

No-Passing Zone System User's Manual



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No-Passing Zone System

User's Manual

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Section 1. Introduction

On two-lane roads, drivers rely on the centerline striping to assess whether sufficient sight distance is available to pass a slower-moving vehicle. The *Manual on Uniform Traffic Control Devices* (MUTCD) and the AASHTO *Green Book* provide guidance on the minimum passing sight distance that must be available to permit passing on a two-lane highway. This guidance is based on the posted or design speed for the roadway. Where sufficient sight distance is available for at least 400 continuous feet along the roadway, a “skip” stripe is used to indicate that passing is permitted. Where sufficient passing sight distance is not available, a solid stripe is used to indicate that passing is not permitted. Passing sight distance is measured for each direction of travel independently, so it is possible for passing to be permitted in one direction of travel and prohibited in the other direction of travel at a certain point on the roadway.

Safety and traffic engineers must be able to determine the available sight distance at every point along a two-lane roadway in order to determine the appropriate centerline striping for each direction of travel along that road. Traditionally, this has been accomplished by identifying the minimum required passing sight distance for a given road, based on the speed of that road, and driving two vehicles along the road with a constant spacing between the vehicles equal to the minimum passing sight distance. As the two vehicles progress along the road, the driver of the following vehicle manually indicates the locations where a target on the lead vehicle comes into and out of view. Where the lead vehicle is visible, sufficient passing sight distance is available and passing could potentially be permitted. Where the lead vehicle is not visible, sufficient passing sight distance is not available and passing is not permitted.

Several methods have been employed for keeping the two vehicles at the desired spacing, ranging from dragging a rope the length of the minimum passing sight distance between the vehicles, to using an electronic distance measuring device in each vehicle and communicating the distance traveled by phone or radio. Generally, these methods require both vehicles to travel slowly and lack the precision and accuracy in measurements that are desired. Boundary locations between passing and no-passing zones along the roadway are either physically marked with spray paint as the measurements are recorded, or noted by a passenger in the vehicle as a log mile or distance traveled from the data collection start point.

1.1 Project Background

MoDOT desired to replace their existing passing zone measurement system with a more modern tool with the following characteristics:

- Report boundaries of passing and no-passing zones in GPS coordinates
- Allow measurements to be taken at or near highway speeds
- Keep MoDOT staff out of the roadway and roadside
- Be easily transferred among MoDOT fleet vehicles

- Maintain the basic characteristics of the two-vehicle system, in which the driver of the following vehicle manually confirms the visibility (or lack thereof) of the target on the lead vehicle continuously along the roadway

1.2 System Functionality

This system includes several hardware components, field data collection software, and post-processing and reporting software. Each is described in detail later in this manual. This system was designed to operate similarly to previous methods of passing sight distance measurement procedures used by MoDOT, in which two vehicles travel a set distance apart from each other along a two-lane highway. However, the method for maintaining the desired distance relies on highly accurate GPS devices, and real-time radio communication between those GPS devices. The driver in the following vehicle is continuously shown his or her distance along the roadway from the leading vehicle so he or she can alter his or her travel speed as needed to maintain the correct distance. Rather than manually noting boundary locations between passing and no-passing zones, the driver of the following vehicle uses a switch to indicate when the lead vehicle goes in and out of view. When the switch is flipped, the system records the point in space where this happens.

Raw data files from field data collection runs are processed in the office to link both directions of travel along the route and output a report that shows where the centerline striping should be skipped and where it should be solid in both directions of travel for a given route.

1.3 Audience and Scope

This User's Manual is intended for traffic engineers and technicians who will be either conducting passing sight distance measurement runs in the field or processing the collected data in the office.

This User's Manual includes:

- A description of the individual hardware components of the system
- Instructions for connecting and powering hardware components for data collection
- Functional specifications of field data collection software
- Instructions for completing field data collection software set-up
- Instructions for completing a data collection run in the field
- Guidance for managing and storing field data
- Functional specifications and report descriptions for post-processing software
- Instructions for generating and interpreting reports

This manual does not include detailed information about the development of the system or the testing that was conducted to validate it. That information can be found in the final report for the development of this system, located here: <http://library.modot.mo.gov/RDT/reports/TR201514/>

1.4 Organization of this Document

The information presented in this User's Manual is organized into six sections, including this Introduction. The sections themselves, as well as the information presented within each one, move sequentially through the process of preparing for, setting up, and conducting a travel time run, as well as creating a recommended striping report in the office after the data collection runs have been completed.

Section 2 identifies and describes the system hardware components. Section 3 describes the process of preparing for a field data collection run, including setting up the hardware in both vehicles. Section 4 provides guidance on collecting data in the field, including initializing the field data collection software and inputting all required information. Section 5 discusses how the raw data collected in the field should be managed, and Section 6 describes the procedure for using the post-processing software to create a recommended striping plan based on the raw field data.

Section 2. System Hardware Components

The system includes several hardware components and connection cables. The hardware components are all labeled with brightly colored tags and labels to indicate what they are and in which vehicle they are used (LV for lead vehicle and FV for following vehicle). The hardware components are listed in the following table.

Component	Number of units	Description	Vehicle Location
GPS module	2	Arduino A3 Uno microcontroller and Adafruit GPS Logger Shield in plastic housing	One GPS module in each vehicle: In LV, GPS module connects to radio via RS232 cable. In FV, GPS module connects to laptop via USB.
Radio	2	Digi 900-MHz radio modem	One radio in each vehicle: In LV, radio connects to GPS module via RS232 cable. In FV, radio connects to laptop via USB.
GPS antenna	2	External GPS antenna with magnetic base	Placed on roof of both LV and FV; connect to GPS module in vehicle
Radio antenna	2	Supplementary radio antenna with magnetic base	Placed on roof of both LV and FV; connect to radio in vehicle
Laptop	1	HP 15.6-in, with anti-glare screen; AMD Quad-Core A8-6410 processor; 4GB of memory; 500GB hard drive; Windows 7 Professional operating system	Passenger seat (or passenger lap) in FV
Monitor	1	Lilliput 7-in USB LCD video monitor	Center dashboard of following vehicle; sits on non-slip mat
Switch	1	2-pin rocker switch	Wired directly to GPS module in following car; switch held in hand of following vehicle driver
Power supply	2	Power hardware components through vehicle 12V DC outlet	12V DC splitter used in LV to power GPS module and radio; AC power inverter used in FV to power laptop

2.1 Lead Vehicle Components

The hardware components installed in the lead vehicle include a GPS module (Figure 1), radio modem (Figure 2), GPS external antenna (Figure 3), radio antenna (Figure 4), serial cable (Figure 5), two power adapters, and DC power splitter (Figure 6).



Figure 1. GPS Module (inside plastic housing case), front and back.

The GPS module (Figure 1) is comprised of a microcontroller board (Arduino Uno R3) and an add-on GPS logger shield housed together inside a hard plastic case. The GPS logger shield gathers location data from an external antenna that retrieves global positioning information from satellites. The GPS logger shield specifications indicate that it is accurate to within 10 ft. The Arduino is used to parse that location message into the elements needed for the system and to send that location message to the radio. An RS232 cable connects the GPS module to the radio.

The radio used to transmit the GPS location data from the lead vehicle to the following vehicle is a 900-MHz radio modem manufactured by Digi (Figure 2). Digi claims the radio can transmit over 3,000 ft indoors and over 40 mi outdoors when a clear line of sight is available. The radio is connected directly to the GPS module via an RS232 cable.



Figure 2. Digi XTend-PKG 900 MHz radio modem, front and back.

An external antenna (Figure 3) is needed to improve reception of the satellite signals. This antenna plugs into the GPS module case and has a magnetic base to attach it to the roof of the lead vehicle. The radio antenna (Figure 4) has a strong magnetic base to attach to the roof of the lead vehicle.

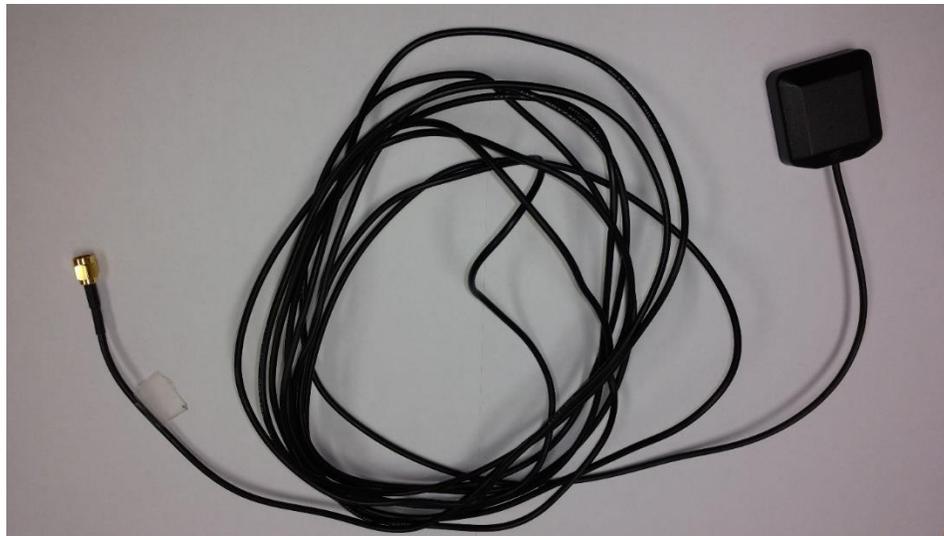


Figure 3. External GPS antenna.



Figure 4. Radio antenna.

A serial cable (Figure 5) is used to link the GPS module to the radio. Both the radio and GPS module are powered through a DC power adapter that plugs into the 12V DC outlet of the lead vehicle (Figure 6).



Figure 5. Serial cable to link radio and GPS module.



Figure 6. DC power adapter (2) and DC power splitter.

