HARDWARE-IN-THE-LOOP SIMULATION SYSTEM INSTRUCTION MANUAL

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Purpose of Hardware in the Loop Simulation (HILS):

A variety of signal phasing and timing alternatives have been developed over time, some, such as adaptive solutions are complex and can require extensive testing and adjustment for each specific use case to realize operational and safety benefits. This becomes especially important when considering fluctuations in vehicle loading and travel patterns that arise over time. Drastic changes in these aspects may require retiming or adjustments to be made; These can be done in the field but present the risk of uncertain outcomes and additional cost expenditures. As an alternative option, simulation modeling has been noted to be an efficient avenue for reviewing signal timings and testing potential countermeasures. One consideration when selecting this alternative is that more advanced signal controller operations may not be readily available within the default simulation platform. A work-around solution to this limiting factor is designing a signal-controller-in-the-loop simulation that leverages input from one or multiple physical signal controllers within the microsimulation environment. As such, HILS helps prevent costly errors by allowing real-world signal controllers to be tested in real time within a lab environment before deploying signal timings in the field, ultimately saving time and resources.

Summary of System Configuration:

Virtual Controller Interface Device-based (VCID) Hardware in the Loop Simulation (HILS) is a novel concept which addresses the cost and communication reliability limitations posed by HILS which used physical controller interface device as link between microsimulation and real signal controllers. It connects real traffic signal controllers with simulation software wirelessly using the National Transportation Communications for ITS Protocol (NTCIP) and allows the user to update, in real time, signal controller parameters while running the simulation.

Development of a robust VCID required the consideration of several design elements. Packet losses and data transfer errors must be accounted for. As such, it is necessary to design a reliable processing technology to avoid these errors. To model complex traffic signal systems, a mapping of traffic signal display and detector calls to the controllers and simulation software package is required. During the simulation process, a large amount of data is exchanged. For real-time simulation applications, a data processing frequency of 10 Hz is required, both for the controllers and the microsimulation environment. When the communication bandwidth is narrow, the threads of the VCID should also be synchronized. Finally, in multi-threaded programming, special attention must be paid to memory operation and thread stability to avoid memory leaks and thread loss. The data flows for VCID are given in Figure 1.

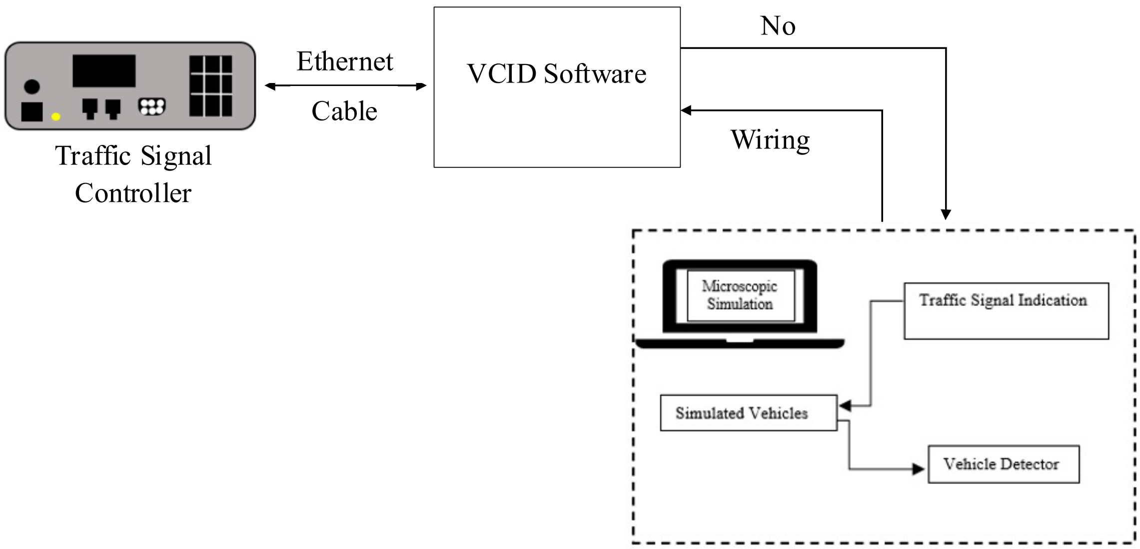

Figure 1: Structure of VCID based HILS

The details for building and connecting all components of the VCID-based HILS are provided below in the form of a series of questions.

Question 1: What is the standard sequence of tasks for using the HILS system?

Answer: The workflow of a simulation study using the HILS system can be described by the following four steps.

i) **Study Setup** – Users define the study scope and prepare relevant data inputs.
ii) **Model Development** – Users build a simulation environment in VISSIM, Waysync, develop traffic signal control configurations and interface in the Physical Arterial Signal Simulation System (PASS[1]) software, and modify settings in the physical traffic signal controller accordingly.
iii) **Simulation Execution and Performance Measurement Extraction** – Users perform hardware-in-the-loop simulation and extract performance measurements from VISSIM and PASS (e.g., simulated vehicle trajectories, vehicle delay etc.)
iv) **Analysis and Implementation** – Users conduct simulation validation and data analysis. As outcomes of the simulation study, users document simulation findings and potentially implement the simulation-tested signal timing plans in the field.

For step 2 **Model Development**, the sequence of tasks is as follows:

[1] PASS will be used throughout the remainder of this document

i) **Build a model in VISSIM** to simulate the traffic operational environment in the field and provide realistic detector actuations to the hardware in the simulation loop.

ii) **Build a model in Waysync-D,** an optimization tool used for signal coordination and various types of traffic signal optimization. For corridor-level optimization, the software does not require volume data. However, when optimizing a single intersection, the tool requires geometric characteristics and traffic volume data. The optimized signal timings generated by Waysync D can be transcribed into PASS to evaluate performance measures. A module describing workflows in Waysync-D tutorial can be observed by watching video 16 in this playlist (https://www.youtube.com/watch?v=NLYbqrvcLTE&list=PLzVcFW-6ljsa9CSXaQbSMDc4sUt42dpTQ).

iii) **Build a model in Waysync-M,** an iOS application designed for iPads and iPhones, used to validate existing traffic signal timings in field. The user will build an existing conditions signal model in Waysync-D and transfer that file to Waysync-M. A Waysync-D tutorial is described in this video (https://www.youtube.com/watch?v=P30M_xXi350&t=122s).

iv) **Build a model in PASS**, allowing for signal timing development and visualization of a time-space diagram with the extracted vehicle trajectory from the simulation. Signal timing settings, such as cycle length, phase split, offset, and phase sequence, can be coded in PASS or downloaded from/uploaded to physical controllers.

v) **Configure the VCID in PASS**, where users verify and update the "VCID.Config.txt" file in PASS's directory.

vi) **Set up physical signal controllers** with proper IPs and **update the controller settings** that PASS cannot remotely modify. Users can use controller management software (e.g., Q-free's MAXTIME) to control and monitor the physical controllers.

vii) **Run the simulation**.

A Flow chart of this process is presented in Figure 2.

Video Demonstration: https://media.oregonstate.edu/media/t/1_3jzjekhp

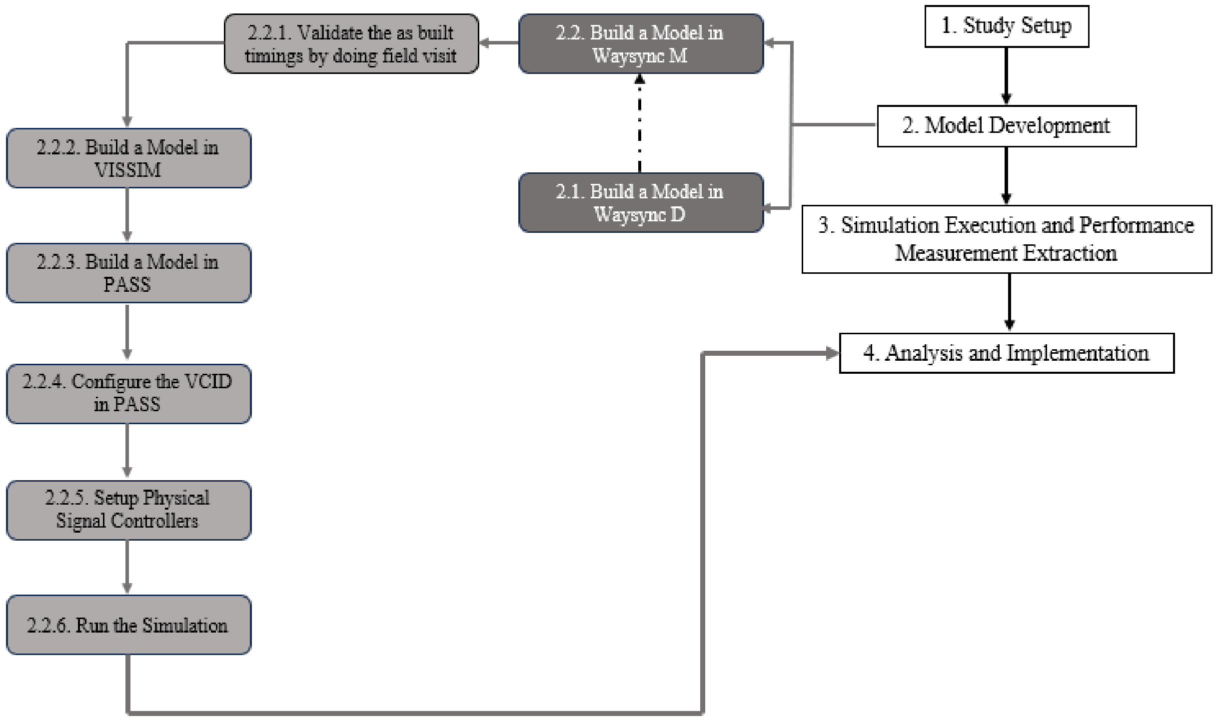

Figure 2: Workflow of a Simulation Study in HILS

Question 2: What are the hardware and software elements of HILS?

Answer: There are five components of this system:

i) **Physical traffic signal controllers** – the controllers used in HILS should support relevant National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) standards. The HILS can currently accommodate Q-free 2070/NEMA and Econolite NEMA controllers, as the management information base (MIBs) may differ from manufacturers. Controllers should be configured with static IPs to enable communication. Controller management software, such as MAXTIME software/application developed by Q-Free, can be used optionally to facilitate HILS, allowing users to conveniently update controller settings and monitor controller operations.

ii) **HILS host computer** – Traffic simulation software, PASS, and controller management software should all be installed on the host computer used in HILS. The computer must have the .NET Framework, with at least version 4.8. This requirement is typically met, as most Windows operating systems come with .NET pre-installed by default. .NET is a secure, reliable, and high-performance application platform that supports the efficient execution of software programs.

iii) **PASS software** – PASS includes two modules: 1) signal timing development interface and 2) Virtual Controller Interface Device (VCID). The signal timing development interface allows users to develop signal timing and coordination, visualize time-space diagrams, and extract simulated vehicle trajectories for performance measures. VCID is the core module to support communication between PASS, traffic simulation, and physical controllers. VCID can be configured by modifying the "VCID.Config.txt" file in terms of simulation settings, controller phase scheme, detection configuration, etc. Currently, PASS version 1.0.0.0 is being used.

iv) **Traffic simulation software** – The current HILS supports PTV VISSIM and Caliper TransModeler. The configuration presented to the agency was configured with VISSIM 2022 because of its reliable simulation execution and communication. A valid license for the traffic simulation software is required. Basic knowledge of using traffic simulation software is very helpful.

v) **Communication hardware** – Ethernet will be required to support communication between physical controllers, PASS, and traffic simulation software. Category 5 enhanced (Cat 5e) cables for controllers are included in the system. These Cat 5e cables should not be on firewall internet.

Video Demonstration: https://media.oregonstate.edu/media/t/1_dakiv7ji

Question 3: What is a Cat 5e cable?

Answer: Cat5e cable, short for Category 5 Enhanced, is a common type of Ethernet cable used for wired internet connections, offering improved performance and faster data transfer speeds compared to older Cat5 cables, supporting speeds up to 1 gigabit per second shown in Figure 3.

Figure 3: Cat 5e Cable

Question 4: Why should the controllers be configured with static Internet Protocol (IP) Addresses?

Answer: A static IP address of a physical signal controller enables stable and consistent identification of the controller in the network. In practice, real-world signal controllers communicate with a dedicated server or VPN endpoints, where static IPs are assigned to all controllers in the network, allowing for access through controller management software (e.g., MAXTIME) by users. However, HILS is commonly conducted under a general-purpose public

internet (e.g., using the agency's office internet service, where dynamic IPs are typically used). As a result, static IPs need to be particularly requested.
In addition, the gateway and port information of the physical signal controllers should be configured in VCID correctly.

Question 5: How should the controllers be wired?

Answer: Controllers should be connected for power and communication in the following way:

i) Connect each 2070 Controller to a power source. It can support a variable power supply (89-250 VAC 50/60 Hz or 48VDC).
ii) Connect the Cat 5e cables with the controllers and the HILS host computer. Ensure that the physical traffic signal controllers connected through Cat5e cables and the host computer are within the same network. All Cat5e cables should be plugged into a router or network switch to enable communication between the controllers and the host computer over the shared network.

