The Alameda Corridor – East IR/RIS Demonstration Project – Applying New Technologies
to Manage Grade Crossing Traffic

By

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ABSTRACT

The Alameda Corridor – East (ACE) grade crossing elimination and improvements program, now under construction by the Alameda Corridor – East Construction Authority along the Alhambra and Los Angeles subdivisions of the Union Pacific Railroad includes an Intelligent Transportation Systems (ITS) element to manage traffic at grade crossings. The ITS effort, known as the Intelligent Roadway / Rail Interface System (IR/RIS), is being developed as a separate “overlay” system that operates independently in the background to existing railroad communications, grade crossing predictors and vital warning systems at the grade crossings. The IR/RIS implementation is testing the feasibility of the following traffic management techniques:

- Display of motorist advisories regarding predicted or monitored blockages of grade crossings
- Adjustment of areawide traffic signal timing plans in response to detected train movements
- Modification of intersection timing plans to minimize the disruption associated with signal pre-emption

The IR/RIS Demonstration recently proved out a “Pilot” installation of Train Position and Speed Detectors (TPSD) in the vicinity of Pomona, California. The function of the TPSD units is to provide detection of presence, speeds and lengths of trains approaching a set of grade crossings in downtown Pomona with up to five minutes advance notice. Other elements of the IR/RIS architecture include:

- Independent Detection of Train Presence, Speed and Length
- Spread Spectrum Radio and Fiber Optic Field Communications
- Upgrade of Citywide Traffic Signal Control System Vehicle Detection
- Dynamic Message Signs (DMS)
- Closed-Circuit Television
- Traffic Control Center
- Train Predictor Software
- Rule-Based Interface to Traffic Signal Control Software
This paper describes the system architecture, concept of operations and status of deployment for the IR/RIS Demonstration Project, as well as some of the issues and accomplishments to date.
OVERVIEW

The Alameda Corridor – East (ACE) grade crossing elimination and improvements program includes a mix of new as well as traditional improvements to address mobility and safety concerns at some 55 grade crossings along the transcontinental main lines of the Union Pacific Railroad through the San Gabriel Valley east of downtown Los Angeles. Part of the “Jump Start” effort of the ACE Project includes an Intelligent Transportation Systems (ITS) element known as the Intelligent Roadway / Rail Interface System (IR/RIS) – the IR/RIS traffic management system is being developed as a separate “overlay” system that operates independently in the background to existing railroad communications, grade crossing predictors and vital warning systems at the grade crossings. The IR/RIS implementation is testing the feasibility of the following traffic management techniques:

- Display of motorist advisories regarding predicted or monitored blockages of grade crossings
- Adjustment of areawide traffic signal timing plans in response to detected train movements
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The IR/RIS system recently proved out a “Pilot” installation of Train Position and Speed Detectors (TPSD) in the vicinity of Pomona, California. The function of the TPSD units is to provide detection of presence, speeds and lengths of trains approaching a set of grade crossings in downtown Pomona with up to five minutes advance notice. With successful ability to detect and predict trains, the balance of the IR/RIS Demonstration has recently been bid for construction. Other elements of the IR/RIS system include:

- Development of Train Predictor Software with Rule-Based Interface to Traffic Signal Control Software
- Upgrade of Citywide Traffic Signal Control System Vehicle Detection and Central Software
- Provision of Dynamic Message Signs (DMS) and Closed-Circuit Television Cameras (CCTV)

This paper describes the IR/RIS system as well as experience gained to date in deployment of the system.
PROJECT BACKGROUND

Purpose and Objectives

The purpose of the advanced traffic signal element of the ACE Project is to apply emerging Intelligent Transportation Systems (ITS) technologies to address traffic operations at and near crossings that will remain at grade for the foreseeable future. The primary objective of the IR/RIS project is to provide a mobility improvement for locations which don’t warrant grade separation; specifically, to reduce motorist delay. A secondary objective is to achieve consequential safety benefits such as less risky behavior by motorists near crossings due to less queuing and reduced driver frustration.