2.2 Following Vehicle Components

The following vehicle contains a GPS module with a passing sight distance rocker switch (Figure 7), a radio modem (Figure 8), external GPS and radio antennae (Figure 3 and Figure 4 above, respectively), USB cables for GPS module and radio (Figure 9 and Figure 10, respectively), a secondary dashboard monitor (Figure 11), a laptop computer (Figure 12), and a DC to AC inverter (Figure 13) to power the laptop.

The following vehicle includes the same GPS module and radio as the lead vehicle. However, in the following vehicle, these devices do not connect directly to each other, but instead each connects to the laptop through USB ports, which provides the power these devices require during field operation. The rocker switch, which is used to indicate the locations where the target on the lead vehicle transitions from visible to not visible and vice versa, is hard-wired to the GPS module so that the switch position can be indicated directly in the following vehicle GPS data file. The cord connecting the switch to the module is sufficiently long to allow the driver to hold the switch comfortably in his or her hand during the data collection run. Both the GPS unit and the radio in the following vehicle have external antennae with magnetic bases identical to those on the lead vehicle.



Figure 7. GPS module with rocker switch.



Figure 8. Radio for following vehicle.



Figure 9. USB cable for GPS module.



Figure 10. USB cable for radio.

A secondary dashboard monitor displays the current distance between the lead and following vehicles in a clear, easy-to-read format (Figure 12). The secondary dashboard monitor sits on a high-grip rubber mat on the following vehicle's dashboard. The driver uses this display to maintain the appropriate distance (the required passing sight distance) between vehicles during the data collection run. This monitor is a Lilliput 7-in USB LCD video monitor, and the display is generated by the field data collection software.



Figure 11. Dashboard monitor.

A basic laptop computer is used to run the field data collection software, store the data files as they are collected in the field, and power the dashboard monitor, GPS module, switch, and radio. The laptop is an HP 15.6-in, with anti-glare screen, running an AMD Quad-Core A8-6410 processor. It has 4GB of memory and a 500GB hard drive. It runs the Windows 7 Professional operating system.

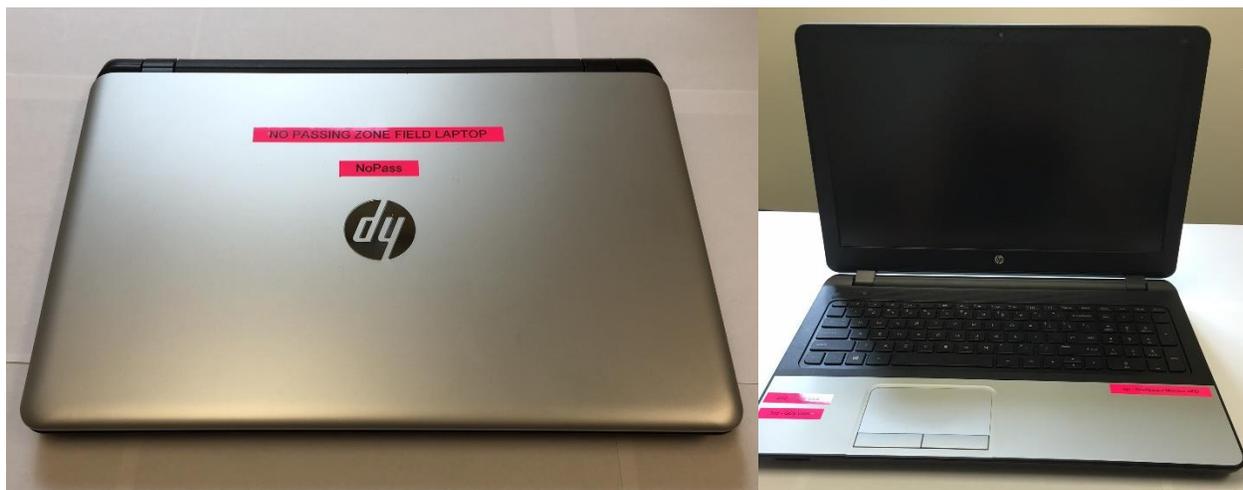


Figure 12. Field laptop.

The laptop battery does not provide sufficient power for the dashboard monitor, GPS module, switch and radio without itself being externally powered. An AC power inverter is used to plug the laptop into the following vehicle's 12V DC outlet.



Figure 13. AC power inverter.

2.3 Storage

All components of the system are stored in a protective case, except for the field laptop and laptop power adapter.



Figure 14. Protective storage case for system components.

When packing the components into the storage case, first fit the components into their designated slots.



Figure 15. Protective storage case—Open view #1.

The radio antennae should be inserted upside down such that the magnetic bases are facing upwards. Lay the wires neatly on top of the foam insert containing the components. Insert the GPS receivers into their slot such that the wires also lay on top of the foam insert containing the components.



Figure 16. Protective storage case—Open view #2.

Next, lay the wound cables on top of the already inserted components. The AC power inverter can sit on top of the foam insert as well.



Figure 17. Protective storage case—Open view #3.

Lastly, place the solid foam insert on top of the cables and place the non-slip mat and dashboard monitor on top of the solid foam insert. Place the dashboard monitor with the screen facing down.



Figure 18. Protective storage case—Open view #4.

Section 3.

Preparing for Field Data Collection

3.1 Ideal Conditions for Data Collection

In order for the following vehicle driver to see the lead vehicle, clear conditions are necessary. Fog and precipitation will impede visibility and should be avoided. Also, dry surface conditions are highly preferable so that the two vehicles may maintain proper spacing without worrying about slick roadway surfaces.

The eye level of the driver in the following vehicle must be 3.5 ft above the roadway. Therefore, it is recommended for the following vehicle to be a sedan. The lead vehicle may be any type of vehicle, but a target must be located on the back of the lead vehicle 3.5 ft above the roadway. Both vehicles must have a working 12V DC power outlet to run the equipment.

3.2 Hardware Setup

The following subsections present procedures for setting up the hardware in each vehicle. A basic schematic of the set-up of the hardware components is shown in Figure 19.

3.2.1 Lead vehicle hardware setup

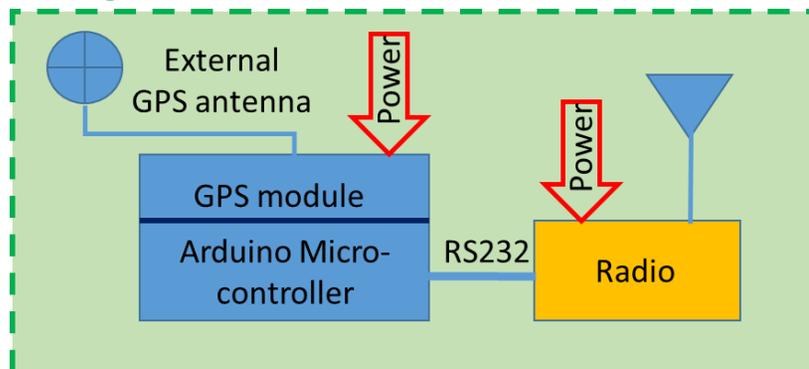
The lead vehicle hardware components are (number in parentheses refers to number located on component label):

- Radio modem (#1)
- GPS module (#2)
- Two (2) DC power adapters (#3)
- Serial cable (#4)
- Radio antenna (#5)
- GPS receiver (#6)
- DC power splitter (#7)

Steps for connecting hardware

1. Affix magnetized radio antenna to the top of the lead vehicle
2. Affix magnetized GPS receiver to the top of the lead vehicle at least 2 ft from the radio antenna
3. Plug screw-in connection of GPS receiver into GPS module (#6 into #2)
4. Plug screw-in connection of radio antenna into radio modem (#5 into #1)
5. Connect the GPS module and antenna modem with the serial cable (Connect #1 and #2 with #4)
6. Plug the two DC power adapters into each the GPS module and antenna modem (each #3 into #1 and #2)
7. Plug the two DC power adapters into the DC power splitter (Both #3s into #7)
8. Plug the DC power splitter into a 12V DC outlet in the lead vehicle

Leading Vehicle



Following Vehicle

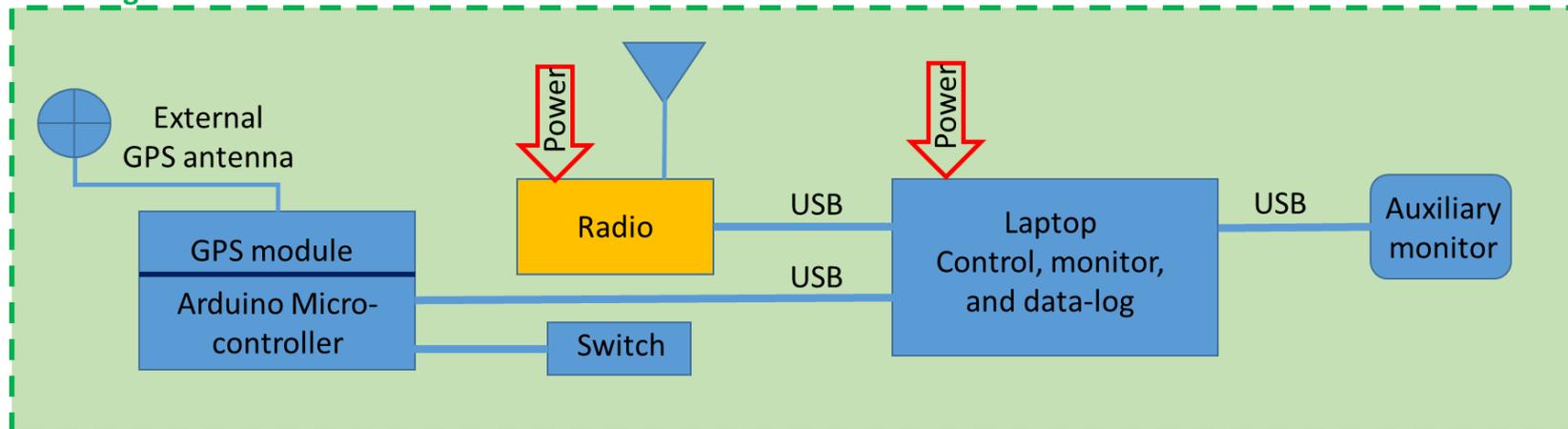


Figure 19. Schematic of hardware configuration.

