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16. Abstract

Hardware-in-the-loop (HITL) simulation is a new technique in traffic engineering that uses real traffic signal controller hardware to control traffic that is being simulated in a traffic simulation program. The tool allows traffic engineers the ability to assess modifications to traffic signal timing plans prior to deploying them in the field. The purpose of this implementation project was to 1) transfer the software components of the Hardware-in-the-Loop Traffic Signal Controller Evaluation System, developed by the Texas Transportation Institute (TTI) as part of the TransLink® Research Project (Project 0-1752), to the Texas Department of Transportation (TxDOT), and 2) demonstrate the capabilities and use of the system through a series of workshops.

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TTI'S HARDWARE-IN-THE-LOOP TRAFFIC SIGNAL CONTROLLER EVALUATION SYSTEM

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Kevin N. Balke, P.E. #66529.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. Guidance was provided by Henry Wickes, TxDOT project director; and Wade Odell with TxDOT's Research and Technology Implementation office. We would like to thank these individuals for the time and effort they made to make this project a success. We would also like to thank the Texas Department of Transportation for its support of this implementation project.

TTI's Hardware-in-the-Loop Traffic Signal Controller Evaluation System was originally conceived by Mr. Roelof Engelbrecht, who tragically passed away after an extended battle with liver cancer before this project could be completed. We honor him by dedicating this report and this simulation system to his memory.

Roelof J. Engelbrecht
1966-2004

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TTI'S HARDWARE-IN-THE-LOOP TRAFFIC SIGNAL CONTROLLER EVALUATION SYSTEM

Although it has been used extensively in the past in the aerospace and defense industries, hardware-in-the-loop (HITL) simulation is a new technique in traffic engineering. Typically, when a system consisting of a number of components is simulated, most of these components are emulated in software; however, when one or more components are pieces of equipment that are used in the actual system, it is called the "hardware-in-the-loop."

Hardware-in-the-loop traffic simulation uses real traffic signal controller hardware to control simulated traffic. This simulation is done by interfacing a traffic simulation model with one or more traffic signal controllers. The traffic simulation model is a computer model of the interaction of vehicles with each other, vehicles with the roadway, and vehicles with the traffic control system. In most traffic simulation models the traffic control system is emulated in software, but with hardware-in-the-loop simulation the emulated traffic control system is replaced with real traffic control hardware.

While the simulation runs, simulated vehicles drive over simulated detectors, generating simulated detector calls. These simulated detector calls are sent to the real controller hardware, resulting in phase changes in the controller. These phase changes in the real hardware are sent back to the simulation, specifically to the simulated traffic signals. The simulated vehicles then react to the simulated signals, for example, by stopping when the signal turns red. Figure 1 illustrates the data flow in the hardware-in the-loop setup.

Using traffic simulation has many advantages:

- It is less costly than field studies, and results are obtained quicker.
- It yields extensive measures of effectiveness, allowing for more comprehensive comparisons of alternative operating strategies.
- Traffic operations are not disrupted.
- Physical changes to the road network may be made.
- It is the only way to analyze future demand.
- The user has complete control over all variables, such as traffic demand.

