicles.

In addition, the District of Columbia DOT led the TSP design and implementation effort for over 100 signalized intersections along four corridors. Also, extensively tested the TSP module of the BITran 233 controller to assess its capabilities and limitations (8). In March 2013, the Montgomery County Department of Transportation (McDOT) commissioned Rapid Transit System (RTS) Transit Signal Priority (TSP) Concept Study to assist in determining how TSP and its operations integrate and operate within the overall RTS system. The researchers’ primary goals are to “define the appropriate metrics for the implementation of TSP systems on each RTS corridor, building on what was developed for TSP for local bus operations” (7). In addition, according to (16) based upon the consultation with Washington Metropolitan Area Transit Authority (WMATA), Montgomery County Ride On, County DOT traffic Engineering and operations division, Maryland State Highway Administration (MHSA) office of traffic safety staff, 18 corridors were recognized form further study. Out of the approximately 800 intersections in Montgomery County 18 recommended corridor captured 366 intersection that were considered for additional analysis and potential TSP implementation. Out of 366 intersections 225 intersection passed mandatory feasibility criteria for potential TSP implementation. In addition. These were then ranked based on TSP weighing factors reflecting the potential of TSP to provide benefits to transit operation without causing significant traffic disruptions.

Sample of Cases of Study of Transit Signal Priority in Florida

In Tampa, Florida Kittleson and Associates led a project to assess the TSP along portions of three selected corridors: Fletcher Ave, N 56th St, and Nebraska Ave. The results of the research delivered critical input into the completed design of initial implementation of the BRT system in Tampa (known as Metro Rapid) along the Fletcher Ave and Nebraska Ave corridors. Due to the stakeholder input the TSP technology chosen was a GPS/Radio based system that could be integrated with the previously existing Automatic Vehicle Location (AVL) system installed on buses to provide conditional priority. The project included the demonstration of emergency vehicle preemption using the same TSP technology and participating emergency reaction agencies include Hillsborough County and the City of Temple Terrace, Florida (9).

In addition, another TSP project was implemented along Atlantic Boulevard in Jacksonville, Florida with six Naztec controlled signalized intersections. The project included reviewing alternate TSP strategies and technologies as well as conducting “before” and “after” evaluations of bus and auto performance measures, and the Opticom GPS system was selected as the bus detection system for the implementation. An interface amid the bus detection system and the bus Automatic Vehicle Location (AVL) system was developed to test “conditional priority” along the corridor. The project identified an implementation strategy to expand TSP implementation to other portions of the Jacksonville region (9).

There are three projects in the State of Florida that highlight the implementation of TSP systems. The first project included, the installation of a TSP systems on fifty (50) intersections on Pines/Hollywood and Broward Boulevards in Broward County. The evaluation of this project, showed a reduction in travel times and better schedule adherence during the AM peak hours; however, the PM peak hours had no recognizable impacts because of the TSP systems. Next, a TSP system will be installed on 32 intersections in Duval County connecting Downtown Jacksonville to Jacksonville Beach. Six of those intersections also included the queue-jumping feature. This project is known as the First Coast Flyer East Corridor BRT Project and there are four other extensions of this project. The North Corridor was completed in December of 2015 and is comprised of the latest TSP technology and has dedicated bus lanes (10). The remainder of the project is to be completed soon (10). The last project, is in Central Florida which connects a five-county area. It is comprised of 39 intersections throughout the Downtown Orlando area that have TSP systems (11).

In July 2014, the Florida Department of Transportation (FDOT) identified key factors for the successful application and implementation of TSP systems in metropolitan arenas. The core skeleton of the guidelines is consequent from the USDOT’s 2005 *TSP: A Planning and Implementation Handbook*. The research involved a complete overview of TSP systems planning, installation, operation, and evaluation. The information provided in the FDOT report, however, was based on the input provided by numerous municipalities with successful TSP systems. This four-phase process is critical for the application, guidance, and strategy required of all stakeholders involved. The most important key point that heavily impacts the success of a TSP system is to involve and coordinate with all affected agencies. According to (11) there are seven key factors for choosing the primary stakeholders of TSP systems project. The seven key factors are the following:

- Geography – interagency communication
- Jurisdictional Responsibility – maintenance
- Type of Transit Agency – public or private ownership, interagency relationships
- Funding – state, federal, or private and guidelines
- Technology – personnel training and involvement
- Extent of project – scope of work
- Extent of Institutional Knowledge – prior knowledge equals less stakeholders

Stakeholders for most projects include individuals involved in the following categories: planning, scheduling, technology, and finance. In all TSP system projects the core stakeholders should comprise at least two primary points of contact, i.e., Project Manager and Traffic Operations Engineer. With the proper stakeholders involved project goals, approach, and timeline are more easily achieved. For example, signal operators training is very important to the operational efficiency of the TSP system. Guidelines and expected outcomes should be used as a foundation in the early planning phase of every TSP system project. Application of these principals have been shown to pay dividends throughout project and at completion. Research discovered that TSP can be activated during incident or emergency conditions. For example, research suggested to use TSP during urban evacuations in cases where police-assisted traffic controls are not an option (15). With only a finite number of available units, buses were making multiple trips in and out of the evacuation zones. Hence, it is within reason that some regional municipalities would want to allow transit priority to hasten trips made by buses. Nevertheless, studies in the past had shown that, during time of high roadway demand transit priority causes greater delays for vehicular traffic.

In Orlando, Florida a research was conducted for implementation of TSP on a test corridor along International Drive (I Drive) to see if it was successful and justified for expansion to a regional implementation of TSP for bus tie-ins to the new regional SunRail commuter rail in Central Florida (16). The research was conducted by using a microsimulation platform to compare Unconditional and Conditional TSP with the No TSP scenario. The results of the simulation demonstrated that Conditional TSP notably improved bus travel times with a very little effect on the cross-street delay. Unconditional TSP resulted in notably crossing street delays at few intersections with only a minor improvement to bus travel time compared to both Conditional TSP scenario.

3. METHODOLOGY

In this research study, we decided to do a study on TSP in South East Florida, therefore, one case study have been identified by the research team which are very important for Florida Department of Transportation (FDOT). After meeting with different local agencies such as Palm Tran in West Palm Beach, Palm Beach Metropolitan Planning Organization in West Palm Beach, and FDOT district 6 in Miami it was decided to evaluate and implement TSP at Okeechobee Blvd in West Palm Beach, Florida. By following the suggestion given by the Traffic Division of the Palm Beach County in West Palm Beach it was decided that the area of research study at Okeechobee Blvd is bordered from Haverhill Rd (West border) to Church Street (East border) with 9 signalized intersections. Okeechobee Blvd is located in West Palm Beach and is a major and very congested corridor which has few industries in the region, it connects the west part with the east.

This section of the paper is organized as follows: (A) area selected for the research study (B) use of simulation platform PTV VISSIM (C) a newly modified overview of the established guidelines from Montgomery County report (7) (D) field data collection (E) simulation.

(A) The area selected for the research study is bordered from Haverhill Rd to Church St in Okeechobee Blvd, West Palm Beach, FL. The area is selected due to the growing of traffic congestion and availability of public transportation in the area, to serve high demographics needs. The area is comprised of 2.6 miles. The list of intersections of the selected corridor for the simulation model are in Table 1:

Table 1: List of Intersections at the Studying Corridor

1.	Haverhill Rd
2.	N Military Trial
3.	Biscayne Blvd
4.	Indian Rd
5.	Palm Beach Lakes Blvd
6.	Spencer Drive
7.	Loxahatchee Drive
8.	North Congress Avenue
9.	Church Street