3.2.2 Following vehicle hardware setup

The following vehicle hardware components are:

- GPS module with rocker switch (#11)
- Radio modem (#12)
- GPS receiver (#13)
- Radio antenna (#14)
- GPS USB cable (#15)
- Radio USB cable (#16)
- AC power inverter (#17)
- Field laptop
- Laptop power adapter

Procedure for connecting hardware

1. Affix magnetized radio antenna to the top of the following vehicle
2. Affix magnetized GPS receiver to the top of the following vehicle at least 2 ft from the radio antenna
3. Plug screw-in connection of the GPS receiver into GPS module (#13 into #11)
4. Plug screw-in connection of radio antenna into radio modem (#14 into #12)
5. Plug radio USB cable into radio modem (#16 into #12)
6. Plug GPS USB cable into GPS module (#15 into #11)
7. Place dashboard monitor on dashboard of following vehicle. Use the non-slip mat if needed.
8. Plug laptop power adapter into AC power inverter and plug AC power inverter into 12V DC outlet in following vehicle
9. Power on the field laptop (**NOTE: DO NOT CONNECT ANY USB CABLES TO THE LAPTOP YET**)
10. When Windows has fully booted on the field laptop, plug the USB cables into the field laptop in the following sequence:
 - a. Plug dashboard monitor USB into the USB port on the right side of the laptop
 - b. Wait for dashboard monitor to show a background
 - c. Plug radio USB into the USB port on the left side closest to the screen
 - d. Wait five seconds
 - e. Plug GPS USB into the USB port on the left side closest to the front of the laptop

3.3 Establish Parameters of Data Collection

Before going out to the field to conduct a travel time run, system operators should decide on the desired running speed, the beginning and end points of the data collection run, and the locations where the vehicles will meet prior to and at the conclusion of the run.

Running speed—The running speed refers to the speed at which the lead and following vehicles travel. It is recommended to drive 5 to 10 mi/h below the posted speed limit. It is also recommended for the lead vehicle to use cruise control as much as possible so that the following driver can easily maintain proper spacing. On roadways with horizontal curves requiring speed reduction, the following vehicle must anticipate the lead vehicle slowing through the curve. Also, the lead vehicle must maintain a slow speed until the following vehicle traverses the curve.

Data collection endpoints—Prior to beginning a data collection run, establish which points will be the beginning and end of the data collection.

Staging locations—Before going out to the field to conduct a data collection run, identify appropriate areas to park the vehicles prior to the start and after the end of the data collection run. These locations could be wide shoulders, public driveways, roadside parks, or field entrances large enough to store both the lead and following vehicles. A staging area allows the driver of the following vehicle to initialize the field data collection software and enter the required input data for the run near the beginning of the run, but away from the flow and pressure of traffic. It also allows the drivers of the two vehicles the opportunity to communicate any changes to the running speed or data collection end points before beginning the run. Identifying these staging locations prior to leaving the office provides an agreed-upon spot for the vehicles to meet prior to the start of data collection, should they become separated during the drive to the data collection route.

Section 4.

Conducting a Data Collection Run

When all hardware is set up according to the instructions given in the previous section, data collection may begin. The system design requires at least two operators—a driver for the lead vehicle and a driver for the following vehicle. This section discusses the procedure for conducting a data collection run and using the field software. At the end of this section, a summary of the operator responsibilities addresses the option of using a third operator to help manage the workload for the driver in the following vehicle.

4.1 Vehicle starting positions

Before starting the software, determine where and how the two vehicles will start the data collection run. Presented here are a few suggested strategies; however, the users may develop their own strategies based on experience and local conditions.

- *Vehicles begin at running speed*
Some roadway segments may begin at a point where it is possible for both vehicles to be at operating speed and properly spaced at the beginning of the roadway segment.
- *Vehicles start from stop, closely spaced*
Some roadway segments may begin at a stop-controlled intersection. In this case, both vehicles can start from a position just past the intersection. The lead vehicle should accelerate first and the following vehicle should start slowly and then accelerate to match the lead vehicle's speed when the distance between the vehicles is approaching the target distance.
- *Vehicles start from stop, properly spaced*
Similar to the previous strategy, this strategy may be used on roadway segments that begin after a controlled stop. But rather than the vehicles beginning closely spaced, the vehicles could start from a position such that the distance between vehicles is near the target distance. Then both vehicles can begin and accelerate simultaneously.

4.2 Define run details in software

The driver of the following vehicle is generally responsible for operating the field data collection software. The following instructions apply to the driver of the following vehicle.

Open the field software by double-clicking the icon on the field laptop . The setup screen appears first, which is labeled as the “Trial setup” tab.

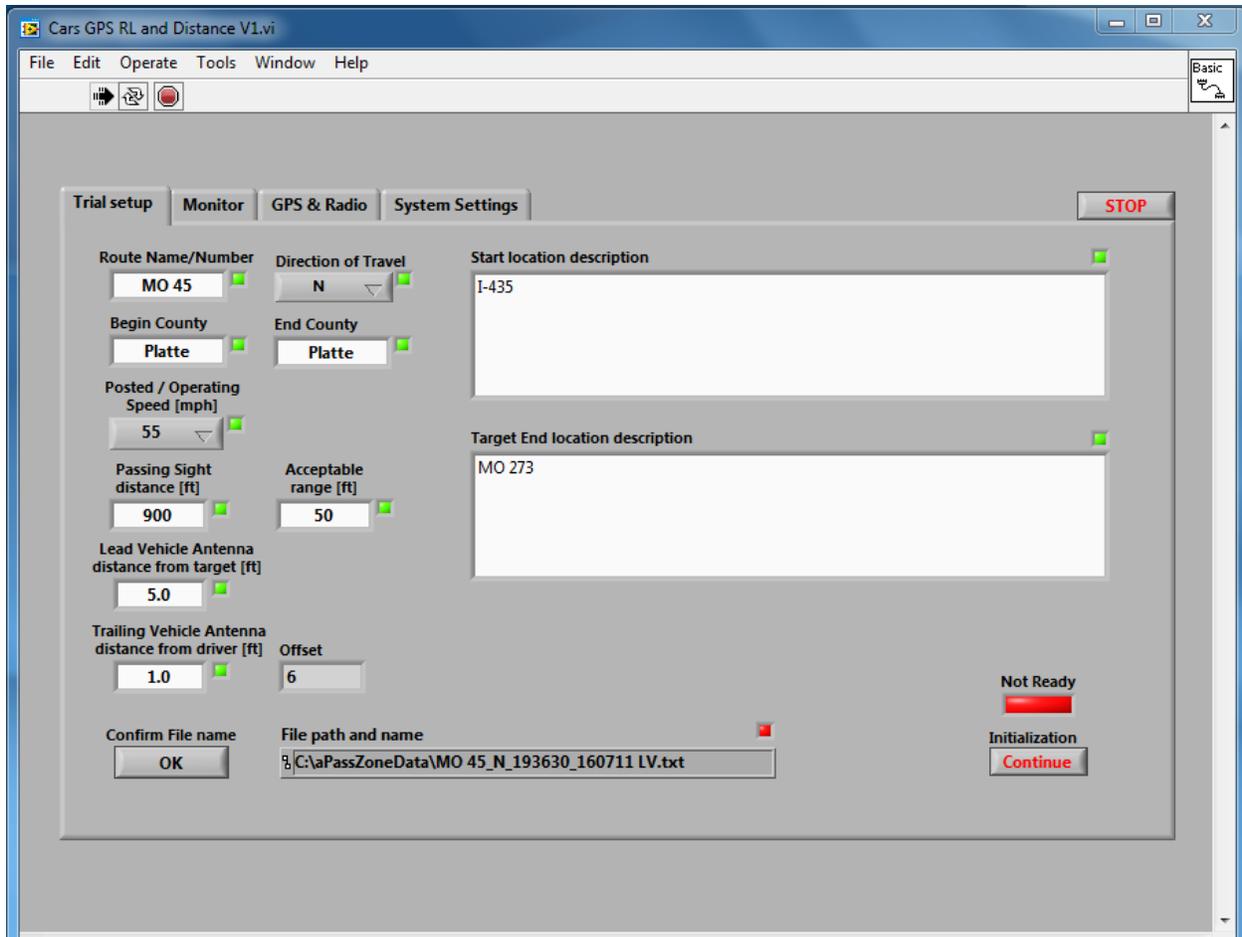


Figure 20. Screen shot of field software GUI on laptop in following vehicle—Trial setup tab.

Enter all information about the data collection run in the setup form:

- **Route Name/Number:** name or number of route where the data will be collected
- **Direction of Travel:** drop-down menu indicating the general direction of travel for the run. This information is important so opposing directions of travel can be differentiated during post-processing.
- **Begin County:** Name of county in which data collection begins.
- **End County:** Name of county in which data collection ends.
- **Posted/Operating Speed (mph):** This value may be based on the 85th-percentile speed of traffic (if available), the posted speed limit, or the speed limit applicable by statute (if no speed limit is posted). This value determines passing sight distance.
- **Passing Sight Distance (ft):** This value will be automatically populated once the posted/operating speed is selected.

