Vehicle-to-Infrastructure Program

V2I Safety Applications
Connected Work Zone Software Toolchain User Guide
Version 1.1

September 3, 2019

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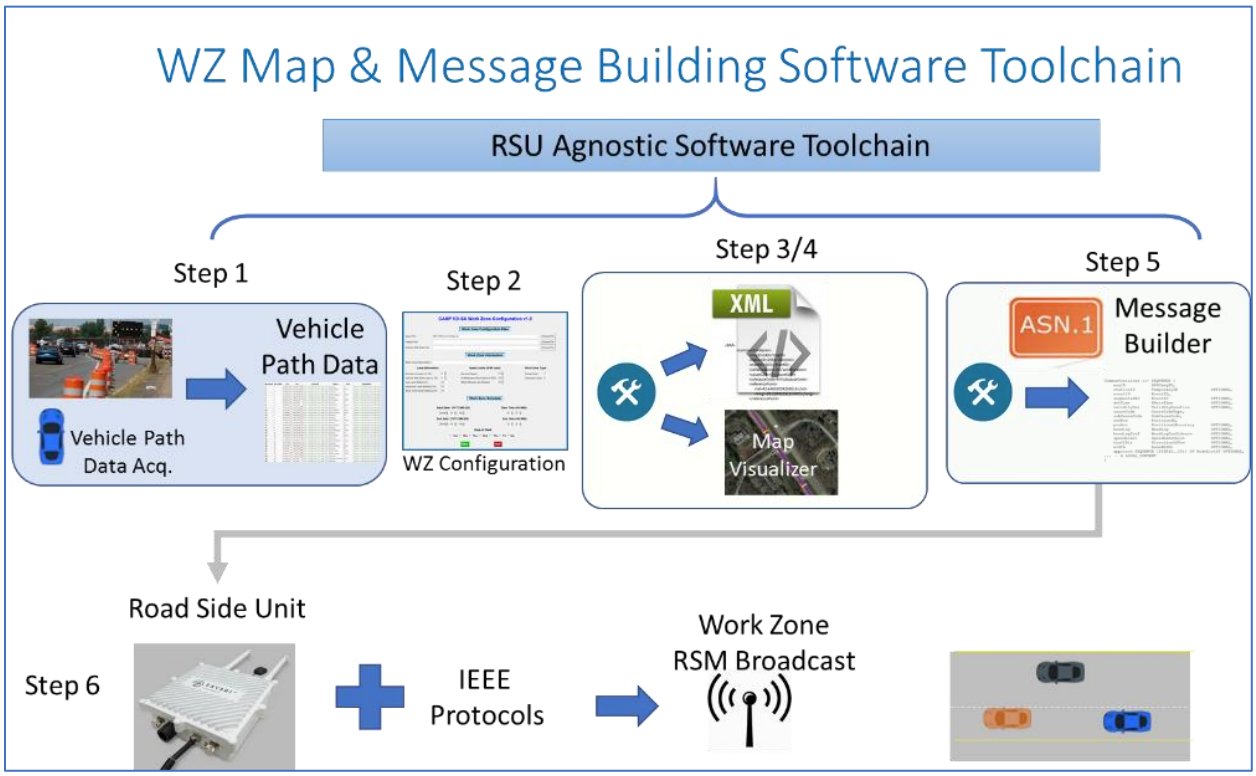
List of Acronyms

API	Application Program Interface
ASN.1	Abstract Syntax Notation One
CAMP	Crash Avoidance Metrics Partners LLC
CSV	Comma Separated Value
CVMB	Connected Vehicle Message Builder
CWZ	Connected Work Zone
EXER	Extended XML Encoding Rules
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HDOP	Horizontal Delusion of Precision
NMEA	National Marine Electronics Association
PNG	Portable Network Graphics
RSM	Road Safety Message
RSZW	Reduce Speed Zone Warning
RSZW/LC	Reduce Speed Zone Warning with Lane Closure
SA	Safety Applications
SAE	Society of Automotive Engineers
UPER	Unaligned Packed Encoding Rules
V2I	Vehicle-to-Infrastructure
V2I-SA	Vehicle-to-Infrastructure Safety Applications Project
XML	eXtensible Markup Language

1 Introduction

This document provides the user guide for a software toolchain developed for the Connected Work Zone (CWZ) Safety Application developed under Vehicle-to-Infrastructure (V2I) Safety Applications (SA) Project by Crash Avoidance Metrics Partners LLC (CAMP). The toolchain contains several modules (tools) to acquire vehicle path data, to build a map that describes work zone geometry, to visualize and verify the built map and to build Road Safety Message (RSM) for Reduced Speed Zone Warning with Lane Closures (RSZW/LC) Safety Application for over-the-air transmission. The RSM is built as per the specification defined in Abstract Syntax Notation one (ASN.1) schema and Society of Automotive Engineers (SAE) J2735 (March 2016) data dictionary being developed as SAE J2945/4 document. The generated message for transmission is encoded as Unaligned Packed Encoding Rules (UPER). Steps to generate the RSM for connected work zone using the toolchain is shown in Figure 1.



Source: Map images from Google. Used with permission. Data from CAMP – V2I Consortium

Figure 1: Connected Work Zone Map and Message Building Software Toolchain

The CWZ software toolchain contains the following tools to perform the following actions:

- Vehicle Path Data Acquisition: Collect vehicle path data of an instrumented vehicle equipped with a high-resolution GPS receiver
- Work Zone Configuration: Configure work zone parameters such as number of lanes, average lane width, posted speed limits and work zone schedule

- Work Zone Map Builder: Build work zone map geometry using collected vehicle path data that describes waypoints (node points) for each lane in work zone including lane closures and workers presence zone. The map is represented in extended XML encoding rules (EXER).
- Work Zone Map Visualizer: Visualize the generated map waypoints (node points) on google map satellite view for verification
- Connected Vehicle Message Builder (CVMB): Build UPER encoded message as per the RSM defined specification for over the air transmission

1.1 System Requirements

Software tools in the toolchain are developed using different programming languages to gain portability, to provide inherent programming language efficiency and to provide the capability for rapid prototyping and ease of deployment. Required software packages / application software and hardware are listed in Table 1 for the target machine running the Windows operating system.

