

FINAL REPORT ~ FHWA-OK-19-02

IMPROVING THE EFFICIENCY AND ACCURACY OF ODOT TEMPORARY TRAFFIC MONITORING SYSTEM

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September 2019



OKLAHOMA
Transportation

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IMPROVING THE EFFICIENCY AND ACCURACY OF ODOT TEMPORARY TRAFFIC MONITORING SYSTEM

FINAL REPORT ~ FHWA-OK-19-02
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.(Revised March 2003).

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1. Abstract

Vehicle detection, counting, and classification are keys for not only improving road designs and maintenances, but also driver safety. In pursuit of these objectives, the authors proposed an automated system for collecting temporary vehicle data (e.g., count, speed, vehicle classification based on axles, collection date, time, etc.). The framework is composed of three main components: 1) an inexpensive portable sensor for counting and classifying vehicles; 2) an Android app to easily calibrate and configure the sensor on-site and fetch collected sensor data; and 3) a server that leverages wireless communication and cloud technology for processing, storing, and presenting data. A first-phase system was deployed and tested by Oklahoma Department of Transportation in 2017. A project extension was done for further system development and debugging where its functionality was validated. The two-year extension includes server improvement, maintenance, and support for the Traffic Counting and Monitoring System web service and android application.

2. Executive Summary

For many years ODOT used an exclusively manual process to collect and log temporary vehicle data (i.e., vehicle count, site information, device used, collection date and time, ODOT operator, and other vital information) into a computer database. This process was slow and inefficient. Furthermore, mistakes in data entry are likely throughout the arduous process. The system detailed herein replaces manual data handling with machine handling, eliminating possible errors in data recording and/or entry.

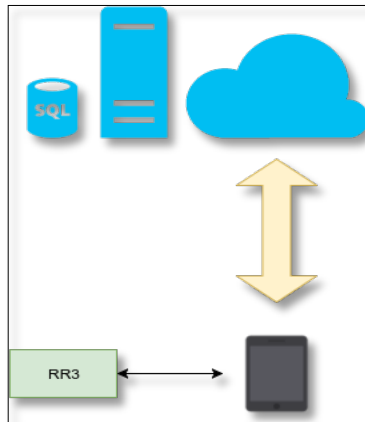
This report introduces the use of Diamond Traffic Inc.'s vehicle classification Road Runner 3 (RR3) as a portable and inexpensive replacement for the ADR1000 vehicle counting device that ODOT used for many prior years. The extension of this project added several objectives, including web server and android application support for Traffic Counting and Monitoring System (TCMS). Furthermore, the possibility of leveraging wireless communication and replacing cabled connection for data was investigated. Various data mining techniques were developed for data validation purposes and to evaluate deployment success. An Android app was designed to provide an easy way to program and configure RR3 units on the fly. A back-end server was setup at the University of Oklahoma–Tulsa campus where data is stored, processed and monitored. A new set of algorithms operated on the back-end server for decrypting, processing, extract counting, and/or classifying data from RR3 binary output files. The algorithms also validate data collection based on historical data and track successful/unsuccessful deployment. Finally, a TCMS web service was created to display processed data in a format requested by the ODOT administration board to aid in the decision-making process. The system was successfully tested at various Tulsa sites while debugging and system development continued. The resulting upgrades developed and tested during the extension period were also successful. This project including the development of Android application, Bluetooth wireless interface to RR3, and server website interface was accomplished in collaboration with Innovative Traffic Systems & Solutions, LLC.

3. Introduction

Temporary count and classification data collection is performed annually at thousands of ODOT predetermined sites on roadways and highways located throughout the state. To execute this process, a classifier device is deployed at a site for a period of 24 to 48 hours. Road tubes are used to count vehicle-tube impacts and record impact times. ODOT uses vehicle volume to improve road design, and the business community uses the data to plan neighborhoods and retail centers. As such, it is important to ensure data accuracy and to make data rapidly available. The former method for data collection proved to be slow, inefficient, and suffer from human error. System improvements were required to reduce and perhaps eliminate manual processes, replacing them with an automated, easy-to-use framework.

The proposed system is composed of three main components: 1) the small, portable Diamond Inc. Road Runner 3 vehicle classification device to leverage existing infrastructure based on tube technology (See Section 4 for specifications and modifications); 2) an Android app to configure and fetch RR3 data (See Section 5); and 3) a back-end server to process and present collected data (See Section 6 for server-side details. Note that conclusions and future works are discussed in Section 7.)

4. System Architecture



As previously mentioned, the proposed framework is composed of three main components: classification sensor, Android device (Tablet) with TCMS app, and back-end cloud to support a web server and database. This section details the RR3s classification sensor. See Figure 1 for an overview system architecture.