Overlay System

In order to assure integrity of existing rail signaling and grade crossing warning systems, the IR/RIS system will operate as an independent “overlay” system with respect to the existing rail signaling and crossing protection circuitry. Although IR/RIS will have the capability to acquire data from the railroad, IR/RIS will not affect the operation of rail signal displays or grade crossing gear. In addition, IR/RIS will not over-ride or supplant existing provisions for traffic signal pre-emption at crossings where pre-emption is presently provided. (See Figure 1, which shows the IR/RIS system with separate train detection and control of the traffic management functions.)

This is a very important consideration since it means that the IR/RIS system will not be considered a “vital system” from the point of view of the Union Pacific Railroad. Therefore, the project will not need to have redundant, fail-safe design nor will the California Public Utilities Commission need to evaluate any direct impacts on the safety of the rail or grade crossing operations as a result of the operation of the project.

Prediction Capability

In order to provide adequate response time for the areawide traffic signal system to respond to train arrivals, the following criteria were established:

- Initial train prediction up to 5 minutes ahead of arrival at the first grade crossing, with an accuracy of about 15-20 seconds were selected as initial design parameters, based upon the existing grade crossing protection
circuitry and anticipated traffic signal timing parameters to be in effect in the traffic control zone.

- Updates to the prediction based upon additional train detectors, located at about 1 mile spacing along the approach trackage.

Use of Demonstration Project

Because the IR/RIS system is to utilize emerging technologies, development of and testing of prototype solutions is an integral aspect of the project development process. The prototyping is being facilitated by construction of a Demonstration Project. The Demonstration Project is to develop an operational system in a sub-area of the San Gabriel Valley that can be used to test and prototype the technologies and control schemes applicable to management of traffic in a rail corridor with at-grade crossings.

POMONA DEMONSTRATION SITE FEATURES

The ACE Board selected the City of Pomona as the site for the Demonstration Project. Pomona was selected for the following reasons:

- Roadway Network – The roadway system in Pomona is a grid system with major parallel arterial roadways both north of, and south of the rail trackage. There are additional collector / minor roadways which can serve to handle diverted movements. Perhaps more importantly, the street grid provides an interspersed mix of grade-separated (and proposed grade separations) with at-grade crossings between. Figure 2 depicts the downtown Pomona street grid – note the seven existing grade crossings (two will be grade separated in the future) and three existing underpasses. The boundaries of the IR/RIS traffic management zone are Holt and Mission to the north and south, and by Hamilton and San Antonio to the west and east.

- Rail Operations – There is a full range of sources of grade crossing occupancy in Pomona, including:
  - Frequent, long through freight trains that do not stop in Pomona
Occasional, long freight trains that slow or pause in Pomona

Peak period commuter trains

Occasional service to local industries with short freight trains (using local sidings and spurs)

Occasional service to the Chino Branch line, which connects near Reservoir Street within the Demonstration area

Infrequent moves of cars and motive power between the Colton Yard and the Riverside track, changing direction in Pomona

- Favorable Institutional Factors – All of the traffic operations that would be affected are wholly within the City of Pomona, and the principal elements of the system will not need to be implemented across jurisdictional boundaries. The City of Pomona is interested in participating in the Demonstration Project and has committed staff support to the effort.

SYSTEM REQUIREMENTS

In accordance with the project purpose and objectives, the following system requirements were identified to guide the conceptual design of the IR/RIS demonstration:

- Capable of adjusting traffic signals in vicinity of grade crossings to minimize motorist delays due to train operations

- Capable of overcoming problems of interruption of cross-street progressions due to mandatory pre-emption of traffic signals at grade crossings

- Capable of developing reduced queuing approaching crossings when gates are down

- Capable of providing motorist advisory signs advising of alternative routing to avoid long delays.