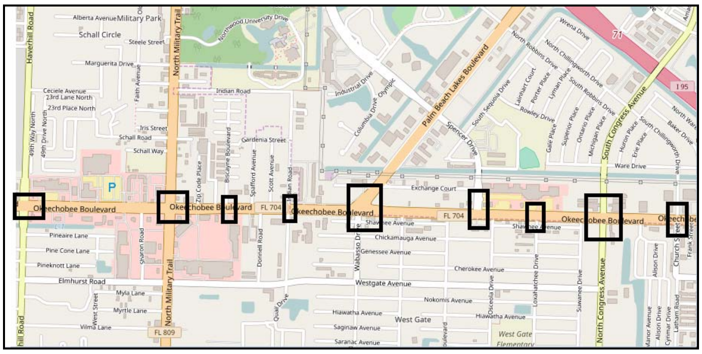

Figure 1: Map displaying area for simulation model

(B) In this research study, use of micro simulation platform PTV Vissim is selected due to its wide range of advantages. Firstly, for its multimodality as dedicated motion models for bicycles, motorized traffic and pedestrian makes a very valid evaluation and a realistic depiction of all traffic related aspects probable. Secondly, PTV Vissim has maximum precision of detail with its links and connectors conception, the network can be mapped in detail and model various geometries from any standard node to complex intersections. Thirdly, it allows TSP and Queue jumper's technology to be tested in different environments and their advance autonomous vehicle collaborations integrated in a single tool. Fourthly, the software ease of use is incredible. Moreover, its integration capacity is good and its software package provides a good platform for intensive research. Furthermore, the visualization is in 2D and 3D.

(C) By following the newly modified established guidelines findings in the research are as follows:

1. By following the set of mandatory feasibility traffic operations criteria.
2. By qualifying to attend secondary set of 7 weighting factors based on geometric and transit operations.

- By following the set of mandatory feasibility traffic operations criteria:

Volume-to-capacity ratio: This measure is defined as the ratio of the traffic volume to capacity. Capacity is the maximum hourly rate at which vehicles can reasonably be expected to proceed through an intersection under prevailing roadway, traffic, and control conditions. A V/C ratio at or above 1.0 indicates that an intersection operates at or beyond its capacity. The V/C ratio is an indicator of where mobility might be an issue due to roadways having traffic volumes that exceed their capacity. For the purposes of TSP, **an ideal V/C**

ratio would be between 0.65 and 0.85. At greater than 0.85, the intersection is approaching capacity and the opportunities to grant TSP requests may be limited. At less than 0.65, the intersection would likely be operating with minimal delay and the effectiveness of TSP may be marginal.

<u>*Slack Time*</u>: Slack time is defined as the additional time in a cycle that is more than the minimum split times for the phases at the intersection. Minimum split times for a phase may include required clearances minimum vehicle green, yellow and all-red vehicle clearances, pedestrian WALK and FLASHING DON'T WALK clearances. If slack exists, this time can be reallocated from one phase to another phase, for example to provide TSP by extending the mainline green time and shortening the side street green. Slack time for TSP can typically be taken from the conflicting and/or left-turn phases. The minimum slack time needed in a signal cycle during any weekday peak hour to satisfy this mandatory criterion is **at least 5 seconds**, provided that minimum pedestrian clearances for the conflicting phases, and minimum splits for the left-turn (5 seconds of green + yellow + all-red) are all met.

- By qualifying to attend secondary set of 7 weighting factors based on geometric and transit operations

<u>*Overall Corridor Ranking*</u>: The overall corridor ranking is a qualitative assessment of the relative benefit to transit operations that TSP may provide versus the likely impact to overall traffic operations. The influencing metrics include average bus speeds, average bus productivity (passengers per revenue mile), number of failing intersections and vehicle speeds. Corridors with high bus frequency and ridership, but low bus speed and a low number of failing intersections would be considered more attractive for prioritizing TSP deployment.

<u>*Cross-Street Facility Type and Transit Service*</u>: This factor considers whether the intersecting roadway at a signalized intersection is a primary facility (e.g. major highway or principal arterial). If the intersecting facility is not a principal arterial it is more likely that TSP will be beneficial as side street traffic operations can be disrupted temporarily and the side street is not carrying other bus routes. Also, as part of this criterion, it was noted if the cross street had bus transit service.

<u>*Bus Stop Location*</u>: This factor considers whether the bus stop location is a near-side (before the stop line) or far-side (after the stop line). For TSP-only applications (e.g. not combined with any other priority treatments) a far-side stop is preferable due to dwell time variability and to avoid false calls for TSP.

<u>*Presence of Other Priority Treatments*</u>: This factor considers the presence of other priority treatments for transit vehicles such as a queue jump or dedicated lane. The combination of TSP with these other investments can significantly improve travel time reliability and reduce signal related delay for buses over the provision of TSP alone.