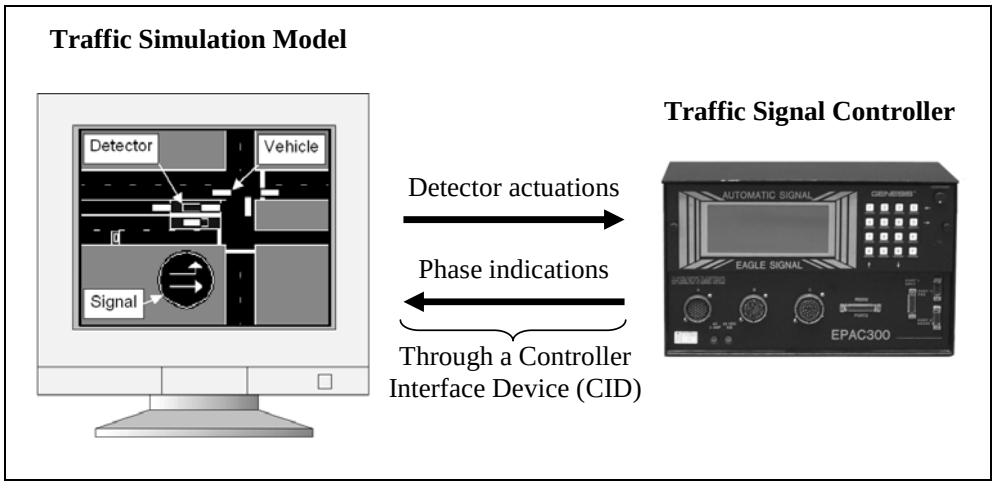

Figure 1. Flow of Data during a Hardware-in-the-Loop Simulation.

Combining traffic simulation with hardware-in-the-loop simulation yields additional advantages:

- It adds realism to the simulation since real traffic signal controllers are used.
- Some controller functions cannot be emulated in software, especially advanced features such as preempts and some coordination modes.
- The user can set up and test a controller in the lab with hardware-in-the-loop simulation and then deploy it directly in the field.

The TransLink® Laboratory is a leader in the field of hardware-in-the-loop traffic simulation. A distributed architecture for the simulation, control, and optimization of surface transportation has been developed at the lab to facilitate hardware-in-the-loop traffic simulation of large, multimodal transportation networks. This architecture allows the use of different simulation models and any type of traffic signal controller, including ramp meter controllers. Transferring these capabilities to TxDOT will allow the engineers and technicians to test hardware and their capabilities as well as evaluate and fine-tune strategies developed to improve traffic operations without deploying them in the field, saving a lot of resources as well as improving safety. This document describes the installation and use of the TTI Hardware-in-the-Loop (HITL) Traffic Signal Controller Evaluation System with Traffic Software Integrated System (TSIS) version 5.0 and later. An appropriate version of TSIS should be installed on the computer before continuing with these instructions.

GUIDELINES FOR PURCHASING EQUIPMENT AND SOFTWARE FOR TTI'S HITL TRAFFIC SIGNAL CONTROLLER EVALUATION SYSTEM

The following equipment is needed in order to use TTI's HITL Traffic Signal Controller Evaluation System:

- The software application TSIS version 5.0 or 5.1. The TSIS software is provided by the Federal Highway Administration and is available from the Center for Microcomputers in Transportation (McTRANS) at the following address:

  McTRANS Center
  P.O. Box 116585
  Gainesville, FL 32611-6585
  Phone: (325) 392-0378
  Toll Free: 1-800-226-1013
  http://mctrans.ce.ufl.edu/

- The TTI HITL Simulation Software Installation CD.
- A TS1 or TS2 traffic controller and a TS1 or TS2 controller interface device (CID). If you are using an Eagle or Naztec TS2 controller, you need to use a TS2 CID (Naztec or Eagle) with it. On the other hand, if you are using a TS1 traffic controller (Eagle or Naztec), you need to use a McCain TS1 CID with it.
- A TS2 cable and an RS-232 cable that usually come with the TS2 CID order.
- A personal computer (PC) with a minimum of 1 Gigahertz central processing unit (CPU) and 512 megabytes (MB) of random access memory (RAM), running one of Microsoft's operating systems: Windows NT, Windows 2000, or Windows XP.

PRODUCTS AND DELIVERABLES

Table 1 lists the components of the Hardware-in-the-Loop Traffic Signal Controller Evaluation System that were developed as part of this project. Copies of official deliverables can be obtained with permission from the TxDOT Research and Technology Implementation (RTI) office.

Table 1. Name and Description of Hardware-in-the-Loop Traffic Signal Controller Evaluation System Products.