Table 1: System Requirements for Software Toolchain

Software Package / Application S/W	Version	Function / Application
Microsoft Windows PC	Version 7 or later	• Target platform to run software toolchain
Python for Windows	Version 3.6.4 or later	• Vehicle path data acquisition • Works zone map builder ○ Create work zone map in XML format ○ Create data elements and data arrays for JavaScript for map visualizer
pySerial	Version 3.3 or later	RS-232 Serial communication for GPS receiver
Web Browser - IE, Chrome, Firefox	Latest version	Work zone map visualizer
Java Runtime Environment (JRE)	Version 7 or later	Building UPER encoded Road Safety Message (RSM) for mapped work zone
U-blox EVK-M8N GNSS Receiver	U-center version 8.25	Vehicle Path Data Acquisition

1.2 Toolchain Software Module Hierarchy

The hierarchy of the software modules used in the toolchain along with the directory structure is provided in Appendix A in Tables 4 and 5, respectively.

1.3 U-blox GNSS Receiver Configuration

Prior to starting the vehicle path data acquisition, the U-blox GPS receiver must be configured to interface with the data acquisition computer for serial communication and acquire the appropriate NMEA string from the receiver at a specified frequency. The steps for a one-time setup of the configuration of the U-blox GPS receiver are described here.

1. Install U-blox supplied u-center software (v8.25)

2. Connect GPS receiver with supplied USB cable to a USB port on PC. The USB connection between the GPS receiver and the PC establishes virtual serial port connectivity.
3. Launch the u-center application
4. To setup baud rate for serial communication:
    a. Select Receiver → Port – Note down the virtual serial port number. This port number will be used by the Vehicle Path Data Acquisition tool. In most cases the port is COM 7.
    b. Select Receiver → Baud rate → 115200
5. To apply configuration file: "ALL_CAMP_V2V_MD_UbloxM8N-10Hz_GPS_Only_Config_v1.2.txt" located in U-blox EVK M8N folder in the toolchain distribution package
    a. Select Tool → GNSS Configuration
    b. Apply the configuration file as shown in Figure 2
    c. You may get a message box indicating that the configuration file version does not correspond to the version of the GPS receiver as shown in Figure 3. Select Yes and continue.

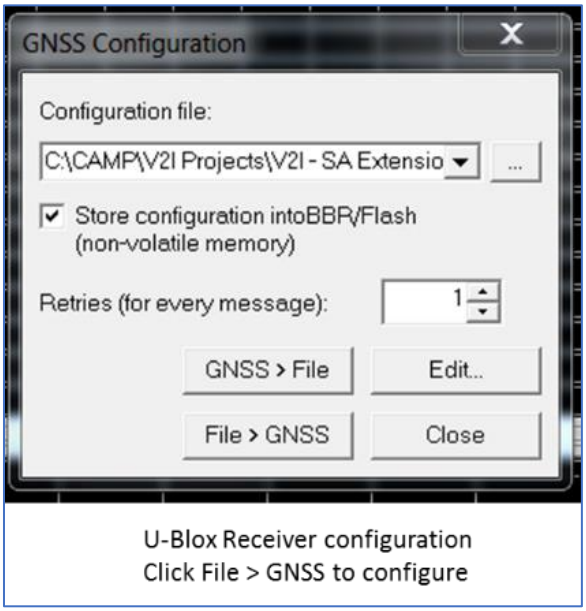


Figure 2: U-blox GPS Receiver Configuration

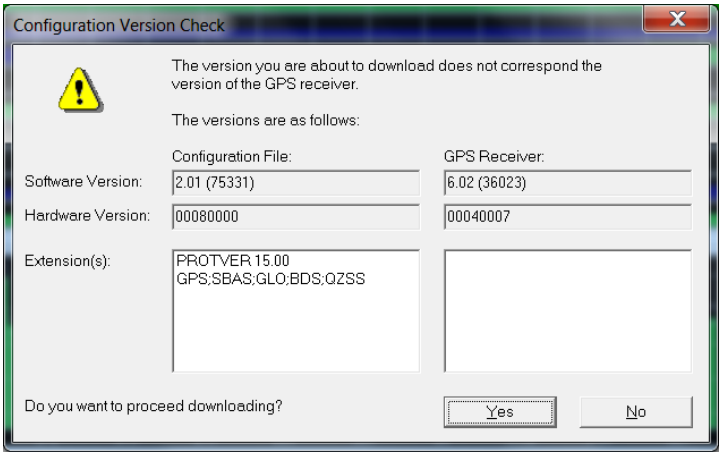
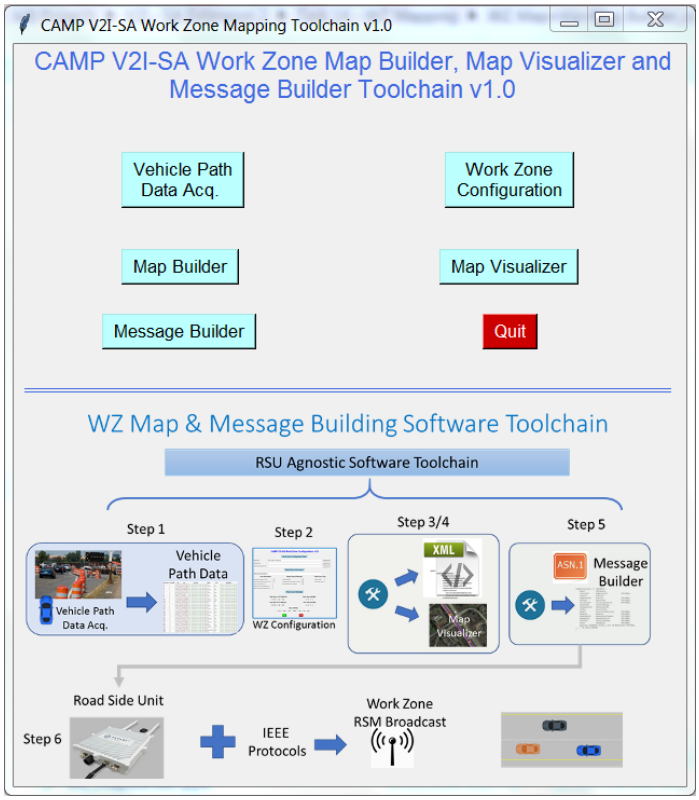


Figure 3: U-blox GPS Receiver Configuration Check Message

1.4 Software Toolchain

The toolchain can be launched by running the *WZ_Map_Toolchain.pyw* program from the installed directory. The main menu for the toolchain and the various steps associated in building various elements for a connected work zone are shown in Figure 4.