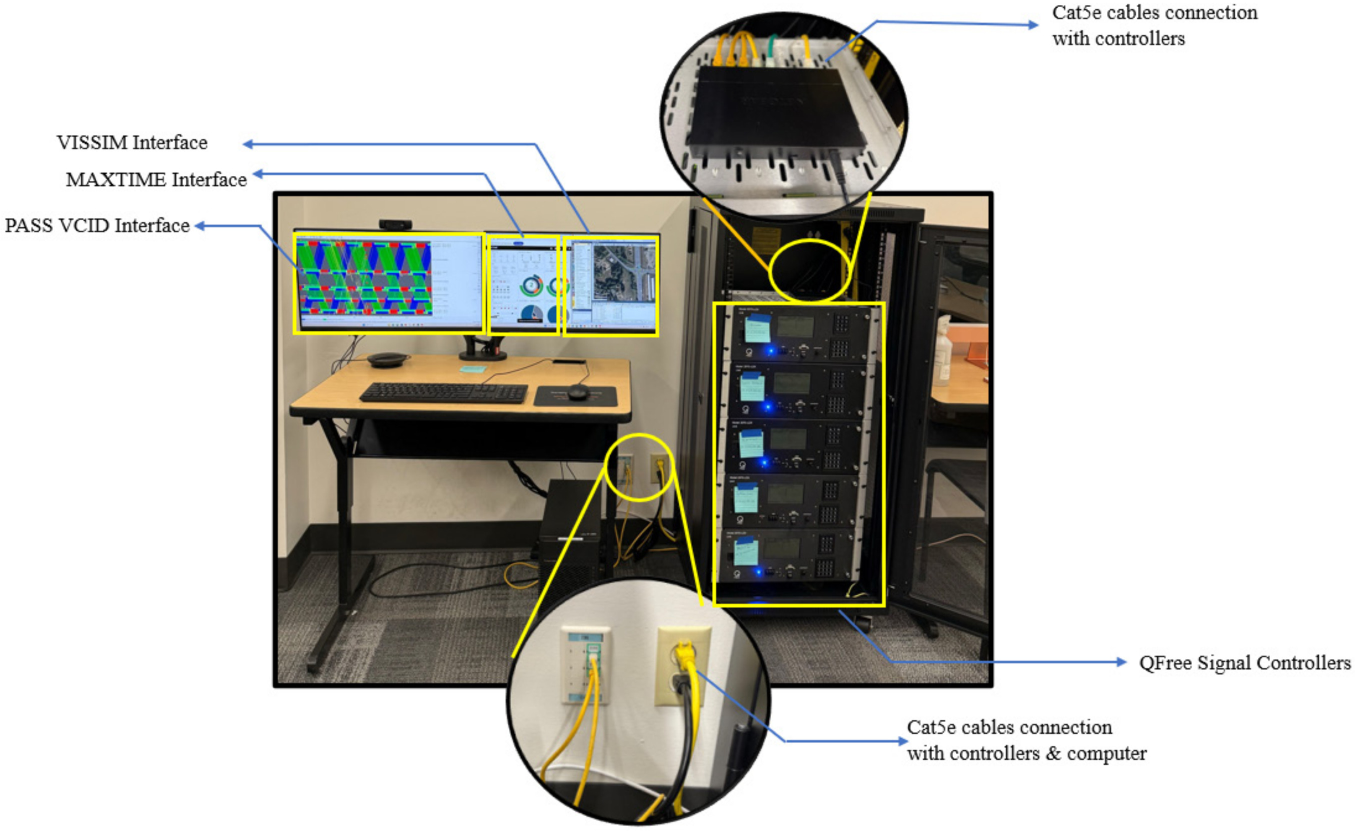

Figure 4: Physical Configuration of Signal Controllers

Question 6: How should I configure my network security?

Answer: Network security settings can influence the connection among HILS components, such as firewalls, VPNs, and encryption, which can introduce latency and potentially disrupt HILS by blocking necessary communication protocols or ports. It is recommended to use dedicated, segmented networks specifically for HILS to isolate them from general traffic and reduce security complexity. Or configure targeted firewall rules and allow required ports and protocols explicitly for HILS hardware and software. At OSU, we asked the College of Engineering (COE) Information Technology (IT) department to help us configure a network independent of the university firewall.

Question 7: How do I turn on my controllers?

Answer: Turn on the Q-free 2070 controllers using the following three-steps, as described by the list and in Figure 5. Please note that the initialization for different controller types can vary.

i) Slide the button on the right edge of the cabinet to the right with little force.
ii) Pull the front plate of the cabinet towards you.
iii) Lift the small lever button and navigate to the desired menus.

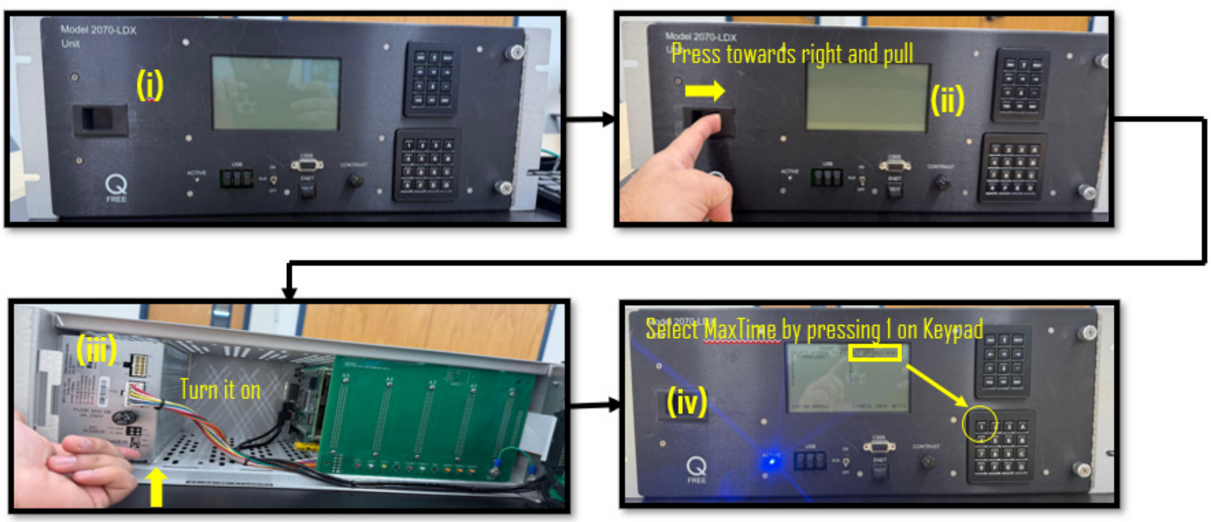

Figure 5: Startup of Controllers

Question 8: How do I configure the controllers?

Answer: Controllers can be configured through the following steps:

i) Users need to manually assign each signal controller with an IP address and configure the NTCIP (National Transportation Communications for ITS Protocol) port settings for communication. Each controller's IP should be unique. Users need to use the controller's onboard interface panel and keypad to produce configuration modifications for each physical signal controller. NTCIP port numbers must also be assigned within the cabinet for proper network communication. Additional details are provided in response to Question 10.

ii) The next step is to assign IP addresses to the controllers before MAXTIME can access them. There are three options to code/edit the controller configuration and function settings: 1) directly use the controller interface panel, which can be tiring. 2) use MAXTIME after IP is assigned and connection is established. This is very convenient and flexible. But users need to modify controllers one-by-one; and 3) use the PASS signal timing development module after VCID is properly configured. This can edit signal timing settings for a group of coordinated controllers at once, but only certain signal timing settings can be edited. Additional details are provided for using the PASS VCID in response to Questions 21 through 24.

Question 9: How do I install MAXTIME on the primary computer?

Answer: The MAXTIME software installation package is provided by Q-free with the controller acquired. If not, users can request from Q-free without cost. Users need to provide license details and install the software onto the HILS host computer. After installing the software, establish a Q-Free shortcut on the desktop. Double-click the Q-Free icon and install MAXTIME as shown in Figure 6. Give a new username and password for the controllers as shown in Figure 7. Configure the controllers with a username (xxx) and password (xxx).

Figure 6: Q-Free Installation

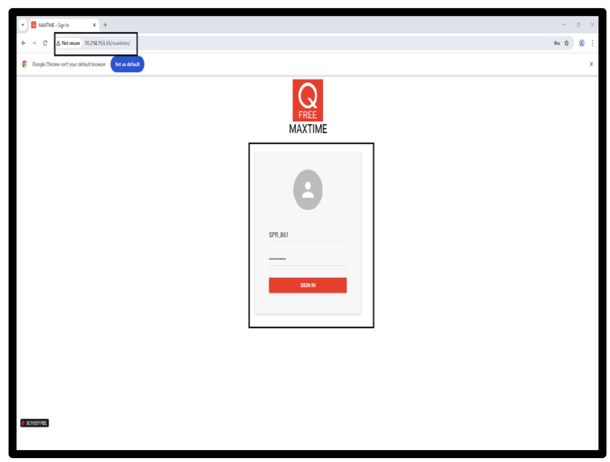

Figure 7: Typing the IP address in the browser and entering credentials

Users can then access each controller used in HILS via MAXTIME by opening a browser, such as Google Chrome or Internet Explorer, and typing the IP address of the controller under consideration, as shown in Figure 9.

Video Demonstration: https://media.oregonstate.edu/media/t/1_fbxkhri5

Question 10: How do I assign static IPs to controllers?

Answer: Complete the following actions:

i) **Turn on the controllers**: Make sure the controllers are powered on and fully booted.

ii) **Navigate to MAXTIME:** Press 1 on the main screen to open the MAXTIME software. Please note that MAXTIME mentioned here is the software installed on physical signal controllers. The controller management software on the HILS host computer shares the same name "MAXTIME".

iii) **Go to Administration:** Press 3 to access the Administration menu.

iv) **Select Communication:** Press 2 to enter Communication settings.

v) **Choose Ethernet:** Press 1 to open Ethernet configuration.

vi) **Enter the assigned static IP:** Use the keypad to type in the static IP address given to you.

vii) **Press Enter:** Confirm and save the settings by pressing the Enter key.

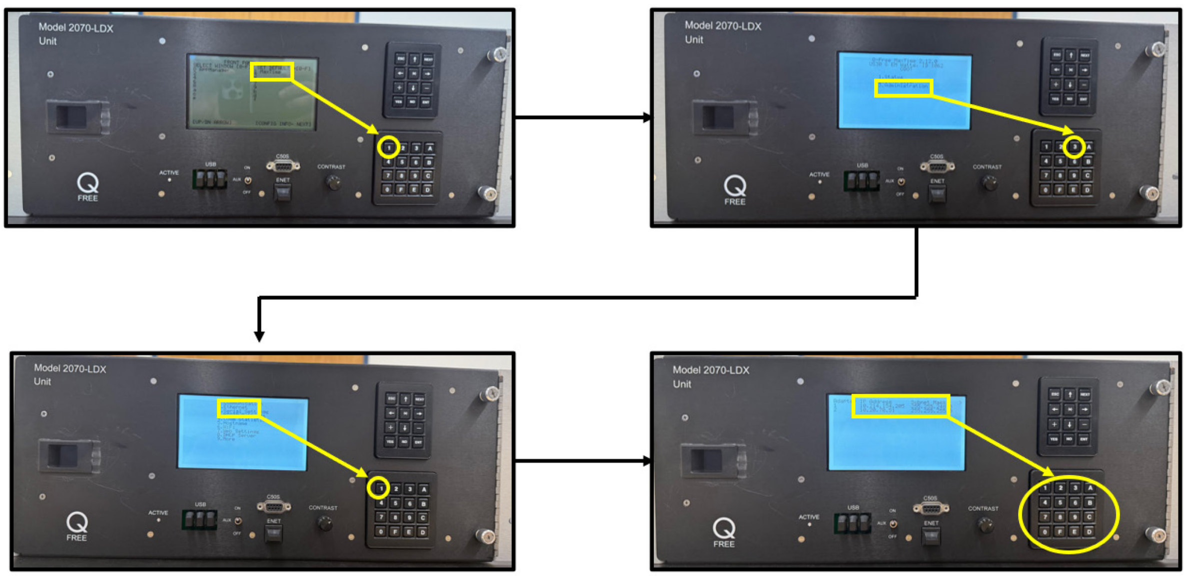

Figure 8: IP Address Assignment

Video Demonstration: https://media.oregonstate.edu/media/t/1_kikj55ur

viii) **IP Match Verification**: Users can verify the correct assignment of IP addresses to controllers using MAXTIME. To perform this verification, users should input the controller's IP address into the browser on the host computer, as illustrated in Figure 7. If the IP is correctly assigned, the MAXTIME interface for the controller will appear successfully, as depicted in Figure 9. If MAXTIME is not installed on the host computer, users may use the Windows command prompt to ping the controller's IP address. A successful ping will return replies confirming that the device is reachable; otherwise, it will indicate a connectivity issue.

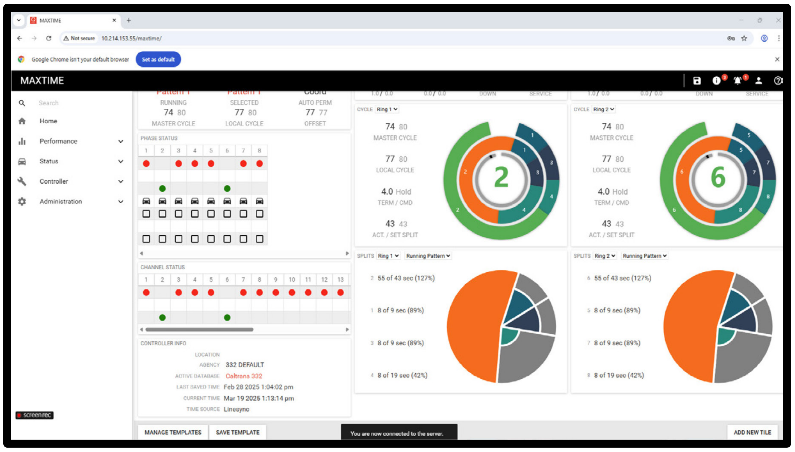

Figure 9: MAXTIME UI

Question 11: How do I configure NTCIP protocol and the signal communication port?

Answer: Complete the following steps:

i) **Turn on the controllers:** The controllers should be powered on and fully booted.
ii) **Navigate to MAXTIME:** Press 1 on the main screen to open the MAXTIME software on controller.
iii) **Go to Administration:** Press 3 to access the Administration menu.
iv) **Select Communication:** Press 2 to enter Communication settings.
v) **Open NTCIP Settings:** Press 3 to access NTCIP configuration options.
vi) **Go to Ports:** Press 1 to open the Ports settings menu.
vii) **Enable NTCIP:** Press "*" to enable NTCIP. It should always remain enabled.
viii) **Enter the port number:** Type 55502 using the keypad. Please note that the port number of "55502" is determined by the OSU team. Port 55502 is within the **dynamic/private port range (49152–65535),** which can be suitable if users desire a dedicated, custom port to minimize conflicts with other common services or devices, particularly if HILS is not independently hosted from the in-field controller network. The in-field signal controllers are using UDP 161 for NTCIP by default.
ix) **Press Enter:** Confirm and save the settings by pressing the Enter key.
x) **Repeat** this step for all controllers under consideration.