TxDOT Product #	Product Name	Product Description
P1	Hardware-in-the-loop simulation system core software	This software program is needed to establish the connections and communications between the traffic signal controller and the TSIS/CORSIM simulation program. It is contained on the HITL Simulation Installation CD and is installed automatically during the installation process.
P2-P4	Interface software for different manufacturers of TS1/TS2 signal controllers	This interface software allows the hardware-in-the-loop software to communicate with the following controller interface devices from different signal manufacturers: Naztec TS2 CID, Eagle TS2 CID, and McCain TS1 CID. This software is located on the HITL Simulation Installation CD.
P5	CORSIM interface software	This software program allows the HITL core software system to interact with the TSIS/CORSIM simulation software. This program is included on the HITL Simulation Installation CD and is installed automatically during the installation process.
P6	Electronic suitcase tester software	This program, called "Snooper," is a utility program that allows the user to see phase indications, and to see and place detector actuations to the controller. It provides similar functionality to a traditional TS1/TS2 suitcase tester, but it can also operate during a simulation. The software can be used to place calls for preemption and pedestrian phases in a simulation scenario. This program is included on the HITL Simulation Installation CD and is installed automatically during the installation process.
P7	Data logging software	This program, called "Data Logger," is a utility program that records changes in the status of the inputs and outputs of the traffic signal controller through the controller interface device. It is a useful tool in monitoring changes in the traffic signal controller and can be used to compute performance measures such as phase and interval durations, cycle lengths, etc. This program is included on the HITL Simulation Installation CD and is installed automatically during the installation process.
P8	Hardware-in-the-loop simulation system configuration software	This software program automatically installs and configures the HITL simulation system on the user's computer. It installs the core HITL simulation software, installs all of the interface software, and configures the system to run based on the version of TSIS already loaded on the computer (TSIS 5.0 or TSIS 5.1). This program is included on the HITL Simulation Installation CD.
P9	User's guide	A user's guide was prepared and included on the HITL Simulation Installation CD. The user's guide provides instructions for installing the HITL system on the computer and instructions for executing an HITL evaluation. Installation troubleshooting tips have also been included in the user's guide.

Table 1. Name and Description of Hardware-in-the-Loop Traffic Signal Controller Evaluation System Products (continued).

TxDOT Product #	Product Name	Product Description
P10	Guidelines for purchasing hardware-in-the loop simulation equipment and software	Hardware and software specifications needed to establish an HITL system were developed. These purchasing specifications are contained in the user's guide on the HITL Simulation Installation CD. They are also contained in this report.
P16	Technical support—frequently asked questions	These include solutions, frequently asked questions, and troubleshooting reports encountered during the demonstration workshops. These Frequently Asked Questions are included at the end of this report.

DEMONSTRATION WORKSHOPS

TTI conducted a total of five, one-day demonstration workshops around the state highlighting the functionality and potential uses of TTI's HITL Traffic Signal Controller Evaluation System. The dates and locations of these workshops are shown below:

- Traffic Signal Office, Traffic Management Division – July 8, 2005;
- Bryan District – July 14, 2005;
- Waco District – July 28, 2005;
- Corpus Christi District – August 12, 2005; and
- Fort Worth District – August 22, 2005.

As part of this workshop, TTI went to the TxDOT district offices, installed the system on equipment provided by the districts, and provided district personnel with hands-on instruction on setting up and executing a hardware-in-the-loop simulation. Each participant was provided with a handout (see TxDOT Products 5-1752-01-P11 through P15) that provided step-by-step instructions that showed users how to run a hardware-in-the-loop simulation, and how to make traffic volume, signal phasing, detectorization, and geometric changes in the CORSIM files so that local conditions could be modeled more directly. TTI provided each district with example CORSIM files for a T-intersection (three legged), a standard intersection (four legged), a tight diamond interchange, and a wide diamond interchange. These were provided to the district on a CD.

TECHNICAL SUPPORT AND FREQUENTLY ASKED QUESTIONS

Listed below are a series of frequently asked questions and solutions to problems encountered during the workshops or in the operations of the system.