- Capable of interfacing with surrounding areawide traffic signal systems for purposes of developing regionally beneficial background timing patterns and for sharing information about traffic conditions
- Capable of acquiring information on train movements and predicting time and duration of crossing occupancies at least five minutes in advance

- Capable of analyzing train and traffic data to determine most appropriate strategies for adjustment of traffic signal timing plans and for display of motorist advisories

- Ultimately capable of providing remote display of processed data, for example, emergency responders would be able to determine the status of grade crossings and trains on approach for the purpose of selecting the most appropriate emergency response routes

- Ultimately capable of sharing information with adjacent and regional traffic control systems through the regional network

**IR/RIS ELEMENTS AND ARCHITECTURE**

The IR/RIS project includes the following elements, each of which is further described below:

- Independent Detection of Train Presence, Speed and Length
- Spread Spectrum Radio and Fiber Optic Field Communications
- Upgrade of Citywide Traffic Signal Control System Vehicle Detection
- Dynamic Message Signs (DMS)
- Closed-Circuit Television (CCTV) & Traffic Control Center
- Train Predictor Software with Rule-Based Interface to Traffic Signal Control Software

**Independent Detection of Train Presence, Speed and Length**

As noted previously, the IR/RIS project is being implemented as an independent overlay system and will not utilize existing rail signaling for train detection. One of the first ACE contracts for IR/RIS was a design-build contract for provision of Train Presence and Speed Detector (TPSD) units. The TPSD contract was bid as a non-technology specific procurement subject to meeting identified performance and cost criteria. ACE identified one responsive bidder to the specification and awarded the contract to a supplier of magnetometer technology. The Pilot implementation of the TPSD units has been completed and evaluated and ACE has authorized expansion of the
TPSD sites to the full Demonstration Project area, which includes approaches about five miles (8 km) distant from the downtown Pomona traffic control zone.

In addition to remote detectors, TPSD units will be emplaced at selected locations within the traffic management zone to detect stopped trains or switching movements blocking the crossings for extended periods of time – such movements can occur due to use of two industry spurs in Pomona, due to the use of an existing pocket track accessed via hand-throw switches, or by reversing movements to and from the Chino Branch line, which takes off at Reservoir Avenue immediately east of the traffic control zone.

The ACE TPSD is a state-of-the-art unit developed from commercially available components. As such, it was imperative to verify the detectors would be able to support the project requirements.

**Spread Spectrum Radio and Fiber Optic Field Communications**

The IR/RIS Demonstration project includes two primary types of field communications – spread spectrum radio and fiber optic lines. Spread spectrum radio has been incorporated into each field TPSD unit so that train detections can be beamed back to the control center at Pomona Station without need to provide land lines along the railway corridor which would be subject to disruption by railroad maintenance activity. In addition, Pomona, which is the ultimate maintainer of the system, was familiar with the technology due to existing public works applications. Within the public roadway rights of way, fiber optic communications lines are being provided to connect all of the traffic signal controllers within the Demonstration Zone with the traffic control center. These lines are being installed with specifications similar to those used for existing centralized roadway traffic control centers.

**Upgrade of Citywide Traffic Signal Control System Vehicle Detection**

In order for the roadway network to adjust to changed traffic patterns as a result of diversion advisories, the traffic signal system is being upgraded to provide a traffic responsive capability and interface with new central control software. The traffic responsive nature of the system requires provision of loop detection for all major approach movements as well as upgrade of local traffic signal controllers to “type 2070” to support more sophisticated controller software.
Dynamic Message Signs (DMS)

The purpose of the Dynamic Message Signs (DMS) is to advise motorists of conditions at downstream grade crossings, and, if warranted, to suggest drivers utilize alternative routes. For the Demonstration Project, the DMS units will be located in strategic positions upstream from the grade crossings – The location of the DMS units has been selected to maximize the likelihood that drivers who can see the signs will in fact be likely to utilize the grade crossings while providing adequate advance notice so drivers can select alternative routes in the event warnings are posted. The specification of the DMS units for the Demonstration Project in Pomona will be slightly smaller than the large units typically emplaced on freeways, e.g., the faces will be 3 x 6 foot (0.9 x 1.8 m), in keeping with the low scale urban character of downtown Pomona roadways.