<u>*Average PM Peak Hour Bus Speed on Approach:*</u> Based on AVL data, the average bus speed on each link approach can be used as a good indicator of current transit operations. Although influences other than signal delay such as dwell time and stop locations may also reduce bus speeds, when compared to average vehicle speeds a larger speed differential can indicate a greater benefit of TSP in improving bus travel time reliability. A maximum 10 mph average bus speed threshold was set for satisfying this weighting factor.

<u>*Peak Hour Bus Passengers*</u>: Based on ridership data, the average bus passengers on each link approach can be used as an indicator of TSP's ability to improve person-throughput along a corridor. A combined link ridership of 100 passengers per peak hour per direction was set for satisfying this weighing factor.

<u>*Bus Frequency*</u>: The route density and headways on each link approach can be used as a possible indicator of the frequency of TSP requests. A minimum 5 buses per hour was set for satisfying this weighting factor.

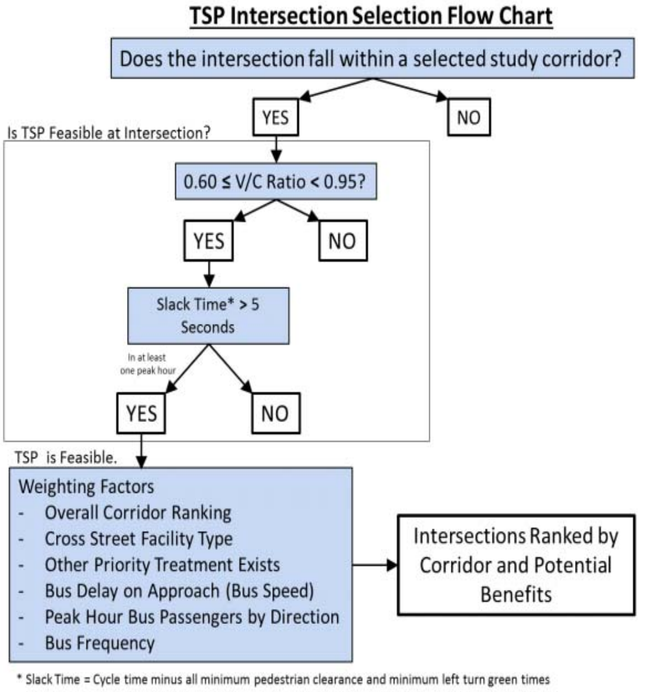

Figure 2: Flow Chart for TSP Intersection Selection (7)

After determining the feasibility of TSP at each intersection using the mandatory criteria the intersections are ranked based on the weighting factors to show the relative likelihood that they will provide significant TSP benefits to transit without significant negative impacts to traffic operations.

The intersections that meet the most thresholds are likely to produce more benefits than those that meet the fewest (1 or 0). Likewise, the more intersection along a corridor that meet a high number of weighting factor thresholds the more likely that coordinated TSP implementation within the corridor will produce benefits.

(D) First, the field data was collected for different TSP scenario from Haverhill Rd to Church St in Okeechobee Blvd,

Florida. These data were then analyzed and modeled using microsimulation platform VISSIM.
(E) The simulation model for this research study is built successfully, and now the model is in the calibration and validation phase.

4. CONCLUSION AND FUTURE WORK

For the purpose of implementing TSP and Queue Jumpers a microsimulation model was coded in VISSIM to record travel time, cross street delay and overall network performance. After following the established guidelines, the preliminary results show improvement in travel times in each directional of travel and various scenario that implemented some of the transit preferential treatments, when compared to base scenario. For the preliminary results the authors narrowed the V/C ratio from 0.50 to 0.85 for the selected intersection and keeping the slack time to 5 seconds. The analysis of the V/C ratios on the side streets shows that these streets have enough capacity to lessen the negative impacts of the preferential transit strategies. The study's primary purpose is to develop a guidance for the transit agencies in identifying corridor conditions that warrant TSP and queue jump. This research study, compares and evaluates existing guidelines and form new modified guidelines for transit signal priority. The next steps are to execute a detailed calibration and validation the model to replicate with maximum accuracy of the simulation model and field scenario.

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