4.1 Classification sensor

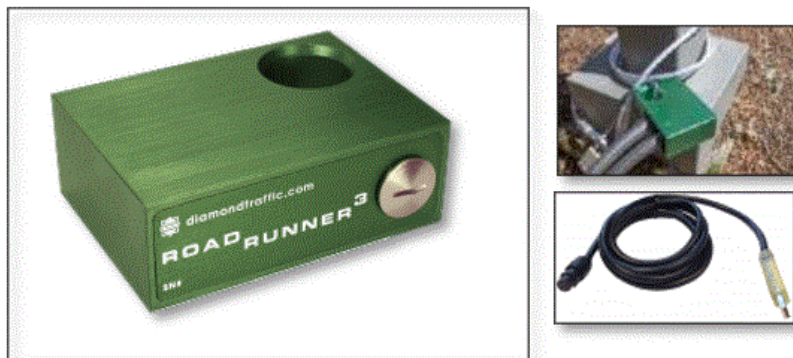


Figure 2. Road Runner 3 classification sensor with FTDI cable.

RR3 [1] is widely known as Diamond Traffic Inc's counter/classifier unit for counting and classifying vehicles at each site (See Figure 2). The device can count to four lanes and classify up to 2 lanes. The system is compact in size and does not require external power.

Specifications:

Table 1. RR3 Specifications.

SIZE	3.5" x 2.5" x 1.25"
DATA EVENT RECORDING	2 Channel Event Timestamp data at a resolution of 30.5uS (0.0000305 sec). Adjustable timeout range of 1-2000ms per channel.
CASE	Machined 6061 aircraft aluminum casing, anodized green.
WEIGHT	Compact at under 14 ounces (less than 1lb).
POWER	Engineered Ten (10) year lithium long-life battery.
MEMORY CAPACITY	512MB flash chip holds 120 million timestamps; approximately 25 million vehicles. Can store up to 65k Individual studies.
TUBE NOZZLE	Dual nozzle for mini (low profile) or standard tube sizes.
ENVIRONMENTAL TEMPERATURE RANGE	-40°F to +160° F (-40° C to 72° C)
OUTPUT PORT	Military spec weather resistant plug for high speed communication via USB cable. Up to 12MBaud download speeds.
SOFTWARE	Centurion Free is a complete and comprehensive software package that includes common export and printing formats such as Excel, PDF, text, and more. Windows based. Easy to use. Powerful data analysis.

4.2 Wireless communication for data collection

4.2.1 FTDI wired cable connection

The original interface for data collection consists of a wired connection between the RR3 unit and a Tablet device (i.e., data collection unit), which need to be equipped with OTG USB capability and are supported by the TCMS app. Communication protocol

between the unit and tablet is dictated by the UART protocol—an asynchronous serial communication that facilitates configurable data transfer speed and byte format. The communication cable used in this interface is an FTDI RS232-USB. To expedite data collection, we proposed a wireless interface to replace this cabled connection.

4.2.2 Wireless Interface

The prototype utilizes Nordic Semiconductor’s nRF52480 chip, leveraging BLE 5 connectivity. Two development kits based on the chip were used—one for the Road Runner 3 and another for the tablet.

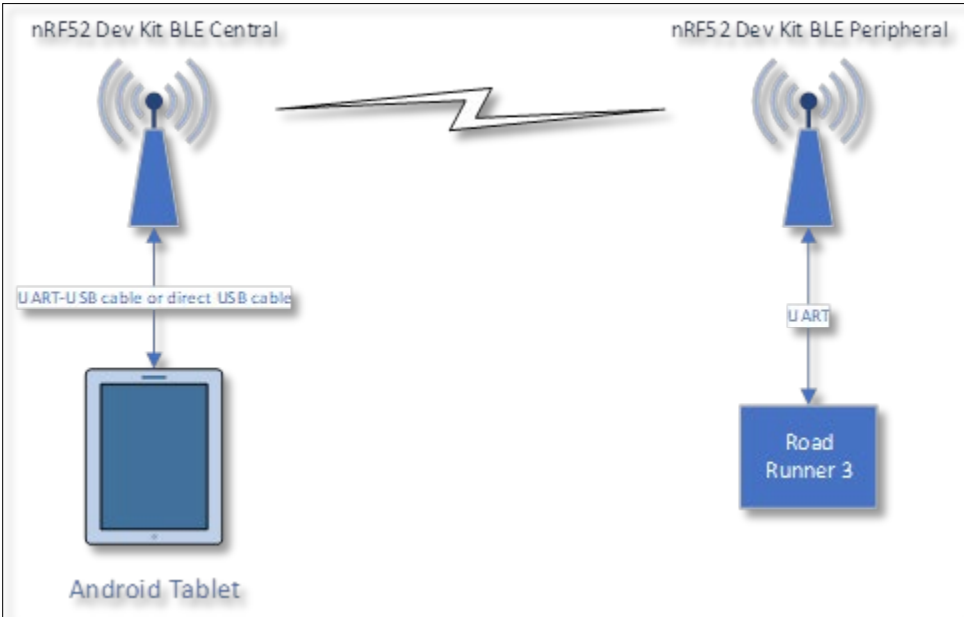


Figure 3. Wireless interface prototype design.