Closed-Circuit Television (CCTV) and Traffic Control Center

Closed-Circuit Television (CCTV) is being deployed at a limited number of locations in the Pomona Demonstration project to allow for monitoring of conditions at the grade crossings as well as queues of traffic along Garey Avenue, one of the principal diversion routes. As such, the CCTV is primarily intended to support operation and evaluation of conditions in the Demonstration Project zone from the traffic control center. The site selected for the Pomona Demonstration project traffic control center is Pomona Station, the historic Southern Pacific Railway depot that presently serves as a focal point for the Amtrak and Metrolink stop in Pomona as well as a local bus transfer center. Pomona Station includes a sub-station of the Pomona police department, and will become the new site for housing the upgraded central traffic control equipment.

Train Predictor Software with Rule-Based Interface to Traffic Signal Control Software

The heart of the system is the train predictor software, which interfaces to the traffic control system through a rule-based traffic control module presently under development. The train predictor software obtains individual train observations from the field and tracks the movement of trains towards the Pomona traffic control zone. Predictions are made based upon the observed speed of the train and known characteristics of typical train operations, as determined by simulations run using a train simulator through the Pomona territory. The train predictor is capable of tracking the movements of trains through the Pomona subdivisions so that confirmation of expected arrival time is obtained before commands are issued to the traffic management software. Presently under development is a rule-
based software module that will transmit commands to the traffic control software based upon specified field conditions, as described in the following sections.

**TRAFFIC MANAGEMENT STRATEGIES**

**Micro Simulation Modeling Effort**

In work accomplished to date, the technical services team developed a traffic micro-simulation model of the Pomona traffic management zone. The simulation model was used to answer the following questions:

- What is the break-even point (with respect to duration of crossing blockage) at which point motorists can be assured of reaching downstream locations beyond the grade crossing by diversion as opposed to waiting for a train to clear? – The simulation model identified travel time savings of 100 seconds or more with diversion for blockages exceeding three and one half minutes in duration. (Figure 3, illustrates the diversion study results with a ten-minute crossing occupancy showing time savings in excess of 300 seconds.)

- Do the existing grade-separated routes across Pomona have enough capacity to absorb traffic that may divert based upon display of advisories on the message signs? – Traffic conditions for non-diverted traffic on the principal arterials were found to be essentially the same with diverted traffic in the mix.

- Should traffic be diverted to specific routes, or should drivers make independent decisions on alternative routes? – Evaluation of numerous route alternatives for each blocked crossing, along with the fact that each driver may be heading for a different direction downstream from the grade crossing, led the evaluation team to conclude using the simulation model that specific alternate routes would not be effective nor warranted in the Pomona demonstration.

**Rule-Based Traffic Response**

The technical services team has developed a table of rules that defines a concept of operations for how the DMS and traffic signal timing patterns will be adapted based upon the type of train event predicted. Table 1 indicates the
proposed rules governing response by the DMS and traffic signal pattern selection software based upon the most frequent detectable train events anticipated in Pomona. (Refer to Table 2 for an example of DMS message texts.)

In conjunction with the DMS advisories, the background traffic signal timing plans will be modified – during train passage for trains which warrant diversion, the traffic signal timing pattern will shift to reduce green time for movements which allow vehicles to proceed towards the grade crossings and green time for movements using the three existing grade separations will be increased.

One additional rule which will be tested is synchronization of frontage road traffic signals with train arrivals – the concept will be to anticipate the train arrival and manage the signal so that the green indication for track clearance is already active at the time the pre-emption call comes in to the controller cabinet, thereby avoiding the need to issue a separate track clearance phase which could potentially disrupt traffic operations.

PROJECT ACCOMPLISHMENTS TO DATE
At the time this paper was written, the basic technologies have all been proved out individually, and all of the principal acquisitions necessary to construct the full Demonstration Project are completed or underway. Completion of the Demonstration Project construction activities are expected to require about one year, after which time the testing, final system integration and evaluation will be accomplished. (Prior to that time, ACE intends to accomplish some initial evaluation using available portions of the system and analysis tools.)

To date the following key accomplishments have been attained:

- System Architecture Defined – The overall concept for the traffic management system and the principal elements was identified in the Project Implementation Plan presented to the ACE Board in August 2000.