- **Acceptable Range (ft):** This value is the acceptable range of distance between the two vehicles beyond the passing sight distance. For example, if the passing sight distance is 900 ft and the acceptable range is 50 ft, then it is acceptable for the following vehicle to be 900 to 950 ft behind the lead vehicle.
- **Lead Vehicle Antenna Distance from Target (ft):** This is the horizontal distance between the radio antenna on top of the lead vehicle and the target, most commonly on the rear of the lead vehicle. This is a positive distance if the target is behind the antenna, which is generally the case.
- **Trailing Vehicle Antenna Distance from Driver (ft):** This is the horizontal distance between the radio antenna on top of the following vehicle and the approximate location of the eye of driver of the trailing (following) vehicle. This is a positive distance when the antenna is behind the driver, which is generally the case.
- **Offset:** This is the sum of the lead vehicle antenna distance from target and the trailing vehicle antenna distance from driver. This value is automatically calculated.
- **Start Location Description:** This field should be used to give a description of exactly where the data run begins, such as “Route B Junction”.
- **Target End Location Description:** This field should be used to give a description of exactly where the data run ends, such as “US 24 Junction”.
- **File Path and Name:** This is the location where the data files are stored. The file name is automatically generated based on route direction, date and time. The file location cannot be changed.
- The colored squares next to each field will turn green once the field is populated or a value in the drop-down box is selected.

When all squares are green except for the File Path and Name square, click OK to confirm the file name.

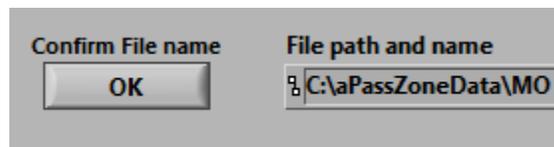


Figure 21. Close up view of Trial Setup tab, showing the Confirm File Name button.

Next, a window will appear asking to confirm the initial setup. If all inputs are correct, click OK. Otherwise click Cancel.

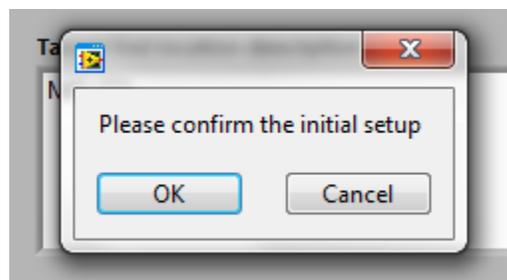


Figure 22. Confirmation button for initial setup.

Upon clicking OK to confirm the initial setup, the “Monitor” tab appears automatically and the dashboard monitor starts displaying distance information. Clicking “cancel” closes this pop-up box and allows the user to make changes to entries on the trial setup page.

4.3 Start run

Note: These instructions are for the operator of the following vehicle.

Before beginning the data collection run, confirm that the GPS antennae are receiving satellite data and the radios are communicating properly. On the Monitor tab, the lead vehicle and following vehicle positions are shown in latitude and longitude coordinates. These are obvious indicators of whether the GPS units and/or radios are functioning properly.

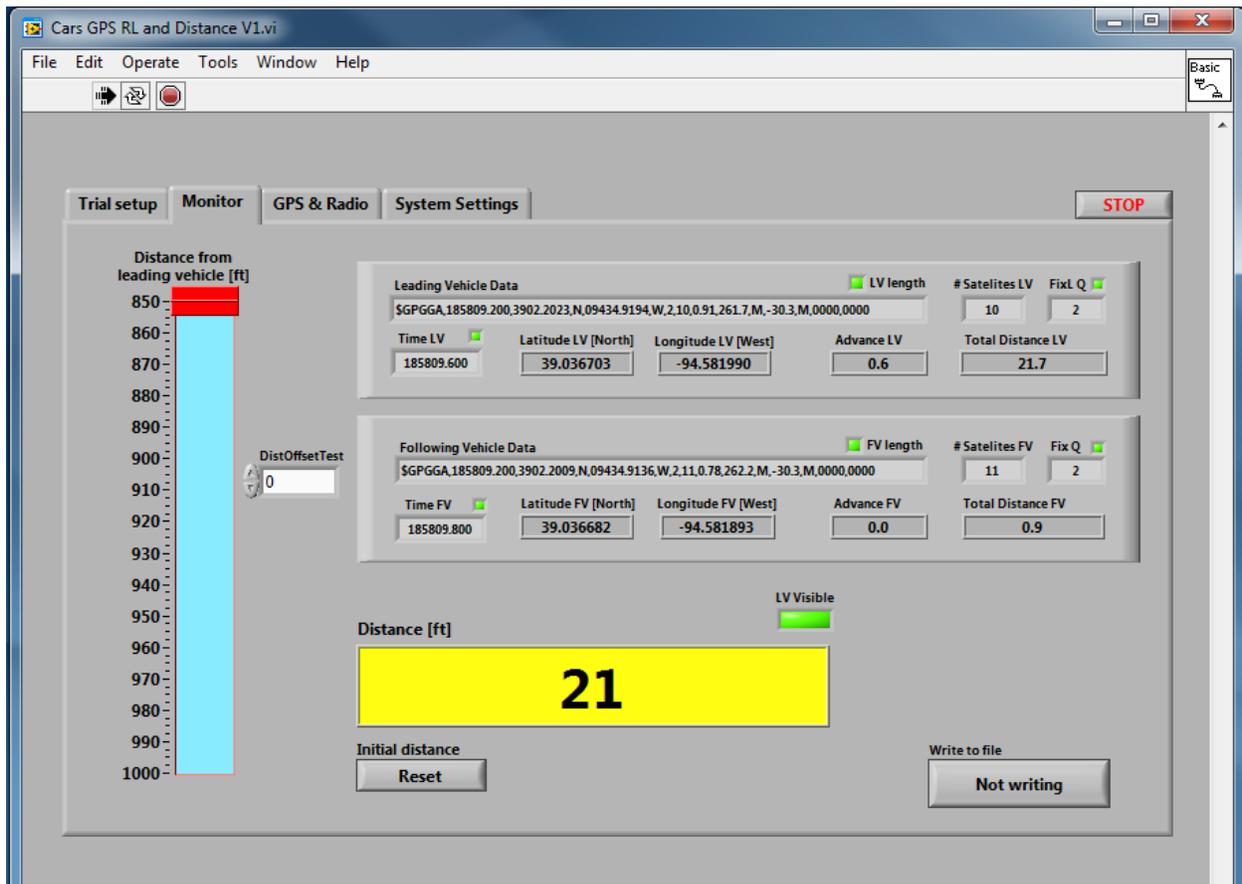


Figure 23. Screen shot of field software GUI on laptop in following vehicle—Monitor tab.

The Monitor tab contains the following data:

- **Leading Vehicle Data:** This is the raw text string transmitted from the lead vehicle. This string contains all necessary data for the software to determine its location and status.
- **LV length:** This is a status box that indicates whether the lead vehicle data is good. A green indicator means that the data is of good quality.
- **# Satellites LV:** This is the number of satellites to which the lead vehicle’s GPS receiver is attached.

- **FixL Q:** This value is used by the software to validate satellite data.
- **Time LV:** This is the reported time from the satellite data received by the lead vehicle. This value is parsed from the raw data string and is in Universal Time, in the format HHMMSS.SSS.
- **Latitude LV [North]:** This is the latitude of the lead vehicle, with a positive value indicating northern latitudes.
- **Longitude LV [West]:** This is the longitude of the lead vehicle, with a positive value indicating eastern longitudes.
- **Advance LV:** This value is the distance (ft) traveled by the lead vehicle during the last 0.2 seconds.
- **Total Distance LV:** This is the total distance driven by the lead vehicle since the beginning of the run plus the initial straight-line distance between vehicles. Note that if the Initial distance Reset button is pressed, the Total Distance LV will reset to the straight-line distance.
- **Following Vehicle Data:** This is the raw text string transmitted from the following vehicle. This string contains all necessary data for the software to determine its location and status.
- **FV length:** This is a status box that indicates whether the following vehicle data is good. A green indicator means that the data is of good quality.
- **# Satellites FV:** This is the number of satellites to which the following vehicle's GPS receiver is attached.
- **FixQ:** This value is used by the software to validate satellite data.
- **Time FV:** This is the reported time from the satellite data received by the following vehicle. This value is parsed from the raw data string and is in Universal Time, in the format HHMMSS.SSS.
- **Latitude FV [North]:** This is the latitude of the following vehicle, with a positive value indicating northern latitudes.
- **Longitude FV [West]:** This is the longitude of the following vehicle, with a positive value indicating eastern longitudes.
- **Advance FV:** This value is the distance (ft) traveled by the following vehicle during the last 0.2 seconds.
- **Total Distance FV:** This is the total distance driven by the following vehicle since the beginning of the run. Note that if the Initial distance Reset button is pressed, the Total Distance FV will reset to zero.
- **LV Visible:** This shows the position of the rocker switch. If the color is green, then the switch is in the "ON" position, indicating the lead vehicle is visible to the following vehicle. Otherwise, the color will be gray.
- **Distance [ft]:** This display shows the roadway distance (ft) between the two vehicles. The background color is yellow when all hardware components are operating properly. Otherwise, a red background indicates a problem in the hardware.

- **Distance from Leading Vehicle [ft]:** This is a slider bar scale that indicates the distance between the two vehicles. The upper and lower bounds of the scale depend on the passing sight distance and acceptable range. The slider bar will be green when vehicles are within acceptable range. Otherwise, the slider bar will be red.
- **DistOffset Test:** This value allows the user to adjust the slider bar scale range for testing purposes.

These data in the Monitor tab are to ensure that all components of the system are communicating and working properly before the data collection run begins. Components that are critical for the following vehicle driver to view during the run are displayed on the dashboard monitor.

- **Write to file:** When all hardware components are operating properly, position the vehicles to begin collecting data. Click the Write to file button, which initially is labeled “Not writing”. When this button is clicked, it will turn dark gray and show “Writing” indicating that data is being written to the log files and data collection may begin.

