

An Intelligent Control System for Detecting and Progressing Platoons at Isolated Traffic Signals

A significant number of the Texas Department of Transportation's (TxDOT's) signalized intersections operate under isolated control. At many of these signals, it is not uncommon for an approaching platoon of vehicles from an upstream signal to face a red signal when it arrives at the stopbar. Often, these platoons are forced to stop because of a single vehicle on one of the conflicting approaches. This condition results in aggravation, excessive stops, and higher delay to motorists in the platoon. In this project, Texas Transportation Institute (TTI) researchers developed and field-tested an intelligent traffic control system for detecting platoons approaching a traffic signal and for progressing detected platoons.

What We Did . . .

Researchers divided the research and development work into several major tasks described below.

Task 1. Requirements Analysis and System Architecture

Providing platoon progression at a signal requires the ability to detect each approaching platoon and ensure that the signal is green when the first vehicle in the platoon arrives at the stopbar. This requirement translates into the need to install an advance detector trap. Furthermore, the signal may be serving a conflicting phase at the estimated platoon arrival time. Any such phase must be quickly, but safely, terminated to provide a green signal to progress the detected

platoon. Researchers decided to use signal preemption to achieve this objective.

An additional objective was to ensure that the system is able to operate under a wide variety of traffic conditions, without adversely affecting vehicles at conflicting phases. Achieving this objective required the ability to monitor phase and detector status in real time and taking appropriate action in real time. In our system architecture, an external personal computer (PC) provides computational needs for executing these functions. We added a timer relay to provide fail-safe operation. Figure 1 illustrates the architecture of the platoon identification and accommodation (PIA) system developed in this project.

Task 2. Development and Testing of Algorithms and Software

In the first step, we developed the platoon detection and progression (PDP) algorithm. This algorithm uses two key parameters — number of vehicles in the platoon and the estimated arrival times, at the stopbar, of the first and last vehicles in the platoon — for initial platoon identification. Number of vehicles in a platoon (n) is a user-specified parameter that defines the smallest platoon to be progressed. In real time, the PDP algorithm keeps track of detections (time and speed)

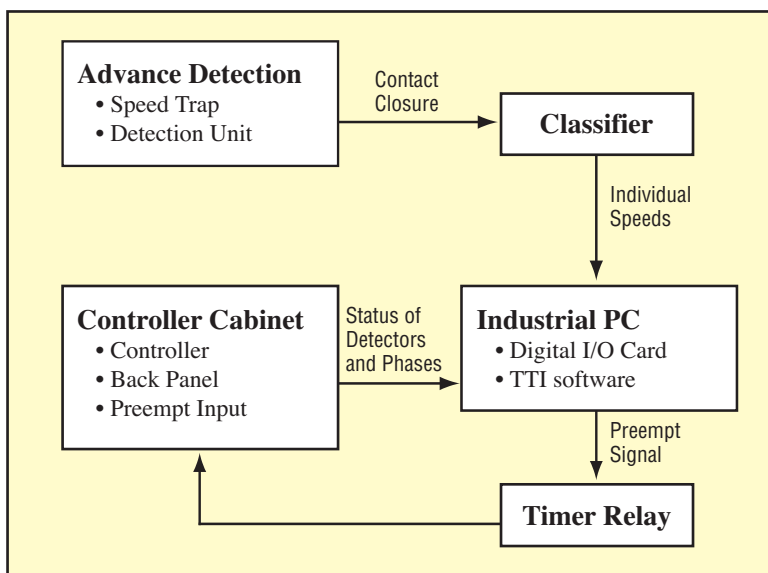


Figure 1. Architecture of PIA System.



for n consecutive vehicles and their estimated arrival times at the stopbar. A platoon exists if the difference between the estimated arrival times of the first and last vehicles in any group of n vehicles is less than a user-specified threshold (called cumulative threshold). Then, the algorithm uses these two estimated arrival times to schedule (the start and end times of) a low-priority preemption, and switches to the platoon extension mode. In this mode, it evaluates each additional vehicle to determine if it is a part of the platoon identified earlier or if it needs dilemma-zone protection.

In the next step, researchers developed the PDP software and tested it using hardware-in-the-loop (HITL) simulation using the Corridor Simulation (CORSIM) program. The researchers also conducted simulation studies to identify optimal locations of advance detection for low- and high-speed approaches. Then, the researchers added software routines to provide an interface to the controller cabinet. This interface uses a digital input-output card installed in the computer to obtain the phase and stopbar-detector status from the controller in real time and send a low-priority preemption signal to the controller.

Task 3. Site Selection, Hardware Acquisition, and System Testing

The project required the researchers to install and test the PIA system at two sites. From an initial list of several potential sites, researchers selected one site located in College Station (CS), Texas, and one site located in George West (GW), Texas. The CS site is in a typical suburban setting with an at-grade railway crossing with a significant number of trains. The main road runs north-south and has high-speed single-lane approaches with left-turn bays.