- Railroad Corridor Communications Installed – The spread spectrum radio units for the Pilot implementation of the train detectors were installed in 2001. Problems with getting power to all units, either through utility company hook-up or expanded solar arrays were resolved in July 2002.
• Train Position and Speed Detector Pilot Constructed and Proved Out – The testing of the initial magnetometer array was completed in September 2002. Testing identified the need for a modified array that was installed in December 2002 and tested in January – February 2003.

• Train Prediction Software Coded and Installed – The “beta test” version of the grade crossing occupancy predictor software was developed in 2001 and installed in to the traffic control center where it is presently being used to verify TPSD operation and conduct train counts.

• Traffic Diversion Strategies Evaluated and Rule-Based System Responses Identified – Micro-simulation of analysis of the Pomona traffic control zone was accomplished in 2001 leading to the identification of traffic management rules in 2002.

• System Central Software Procured – After a lengthy process of evaluation of alternatives, a sole-source procurement of new traffic control software was accomplished in May 2003. The selected vendor is presently developing and interface module to accept the rule-based traffic management strategy commands from the grade crossing occupancy predictor.

• Field Traffic Devices Bid – Required elements for the field traffic devices (controller / system loop upgrades, DMS, CCTV and fiber optic field communications) were identified by June 2002 and an Invitation for Bid (IFB) was issued in July 2003. The field traffic devices procurement is the last major procurement envisioned for the IR/RIS project.

• Traffic Control Center Build-Out – Remaining components of the traffic control center (e.g., furniture & workstations) were identified by summer 2003. The City of Pomona will accomplish tenant improvements at Pomona Station.
CHALLENGES AND LESSONS LEARNED TO DATE

There have been a number of challenges encountered to date. The impact of most of the challenges has been a delay in deployment of the system due to a variety of factors including the scope and complexity of the groundbreaking project, local conditions which have affected all of the ACE procurements, and the difficulty of conducting a demonstration project within an agency process geared to conventional public works civil improvements. To date, the procurements have been within the budget limits initially established for the construct elements; however, there have been unanticipated soft costs associated with development of some of the technical provisions and with program administration. Key issues worthy of note include:

- Railroad Agreement – The IRRIS Demonstration Project was developed under a sub-agreement to the master railroad agreement for the ACE Project as a whole. As such, right-of-entry to construct the IRRIS improvements in the rail right-of-way was obtained after the master agreement. This occurred about one year after the initial construction items were bid out and awarded, resulting in a one-year start-up delay.

- Electric Power – The system design assumed conventional overhead power drops from the utility provider, and TPSD sites were selected to assure ease of access to potential power points of service. However, in the aftermath of electric utility deregulation and the power shortages experienced in 2001 in California, utilities were under extreme financial distress. The overall ACE program for grade separations anticipated maximum exercise of franchise agreements to control utility relocation costs. This provided a context such that when the ACE “Jump Start” construction (spot safety projects and IRRIS) came forward with early construction items, the utility provider was initially unwilling to provide cost-effective power connections.

The IRRIS response was to develop a solar-powered alternative, but the power draw of the field units exceeded the initial solar system capacity. The power requirement was finally resolved with more panels and batteries, by which time the utility provider had agreed to a more cost-effective means of providing service. As a result, the Pilot installations are powered by a combination of utility power and solar power. The Demonstration deployment of some twenty additional TPSD sites will utilize utility power wherever possible. The unreliability of power to the units occurred just as the pilot TPSD units were constructed, and
ACE was unable to test the magnetometer stations until reliable power was available, resulting in an additional delay of more than six months.

- Reliable Train Detection – The initial TPSD procurement would have allowed up to three competing technologies to be installed and tested, but there was only one technology proposal (e.g., magnetometers) that was deemed responsive to the specification by ACE. However, field testing indicated that the magnetometer arrays as initially proposed and installed were not capable of detecting presence for very slow (less than 3 mph / 5 kph) or stopped trains. The vendor proposed the addition of a presence magnetometer and modification of the system software. At this same time, a revised installation plan was proposed to the Union Pacific Railroad that emplaced the detectors closer to the rail, but below the zone typically disturbed by routine ballast maintenance. The upgraded arrays were proved out in January 2003 – given the cumulative impact of the rail agreement, problems obtaining power and the need to identify refinements to the magnetometer arrays, the project is significantly behind the originally anticipated deployment schedule. On the other hand, at this point in time most of the technical and institutional challenges have been met.