Source: Map images from Google. Used with permission. Data from CAMP – V2I Consortium

Figure 4: Software Toolchain - Main Menu

The upper half of the menu screen provides buttons to launch tools to collect vehicle path data, configure the work zone, build work zone map using the collected path data, visualize the built map on the google satellite view and built RSU agnostic UPER encoded message for over-the-air

transmission for the work zone. The lower half of the screen shows the graphical overview of the steps to follow to build a RSM for a work zone ready for transmission. Available tools in the toolchain are described here.

2 Collection of Vehicle Path Data

This is the first step in building a work zone map. It is required to collect vehicle path data by driving an instrumented vehicle with a GPS receiver connected to a PC running the vehicle path data acquisition module. The vehicle path data is acquired at 10Hz. The following data elements are collected and logged in a comma separated value (csv) format for use by the Map Builder tool in the toolchain.

- GPS Date and Time stamp
- Number of satellite seen by the receiver
- Horizontal Delusion of Precision (HDOP) - A factor in determining the relative accuracy of a horizontal position. The smaller the HDOP number, the better the geometry.
- Latitude, Longitude and Altitude in degrees
- Vehicle speed (m/s)
- Vehicle heading in degrees
- Marker and value – list of work zone markers, its meaning and value is described later in this guide

2.1 Steps for Collecting Vehicle Path Data

Follow the steps below to collect vehicle path data:

- Select an open lane through the work zone for driving
- For collecting vehicle path data:
    - Drive the vehicle on the selected open lane and stay on the lane through the entire work zone being mapped
    - Maintain the vehicle position in the center of the lane as much as possible
    - Maintain constant vehicle speed within the speed limit as much as possible
    - Start Data Log (s) at least 600m before the start of the work zone. This portion of logged data provides approach lane leading to the work zone.
- Graphical representation of a work zone and steps describing vehicle path data collection is shown in Figure 5.

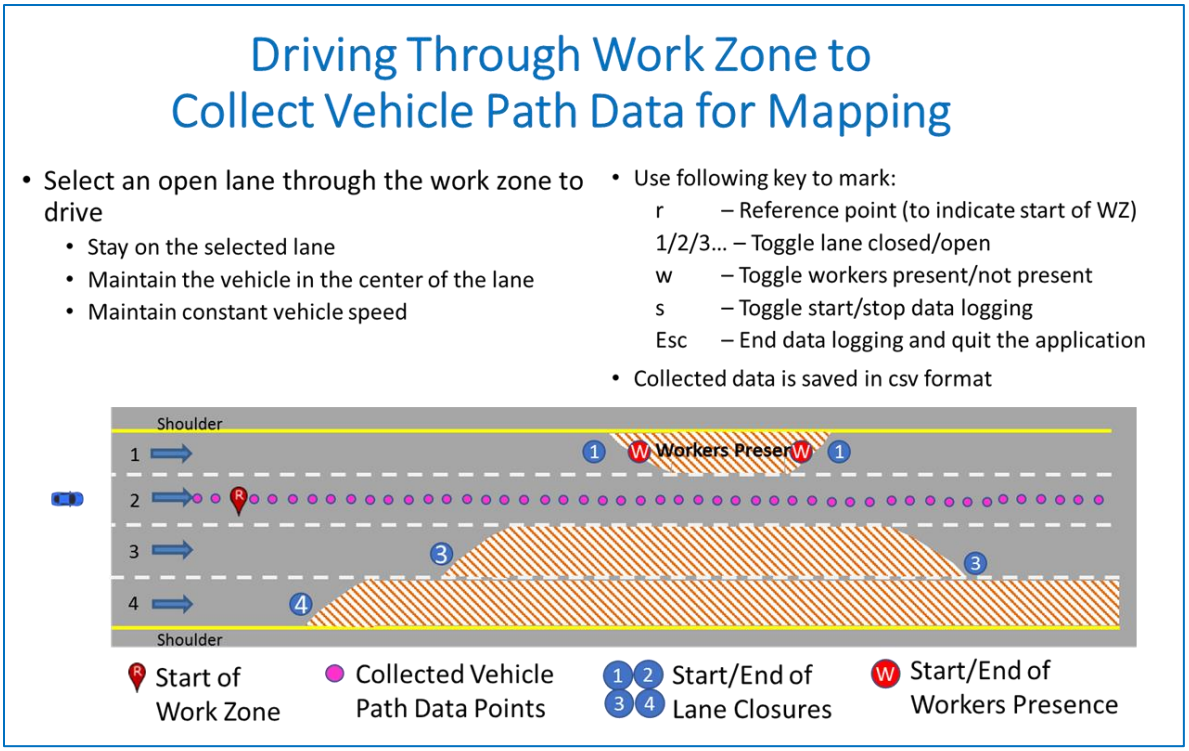


Figure 5: Graphical Representation of Vehicle Path Data Collection

2.2 Initiate Vehicle Path Data Acquisition

Prior to starting the vehicle path data, connect the configured GPS receiver to the data acquisition computer's USB port and place the antenna on the roof of the vehicle along the longitudinal center of the vehicle.

Start the Vehicle Path Data Acquisition either by selecting Vehicle Path Data Acq. on the main menu shown in Figure 4 or by running "*WZ_VehPathDataAcq.pyw"* from windows explorer. Figure 6 shows user interface screen for the Vehicle Path Data Acquisition. If the GPS receiver is not connected to an USB port or the USB port is not configured as virtual COM7 port, a pop-up window with error shown in Figure 6 will be displayed for user action. If the properly configured GPS receiver is found on an USB port, the "Application Message Window" message will indicate "Vehicle Path Data Acquisition is Ready - You May Start Data Logging".