Traffic characteristics and geometry at the GW site are significantly different from those at the CS site in that its main approaches (US 281) are low speed with two through lanes and left-turn bays in each direction. Because of two nearby schools, there are significant crossing school buses and pedestrian traffic during mornings and late afternoons. One of the schools has an open campus with significant

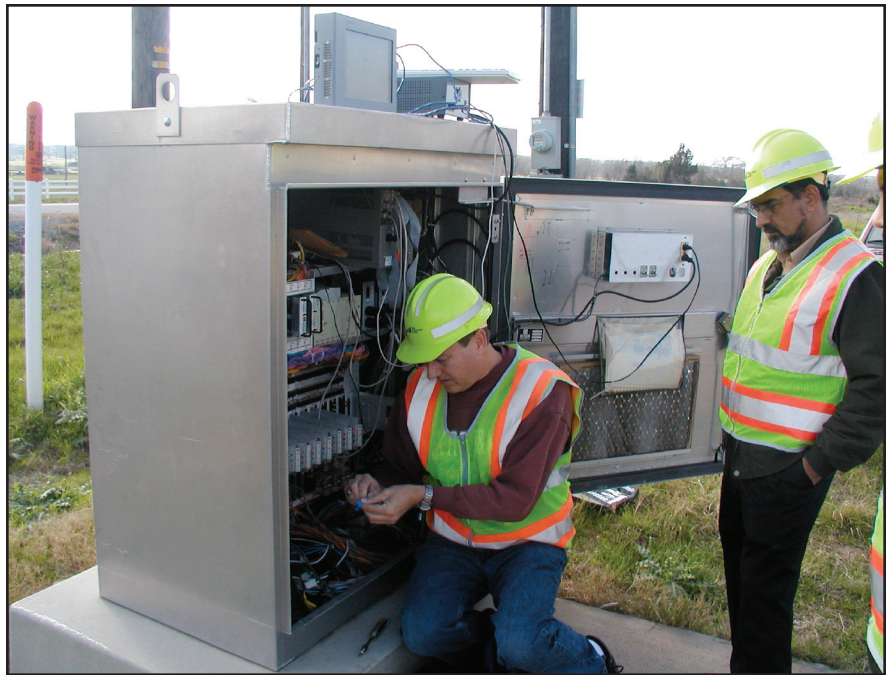


Figure 2. Researchers Installing the System in College Station.

pedestrian activity during lunch time. The school zone flashers are activated three times during each working day. Because US 281 is a major north-south highway, there is significant truck traffic to/from Mexico.

After site inspections, researchers ordered the hardware needed to install the PIA system at these two sites. The CS site already had advance detector traps 1000 ft upstream of the stopbar on the southbound approach. For the GW site, researchers decided to use an Iteris video-detection system. TxDOT staff arranged for the acquisition of an Iteris intersection model processor, a solar panel, batteries, and two wireless cameras for use at this site. The existing controller cabinet in GW did not have room for additional equipment, so TxDOT installed an additional cabinet there. In addition, TxDOT installed a pole for mounting the video cameras, the solar panel, and a pole-mounted cabinet for the backup batteries.

The researchers developed a cabinet-in-the-loop (CITL) simulation system in the lab for comprehensive testing of the full system before installation. This system is similar to an actual implementation, except that the cabinet responds to simulated traffic generated by CORSIM instead of real traffic. The researchers used this system to ensure that all

components of the PIA system were working as intended. Using this setup, the researchers were able to find and fix some discrepancies in the PIA software.

Field Implementation and Testing of the PIA System

In December of 2002, the researchers installed and turned on the PIA system at the CS site (Figure 2). Field-testing revealed the need to enhance the platoon progression portion of the PIA software. The researchers made these enhancements to the software. Starting in March of 2003, the researchers made several multiple-day trips to the GW site. During these trips, the researchers installed the PIA system, evaluated several issues related to the use of video detection for obtaining speeds of individual vehicles, and turned on the system. Different video detection options studied included various locations and positions of the video camera and a comparison of Iteris intersection and freeway models. Evaluation of each combination required defining/calibrating video detectors and comparison with data from a radar gun and a temporary trap installed for this purpose.