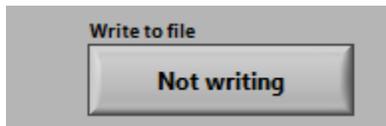


Figure 24. Write to file button on trial setup page.

- **Initial distance:** Once the leading and following vehicles are moving and the vehicles are on a tangent, click the “Reset” button to set the initial distance.

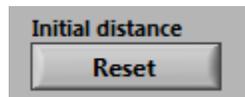


Figure 25. Initial distance button on trial setup page.

4.4 During run

The following vehicle driver should use the dashboard monitor as a guide to stay within proper distance of the lead vehicle.

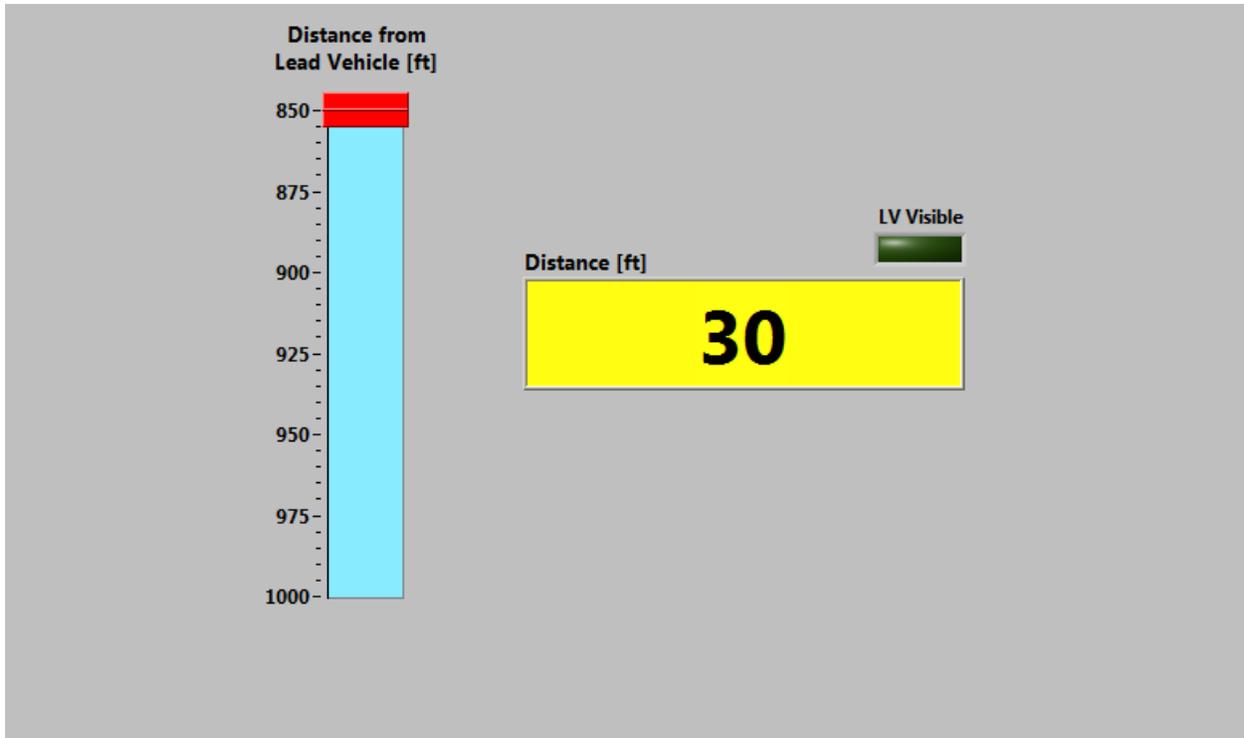


Figure 26. Screen shot of dashboard monitor in following vehicle during run.

The slider bar will turn red when the distance is out of acceptable range. The rocker switch is used to indicate the visibility of the target on the lead vehicle. The switch should be in the “ON” position when the target is visible and in the OFF position when the target is not visible. An indication on the dashboard monitor will appear green when the switch is in the “ON” position, and will be grey when the switch is in the OFF position.



Figure 27. Indication of the switch position on the dashboard monitor.

If during the run the dashboard monitor displays a “99999” on a red background as the distance between vehicles in the Distance [ft] box, then a communication problem has occurred in the system. This could be attributed to any of several factors, such as GPS receivers losing satellite reception or radio communication failure. If this drop out is shorter than 2 seconds, then the system will correct itself and resume reporting the distance between vehicles. However, if the failure is longer, then the dashboard monitor will continue to display a “99999” in the Distance [ft] box until all systems are functioning properly. Once satellite communication is restored, the display will change to “11111” on a yellow background to indicate that the distance calculation cannot be resumed until the system is reset. The operator in the following vehicle must manually reset the distance once both vehicles are on a tangent by pressing the initial distance “Reset” button.

4.5 Stop run

When the run is over, click the “Writing” button to end writing data to the log files. Then click the stop symbol  at the top left of the screen. (The red STOP button at the top right corner of any of the field software tabs can also be used for the same purpose.)

If data collection will continue on the same roadway segment but in the reverse direction, or on another roadway segment, click the run arrow button  at the top of the screen to the left of the stop symbol. This will return the display to the setup screen. Select the new direction of travel and fill out the start and end location descriptions. Repeat the same data collection steps for the opposing direction of travel.

4.6 Advanced menus

The GPS & Radio and System Settings tabs are advanced menus and only need to be used in special cases. The GPS & Radio tab is intended for advanced troubleshooting to be conducted by the software and hardware developers.

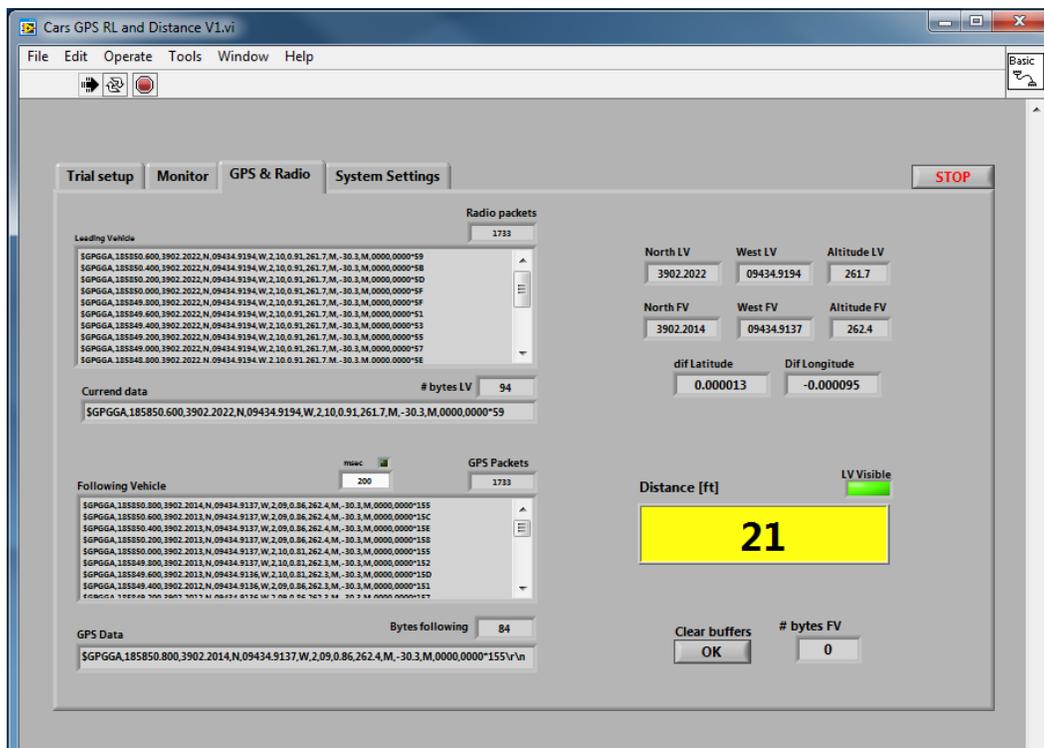


Figure 28. Screen shot of field software GUI on the field laptop in following vehicle—GPS & Radio tab.

The System Settings tab is intended for troubleshooting and advanced settings.

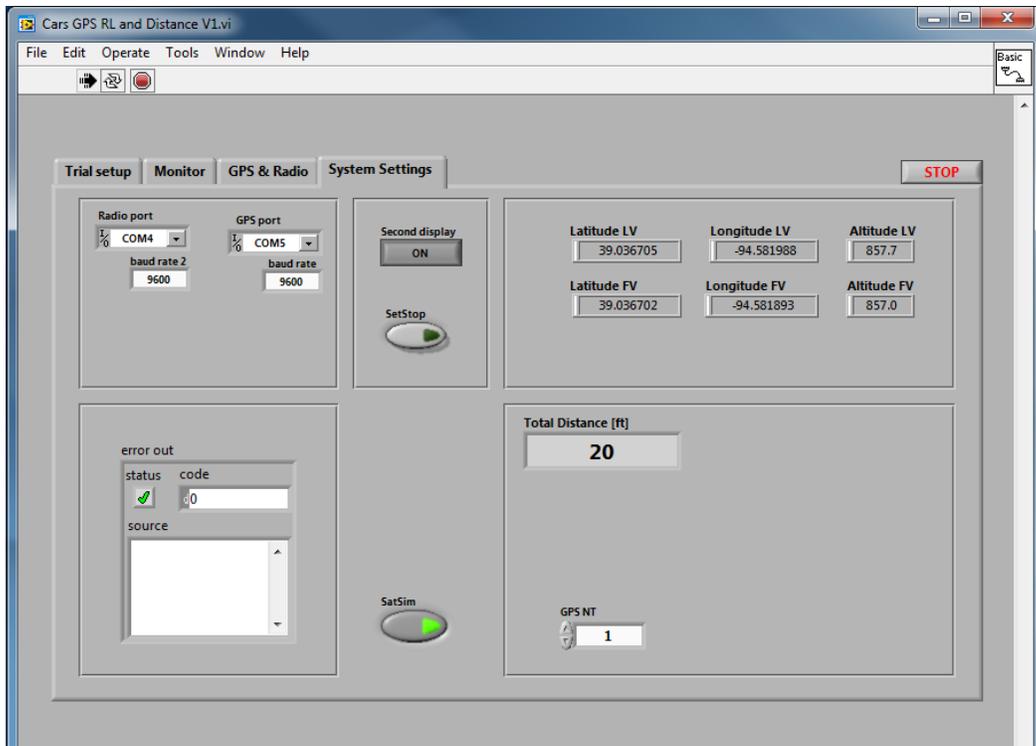


Figure 29. Screen shot of field software GUI on the field laptop in following vehicle—System Settings tab.