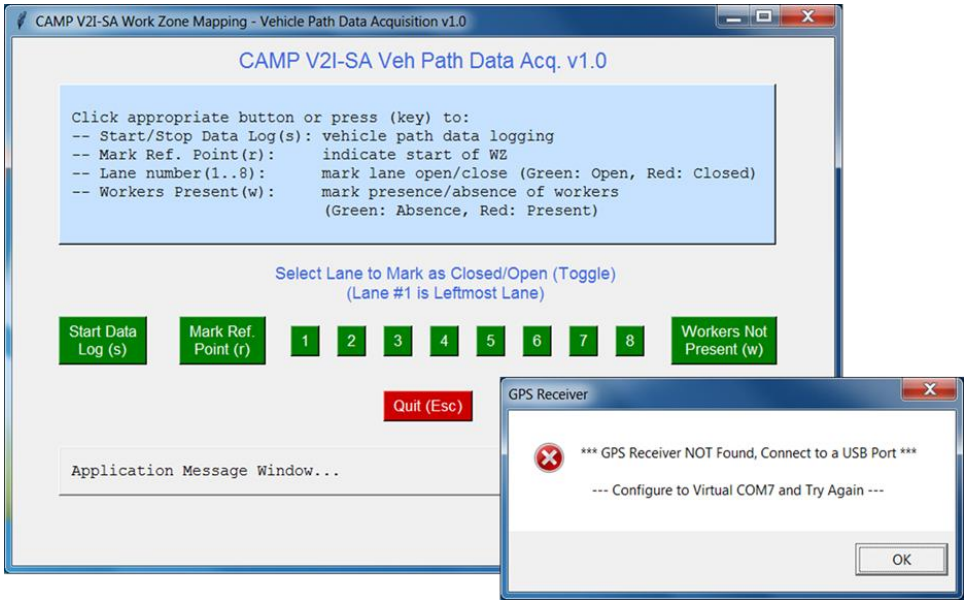
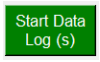


Figure 6: User Interface for Vehicle Path Data Acquisition

Use the following buttons on the screen or press key shown in () to set a marker in data collection. To mark the lane number, either click the lane number button or use the number key on the keyboard. The user interface to set markers in Vehicle Path Data Acquisition is shown in Figure 6.

- 

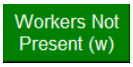
To start data log.
    - The logged data file is created as a .csv file in: ./ WZ_VehPathData folder. The file name is: WZ_Path_Data_yyyymmdd_hhmmss.csv. The current date and time is used to create a unique file name.
- 

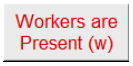
To stop data logging.
    - It should be noted that stopping and starting the data logging does not create a new log file. It continues to append data to the same file. To create a new vehicle path data file, quit the tool and restart.
- 

To mark reference point to indicate start of work zone.
    - In most cases, the start of the work zone is the location where the lane closure starts where the lane closure taper begins. The reference point can only be marked once.
- 

To mark start of a lane closure, click on the lane number button or use the number key on the keyboard. The leftmost lane is lane 1. The start of the lane closure should be marked at the start of a taper for the closed lane.

- 

To mark end of lane closure to indicate the is lane open for traffic, click on the closed lane number or use the number key on the keyboard. The lane closed/open marker button / lane number key toggles the lane closed / open marker.
    - If the reference point is not marked prior to marking the first lane closure, the reference point will also be marked at the same location of the lane closure indicating the start of the work zone. It should be noted that at this point that the Mark Ref. Point (r) button will also be changed to Ref. Point Marked. The reference point can only be marked once for a work zone.
- 

To mark start of workers present zone.
- 

To mark end of workers present zone. Like the lane marker, this is also a toggle between workers not present and present.
- 

To end the vehicle path data acquisition. The logged data file and serial connection for the GPS receive will be closed.

List of markers, associated values and its meaning are described in Table 2.

Table 2: List of Markers for Work Zone, Associated Value and Meaning

Marker	Value	Meaning
Data log	TRUE | FALSE	Data logging true or false (started / stopped)
LC	1|2|3|…|8	Start of lane closure followed by lane number
LO	1|2|3|…|8	End of lane closure (lane open) followed by lane number
RP		Reference point (start of work zone)
LC+RP	1|2|3|…|8	Start of lane closure at start of work zone (reference point)
WP	TRUE | FALSE	Workers presence True or False (start / end of workers presence zone)
WP+RP	TRUE | FALSE	Start of workers presence zone at start of work zone (reference point)
App Ended		Vehicle Path Data Collection Application ended

An example of a collected vehicle path data with markers is shown in Table 3.

Table 3: Example of Collected Vehicle Path Data

GPS Time	# of Sats	HDOP	Latitude	Longitude	Altitude(m	Speed(m/s	Heading(D	Marker	Value
20:16:48:8	12	0.74	42.57763	-83.2397	262.4	7.131743	149.79	Data Log	TRUE
20:16:48:9	12	0.74	42.57763	-83.2397	262.4	7.131743	149.79		
20:16:49:0	12	0.74	42.57762	-83.2397	262.4	7.252638	149.45		
20:16:49:1	12	0.74	42.57762	-83.2397	262.4	7.379191	148.95		
20:16:49:2	12	0.74	42.57761	-83.2397	262.4	7.423948	148.35		
20:16:49:3	12	0.77	42.5776	-83.2397	262.4	7.586512	148.08		
20:16:49:4	12	0.77	42.5776	-83.2397	262.4	7.761423	148.28		
20:16:49:5	12	0.77	42.57759	-83.2397	262.4	7.845278	147.44		
20:16:49:6	12	0.77	42.57759	-83.2397	262.4	8.052599	147.71		
				...					
20:17:22:6	11	0.8	42.57302	-83.2354	253.7	21.41941	145.29	LC+RP	4
20:17:43:6	11	0.8	42.56985	-83.2324	247.4	19.39919	145.35		
20:17:43:7	11	0.8	42.56983	-83.2324	247.4	19.4388	145.44		
20:17:43:8	11	0.8	42.56982	-83.2323	247.4	19.42645	145.11		
				...					
20:17:45:1	11	0.8	42.56963	-83.2322	246.9	19.23405	145.56		
20:17:45:2	11	0.8	42.56962	-83.2322	246.8	19.18775	145.38		
20:17:45:2	11	0.8	42.56961	-83.2321	246.8	19.05142	145.33	LC	3
20:17:45:3	11	0.8	42.56961	-83.2321	246.8	19.05142	145.33		
20:17:45:4	11	0.8	42.56959	-83.2321	246.8	19.15071	145.43		
				...					
20:18:14:2	12	0.77	42.56633	-83.229	242.4	7.279389	145.45	WP	TRUE
20:22:12:6	12	0.74	42.54705	-83.2116	238.5	10.61608	161.7	App Ended	

