UTC Project Information	
Project Title	Next Generation Transit Signal Priority with Connected Vehicle Technology
University	University of Virginia and Morgan State University
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Funding Agencies	CVI-UTC (Tier 1 UTC)
Agency ID or Contract Number	TBD
Project Cost	$149,861.00
Start and End Dates	February 1, 2013 – January 31, 2014
Project Duration	1 year
Brief Description of Research Project	For years, Transit Signal Priority (TSP) has been proposed and studied as an efficient way of improving transit operations. It offers preferences to transit vehicles at signalized intersections and has been proven valuable in reducing transit travel time and improving schedule adherence and customer ride quality. Furthermore, it has been shown that TSP has the ability to cancel out the negative effects due to outdated timing plan [1]. The technology has been applied in many cities in Europe, Asia and North America. In the US, Seattle, Portland, Los Angeles, Chicago and other large cities have all implemented the TSP system [2]. Past studies showed that the benefits of TSP in terms of bus travel time savings vary significantly, as shown in Table 1. Among these 13 quantitative TSP studies we reviewed, the travel time savings ranged between 0.9% and 71%. It is noted that only one out of 13 studies investigates the performance benefits based on field test. This study evaluated TSP deployed in Arlington, Virginia [4], where the only field evaluation we found, the saving on bus travel time was by 0.9% but resulted in 1% increase on total delay. A closer investigation on that particular TSP system indicates at least two possible reasons. First, TSP logic is too simple (only green extension of 5seconds). Second, the progression between adjacent intersections is not coordinated. To be mentioned, there is no study has investigated the coordination of adjacent intersections for TSP. No research has completed combining TSP with connected vehicle technology. Currently, there is an ongoing project that aims to design a multi-modal intelligent traffic signal system that will operate in a connected vehicle environment – the Multi-Modal Intelligent Traffic Signal System (MMITSS) project. This MMITTSS project investigates TSP on a fairly high level basis and is a valuable guideline for TSP research. However, the project does not provide detailed TSP algorithm innovation.

	Apart from the previous mentioned shortcomings, there are several other challenges for the current TSP to be widely deployed. One big holding back is its adverse effect on side streets. Especially for intersections that are nearly operating at their capacity, the benefit of adding TSP is controversial [3]. Another potential challenge of the current TSP is timing. Because of the uncertainty on bus's arrival time, the TSP procedure usually moves a large portion of the green time from the side streets to the street where a bus is expected to arrive. In some worse cases, bus would arrive in the next cycle without taking advantage of any of the green time extend, while the vehicles on the side street keep waiting and accumulating delay time. Of course, this causes significant adverse effect on traffic condition. Finally, the third challenge is the problem of the conflicting TSP request. It is discovered that the current "first come first serve" way of solving conflicting priority request not only do no benefit but also shows negative impacts to the TSP system [6]. Very few researches have been conducted regarding how to resolve conflicting TSP requests of more than 2 buses. As presented in Table 1, all 13 quantitative TSP studies only investigated 1 bus scenario. Only one study was found researching resolve conflicting TSP calls: Zlatkovic et al. proposed a very simple logic which, in short, always provides priority first to the direction with green phase on [6]. This algorithm shows a benefit of more than 30% reduction on traffic light delay compared to "first come first serve". To be noted, the benefit is also measured from computer-based simulation. Based on the background information collected, it is clear that several aspects can be improved for the current state-of-the-arts in the TSP. First, combining TSP with connected vehicle technology is believed to be beneficial. This is because CV technology will provide better real-time information of bus location, and number of passengers to support more TSP possibilities. Second, with the help of CV technology, the logic of TSP could be more flexible instead of simple "green extension" and "red truncation." The CV-based logic will grant extra TSP green time more preciously to where it is most needed. The less waste of extra TSP green time, the less adverse side streets effect would be. Third, the logic of TSP should be able to resolve conflicting TSP requests from more than 2 transit vehicles. Fourth, the cooperation between adjacent intersections needs to be taken into consideration. Therefore, in this proposed project, the team will develop (i) a new TSP method that will fully realize the connected vehicle technology based two-way communications among multiple transit buses and traffic signal, and among the transit buses and vehicles (note that the VCTIR project underway by the UVA team only considers cooperation between the one transit and the signal), and (ii) the coordination method accounting for adjacent intersections where transit buses are bounded to travel. The research team will also put effort on evaluating the TSP logic: (iii) perform smart road

	operational test to ensure the proposed TSP logic harnessed by connected vehicle technology perform as expected, and (iv) field operational test to quantify the benefit of the proposed TSP logic.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	To maximally realize the two-way communications, the proposed TSP logic will allow cooperative control that traffic signal, transit bus, and vehicles work together, unlike conventional logic that a bus (or buses) approaching at an intersection sends priority request and the traffic control tries to accommodate it. In order to consider adjacent intersections, the TSP logic currently being developed in the VCTIR project will be enhanced. Again, the proposed research plans to utilize the connected vehicle technology allowing two-way communications among the vehicles including buses and infrastructure to develop next generation Transit Signal Priority (TSP) that does not have to rely on conventional TSP sensors.
Impacts/Benefits of Implementation (actual, not anticipated)	This study is still in progress, actual impacts and benefits of implementation will be determined in Winter 2014 when the study is completed. This page will be resubmitted in the next round of reporting to state these actual impacts and benefits.
Web Links • Reports • Project Website	http://www.connectedvehicleinfrastructure-utc.org/?q=node/21 https://rip.trb.org/browse/dproject.asp?n=33464