Video Demonstration: https://media.oregonstate.edu/media/t/1_xwljkt72

Question 12: What files should be placed in the folder directory?

Answer: All model files should be placed in the PASS software directory, as shown in Figure 10 as an example. Users can select any root directory on the HILS host computer to place the PASS software, but any changes within the PASS software directory can be sensitive. In this example, PASS project file is located under “TranSync” and VISSIM model file is located under “VISSIM2024”. Users can customize the folder names, but the “VCID.Config.txt” file should be updated with any folder name changes.

Video Demonstration: https://media.oregonstate.edu/media/t/1_8fos78jp

Figure 10: Folder Directory

Question 13: Where should the directory of the VISSIM model be located and where should I construct VISSIM Model?

Answer: Users can develop their VISSIM models independently at any desired location because these models are fully transferable to the PASS environment. Upon completion of the VISSIM model development, verify that the model runs correctly, then copy the entire VISSIM project directory and paste it into the designated PASS software directory. In the current example, the VISSIM model has been developed and stored within the directory named “VISSIM2024”, as illustrated in Question 12. Additionally, the VCID should be configured by editing the file “VCID.Config.txt”, as detailed in Question 21, Step vii.

Video Demonstration: https://media.oregonstate.edu/media/t/1_xxtyeo08

Question 14: How much VISSIM knowledge should I have to use this system?

Answer: Users should have basic knowledge and understanding of VISSIM simulation model components and operations. Such knowledge and understanding can support users in producing VCID configuration. Users should be familiar with “signal heads” in VISSIM and the associated phasing logic in physical signal controllers, as well as detector setup in VISSIM and detection call logic in physical signal controllers. Important notes in configuring VCID are given in Question 21 Step xiv.

Question 15: What simulation parameters are required for running a VISSIM model and why are they important?

Answer: Correctly configuring the VISSIM simulation parameters is essential for successful and stable HILS operations. The navigation path to the Simulation Parameters dialog is shown in Figure 11, and the recommended parameter values are provided in Figure 12. The **Simulation Resolution** must be set consistently in both the VISSIM model and the VCID configuration to ensure synchronized data exchange between VISSIM and the traffic controllers. A resolution value greater than 5 is recommended for improved accuracy; however, higher resolutions may increase the computational load on the HILS host computer. Additionally, the **Simulation Speed** must be set to **"Factor = 1"**, which corresponds to real-time simulation. This setting is crucial to maintain proper synchronization between the simulation and the physical controllers.

Video Demonstration: https://media.oregonstate.edu/media/t/1_90kt1lun

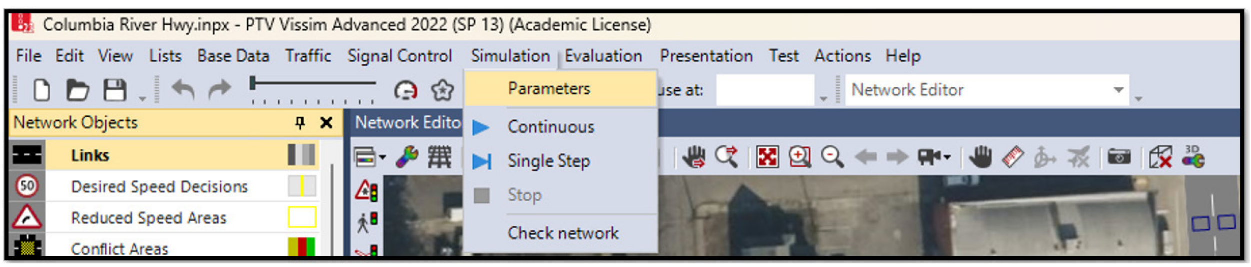

Figure 11: VISSIM Simulation Parameters Selection

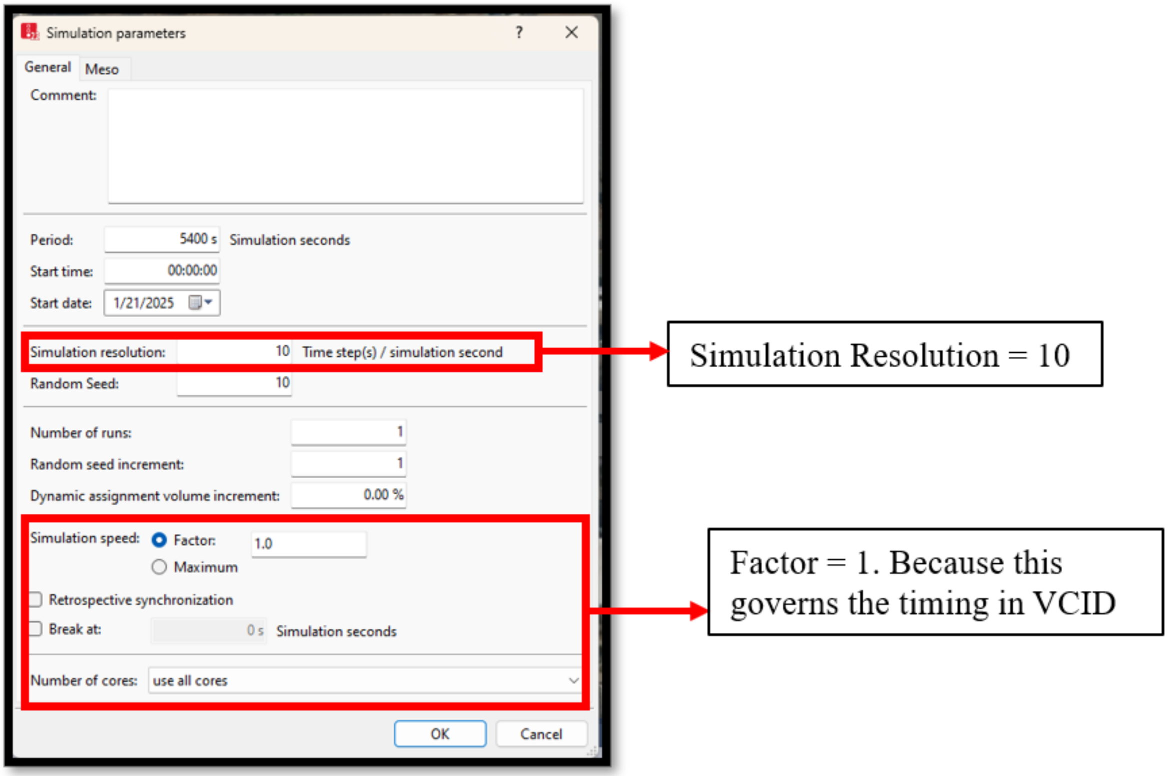

Figure 12: Setting up Simulation Parameters in VISSIM

Question 16: What is a port number and why are PORT NUMBER / DETECTOR NUMBERS important? How should I code PORT / DETECTOR NUMBER in VISSIM?

Answer: In VISSIM, a traffic detector is coded with two identifiers – Detector Number and Port Number. Detector Numbers are determined by VISSIM automatically, which are universally unique in a VISSIM model, while Port Numbers are determined by users to allow series and/or parallel connections to produce traffic actuations for signal control.

For example, in the timing plans provided by ODOT, the northbound through traffic is controlled by Controller 3, Signal Phase 6. Then, the detector(s) for this movement in VISSIM should be coded using a certain Port Number (Port Number 6 in this case) to provide actuations for Signal Phase 6 of Controller 3. Please note that the determination of Port Numbers should be in accordance with field circumstances. If lane-by-lane detection is used in the field, the Port Numbers should be given separately for lane detectors.

In VISSIM, <u>Port Numbers</u> are the reference to establish connections between detectors and signals. However, in VCID, <u>Detector Numbers</u> are used to represent detectors in VISSIM to connect with physical signal controllers. For a detector, its Port Number and Detector Number are **<u>not</u>** necessarily identical. See Figure 13, 14 and 15 for examples.

Video Demonstration: https://media.oregonstate.edu/media/t/1_dqq604pe

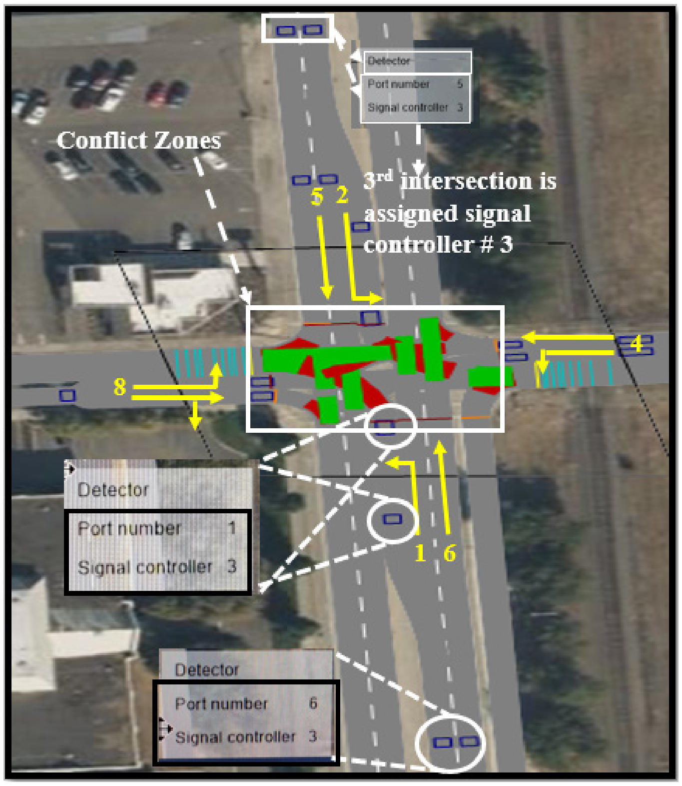

Figure 13: Port Number Assignment in VISSIM at Maple Intersection

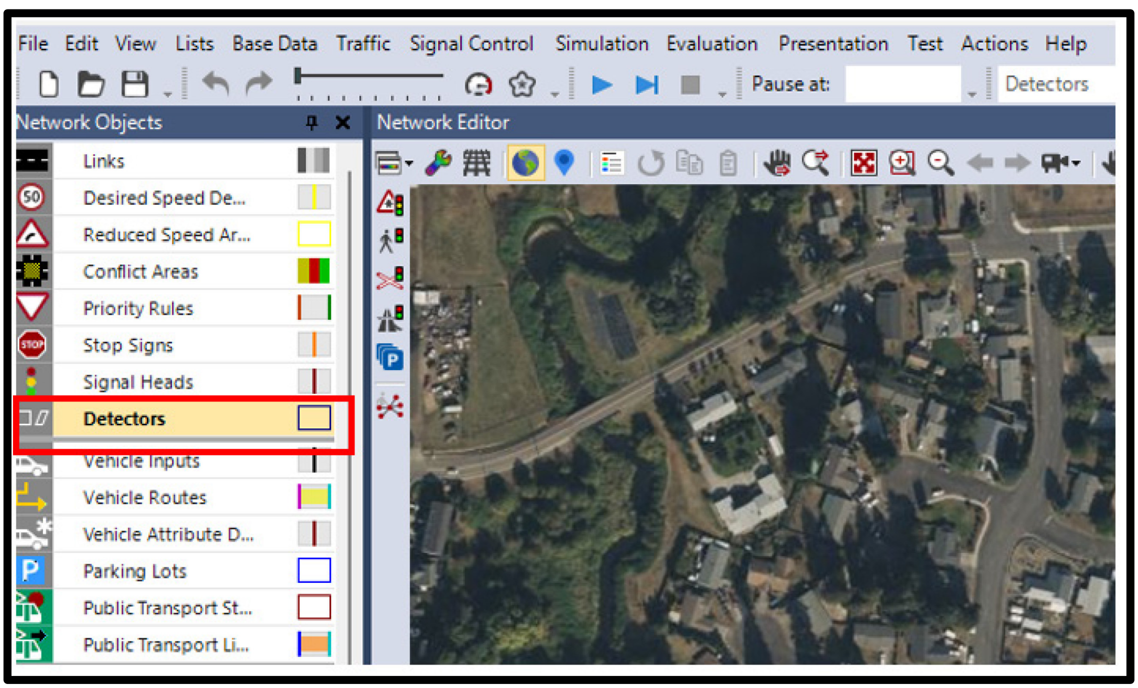

Figure 14: Navigation to Detectors in VISSIM

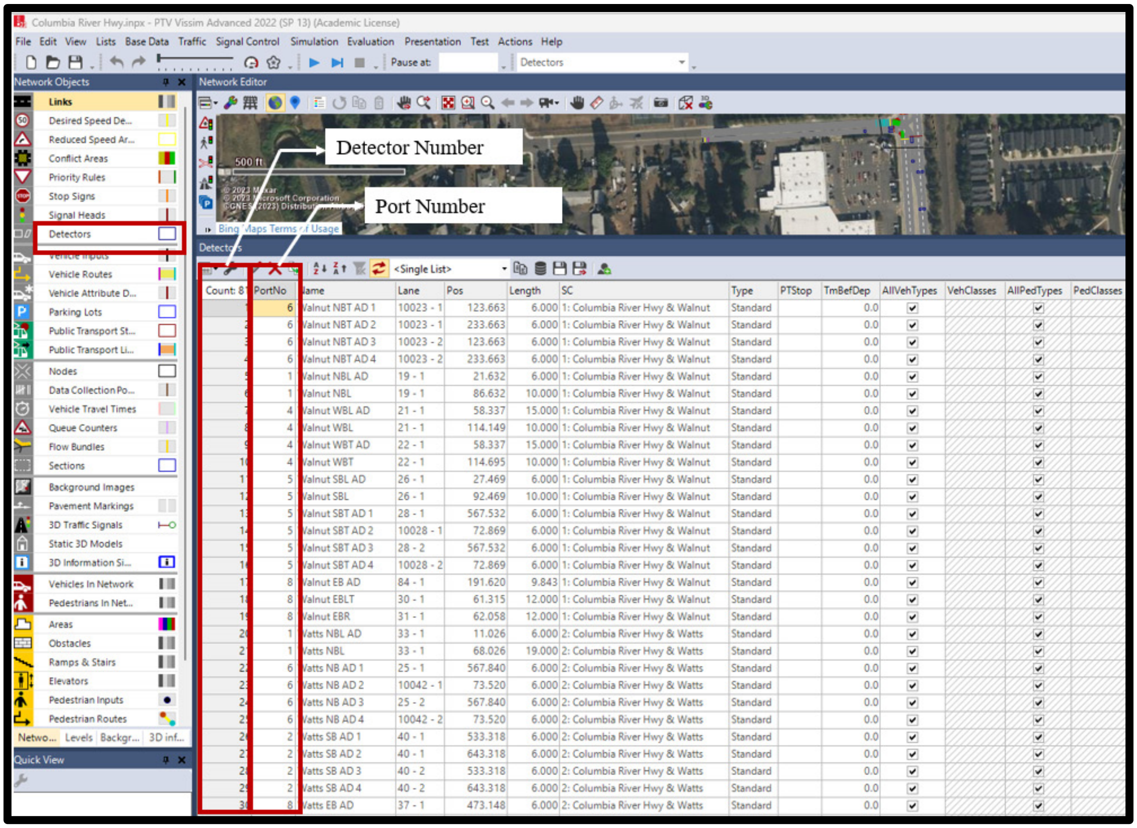

Figure 15: Inputting Port Number in Detector Settings using VISSIM

Question 17: For HILS, I am using physical controllers, do I need to set up controllers in VISSIM?