3 Configure Work Zone

The work zone must be configured with the required parameters before building the map of the work zone. and required parameters must be configured before building the map of the work zone. The Work zone configuration can be initiated either by selecting Work Zone Configuration on the main menu shown in Figure 4 or by running the WZ_Config_UI.pyw from windows file explorer. Figure 7 shows the user interface screen.

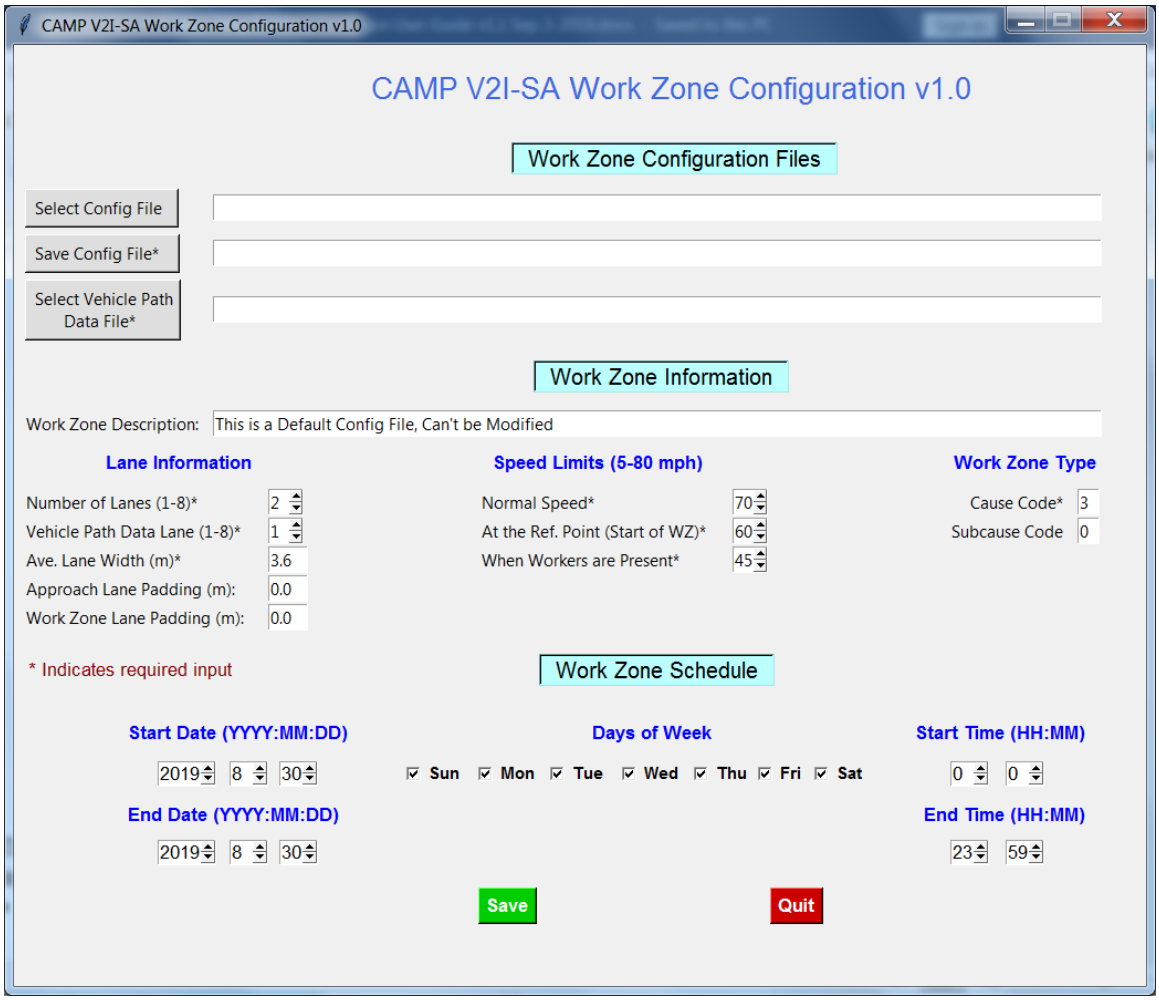


Figure 7: Work Zone Configuration Input Screen

The user input screen for the work zone configuration is organized in three sections. Required input fields are marked with *.

1. **Work zone configuration:**
    1. Select Config File – Select an existing configuration file (.wzc file extension) or leave blank it blank. When an existing file is used, pertinent information from the file is used to fill in the input fields.

2. Save Config File* – Save work zone configuration file.
3. Select Vehicle Path Data File* – User is required to enter a collected vehicle path data file name (.csv file extension) generated in the "Collect Vehicle Path Data" step.