The top left section of the System Settings menu shows which communication ports are being used on the field laptop for the radio USB and GPS USB inputs. The Radio port should always be COM4 and the GPS port should always be COM5. On the drop-down menu, the image of two monitors should appear next to both “COM4” and “COM5”. If either one does not display the image, unplug the USB cable corresponding to that COM port and plug it back into the field laptop. Click Refresh to check that the image displays. If the image displays, restart the software application. If the image does not display, retry a few more times, unplug all USB cables and reboot the field laptop and restart the setup process.

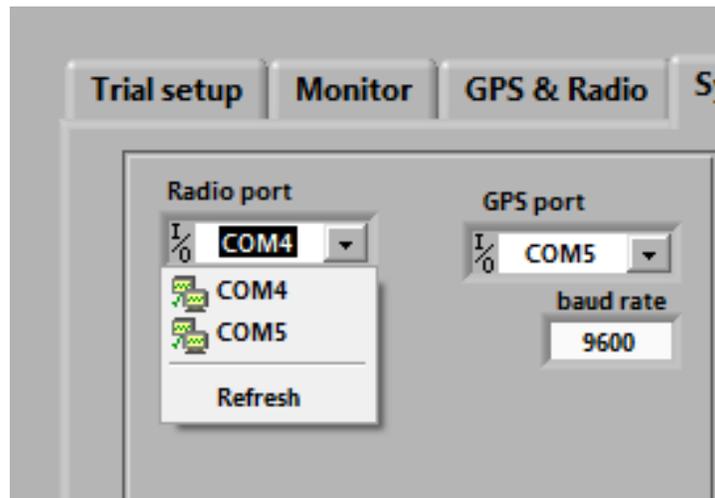


Figure 30. Close-up screenshot of System Settings tab.

The GPS NT setting (see Figure 29) determines the minimum speed at which each vehicle must be moving for the software to record movement. It is recommended to set this setting to 1 for data collection runs. By default, it is set to 5. With the setting at 1, this means that both vehicles need to move at least 1 ft between data collection points, which occurs every 0.2 seconds. Thus, both vehicles need to move at least 5 ft/s (approx. 3.4 mph) before the software considers the vehicles to be moving.

4.7 Operator responsibilities

As described in the preceding sections, the primary operation of the system during a field data collection run takes place in the following vehicle. The lead and following drivers' responsibilities are summarized next.

Lead Vehicle Driver's Responsibilities

- Install lead vehicle hardware components; ensure components are properly powered.
- Stop in a safe place prior to the start of the run to allow the driver of the following vehicle to input all necessary field data.
- When following driver indicates the field software inputs are complete, begin run. Gradually increase speed to pre-determined running speed for the route.
- After reaching the pre-determined running speed, maintain a constant speed throughout the run to the extent possible.
- If running speed must slow to navigate a sharp curve, maintain the reduced speed until the following vehicle has also exited the curve, then slowly accelerate to pre-determined running speed.

Following Vehicle Driver's Responsibilities

- Install following vehicle hardware components; ensure components are properly powered.
- While stopped in a safe place prior to the start of the run, open the field data collection software on the laptop and input all necessary data.
- Indicate to the lead driver that the run can begin.
- Begin the run slowly; accelerate to the pre-determined running speed gradually, allowing the lead vehicle to achieve the proper spacing between vehicles.
- Near the desired start point of the data collection run, click the "begin writing" button (Figure 24) on the GUI on the laptop to begin recording GPS data to the file.
- Watch the display of the distance between vehicles on the dashboard monitor and adjust speed as necessary to maintain the desired distance from the lead vehicle.
- Watch the target on the lead vehicle. Flip the rocker switch when the target goes out of view or comes into view.
- As the lead vehicle approaches a sharp curve that will require a speed reduction, try to anticipate that speed reduction and reduce speed accordingly.

- If data dropouts occur, wait until GPS data communication is available (distance display will go from “99999” or a red background to “11111” on a yellow background). At the next point where both vehicles are again on the same tangent section of roadway, click the reset button on the GUI.
- At the completion of the run, click the “stop writing” button on the GUI and pull off the road at an appropriate location.
- Determine if another run in that direction of travel is desired and communicate to driver of lead vehicle.

The workload for the following driver can be somewhat high at times, especially on rolling or curvy terrain, where frequent changes between passing and no-passing zones are expected. To make this workload more manageable, MoDOT may consider assigning a passenger in the following vehicle to serve as a third operator and share the workload associated with operating the system.

The third operator could be responsible for the following:

- Interact with the field software during the run (such as starting and stopping writing to the file and clicking the “reset” button).
- Operate the switch (although, because passing sight distance is measured from the perspective of the driver, the driver would need to provide verbal indication of when the switch should be flipped).
- Help monitor the distance shown on the dash monitor and telling the driver to speed up or slow down to maintain the desired distance.

4.8 Troubleshooting

The following table provides some guidance for troubleshooting issues that may occur in the field:

Issue	Troubleshooting Procedure
Display of distance between vehicles is quickly flickering between a yellow and red background, and between valid distance data and an error message.	The 12V DC splitter in the lead vehicle may be loose, causing interrupted power to the GPS and radio. Unplug and re-insert the power supply. If this occurs during a data collection run, it is best to end the run, stop the data collection software, and then begin the run again after strong and steady satellite/radio communication is restored.
During hardware set-up, software indicates that no satellite data is being received.	This may indicate a potential problem with the field laptop failing to recognize the devices plugged into the communications ports (USB drives). Check the COM port statuses on the System Settings menu. See Section 4.6 for more discussion on troubleshooting COM ports. If this does not solve the issue, check the status LEDs on the side of both radio modems. If they are not lit, this indicates power is not reaching the devices.
The menu intended for the dashboard monitor is appearing on the field laptop after the field software has been closed.	This will happen if the field software is not properly closed. Open the task manager on the field laptop and force the program to close using the task manager.

Section 5.

Managing Raw Data

After the data is collected in the field, the raw data will need to be downloaded from the field laptop and uploaded to a computer for post processing with Microsoft Excel.

5.1 Raw data format

The data collected by both the leading and following vehicles are saved on the field laptop in the form of text files (.txt). Each run generates one text file for each vehicle. For example, a northbound run on a route will generate two text files:

- The leading vehicle text file name will include the route name, direction, time, date, and “LV” for leading vehicle (i.e. “blue river rd_N_150211_160518 LV.txt”)
- The following vehicle text file name will include the route name, direction, time and date (i.e. “blue river rd_N_150211_160518.txt”)

For the example file names given above, it can be inferred that the northbound run on Blue River Rd began at 3:02:11pm (15:02:11) on May 18, 2016. While it is not necessary to manually open these files and interpret the raw data, the user will need to be able to select the appropriate run files when processing the raw data (see next section).

5.2 Retrieve and transfer raw data

The raw data files will be located in “C:\aPassZoneData”. Use a USB flash drive to transfer the desired text files from the field laptop to the workstation containing the post-processing software. Microsoft Excel must be installed on the workstation. Wherever the data files are saved on the workstation, make sure it is in a location that can be retrieved later during post processing. DO NOT rename any of the raw data files.

Note that only the files from the following vehicle are needed for post-processing. This is because the real-time distance between vehicles calculated during the data collection run and the position of the rocker switch, indicating the visibility of the target on the lead vehicle to the driver of the following vehicle, are recorded to the following vehicle file. The lead vehicle file contains only the timestamp and latitude and longitude data for each 0.2 seconds during the data collection run. The lead vehicle file is currently used only for real-time distance calculations in the field. In the future, this file may provide additional functionality by providing a second set of roadway alignment data that could be used to supplement areas where location coordinates were not being received by the following vehicle GPS unit. For this reason, it is recommended that all the files recorded during field data collection be saved to an office workstation.

Data should not be stored for long periods of time on only the field laptop. It is recommended that all data files collected in the field be transferred to an office workstation as soon as possible after the completion of the day’s data collection runs. Preferably, the workstation used for data file storage and post-processing is one that is connected to a network where regular data backups are performed.

Section 6.

Producing a Recommended Striping Plan Report

The raw data files are processed with custom post-processing software to generate centerline striping recommendations for the portion of the route on which data was collected. This section describes the procedure for opening and running the post-processing software to produce a recommended striping plan report.

6.1 Post-processing software functionality

The post-processing software is contained within a macro-enabled Microsoft Excel spreadsheet. The post-processing tool can be opened like any other Excel workbook; however, when opening the post-processing tool Excel file, the user must enable macros when prompted. The tool analyzes the raw data files from the following vehicle for both the forward and reverse directions of travel on a specific segment of roadway for which a continuous data collection run was completed. It produces a table of the latitude and longitude coordinates for locations along the roadway segment where changes to the recommended centerline striping occur. The tool will also report the number of passing zones identified in the field but removed by the post-processing software because they were shorter than 400 ft (the minimum allowable passing zone length by MUTCD standards). The recommended striping plan report will also indicate whether a valid distance between vehicles was recorded at each point where the centerline striping recommendation changes.