Answer: Users need to accurately develop “Signal Heads”, “Detectors”, and “Signal Controllers” in VISSIM, as shown in Figure 16. The relationship between signal heads and signal controllers in VISSIM determines the signal phasing scheme. The placement and relationship between detectors and signal controllers (particularly to signal phases coded in controller) determine the detection communication. These should be reflected accordingly in the VCID configuration. However, the signal timing settings in VISSIM can be irrelevant as they would be overridden by physical signal controllers.

Video Demonstration: https://media.oregonstate.edu/media/t/1_57fr1udy

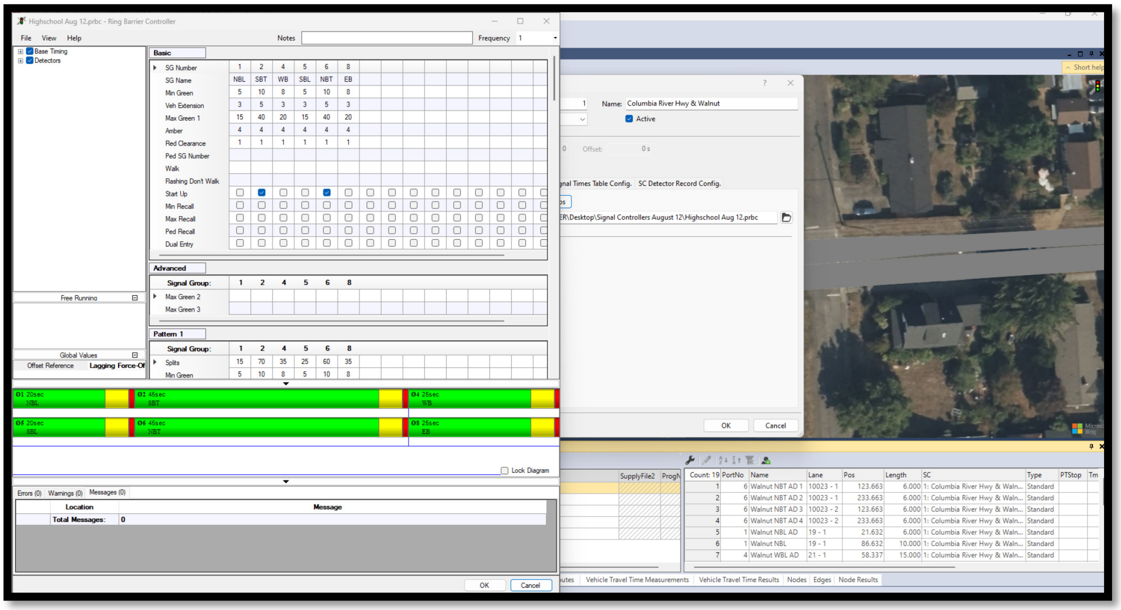

Figure 16: VISSIM Ring Barrier Controller Window

Question 18: I have set up the physical controllers and have developed my network model in VISSIM, what's next?

Answer: The next step is to configure the VCID.

Question 19: What is our Virtual Controller Interface Device (VCID)?

Answer: VCID is embedded within PASS software, and its configuration is editable through a TXT file ("VCID.Config.txt" under the PASS software directory, as shown in Figure 10). Users can use applications, such as Windows Notepad or Notepad++, to access and edit the VCID configuration file. Users should not customize the naming of such a configuration file. As the VCID configuration file is very sensitive and important, it is recommended that users make backups periodically while developing and editing HILS.
Note that the VCID configuration file should be placed under the PASS directory exactly. Users can make a backup somewhere else, but only the one in the PASS configuration takes effect.

Question 20: What are the main components of our VCID?

Answer: The following are thirteen primary attributes of the VCID:

i) Global settings
ii) PASS directory
iii) Agency name and subsystem

iv) Data update interval
v) Simulation settings
vi) VISSIM version
vii) Loading of VISSIM model
viii) Simulation Resolution
ix) Simulation speed
x) Anchor nodes
xi) Assigning IPs to Controllers
xii) Setting up timing plans and phase assignments
xiii) Setting up detectors

Question 21: How do I configure the VCID?

Answer: Detailed instructions to modify/edit the VCID are as follows:

i) Note: The "//" symbol sets off a comment in the code, and as such does not have a programming function. These notes help to explain the VCID components to the user. Please do not write working code after these notations. An example of this notation is presented in Figure 17.

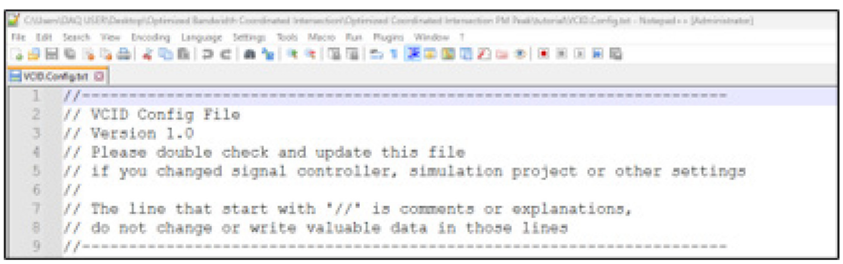

Figure 17: Comments in VCID code

ii) Please do not change the Global Settings line, documented in Figure 18.

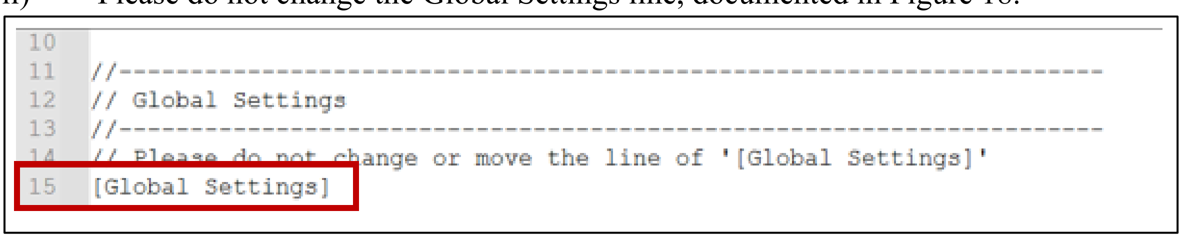

Figure 18: Global Settings in VCID code

iii) Load a PASS project file with a .ti file extension. This file extension is used for PASS. This file is provided in the PASS software directory, demonstrated in Figure 19.

```
// The file name of TranSync project, you should give a full path
// e.g. C:/TranSync/transync_project_file.ti
// If you want to set a relative path to the application startup path,
// use '${Application.StartupPath}' as the root path location.
// e.g. ${Application.StartupPath}/TranSync/transync_project_file.ti
ProjectFileName=${Application.StartupPath}/TranSync/Columbia River Hwy.ti
```

Figure 19: Loading of .ti file in VCID code

iv) When generating a .ti file using PASS, users need to provide “Agency Name” and “Subsystem Name”. Users need to ensure that the setup of Agency Name and Subsystem Name match between the VCID configuration file and PASS project file, as emphasized by the red boxes in Figure 20.

```
// The name of the agency in TranSync project, you can leave it empty to open the first agency
AgencyName=ODOT

// The subsystem name in agency, you can leave it empty to open the first subsystem
SubsystemName=

// The interval of updating data in UI, in ms. Default is 500 (0.5 second).
// Do not change this valud unless you have been told to.
DataUpdateInterval=500

// The sequence code type in TranSync, including 'STD8', 'RENO&LV',
// do not change this value becuase it will be overwritted in TranSync
// CommuSequenceCodeMethod=STD8
```

Figure 20: Naming Agency Name and Subsystem in VCID code

v) The next step is to set the data update interval to 500 milliseconds (i.e., 0.5 seconds), as shown in Figure 21. Please note that this only applies to the PASS interface.

```
// The interval of updating data in UI, in ms. Default is 500 (0.5 second).
// Do not change this valud unless you have been told to.
DataUpdateInterval=500
```

Figure 21: Data Update Interval in VCID code

vi) Next, users will configure the VISSIM settings in the VCID file. Users are recommended to install VISSIM 2022 on the HILS host computer and define the simulation driver, as shown in Figure 22. If other simulation software is used, this setting needs to be updated accordingly.

```
//----------------------------------------------------------------------
// Simulation Settings
//----------------------------------------------------------------------
// Please do not change or move the line of '[Simulation Settings]'
[Simulation Settings]

// The driver of simulation, to decide which simulation program to use, including:
// 'VISSIM' - VISSIM 7.0+
// 'TransModeler' - TransModeler 6.0 SW
// 'VISSIM2022' - VISSIM 2022
// 'VISSIM2024' - VISSIM 2024
SimulationDriver=VISSIM2022
```

Figure 22: Setting up Simulation Settings and Loading Simulation Driver in VCID code

vii) After loading the .ti file, load the VISSIM file, as shown in Figure 23. “VISSIM2024” is the directory where the VISSIM model is stored, which can be customized. The VISSIM file uses the .inpx file extension.

```
SimulationLoadParameter=${Application.StartupPath}/VISSIM2024/Columbia River Hwy.inpx
```

Figure 23: Loading VISSIM file in VCID code

viii) The VCID simulation resolution should be consistent with the setting in VISSIM. In this case, Figure 24 shows a value of 10 was used to match the resolution setting in VISSIM.

```
// Config how many time moved for a signal step (the smaller, the faster) , in ms, default is 5
// This data may be overrided by simulation ,depends on different simulation driver
SimulationResolution=10
```

Figure 24: Setting up Simulation Resolution in VCID code

ix) HILS operates in real-time, and synchronization is required among VISSIM, physical signal controllers, and PASS. To ensure PASS operates in real-time, the simulation speed is configured as 1,000. Additionally, the simulation time drift is set to 0 if communication latency is minimal. Both values are documented in Figure 25. However, if latency is noticeable as vehicle trajectories and signal display presented in PASS are delayed relative to those in VISSIM or the physical signal controllers, SimulationTimeDrift can be used to adjust the PASS display (i.e., time-space diagrams) to accommodate for delays or discrepancies. SimulationTimeDrift can be either positive or negative.

```
// Config how many time moved in simulation for a real 1 second, in ms, default 1000
// (which means 1s simulation time is 1 real second)
// This data may be overrided by simulation ,depends on different simulation driver
SimulationSpeed=1000

// Config if the time drift of GPS trajectory created in simulation system, in second
// The default value is 0 (second), do not change this value unless the trajectory is drifted in TSD.
SimulationTimeDrift=0.0
```

Figure 25: Simulation Speed and Time Drift in VCID code

x) To generate vehicle trajectories, users need to define a specific vehicle type in VISSIM and VCID as shown in Figures 26 and 27. “Trajectory Vehicle” in VISSIM is VehType 700, which aligns with the “700” code in the VCID configuration file. PASS can potentially track all vehicles in VISSIM, but the computational load can be extensive.

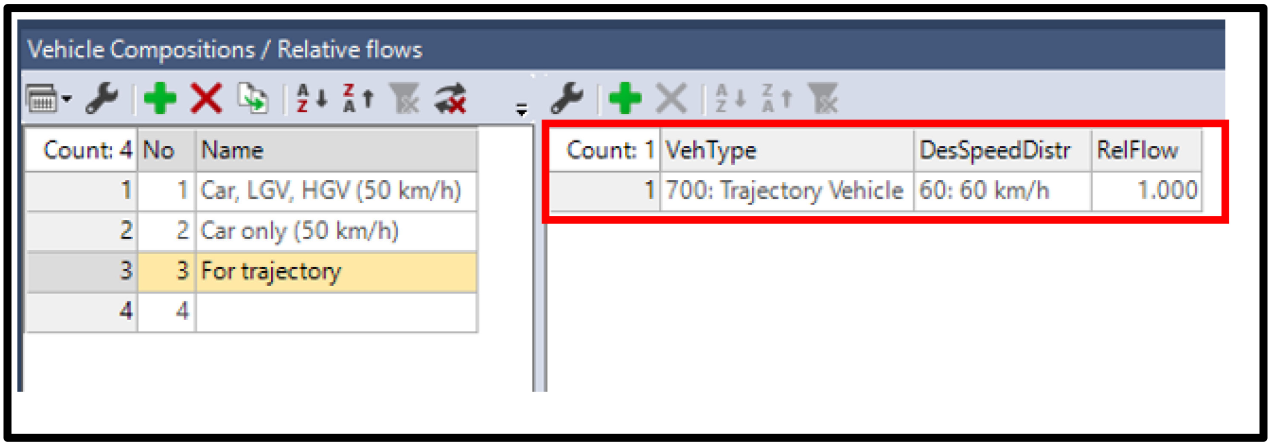

Figure 26: Trajectory vehicle generation in VISSIM

```
// #Column Headers Define#
//    VehicleType: The vehicle type that will generate GPS trajectory.
//
// #Table Data#
// Please input the table to match the following column headers. You should input at least ONE(1) line(s)
// VehicleType
//
// #Example#
// 300
//
700
```

Figure 27: Trajectory vehicle generation in VCID code

xi) To ensure alignment between the simulation scales in VISSIM and PASS, reference nodes, referred to as “Anchor Nodes” in the VCID configuration, need to be defined in the VCID configuration file. As illustrated in Figure 28, the “AnchorNodeId” column corresponds to the signal reference ID used in the PASS environment.

```
// #Table Data#
// Please input the table to match the following column headers. You should input at least TWO(2) line(s)
// AnchorNodeId, AnchorNodeSimulationId
//
// #Example#
// 1, 1
// 2, 2
//
1, 1
5, 5
```

Figure 28: Anchor Nodes in VCID code

Users can locate and edit this ID by right-clicking on a signal icon in PASS and selecting "Edit Signal." The "AnchorNodeSimulationId" corresponds to the evaluation node defined in VISSIM, shown in Figure 29.