- Unanticipated Complexities to Integrate Railroad Block Signaling and Power Switch Status – At the time the Project Implementation Plan (PIP) was written, it was intended to include an interface that would allow IR/RIS to obtain the status of Union Pacific Railroad signal indications and power switch positions. This data was to have been used to refine the time of arrival estimate. This would have been accomplished by development of a “code line interface” capable of reading the rail control line data. After specifications of the existing systems were received by ACE, it was determined that development of the code line interface would result in project delay and would create a maintenance issue for the City of Pomona: Three separate systems were in use by the Union Pacific in the territory within the IR/RIS project, and the railroad was intending to consolidate the systems at an unspecified future date, at which time software developed to interface to the existing systems would require modifications. As a response to this concern, the technical services team will modify the train predictor to require confirmation of the train speed and/or speed profile prior to finalizing a train prediction for use in applying to the traffic management parameters.
• Delays in Selection of Central Traffic Management Software – The IRRIS project initially intended to “piggy-back” on a concurrent County of Los Angeles procurement for central software. However, at the time ACE needed to move forward, the County had not finalized their selection. As a result, ACE elected to develop its own review of available vendors and software. ACE proceeded with sole-source procurement in early 2003. In retrospect, the system software acquisition could have been de-coupled from the County process earlier. However, at present time the system software procurement is not on the “critical path” for Demonstration project completion, so this delay has had no measurable impact on progress.

• Delays in Field Traffic Device Procurement – Management and technical resources of the project were initially focused on the issues noted above affecting construction, testing and refinement of the Pilot TPSD units, since without these units the entire project would be in jeopardy. As a result, action in finalizing the proposed field traffic devices was deferred. However, after the scope and specifications for the field traffic devices was finally established, delays in procurement including determining whether to utilize a Request for Proposal (similar to the procurement used for the railroad corridor gear) or Invitation for Bid (similar to the ACE construction contracts) were encountered so that construction of the field traffic devices is now on the critical path (as opposed to the build-out of the train detectors, which was originally anticipated to be the controlling factor). In retrospect, it may have been better to proceed with the field traffic devices procurement regardless of the viability of the TPSD and related systems.

NEXT STEPS
At the time this paper was written, most of the key technical issues as well as nearly all of the procurements for the Pomona Demonstration have been resolved and or accomplished. Upcoming activities that are anticipated include:

• TPSD Build-Out – ACE has authorized expansion of the train detectors to the full Demonstration Project scope five miles out from the traffic control zone, using the refined magnetometer array. The ACE technical services staff will need to modify the train predictor software to process the revised
dataset that will be provided with the presence detector, including independent validation of train lengths.

- Field Traffic Devices Construction – All of the traffic control and surveillance devices will be installed in the Pomona traffic control zone including controller upgrades, loop detectors, CCTV, DMS, and fiber optic communications lines. The field traffic devices procurement includes provisions for the vendor to maintain continuity of the existing central control system, which resides at City Hall and then accomplish a cutover to the new control center at Pomona Station, using the upgraded version of the system software.

- Software Integration – ACE has procured new traffic management central software, including development of an interface module to link the traffic management system to the grade crossing occupancy predictor. ACE staff will develop the rule-based interface, which will accept the modified TPSD field data and issue commands to the traffic management system based upon a rule-based approach.

- Testing and Evaluation – As each element of the system is deployed, the individual components are tested and refinements are made as necessary. ACE anticipates conducting some initial evaluation of the system based upon available technology and a more comprehensive evaluation after completion of the entire system.

- System Expansion – ACE intends to export successful elements of the technology to other locations (e.g., jurisdictions) within the ACE Project area. Interest has been expressed by one of the ACE cities for obtaining train predictions for use by emergency services responders.
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Ten-Minute Crossing Occupancy
Table 1

**Rule Based Traffic Management Strategies**

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Table 2
Proposed DMS Sign Text