6.2 Running the software

To start processing the raw data files, open the “Post Processing Tool.xlsm” file. This macro-enabled spreadsheet must be located on the workstation where the field data collection raw data files were saved. The following steps will lead the user through running the post-processing software to create a recommended striping plan report.

1. After opening the spreadsheet and enabling macros, open the “Input” worksheet.

No Passing Zone Post-Processing Tool

First, click the "Define GPS File Location" button. You will be prompted to navigate to the folder that contains the raw data files.

Define Raw Data File Location

File Location: \\mriglobal\kcs\shares\Projects\110906\Task 2\Blue River Trial

Second, click the "Process Raw Data Files" button. You will need to select the two text files that correspond to a particular route segment. After the tool has finished analyzing the data, a "Results" worksheet will appear in this workbook containing all points along the route segment in which the centerline striping changes.

Process Raw Data Files

v1.0 2016, MRIGlobal, Kansas City, MO



Figure 31. Screenshot of the No Passing Zone Post-Processing Tool—Input tab.

2. Follow the on-screen instructions. First, define the location where the raw data files are stored for the route segment of interest by clicking the *Define Raw Data File Location* button. The following window will appear:

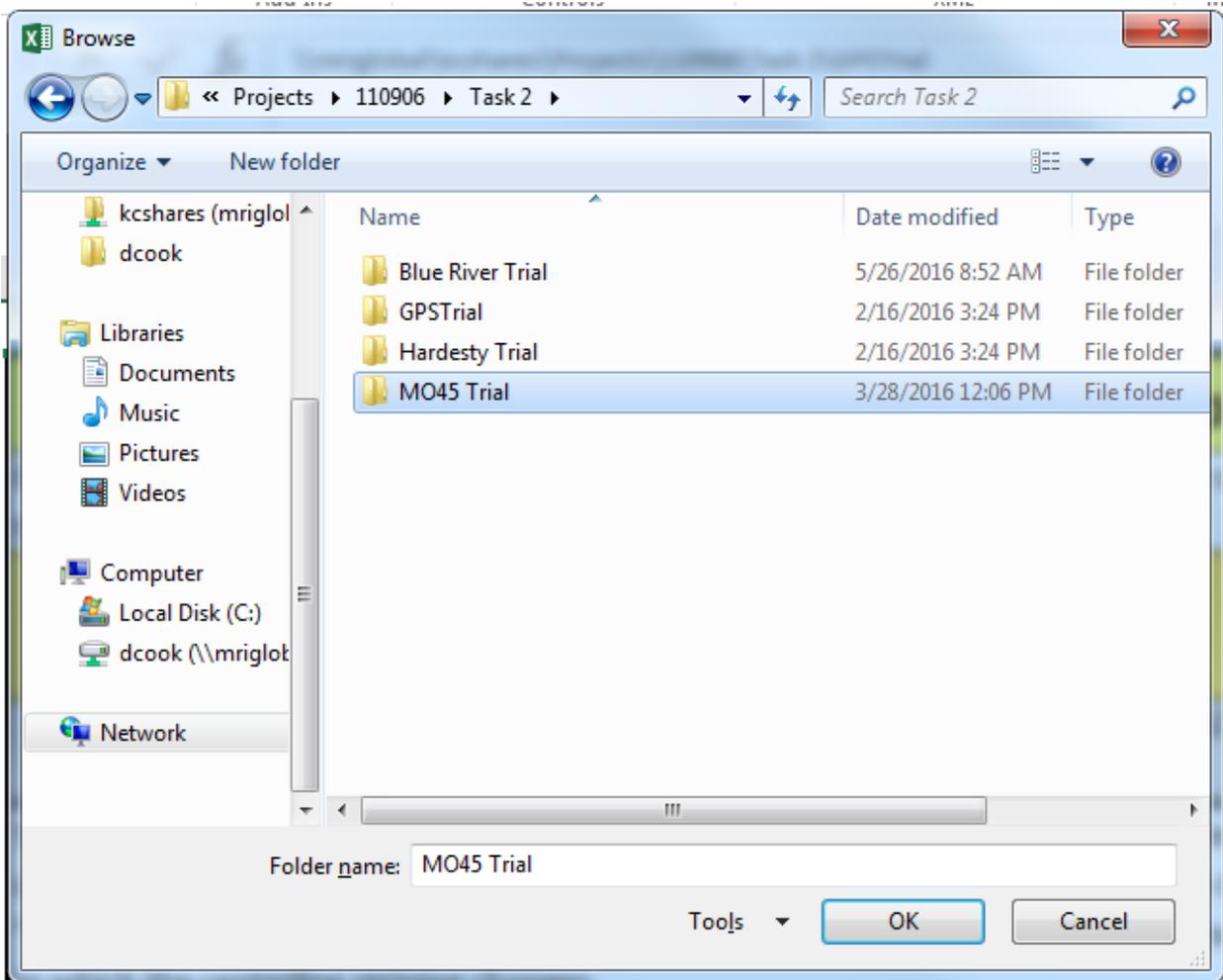


Figure 32. Screenshot of workstation desktop—File location.

3. Browse to the folder containing the raw data files. Select the folder or open the folder, then click *OK*. The file location is listed in the gray area on the post-processing tool input screen after the *OK* button is clicked.

- Next, click the *Process Raw Data Files* button on the input screen. The following window will open:

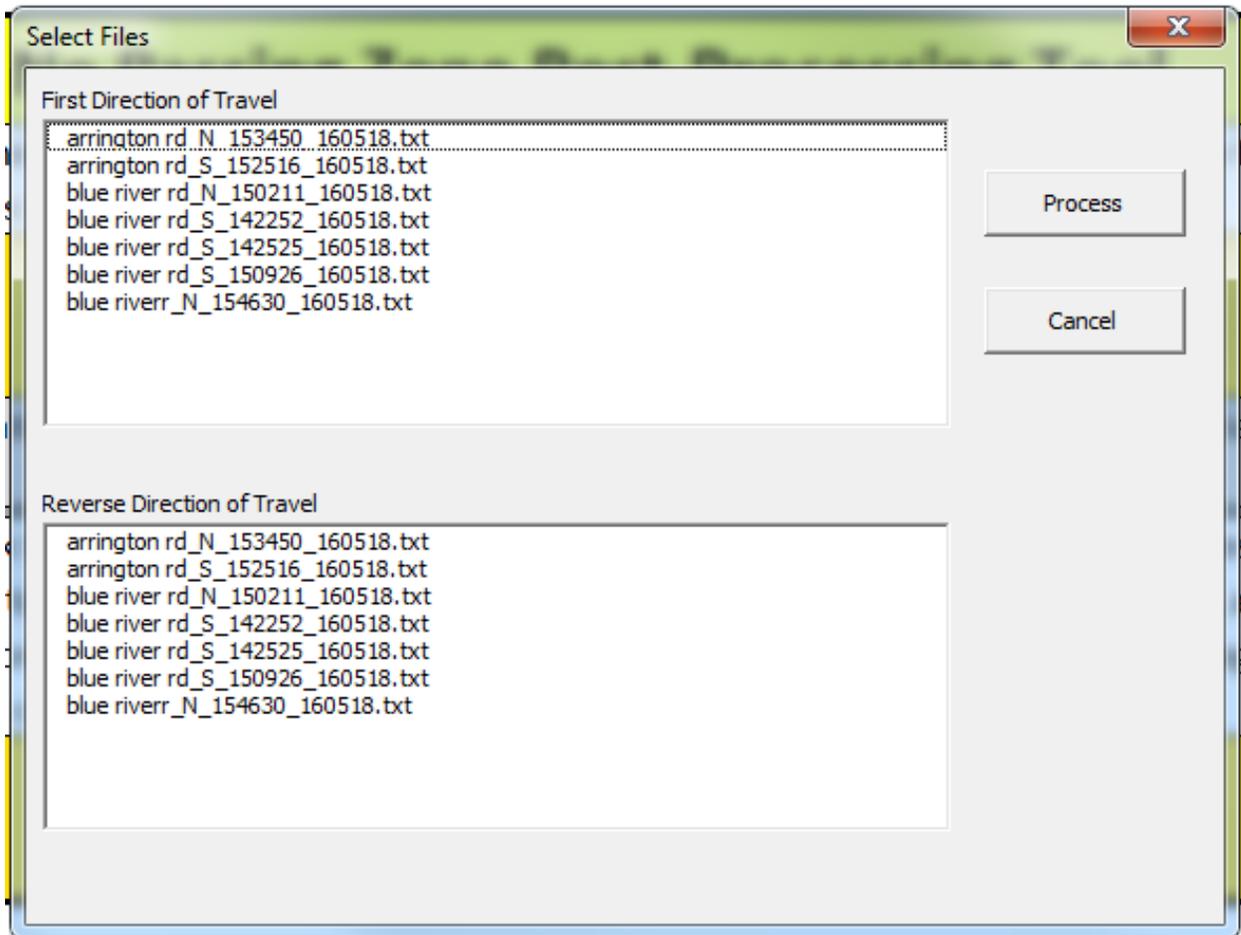


Figure 33. Screenshot of list of raw files to process.

- Select the file pertaining to the first direction of travel on the route segment of interest. Next, select the file for the reverse direction of travel for that route segment. Use the file nomenclature to assist in selecting files (see previous section on Raw Data Format). After the desired files have been highlighted, click the *Process* button on the window to run the post-processing software.