2. Work Zone Information:

1. Work Zone Description – Enter work zone description. This information is later used by the visualizer tool for user information.
2. Lane Information:
   - Number of Lanes (1-8)* – Enter the number of lanes in the work zone.
   - Vehicle Path Data Lane (1-8)* – Enter the lane number on which the vehicle path data was collected in the "Collect Vehicle Path Data" step.
   - Ave. Lane Width (m)* – Enter average lane width in meters
   - Approach Lane Padding (m) – This field allows variation in average lane width by the padding value
   - Work Zone Lane Padding (m) – This field allows variation in average lane width by the padding value
3. Speed Limits:
   - Normal speed* – Normal speed limit of the roadway before entering the work zone
   - At the reference point* – Speed limit at the start of the work zone
   - When Workers are Present* – Speed limit associated when the workers are present in the work zone
4. Work Zone Type:
   - The cause and sub-cause codes are set to 3 and 0, respectively, to indicate a long- term work zone
   - Following Cause Codes are used to indicate different roadway conditions:

```
reserved (0),
trafficCondition (1),
accident (2),
roadwork (3),
adverseWeatherCondition-Adhesion (6),
hazardousLocation-SurfaceCondition (9),
hazardousLocation-ObstacleOnTheRoad (10),
hazardousLocation-AnimalOnTheRoad (11),
humanPresenceOnTheRoad (12),
wrongWayDriving (14),
rescueAndRecoveryWorkInProgress (15),
adverseWeatherCondition-ExtremeWeatherCondition (17),
adverseWeatherCondition-Visibility (18),
adverseWeatherCondition-Precipitation (19),
slowVehicle (26),
```

```
dangerousEndOfQueue (27),
vehicleBreakdown (91),
postCrash (92),
humanProblem (93),
stationaryVehicle (94),
emergencyVehicleApproaching (95),
hazardousLocation-DangerousCurve (96),
collisionRisk (97),
signalViolation (98),
dangerousSituation (99)
```

- Subcause code 0 is used for roadwork

3. Work Zone Schedule:

The work zone schedule provides date and time during which the transmitted message from an RSU for a work zone is applicable for the on-board application.

1. Start and end dates and start and end times for the work zone is specified in this user input section. It should be noted that the end date and time must be later than the start date and time.
2. In addition, days of week can be checked for work zone message transmission by the infrastructure and is in effect for the on-board application.

4 Map Builder

The Map Builder tool performs the following three functions:

1. Reads the vehicle path data file generated in the previous step and builds waypoints (node points) with appropriate node attributes for each lane (approach and work zone) to represent the work zone as defined SAE J2735 specification
2. Generate an output file representing the work zone map message in eXtensible Markup Language (XML) format for later use by the Message Builder tool in the Toolchain. If the map builder tool determines that the built work zone map is large and the payload for message transmission will be larger than the allowable limit, the generated XML file will be in multiple segments. The generated file(s) will be saved in ./WZ_MapMsg directory as: RSZW_MAP_xml_File-yyyymmdd-hhmmss-1_of_n.exer. Where yyyymmdd-hhmmss is current date and time and n is total number of files (message segments) for the same map.
3. Generate an output file containing relevant data and array elements for use by the Map Visualizer tool and will be stored as RSZW_MAP_jsData.js in ./WZ_Visualizer folder.

The Map Builder tool can be launched by either selecting Map Builder on the main menu as shown in Figure 4 or by running the WZ_MapBuilder.pyw from windows explorer. The user interface screen for building a map is shown in Figure 8.

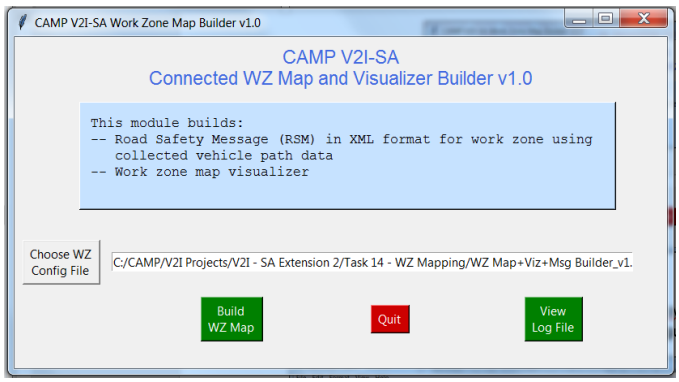


Figure 8: Map Builder User Interface Screen

This step also generates a log file map_builder_log.txt in the WZ_MapMsg directory for user to view the map builder status. An example of map builder log file is shown Figure 9.