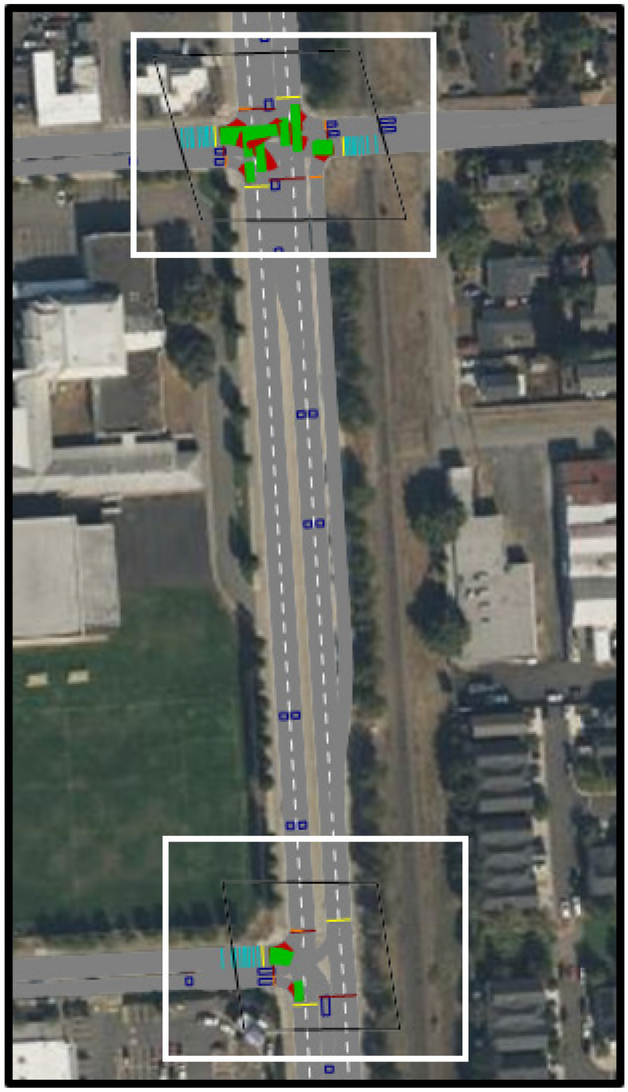

Figure 29: Nodes in VISSIM

Although referred to as a "node" in VISSIM, it is represented as a polygon shape. Users should create this node such that its center point closely matches the center of the intersection (see Figure 30). For each intersection signal, the signal reference ID in PASS and the node ID in VISSIM must be identical for correct mapping.

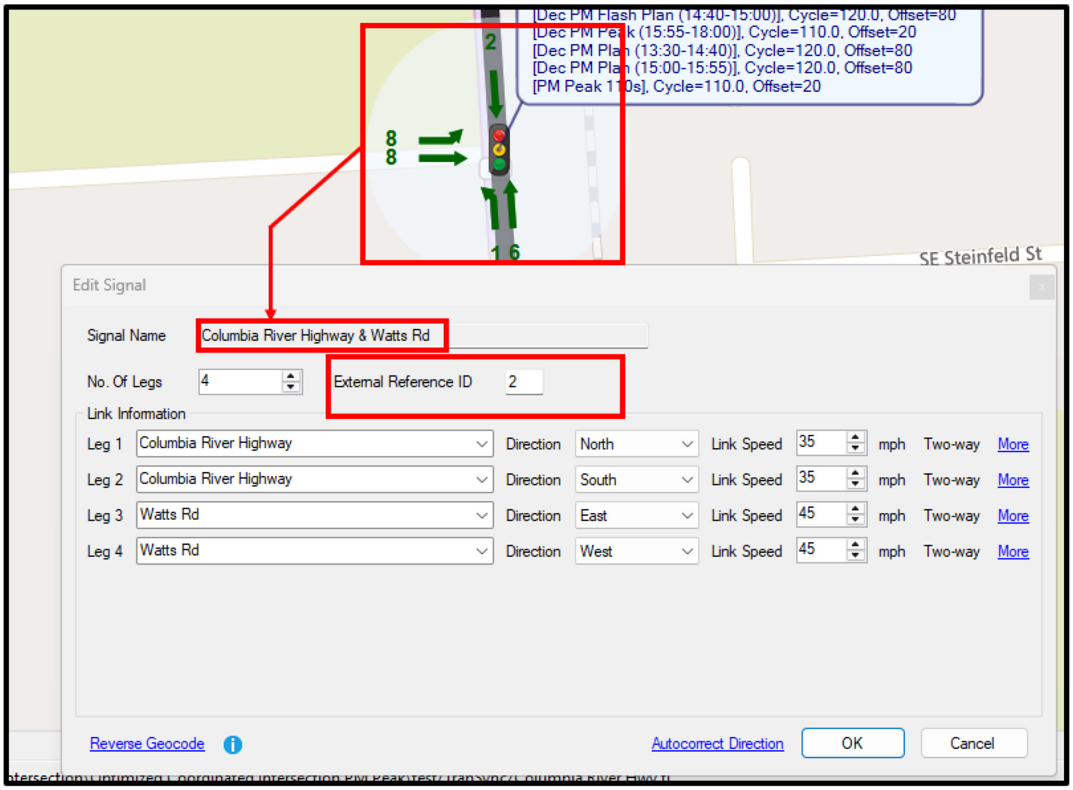

Figure 30: Reference ID of Columbia River and Watts Intersection in PASS

In our pilot test from Scappoose, OR, Node 1 (at intersection 1) and Node 5 (at intersection 5) were designated in the VCID as the start and end reference points, respectively.

xii) With static IPs previously (Question 10) assigned to physical signal controllers, now users need to configure these IP addresses in the VCID configuration file with signal IDs and NTCIP ports, as shown in Figure 31.

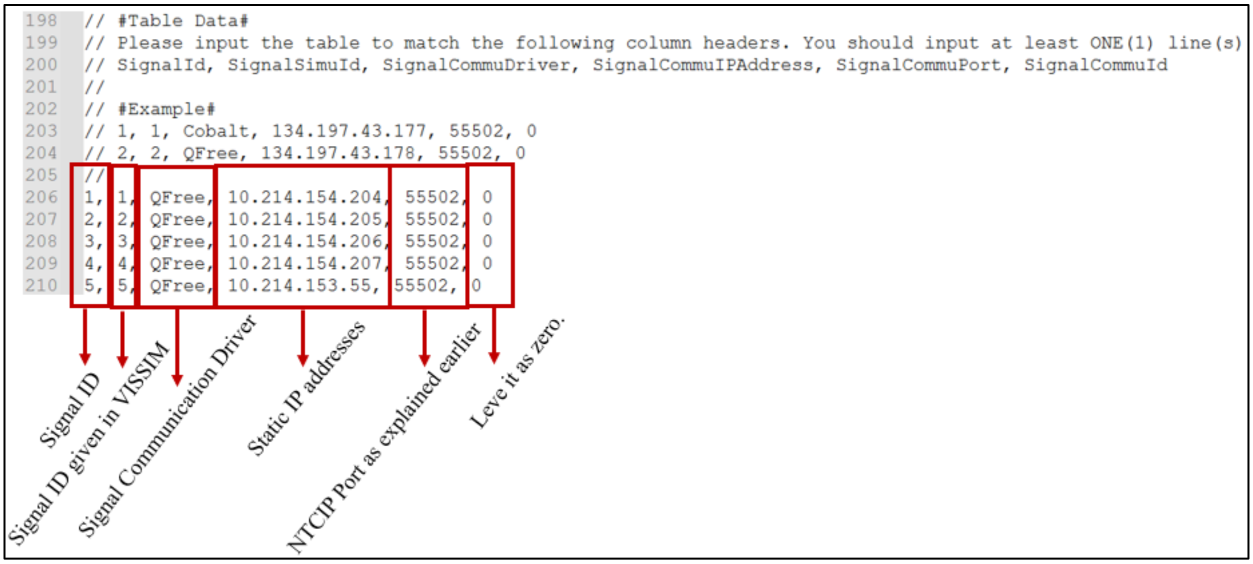

Figure 31: Assigning signal static ID IPs, Signal ID and NTCIP Port

xiii) At this point, users have already loaded the .ti file, VISSIM network, and configured simulation parameters. The remaining steps are to configure traffic signal plan, phasing, and detection. This "Timing Plan Reference" setting in VCID configuration file designates which timing plan in physical signal controllers can be automatically read and written by PASS. As demonstrated in Figure 32, "1" indicates that the first timing plan (i.e., Pattern 1 typically) in each controller's timing plan list will be modified by PASS.

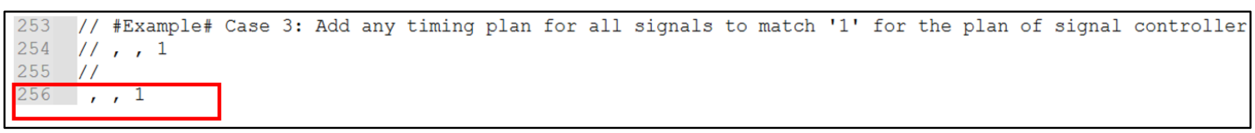

Figure 32: Assigning Timing Plan

xiv) This "Signal Phase Reference" setting designates the relationship of signal phases between VISSIM, PASS, and physical controllers. It is recommended to use standard and consistent phasing scheme (e.g., NEMA STD-8 that is also applicable to 2070 controllers), as shown in Figure 33. Care should be taken to double-check the signal phases are coded correctly and consistently in VISSIM, PASS, and physical signal controllers.

```
// #Example# Case 3: Add phase 1 to 8 for all timing plans in all signals
// , , 1, 1, 1
// , , 2, 2, 2
// , , 3, 3, 3
// , , 4, 4, 4
// , , 5, 5, 5
// , , 6, 6, 6
// , , 7, 7, 7
// , , 8, 8, 8
//
 , , 1, 1, 1
 , , 2, 2, 2
 , , 3, 3, 3
 , , 4, 4, 4
 , , 5, 5, 5
 , , 6, 6, 6
 , , 7, 7, 7
 , , 8, 8, 8
```

Figure 33: Phase assignment

xv) Question 14 provides guidance on assigning Port Numbers and Detector Numbers, along with their interpretation. At this stage, users should configure all detectors and phase numbers to match their corresponding connections in VISSIM, as illustrated in Figure 34.

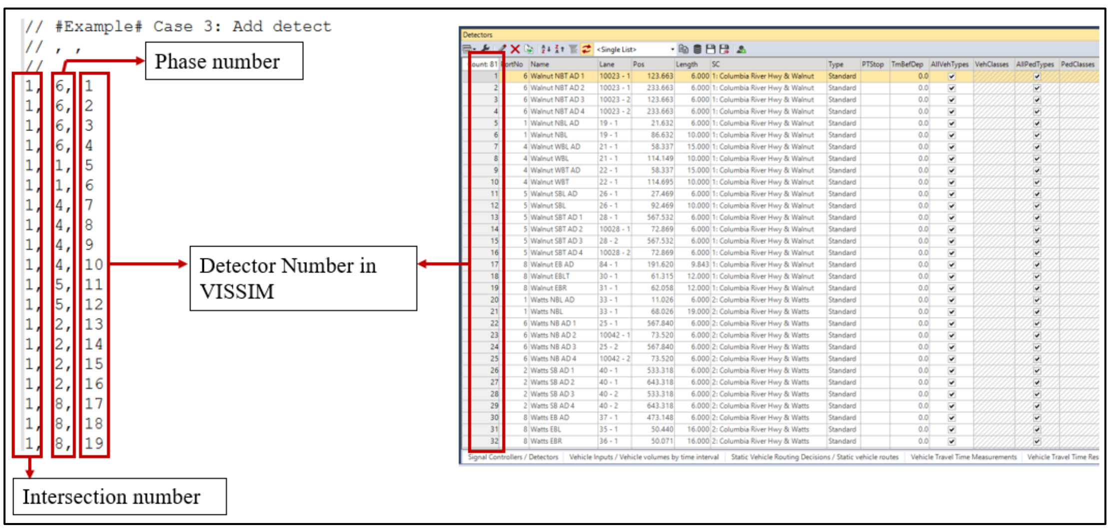

Figure 34: Programming Detector Numbers in VCID

Video Demonstration: https://media.oregonstate.edu/media/t/1_kc02fwma

Question 22: How can I create a new signal system in PASS?

Answer: The following seven steps will allow you to create a new signal system in PASS:

i) Double click and open PASS. The PASS software icon can be found in the PASS software directory. Zoom in to the desired area or intersection on the map. Right click on desired intersection and click on "New Signal" as shown in Figure 35.

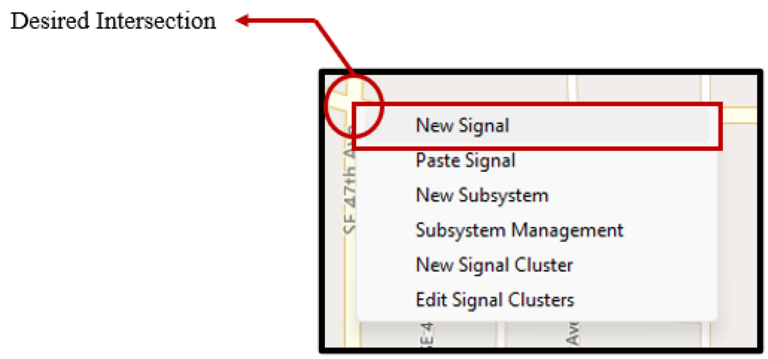

Figure 35: Creation of New Signal in PASS

ii) After clicking on New Signal, users can add the name of intersection. Users should add an "External Reference ID". It can be any number, but that number should match the text in the VCID file as shown in Figure 36.