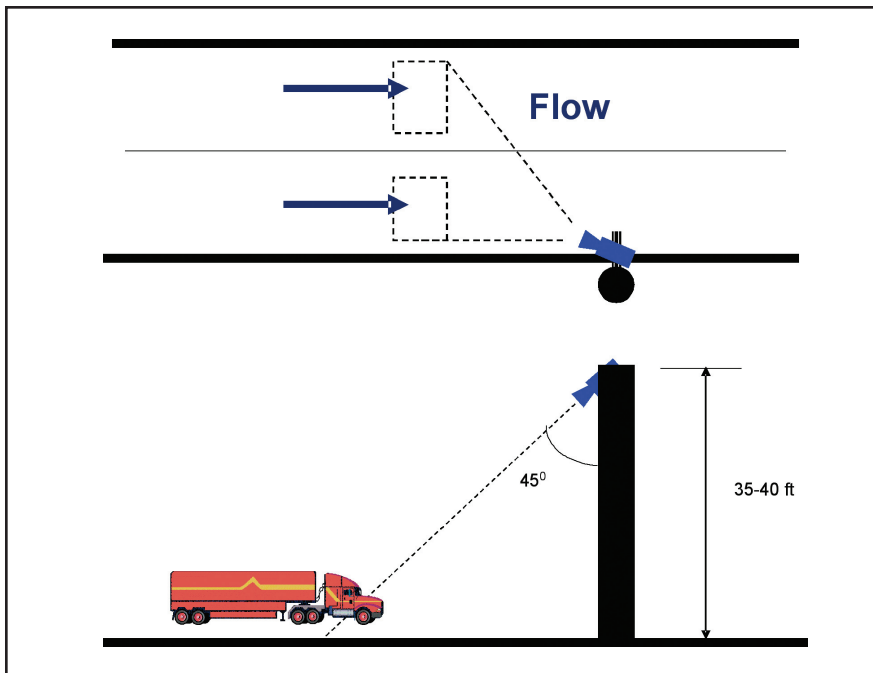


Figure 3. Camera Installation Guidelines for Video-Based Advance Detection.

What We Found . . .

Optimal Algorithm Parameters and Location of Advanced Detection

From the simulation studies using HIL simulation, researchers made the following conclusions:

- The number of vehicles for platoon detection should be set equal to four.
- The cumulative headway should be set equal to 20 seconds. Cumulative headway is the difference between the estimated arrival times at the stopbar of the first and last vehicles in the platoon.
- For a low-speed approach, advance detection should be provided 600-700 ft upstream of the stopbar.
- For a high-speed approach, advance detection should be provided 1000 ft upstream of the stopbar.

From simulation studies, we also found that the system works as intended when algorithm parameters are set to the above values.

Inductive Loops versus Video Detection

From the field studies, we found that inductive loops are more reliable and accurate than video detection for measuring speeds of individual vehicles. We also found that the Iteris freeway model is better than the Iteris

intersection model for this purpose. The Iteris freeway model uses a single loop for emulating a detector trap, and detection errors occur for vehicles accelerating or decelerating when passing over the detection zone. Both video-based systems performed well for passenger cars. The biggest problem observed with video-based systems was a significant number (up to 50 percent for the Iteris intersection model) of double detection of trucks. This error occurred when the roofs of the cab and the trailer had significantly different colors and the system detected one truck as two vehicles. In such cases, the speed measurements were way off the actual speeds. With optimal camera placement (location, height, and angles), researchers were able to significantly reduce these double detections.

System Performance

Field observations from the two sites showed that the PIA system was able to accurately detect platoons and their arrival times when it received accurate detections and speeds of individual vehicles. The ability of the algorithm to provide platoon progression depends on constraints placed by the user and the signal status at the time of platoon detection. If the priority phase is in service at that time, the algorithm efficiently progresses the platoon by extending this phase. If the priority phase is red, the system

services all conflicting phases that cannot be skipped. Phases that cannot be skipped to provide preemption are specified by the user during configuration of the PIA software.

In addition, the system performance depends on controller setting (i.e., minimum and maximum phase times and gap settings). In general, the least restrictive settings improve platoon progression at the expense of conflicting phases, while the most restrictive settings reduce the algorithm's ability to progress all platoons.

The Researchers Recommend . . .

The PIA system can be implemented at additional sites by using the software developed by TTI and by acquiring additional hardware needed for the system. The researchers recommend that the PIA system be implemented at other isolated signals where platoon progression is an important objective. Video-based detection using the Iteris system can be used at sites where trucks are a small fraction of the traffic stream. In this case, it is preferable to use the Iteris freeway model installed as shown in Figure 3.

The equipment cost can be significantly reduced and software efficiency of the PIA system can be improved by implementing the following enhancements to the system:

- Replacing the hardware classifier with a software classifier developed recently by TTI researchers will save approximately \$3000 in equipment costs. The software classifier can be easily modified to take care of any false and double detection.
- Standardization for TS-2 cabinets using bus interface units (BIUs) with serial ports will eliminate the need for a breakout panel (savings of \$1000 per site). TTI researchers have recently developed specifications for these BIUs and successfully tested the first batch manufactured by Naztec, Inc., of Sugar Land, Texas.

Researchers recommend that a follow-up project be initiated to incorporate the above implementation-based improvements and for field-testing of the modified/enhanced system.



For More Details . . .

The research is documented in the following reports:

Report 4304-1, *Guidelines for Installing an Intelligent Control System to Detect and Progress Platoons at Isolated Traffic Signals*

Report 4304-2, *Platoon Identification and Accommodation System for Isolated Traffic Signals on Arterials*

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TxDOT Implementation Status—December 2004

This research project involved the development of an algorithm and associated software for detecting and progressing platoons of traffic approaching an isolated signal on an arterial. As part of the project, researchers acquired necessary hardware for installing the system at two sites. TTI researchers have successfully developed and installed the proposed system at two sites and have demonstrated these systems to the TxDOT project panel. In its current form, the system is ready for installation at additional sites. However, additional modifications described above will reduce costs of implementing additional systems and provide standardization for TS-2 cabinets.

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