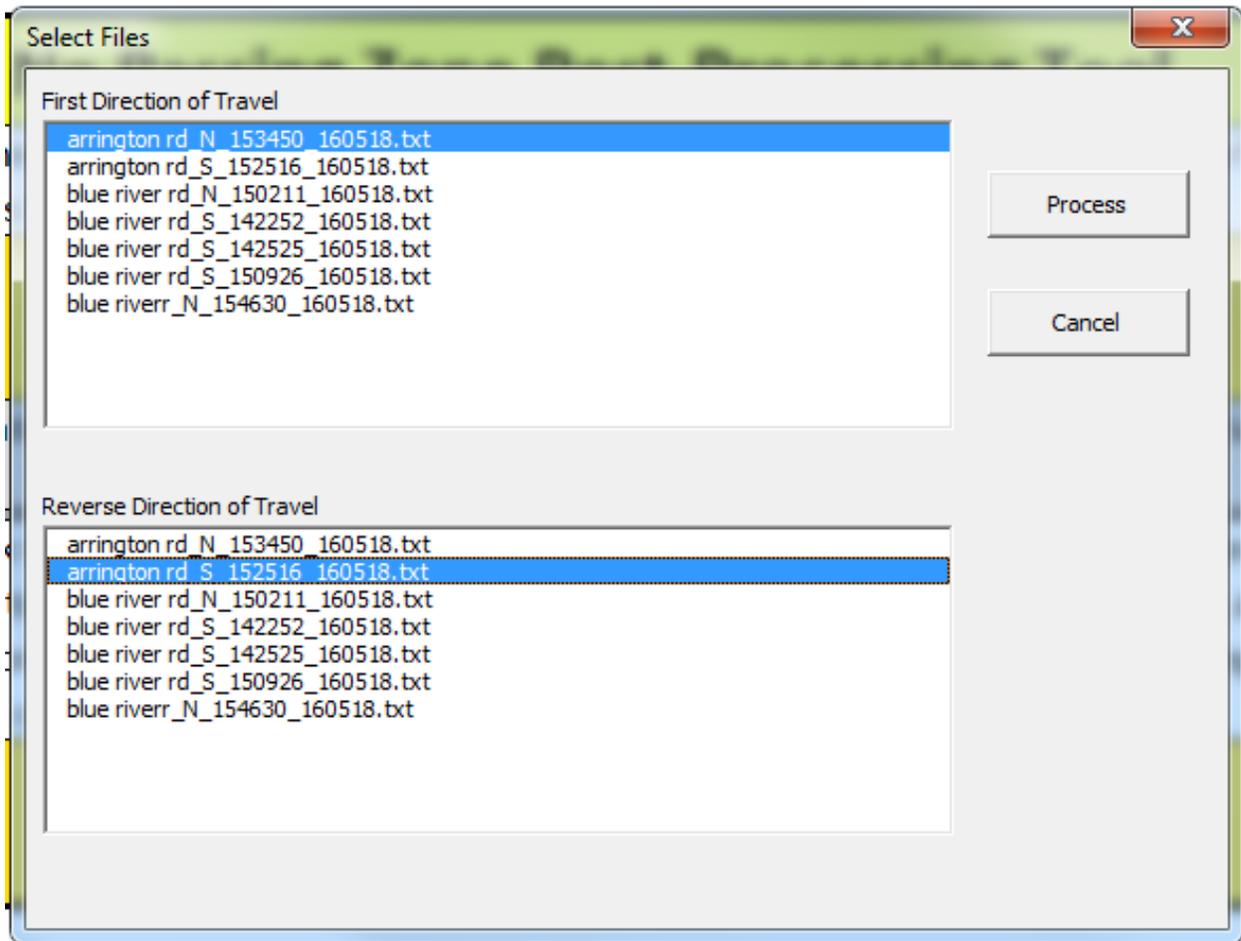


Figure 34. Screenshot of selected text files to process.

When the program completes the analysis, the “Results” worksheet will appear in the Post Processing Tool.xlsm workbook. This worksheet contains summary characteristics of the route segment and a table of the latitude/longitude coordinates where changes to the centerline striping are recommended.

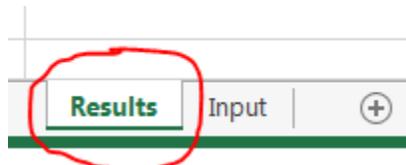


Figure 35. Screenshot of the No Passing Zone Post-Processing Tool—Close-up of Results tab.

6.3 How to interpret results

The results appear automatically in a new worksheet when the macro is finished running. The report includes information about the roadway segment, the time and date of both directions’ runs, and the number of passing zones identified that were shorter than 400 ft and, therefore, removed from the recommended striping plan. The report also provides a table of the coordinates for each point where the recommended centerline striping changes. The report indicates what the striping should change to, and whether the following vehicle was within acceptable range of the

lead vehicle at the striping point of change. If the rocker switch was flipped during a field data collection run at a time during a data dropout, the report will highlight that striping change in red, indicating that reliable distance between the two vehicles was not available at the time of the indication. (See example recommended striping plan report in Figure 36.)

Ideally, satellites are always within range of the GPS receivers, but occasionally a data dropout may occur either because the GPS receiver is not receiving satellite data or because the radios lost communication. Generally, the data dropouts are short, and the vehicles are able to quickly resume the desired spacing in the field after the distance calculation is resumed. However, when the rocker switch is flipped during a data dropout, the true distance along the road between vehicles is not available, so it is possible that the vehicles were closer than the minimum passing sight distance at the point where the visibility of the lead vehicle changed. This can result in errors in the recommended striping plan. The striping plan report warns the user of this possibility by highlighting in red the cells in the report where the data dropout occurred. When this happens, it may be necessary to redo the data collection on that road segment.

The recommended striping plan report also indicates whether the following vehicle is within acceptable range of the lead vehicle. If the following vehicle is closer to the lead vehicle than what is acceptable at the point of centerline striping change, the report will show a negative value in the “distance from acceptability” column and this cell will be highlighted in red. Otherwise, if the vehicle is further from the lead vehicle than what is acceptable at the point of centerline striping change, the report will show a positive value in the “distance from acceptability” column and this cell will not be highlighted in any color. The user may interpret a greater distance as being more conservative and acceptable if the distance from acceptability is not too great. However, the user may decide to recollect the data if the distance from acceptability is negative.

Route	EE	Striping Changes in the Forward Direction					
Forward Run Direction	E	Latitude	Longitude	Reverse Stripe	Forward Stripe	Range Status	Difference from Acceptability
Reverse Run Direction	W	38.815052	-92.590583	Dash	Dash		
County Start	C	38.818193	-92.590497	Dash	Solid	Following Vehicle Out of Range	-4
County End	C	38.819737	-92.590447	Dash	Dash	Vehicles Within Acceptable Range	
Forward Run Start Time	6/7/2016 15:36	38.820782	-92.590415	Solid	Dash	Following Vehicle Out of Range	59
Forward Run Start	87	38.822257	-92.590372	Dash	Dash	Vehicles Within Acceptable Range	
Forward Run End	179	38.822785	-92.590355	Dash	Solid	Following Vehicle Out of Range	-1
Reverse Run Start Time	6/7/2016 15:47	38.825348	-92.590192	Solid	Solid	Vehicles Within Acceptable Range	
Reverse Run Start	179	38.825795	-92.587285	Solid	Dash	Following Vehicle Out of Range	-27
Reverse Run End	87	38.825652	-92.584222	Solid	Solid	Vehicles Within Acceptable Range	
		38.82564	-92.583912	Dash	Solid	Following Vehicle Out of Range	-4
Number of Passing Zones Removed	9	38.825507	-92.580928	Solid	Solid	Vehicles Within Acceptable Range	
		38.828953	-92.571673	Solid	Dash	Following Vehicle Out of Range	-9
		38.830772	-92.571558	Solid	Solid	Following Vehicle Out of Range	-26
		38.831457	-92.571538	Dash	Solid	Following Vehicle Out of Range	-24
		38.833288	-92.571495	Solid	Solid	Vehicles Within Acceptable Range	
		38.835352	-92.571435	Solid	Dash	Following Vehicle Out of Range	11
		38.837832	-92.571357	Dash	Dash	Vehicles Within Acceptable Range	
		38.843538	-92.571183	Dash	Solid	Vehicles Within Acceptable Range	
		38.845665	-92.571112	Dash	Dash	Vehicles Within Acceptable Range	
		38.846138	-92.571093	Solid	Dash	Vehicles Within Acceptable Range	
		38.848328	-92.571033	Dash	Dash	Vehicles Within Acceptable Range	
		38.851322	-92.570963	Dash	Solid	Vehicles Within Acceptable Range	
		38.853887	-92.570748	Solid	Solid	Vehicles Within Acceptable Range	
		38.854288	-92.566373	Solid	Dash	Vehicles Within Acceptable Range	
		38.856202	-92.563652	Dash	Dash	Following Vehicle Out of Range	-10
		38.85638	-92.563385	Dash	Solid	Following Vehicle Out of Range	-10
		38.858047	-92.561085	Solid	Solid	Following Vehicle Out of Range	-24
		38.857853	-92.555527	Dash	Solid	Following Vehicle Out of Range	-3
		38.857403	-92.55315	Solid	Solid	Vehicles Within Acceptable Range	
		38.857353	-92.552892	Solid	Dash	Vehicles Within Acceptable Range	
		38.857193	-92.551197	Solid	Solid	Vehicles Within Acceptable Range	
		38.85711	-92.549115	Dash	Solid	Vehicles Within Acceptable Range	
		38.857075	-92.547685	Solid	Solid	Vehicles Within Acceptable Range	
		38.859112	-92.541498	Solid	Dash	Following Vehicle Out of Range	n/a
		38.85951	-92.538847	Dash	Dash	Vehicles Within Acceptable Range	
		38.85963	-92.538163	Dash	Solid	Vehicles Within Acceptable Range	
		38.860138	-92.534803	Solid	Solid	Following Vehicle Out of Range	53

Figure 36. Results from post-processing software tool.