QUESTION: ***My PC using the HITL software does not have a serial port. Is there any way that I can use the HITL system through my USB port?***

ANSWER: Use a USB-to-serial conversion cable that has similar specifications to Product #540-0070 (RS-232-to-USB converter cable) available at www.zworld.com for $39.

QUESTION: ***I am using TSIS 5.1. When I start the HITL simulation, I get the following error message: "Failed to load the ActiveX control for the TTI Hardware-in-the-Loop Simulation Tool." What do I do now?***

ANSWER: When using TSIS 5.1, configure the TTI Hardware-in-the-Loop simulation tool () manually. Instructions for manual configuration are included in the appendix of the user's guide.

QUESTION: ***I made a change in the ". ini" file; however, when I run the simulation, it doesn't appear to reflect the changes that I've made. What am I doing wrong?***

ANSWER: After any change is made to the ".ini" file, you must reinitialize the controller interface device software. This requires you to close and reopen the ".exe" file in the Hardware-in-the-Loop subdirectory.

QUESTION: ***When using an Eagle EPAC-300® controller, pedestrian activity is seen in overlap buttons and overlap activity is seen in pedestrian buttons in the Snooper. Why does this occur?***

ANSWER: This can happen if the controller was previously operated in the TEXAS DIAMOND MODE (Alternate Sequence 16-18) and has been switched to operate in the FULL FUNCTION MODE. When using the controller in the FULL FUNCTION MODE, the channels for pedestrian phases 2, 4, 6, and 8 need to be swapped with the channels for the overlap phases as seen below.

Channel 9: Overlap A	Channel 13: Pedestrian Phase 2
Channel 10: Overlap B	Channel 14: Pedestrian Phase 4
Channel 11: Overlap C	Channel 15: Pedestrian Phase 6
Channel 12: Overlap D	Channel 16: Pedestrian Phase 8

QUESTION: I'm running TSIS 5.0, and I can't seem to get the simulation started. What could be the problem?

ANSWER: When using TSIS 5.0, the HITL simulation starts when the TTI Hardware-in-the-Loop Simulation button () is clicked. The user doesn't need to click on the  icon to start the simulation. Hence, if the user clicks on the HITL simulation a second time by mistake, the simulation may not work properly. The user cannot even terminate simulation in the normal fashion. In such a case, TSIS 5.0 needs to be terminated by opening the Task Manager and ending the TSIS task. Then the user needs to open the folder where the TSIS case file is residing. If a LU7 file is in the folder, delete the LU7 file. TSIS 5.0 should run normally after that.

QUESTION: I modified my ".sdi" file to add protected/permitted left turns at an intersection, and I got a "CORSIM threw an exception" error message. What did I do wrong?

ANSWER: Check the ".sdi" file to ensure that the left-turn movements have the appropriate left-turn and associated through phases specified.

QUESTION: After hooking up the CID and the controller, I am unable to establish communication with the CID from the HITL software. What do I do now?

ANSWER: First, try powering down all the components and restart them. Make sure that all the components are connected and powered up *before* the controller is powered up. If using a Naztec TS2 CID, you should install the testbox software supplied by the vendor. Start the software using the  icon. Using the toolbar at the top of the software, connect to the controller. You should be able to establish communication with the controller. You can then close the Naztec testbox software and connect to the CID using the HITL software.

QUESTION: ***I've tried everything, and I still can't get it to work. Who can I contact?***

ANSWER: If you have problems setting up the TTI HITL simulation software setup or running it with the TSIS software, please contact the Texas Transportation Institute HITL technical support team at one of the following numbers:

Hassan Charara	phone: (979) 845-1908	e-mail: h-charara@tamu.edu
Srinivasa Sunkari	phone: (979) 845-7472	e-mail: s-sunkari@tamu.edu
Kevin Balke	phone: (979) 845-9899	e-mail: k-balke@tamu.edu