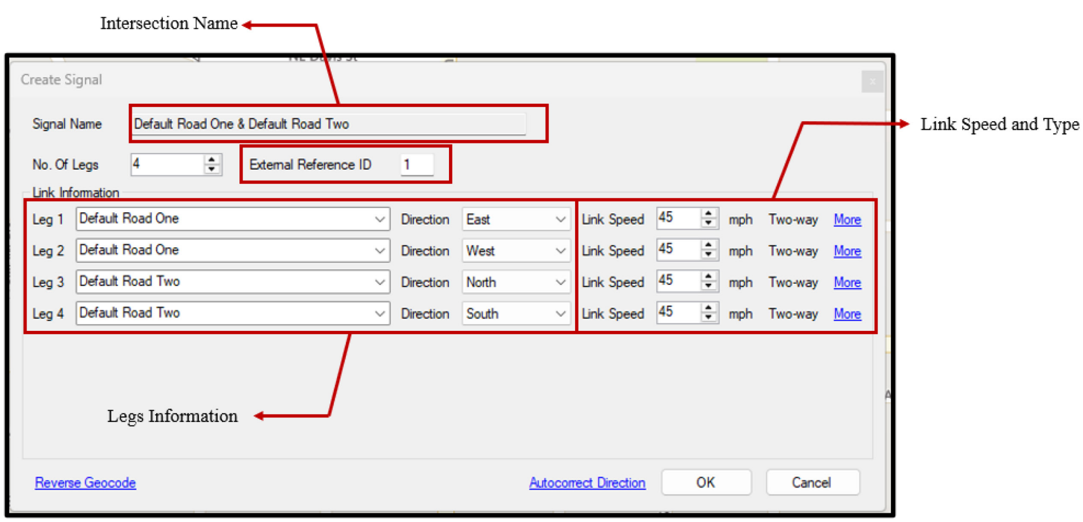

Figure 36: Creation of Signalized Intersection

iii) Users can also select the speed, direction and type of signalized intersection as shown in Figure 37.

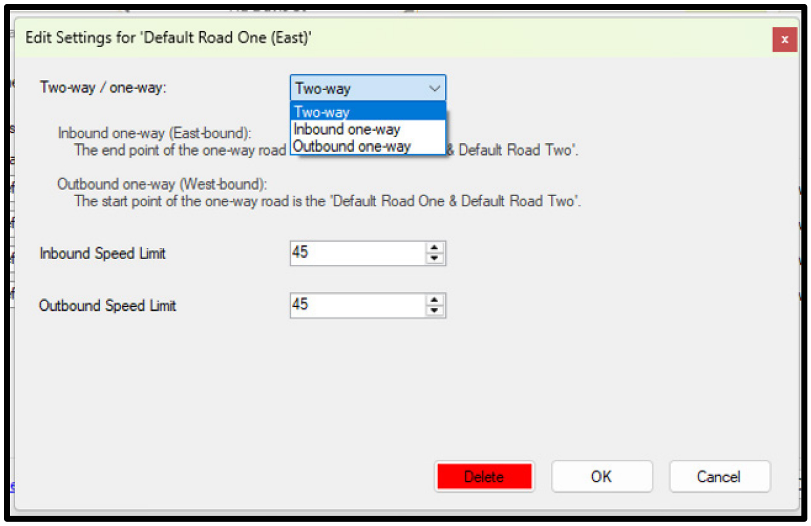

Figure 37: Intersection Settings

iv) After creating the desired signals, right-click anywhere on the map and select "**New Subsystem**". The subsystem dialog box will appear in the lower corner of the maps window.

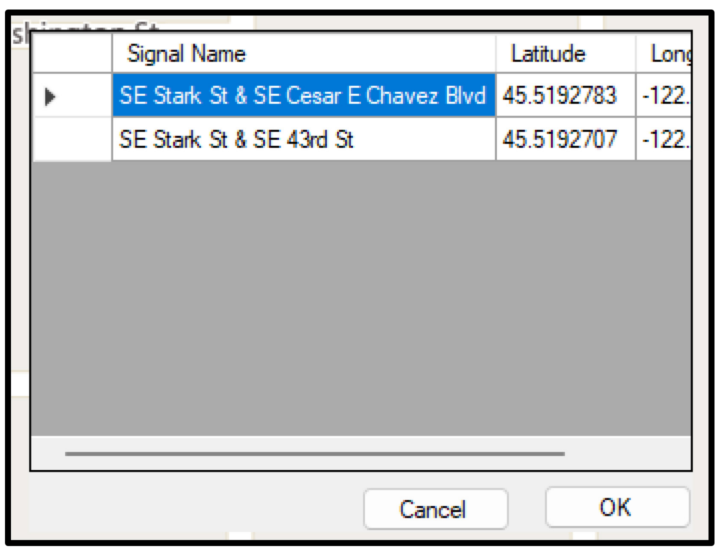

Figure 38: Signal Selections for a Subsystem

v) Select the signals to be included in the subsystem by left clicking on the signal head or by holding the right-click button and moving the mouse over the map to draw a rectangle selecting multiple signals together. All the selected signals will be shown in the subsystem box list. To remove a signal from the system, left click on the signal head circled in red.

vi) Click "**OK**" and open the "**Create Subsystem**" window (Figure 39) where users can define the subsystem. Users can type in a name for the newly created subsystem in the previously selected signals will be listed in the "**Signal**

Information” table below. Additionally, this function automatically identifies the connection between signals based on the link names and their relative positions.

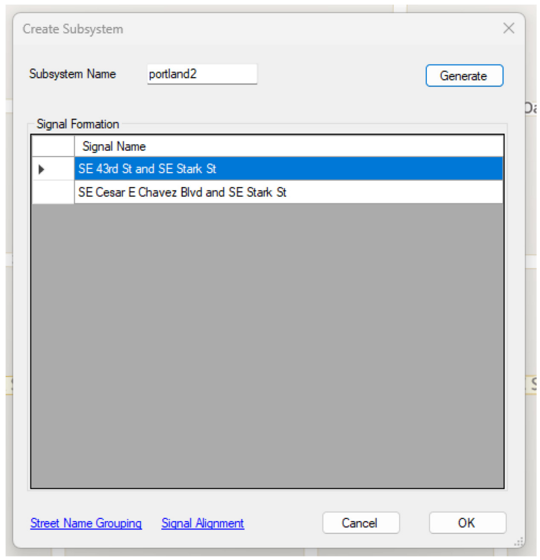

Figure 39: Creating Subsystems

vii) Click “**OK**” to create the subsystem. It will then prompt the user to proceed to the TSD or not. Click “**Yes**” to launch the TSD of the newly created subsystem; click “**No**” to dismiss and go back to the map view.

Note: If the error message shown in Figure 40 appears; it indicates one or all the following problems in this example: a) inconsistent street names are used along the corridor: e.g., part of the street is named Hwy 385 and the other part of the same street is name 2nd Street. This problem usually occurs when the file is imported from Synchro; b) the signals in the subsystem are not placed in the correct order; and c) creating a subsystem on the top of an existing one with skipped signals: e.g., an existing subsystem includes 10 signals from #1 to #10 and one cannot create another subsystem that includes signals from #1 to #6, and from #8 to #10 but misses signal #9. However, new subsystems including signals from #1 to #6, or from #8 to #10 are allowed.

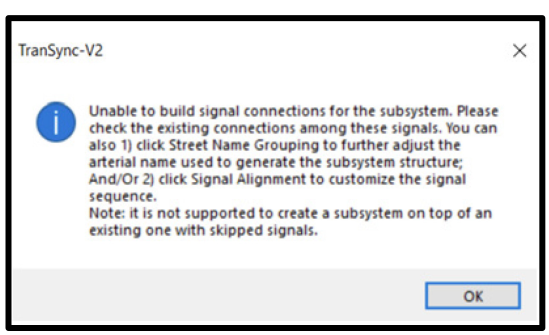

Figure 40: Subsystem Creating Error

Two functions, "**Street Name Grouping**" and "**Signal Alignment**", are provided to correct the error. If a street has more than one name, users can combine them together or simply use one. To combine street names, click the "**Street Name Grouping**" button shown on the bottom and enter the "**Combine Street Name**" window as shown in Figure 41. Uses can select all the names that pertain to the same street from left pool and join them together into the right pool. A subsystem can be created after the street names are grouped.

The other function "**Signal Alignment**" allows users to change the order of the signals in a subsystem if they have been mistakenly coded or listed in a wrong order in the subsystem.

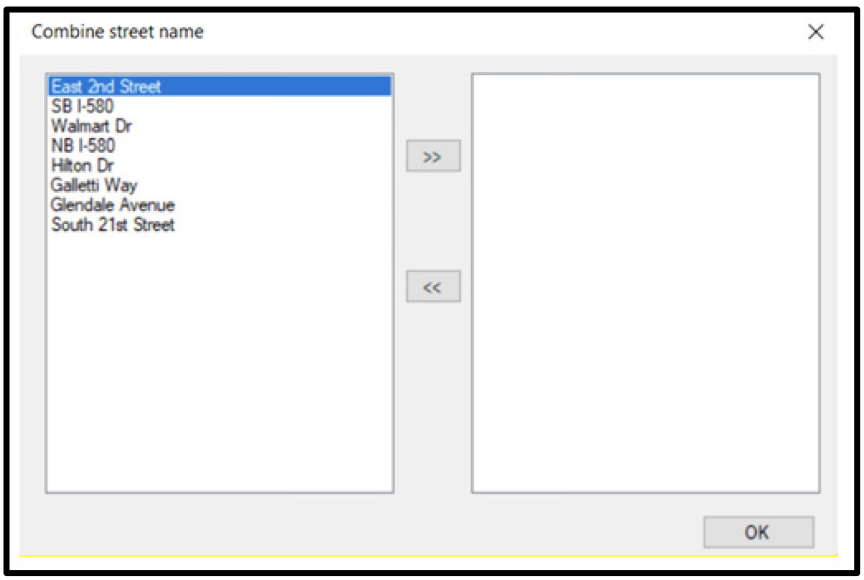

Figure 41: Street Name Combination

Video Demonstration: https://media.oregonstate.edu/media/t/1_d52ttbdj

Users can only create 50 signals in one file. If more signals are needed to produce, then a new file should be created. Details about signals timings, phases and time space diagram (TSD) are provided in Question 23.

Question 23: How can I modify the characteristics of a signal in an existing corridor model in PASS?

Answer: Please follow five-step process described here to modify the traffic signal characteristics at an intersection in an existing corridor model:

i) Double-click and open PASS. The PASS software icon can be found in the PASS software directory. Zoom in to desired area on map. Right click on existing signal and click edit signal as shown in Figure 42. Repeat this step for all intersections under consideration.

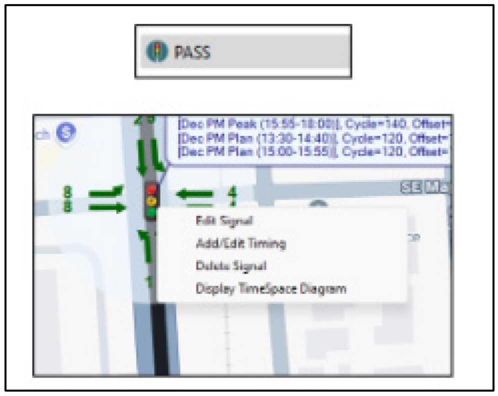

Figure 42: Opening PASS

ii) Users can modify direction and link speeds by clicking on the "Edit Signal" dropdown shown in Figure 42. Figure 43 shows the pop-up window where the user can modify directions and names accordingly. "Signa Name" is automatically updated according to the leg names.

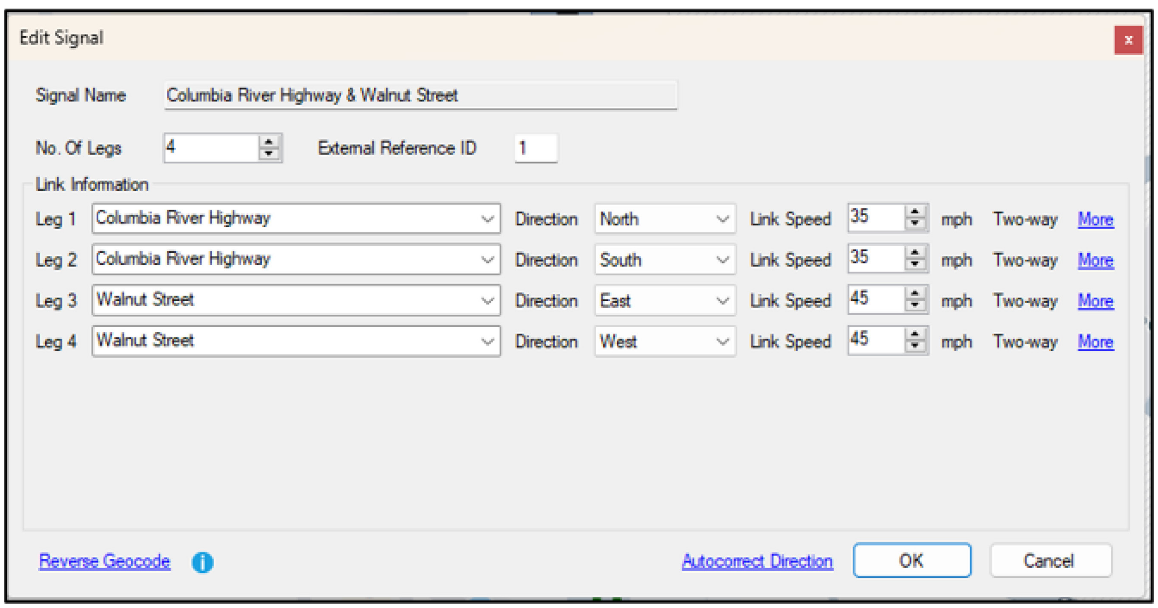

Figure 43: Editing Signal

iii) Signal timings can be modified by clicking on "Add/Edit Timings" as shown in Figure 42, and a new window will appear. In this window, phase numbers and timings can be modified as shown in Figures 44 and 45.