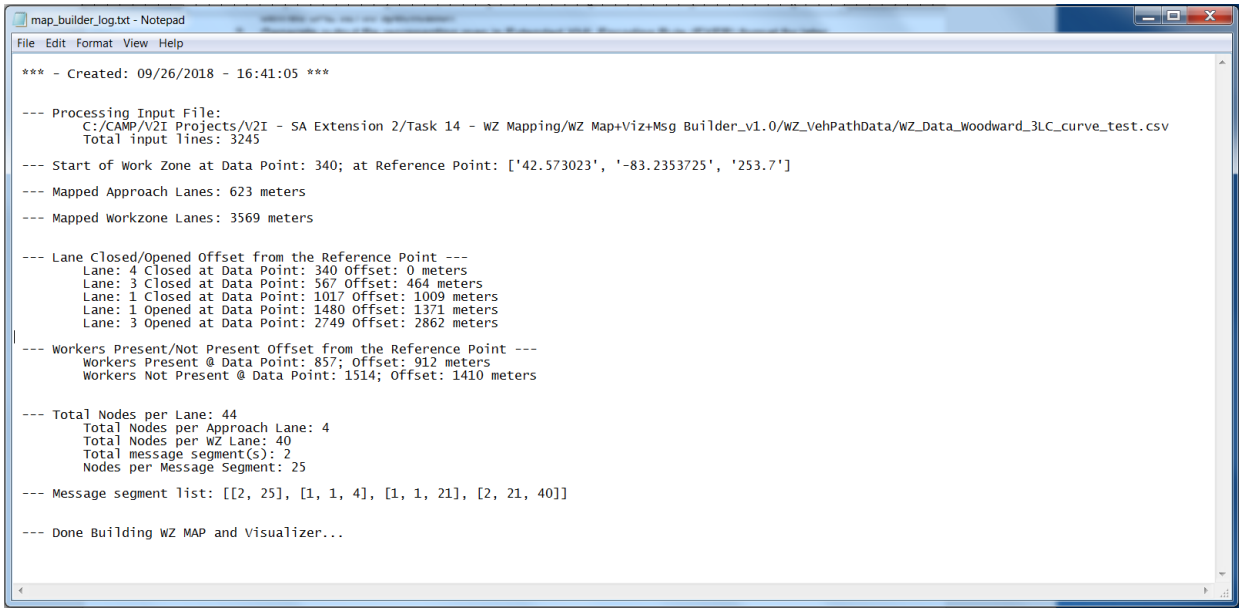
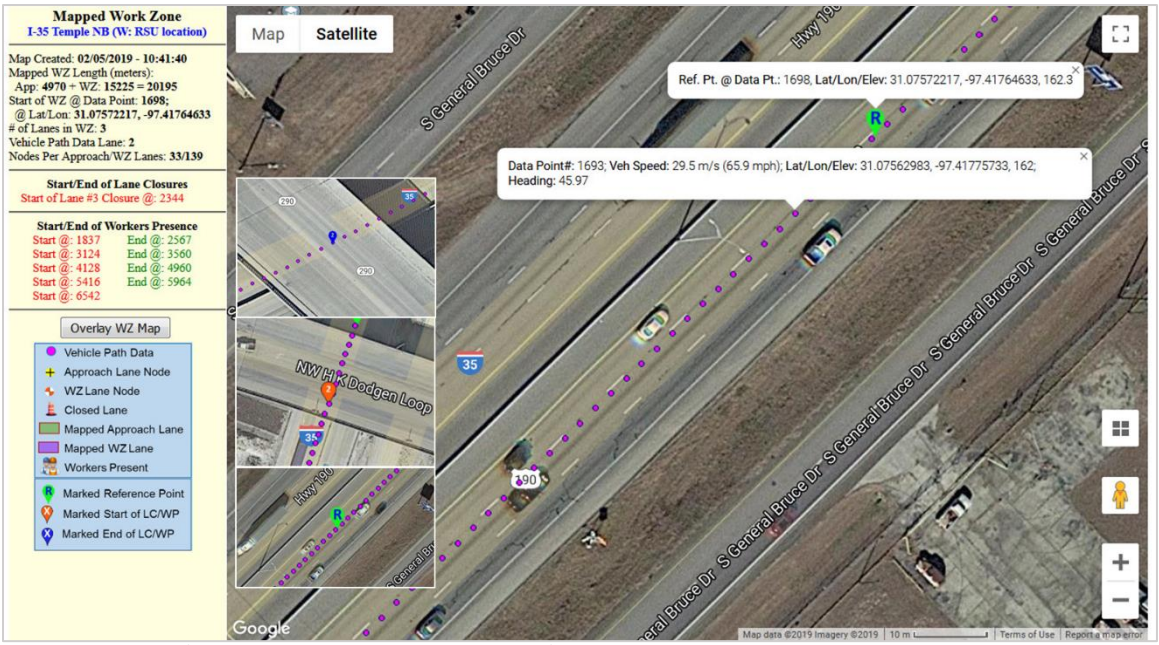


Figure 9: Map Builder Log File

5 Map Visualizer

The Map Visualizer tool provides visual verification of the work zone map built in the Map Builder step in a default web browser set in the user's computer. The visualizer software module is developed in JavaScript and using Google Application Program Interface (API) supported by most web browsers. When launched, collected vehicle path data points are overlaid on Google Satellite view map as shown in Figure 10. Also, in the figure, various elements of the generated work zone map are displayed on the left site. The purple dots indicate collected vehicle path data points. Selecting any purple dot, data point number, vehicle speed, latitude, longitude, altitude and heading information at that location of the vehicle is displayed. Similarly, selecting the marked location for the reference point to indicate the start of the work zone shown by green pin labeled R, latitude, longitude and altitude of the reference point is displayed.



Source: Map images from Google. Used with permission. Data from CAMP – V2I Consortium

Figure 10: Map Visualizer - Vehicle Path Data Points

The location marked by the user at the time of vehicle path data collection to indicate work zone lane status (closed/open) is shown in the inset in Figure 10. Marked lane closed location is represented by an orange pin with and lane open is represented by a blue pin by lane number as shown in the figure. By selecting the pin, data point number and the lane number for the marked status information is displayed. To view the overlaid generated work zone map waypoints (node points) for each lane on the map, click on the Overlay WZ Map button. Additionally, a shaded rectangle bounding box spanning each node segment equal to the specified lane width is drawn to show generated waypoints in the work zone map building step. The green shaded box indicates map of approach lane node segments and the blue shaded box indicates map of work zone lane node segments as shown as inset in Figure 11. By selecting any node point, as shown in the figure, node attribute, lane and node number, lane status, and node position in latitude, longitude and altitude are also displayed.

Source: Map images from Google. Used with permission. Data from CAMP – V2I Consortium

Figure 11: Map Visualizer - Work Zone Map Node Points and Shaded Bounding Box

The description of the work zone such as number of lanes in the work zone, lane used for collecting vehicle path data and the generated map for the work zone as well as the legends used in the visualizer is shown in Figure 12.

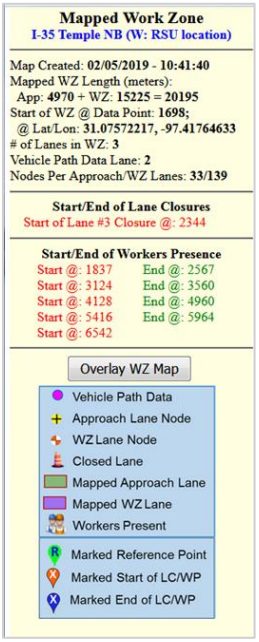


Figure 12: Work Zone Description and Legends Used in Map Visualizer

Selecting a legend icon provides further detail about the data point or the node point as shown in Figure 13.

Source: Map images from Google. Used with permission. Data from CAMP – V2I Consortium

Figure 13: Example of Associated Detail with Legends

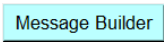
5.1 Google Map API Key

The visualizer module is developed using JavaScript that is supported by all modern web browsers for greater flexibility. The visualizer uses Google Map API to display Google Satellite view for overlaying the generated work zone map and associated attributes. In order to access and use the Google maps, edit the "RSZW_MapVisualizer.html" located in WZ_Visualizer folder and replace "*Your_API_Key*" with key from Google.

```
<script type="text/javascript"
      src="https://maps.google.com/maps/api/js?key=Your_API_KEY&libraries=geometry">
</script>
```

Before new users can start using the Google Maps Platform APIs visit: https://developers.google.com/maps/documentation/javascript/tutorial website for more detail. Before new users can start using the Google Maps Platform APIs, user must sign up and create a billing account. To learn more, see Get Started with Google Maps Platform**.**

6 Message Builder

The Connected Vehicle Message Builder (CVMB) accepts messages in EXER format and generates UPER encoded messages. CVMB can also accept UPER encoded messages and converts them to XML. All messages are based on the ASN.1 schema for the Roadside Safety Message (RSM) and the SAE J2735 (March 2016) data dictionary. Click on 

to build RSM for the work zone.