Figure 44: Modifying Phase Numbers in PASS

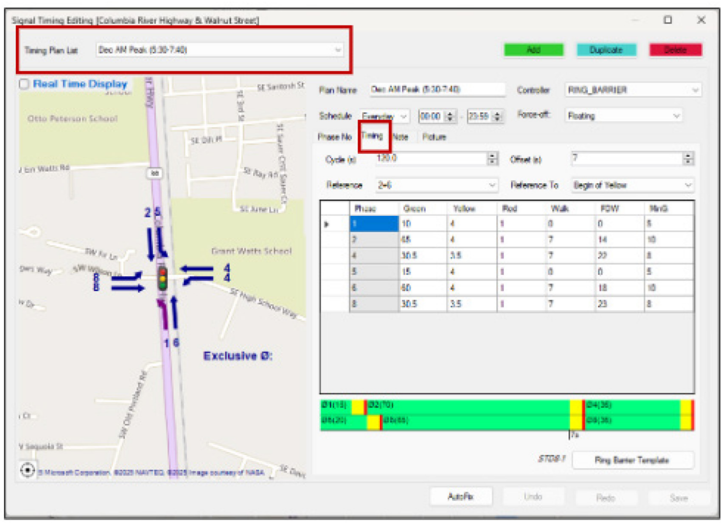

Figure 45: Modifying Timings in PASS

iv) After editing/inputting the appropriate phases and timings, click on save as shown in Figure 46. Then, double-click the icon resembling a snake on the map in PASS as shown in Figure 47. Options will be provided depending on how many timing plans have been saved in PASS. Select the desired timing plan, and a Time-Space Diagram (TSD) will be presented.

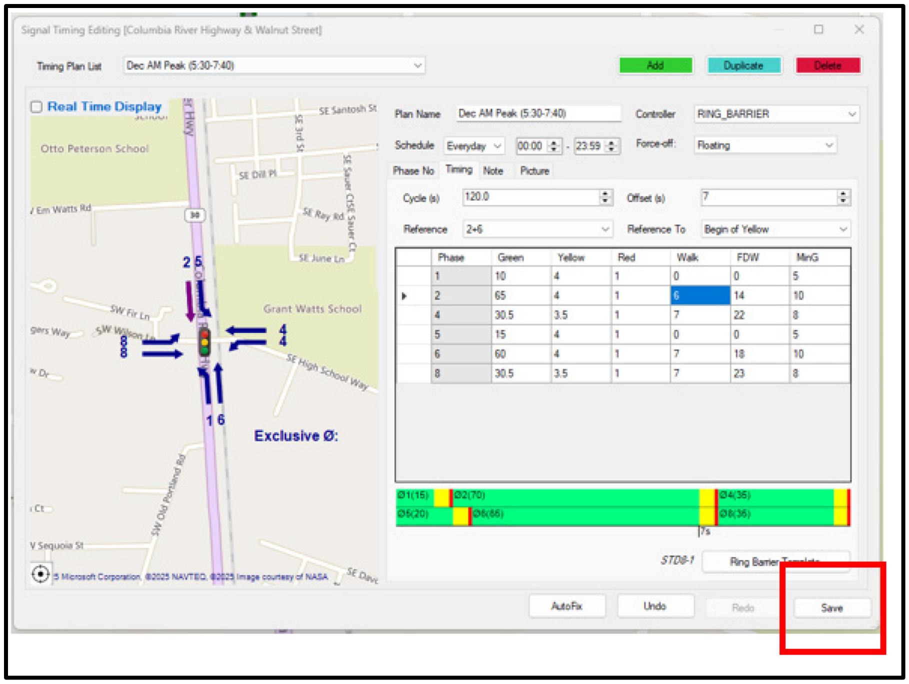

Figure 46: Saving Timing Plans in PASS

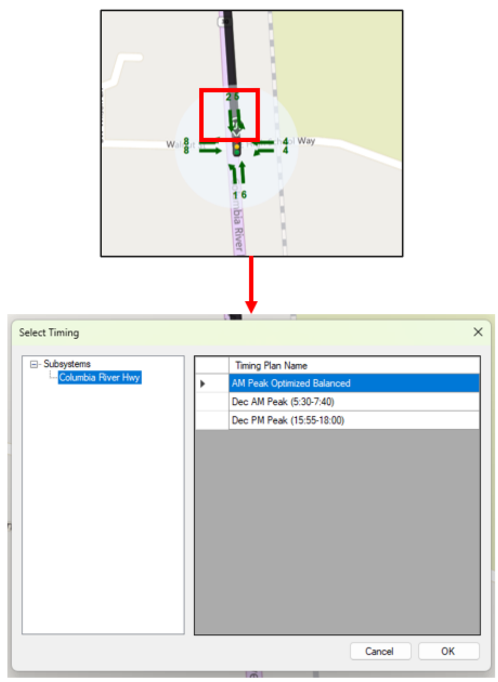

Figure 47: Displaying a Time Space Diagram

v) After clicking on the desired timing plan as shown in Figure 47, TSD will appear. This TSD window will give information about the phase number with associated timings in a ring-barrier structure with corridor segment speeds and offsets as shown in Figure 48.

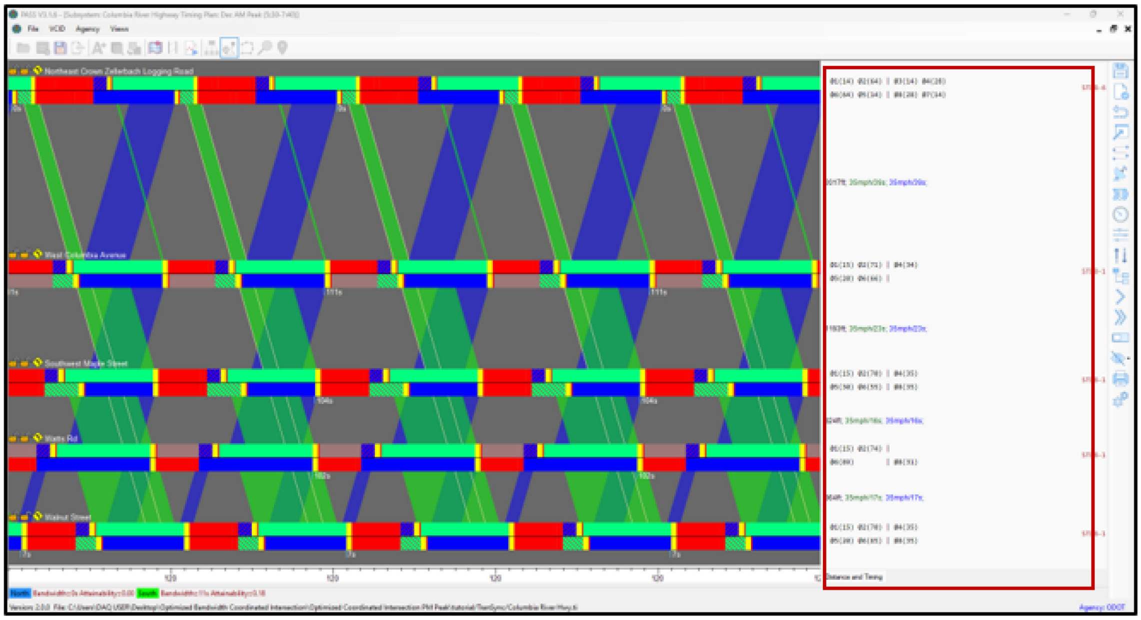

Figure 48: Time Space Diagram

Question 24: I have set up VISSIM, VCID, and PASS. How can I upload timings from VCID to Q-Free controllers at this point?

Answer: Users can type the IP addresses of controllers into any browser (e.g., Chrome, Explorer) to open the MAXTIME controller management interface. It will show a window like that shown in Figure 49. Users will need to use the correct username and password to log in to the interface for each controller.

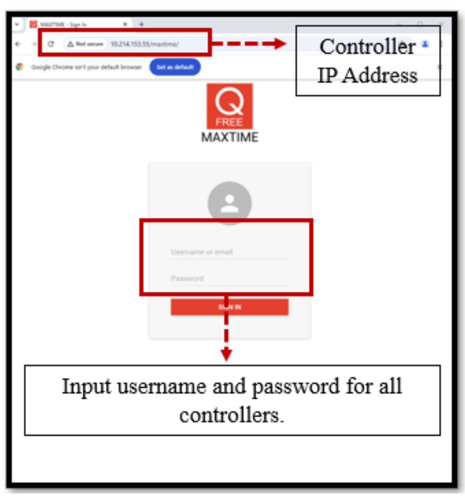

Figure 49: Logging in Controllers

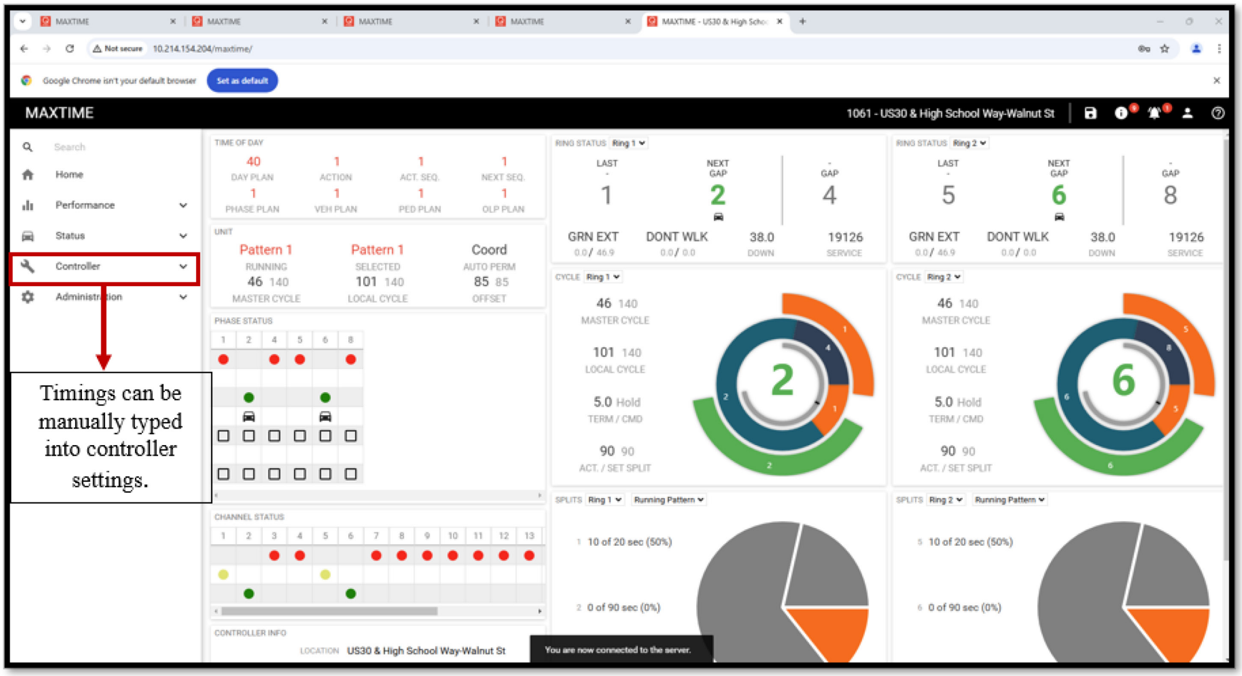

Figure 50: MAXTIME UI

Users need to set up the timing plan, schedule, and pattern settings in the following sequence:

i) Go to "Controller" → "Scheduler Configuration" → "Schedules" → Select the desired schedule and disable other schedules. In OSU's experience, we only used Schedule 40 and named it "Schedule 40 – Test". See Figure 44 for an example.
ii) Now go under "Scheduler Configuration" → "Day Plans" → "Day Plan 40" → Action 1. This action 1 refers to pattern 1.
iii) Repeat steps (i) and (ii) for all controllers.

The logic is, you have a "Schedule", link it with "Day Plan." This "Day Plan" will link to "Action" and that "Action" will link to "Pattern." Do not change the pattern in settings because the VCID will automatically update Pattern 1 as designated in the VCID configuration file. See Figures 51 and 52 for examples of the interface coding:

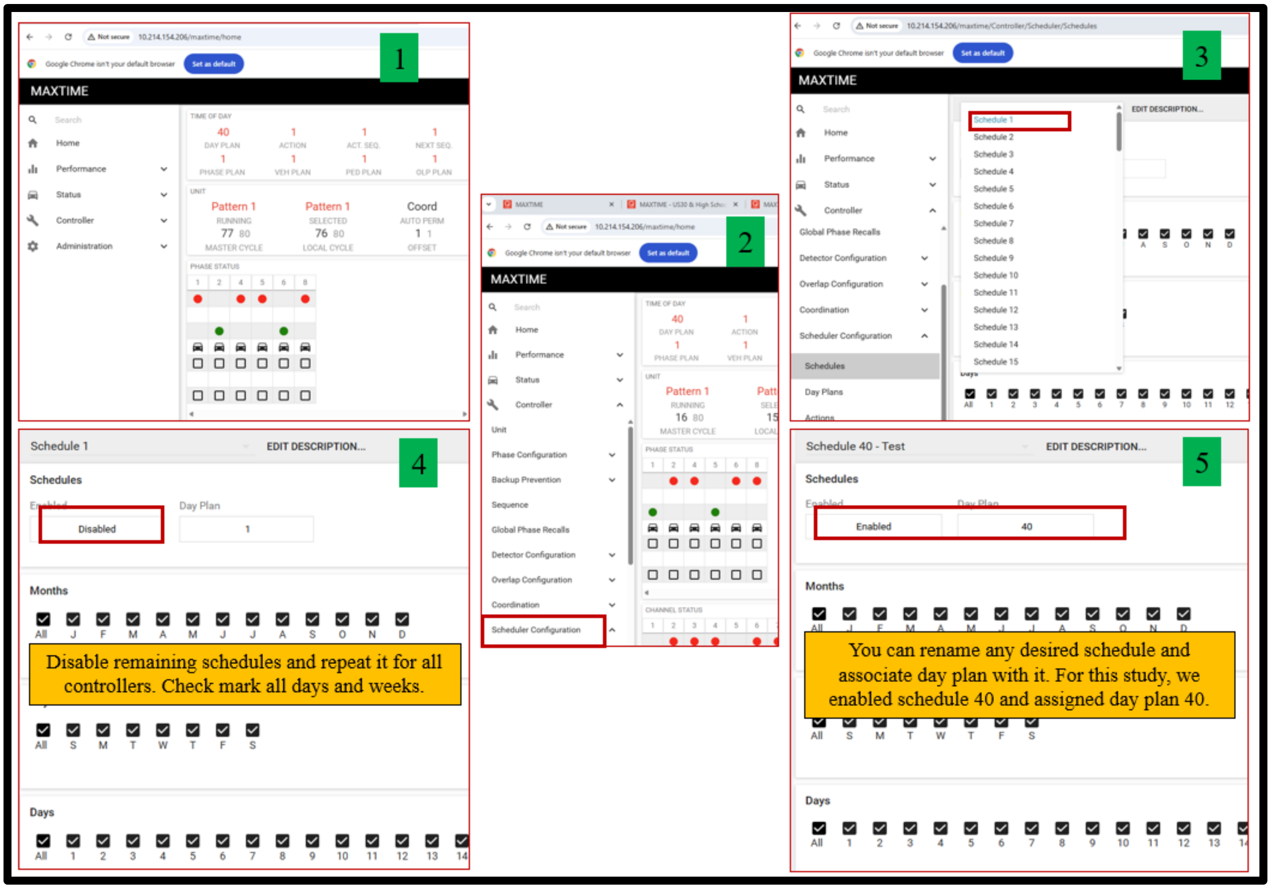

Figure 51: Setting Up Desired Schedule in Q-Free Controllers using MAXTIME

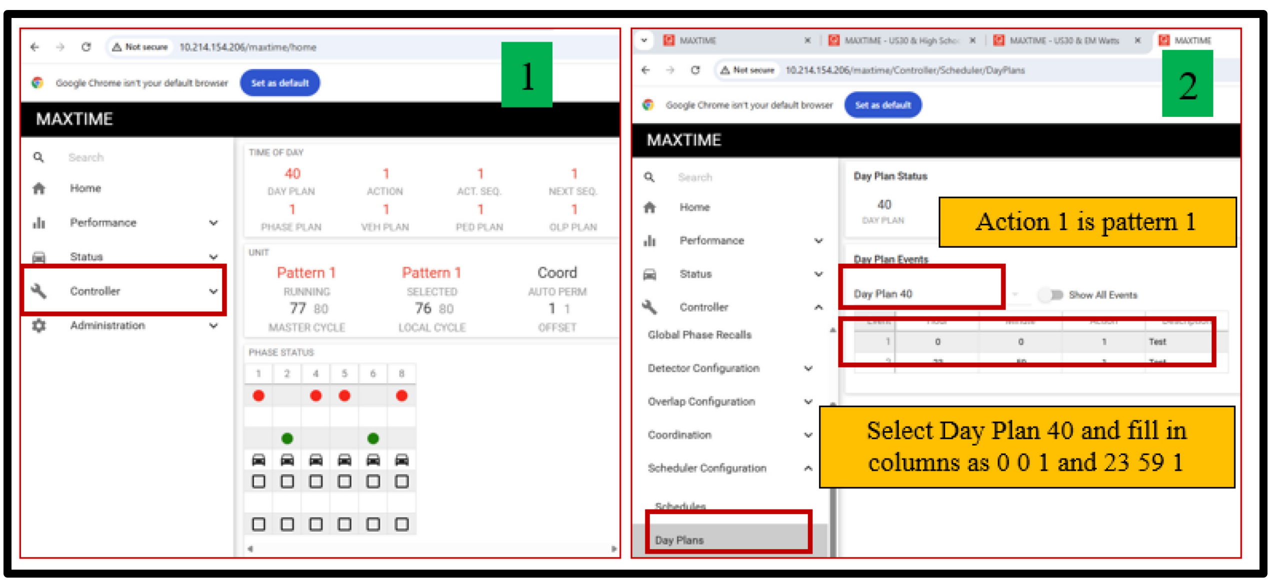

Figure 52: Setting up Desired Day Plan in Q-Free Controllers using MAXTIME

Then, users can use PASS to read and write signal timings from and to physical signal controllers. Users need to open a time-space diagram that represents a timing plan, save all changes into the PASS database, and finally click on “VCID” from the top menu bar and select

"Upload Timing to Controllers" as shown in Figure 53. This series of operations will upload the timings to all controllers. After the timing is successfully updated onto physical signal controllers, a notification window will be presented.

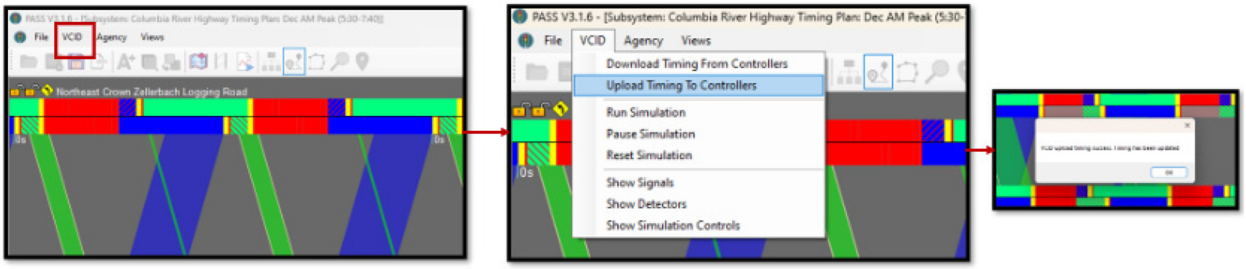

Figure 53: Uploading Timings to Signal Controllers using PASS VCID

Currently this signal configuration in PASS can only run with standard 8 phase ring and barrier configurations. If a user wants to code overlaps or other non-standard phasing, it must be done by using the MAXTIME interface or by coding directly into the controllers.

Video Demonstration: https://media.oregonstate.edu/media/t/1_e55r4cfd

Question 25: I have set up VISSIM, VCID, PASS and uploaded timings to the controllers. How can I run the simulation at this point?

Answer: Click on the PASS icon, and it will open VISSIM automatically. As you have already configured all the required parameters, now the simulation is ready to run. To run the simulation, click on the "VCID" menu tab and then click on "Run Simulation". A TSD window will appear with vehicle trajectories represented as yellow and white lines (yellow and while colors indicate different travel directions along the corridor), as shown in Figure 54.

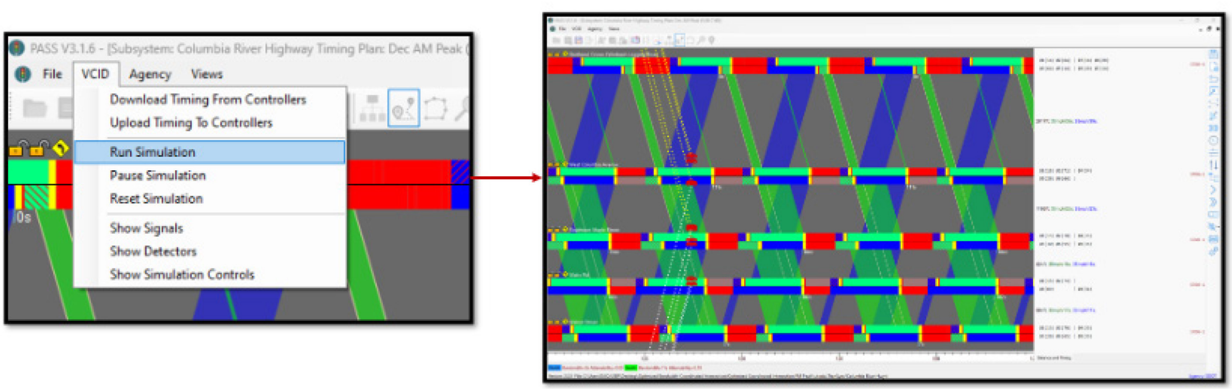

Figure 54: Running Simulation using PASS VCID

Question 26: How can I get access performance measurements for my modeled corridor, e.g., vehicle delay, stop delay, queue lengths, number of stops?

Answer: PASS provides trajectory-based evaluation results. Users can produce a simulation run, waiting for trajectories to accumulate on the time-space diagram. Then click "performance report" icon from the top toolbar to obtain trajectory-based performance measurements as shown in Figure 55.

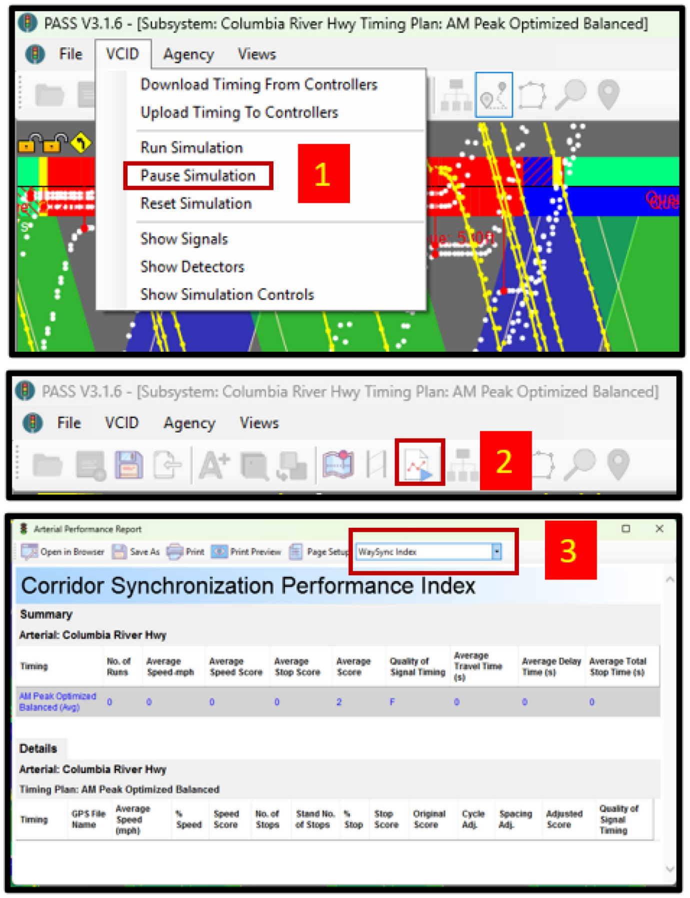

Figure 55: Performance Report Generation from PASS

Please note that the trajectories extracted from VISSIM are sampled. Performance measurements can also be extracted in VISSIM. For detailed information please refer to VISSIM 2022 User Manual.

Video Demonstration: https://media.oregonstate.edu/media/t/1_oyvh976c

Question 27: What are some common errors that can be encountered when using the HILS?

Answer: The following are four examples of common errors and their associated solutions:

i) If one or all of the controllers are not turned on or if communication is interrupted, PASS will present an error, as shown in Figure 56. If users see this error, ensure all controllers are in good operation and communication is effective.

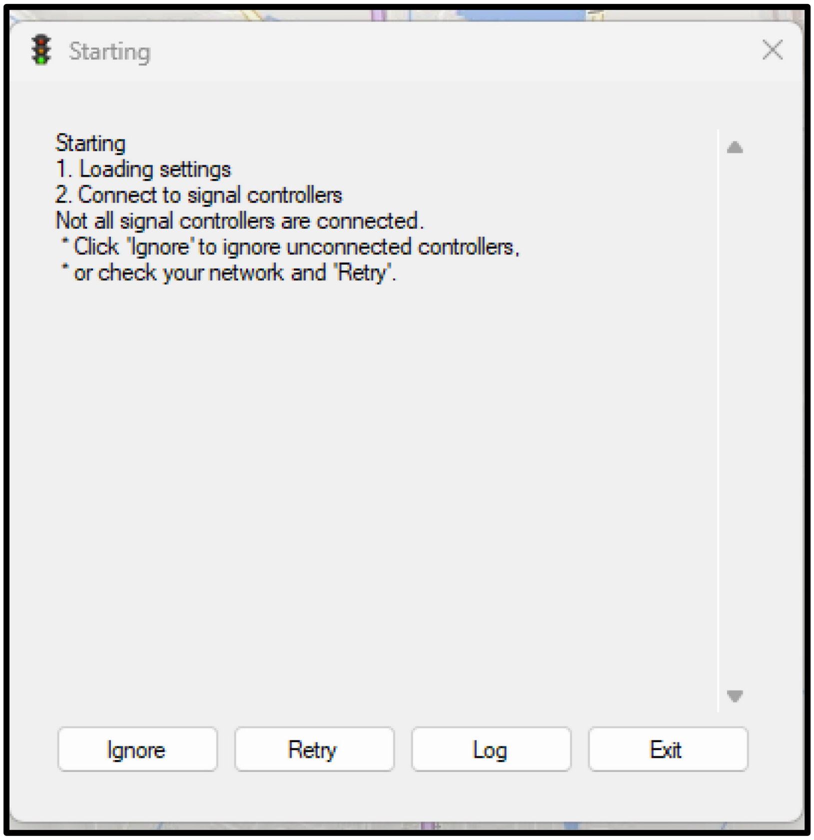

Figure 56: Error if any controller(s) is not in operation or communication is interrupted.

ii) The simulation resolution in VISSIM and the VCID should be identical, as described in Question 15. If this is not the case, the HILS will be more prone to crashing.

iii) Based on experience, for optimal functionality of HILS, controllers should only have a single plan activated in any individual trial; users should disable all other plans according to Question 23.

iv) If any controller is off or communication is interrupted, traffic at that intersection will be influenced, causing long queues and potentially halting the VISSIM simulation.

Question 28: How to acquire the 85th percentile speed from VISSIM?

Answer: To obtain the 85th percentile speed from VISSIM, you need to analyze the speed distribution data after running the simulation. You can add the 85th percentile speed as a result measure and then observe the simulation output. This is typically done by right-clicking in the result and adding a percentile (e.g., 85). The 5-step process is described here:

i) Run your VISSIM simulation, ensuring that you have the desired speed distribution defined and assigned to relevant links in your network.
ii) After the simulation, navigate to the result list where you can view various performance metrics.
iii) Right-click on the results list and select "Add" and then enter the desired percentile value, 85 in this case.
iv) The 85th percentile speed will be displayed in the result list along with other performance indicators.

Please refer to this video link from 7:24 to 31:58 for additional explanation and visualization (https://youtu.be/5mDQlvg0aIU?si=ZWxEhdde9Ihn1AnW).