A detailed user guide illustrates an example using an EXER-encoded message as input to support a RSZW/LC application. Software user instructions and runtime interface descriptions are also provided in the user guide.

Appendix A Toolchain Software Module Hierarchy and Directory Structure

Table 4: Toolchain Software Module Hierarchy

Work Zone Mapping and Message Building Toolchain Software Module Hierarchy			
	Module/File Name	Description	Language/Format
Toolchain Main Menu			
1.00	• WZ_MapToolchain.pyw	• Work zone map and message building toolchain main menu	• Python v3.6.4
Vehicle Path Data Acquisition			
2.00	• WZ_MapVehPathDataAcq.pyw	• Main software module to collect vehicle path data from a vehicle driven in work zone for mapping	• Python v3.6.4
2.10	○ parseNMEA.py	• Software function module to parse GPS/GNSS NMEA sentence and extract required data elements ○ Supports GxGGA, GxRMC and GxGSA sentences	• Python v3.6.4
Work Zone Configuration			
3.00	• WZ_ConfigUI.pyw	• GUI software module to get user input for work zone configuration and for use by other software modules in toolchain	• Python v3.6.4 • https://www.python.org/downloads/windows/
Work Zone Map Builder			
4.00	• WZ_MapBuilder.pyw	• Main module to: ➢ Build node points for WZ lane map geometry ➢ Generate WZ map in .exer (xml format) for conversion to UPER ➢ Generate WZ map data array (JavaScript format) for visualization	• Python 3.6.4

Work Zone Mapping and Message Building Toolchain Software Module Hierarchy			
	Module/File Name	Description	Language/Format
4.10	○ wz_map_constructor.py ↳ getLanePoint ↳ getEndPoint ↳ getDist	○ Software function module to construct node points for WZ map lane geometries ↳ Software function module to parse vehicle path data array and generate node points for lane geometry using right triangle method ↳ Software function module to calculate latitude, longitude of an end point from origin latitude, longitude, distance and bearing (heading) ↳ Software function module to compute distance in meters between two latitude and longitude points	• Python 3.6.4
4.11	○ wz_msg_segmentation.py ↳ buildMsgSegNodeList	○ Function to break the message payload in multiple segments, if required ↳ Build node list for segmenting message payload	• Python 3.6.4
4.12	○ wz_xml_builder.py ↳ build_xml_CC ↳ build_xml_WZC	○ Software module to build .exer (xml format) file based on RSM.4.8.ASN.1 definition ↳ Function to create "Common Container" in .exer ↳ Function to create "Work zone Container" in .exer	• Python 3.6.4
4.13	○ wz_jsarray_builder.py ↳ build_jsvars ↳ build_jsarray	○ Software module to build .js file containing variables and data arrays for processing by JavaScript based visualizer tool ↳ Build set of JavaScript variables ↳ Build set of JavaScript arrays	• Python 3.6.4
Work Zone Map Visualizer			
5.00	• WZ_MapVisualizer.html	• HTML file for JavaScript functions to visualize generated WZ map on Google Satellite view	• HTML
5.10	○ WZ_MapVisualizer.js	○ Software module in JavaScript functions to overlay constructed WZ map on Google Satellite map	• JavaScript
5.11	↳ *.js	↳ File containing variables and arrays generated in WZ map builder step for use by visualizer	• JavaScript

Work Zone Mapping and Message Building Toolchain Software Module Hierarchy			
	Module/File Name	Description	Language/Format
5.12	↳ *.png	↳ Various icons used to overlay on google map	• PNG
Icons Used in Work Zone Map Visualizer			
1	Icons/refPoint3Green.png	Work zone event - Reference point pin	• Portable Network Graphics (PNG)
2	Icons/vehPath2.png	Collected vehicle path data	
3	Icons/laneXOpenPoint.png	Lane open pin, where X=1|2|…|8	
4	Icons/laneXClosedPointO.png	Lane closed pin, where X=1|2|…|8	
5	Icons/wpPointO.png	Workers present pin	
6	Icons/wnpPoint.png	Workers not present pin	
7	Icons/approachPoint.png	Generated approach lane map node points	
8	Icons/wzPoint2.png	Generated WZ lane map node points	
9	Icons/wzLaneOpen3.png	WZ Lane open	
10	Icons/orangeBarrelSmall1.png	WZ Lane closed	
11	Icons/wzWorkers4.png	Workers present	
12	Icons/Legends-RSZW8.png	List of legends used in visualizer	
Connected Vehicle Message Builder (CVMB)			
6.00	• CVMsgBuilder.jar	• Software to: Encode .exer (xml) file to UPER Decode UPER file to xml	• Java V1.7 or above
6.10	○ oss.jar ↳ CVMB User Guide v1.2 ↳ README.rtf ↳ rsmv5.1.asn	○ OSS Nokalva Library ↳ CV Message builder user guide ↳ Readme before you start ↳ RSM - ASN.1 Definition	• Java V1.7 or above • MS Word • MS Word • ASN.1 definition

Table 5: Toolchain Directory Structure

Work Zone Mapping and Message Building Toolchain Software Folder Hierarchy			
	Folder Name	Description	Content
1.0	• WZ Map+Viz+Msg Builder_v1.0	• Root folder • Work zone configuration files	• Subfolders • Main and submodules • .wzc files
2.0	• WZ_MapMsg	• Generated .exer files representing WZ map in XML format • Map builder log file • Generated .uper files from CVMB for over the air transmission	• .exer files • .txt file • .uper files

3.0	• WZ_VehPathData	• Collected vehicle path data files	• .csv files
4.0	• WZ_Visualizer ○ Icons	• Html, JavaScript files for work zone map visualizer ○ Various icons used for overlay	• .html file • .js files ○ .png files