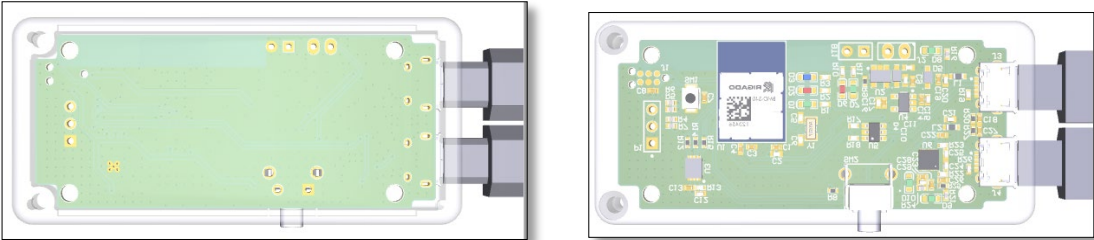


Figure 4. Wireless system printed circuit-board design.

Based on the prototype solution illustrated in Figure 3, a Bluetooth interface was designed and developed on a printed circuit board, as shown in Figure 4. The board will function as plug-and-play device on the tablet side of the system, with two interfaces, a regular UART serial interface and a USB CDC wireless interface. When UART serial interface is used, a UART-over-USB cable is needed to connect to tablet (i.e., original interface) for testing circuit board integrity and providing an alternate option. Given that the over-the-air interface (i.e., USB CDC interface) fails, the user can alternatively collect data using cabled connection via the UART serial, acting as either a wired or wireless interface.

To render the wireless interface functional, the tablet side must first connect with the BLE dongle from Nordic semiconductor. Next, the system's wireless interface will connect to the tablet. The connection must: 1) initiate through the TCMS app, 2) proceed to data collection given that connection is successful, or 3) retry connection or utilize the cabled interface given that connection is unsuccessful.

4.2.3 Connectivity campus field testing

In Section 4.2.3, the OU research team evaluated the Bluetooth adapter which uses BLE 5 technology. According to the chip specification, when transmission (Tx) power is set to 0dBm, the tablet should be able to communicate at a range of 4000 ft. This test methodology was intended to maximize connection range without considering increased power consumption and reduced data rate into account. Regarding the Bluetooth adapter, we conducted a Line-of-Sight (LOS) test and a Non-Line-of-Sight (NLOS) test, where NLOS simulated actual device usage via ODOT's data collection agent.

Table 2. LOS Test Results

Distance (ft)	Successful Connection (Out of 5)	Successful Real-Time (Out of 5)
5	5	5
10	5	5
15	5	5
20	4	4
25	3	3
30	0	0

The LOS test was conducted in a controlled setting on even ground and Tx power of the two devices set to 0dBm. RR3 receiver height (Rx) remained at ground level (RR3 was placed on the ground as a typical deployment by ODOT), while the Bluetooth dongle attached to the tablet remained stationary at an estimated 5.8 feet above ground level. Each test was repeated five times with identical testing conditions and environment setting to minimize factors negatively impacting radio transmission between the two devices; at each trial of testing, it was ensured that the entire connection process between the two devices was reestablished as a new connection for each test. Testing criteria was divided: 1) a successful connection to RR3 from the TCMS app and 2) a successful real-time measurement and monitoring of vehicle count by RR3. Results are summarized and tabulated in Table 2 and show that the proposed device works optimally at set condition with maximum range between 15 and 20 ft. While this distance might seem largely reduced from the expected capability reported by Nordic's test and documentation, test results were as we expected for the following reasons. First, the Nordic range test was based on the successful pairing two devices, while our test focused on successful functionality of TCMS software with RR3 hardware. The latter requires much more than merely a successful pairing, as sufficient data transmission rate is required for the system to work successfully. Path loss due to physical

obstruction, humidity, precipitation, and other factors must be considered, as these can largely reduce transmission range. Hence, our transmission range under real-life conditions is expected and acceptable.

Table 3. NLOS Test Results

Height of adapter (ft)	Distance (ft)	Successful Connection (out of 5)	Successful Real Time (out of 5)
0	15	4	0
0	20	1	0
0	25	0	0
1.6	15	5	0
1.6	20	5	1
1.6	25	4	0
3.2	15	5	5
3.2	20	5	4
3.2	25	4	2
4.8	15	5	2
4.8	20	5	4
4.8	25	5	0

Similar to LOS testing, a NLOS test was also conducted in the vicinity of the OU-Tulsa campus. As previously mentioned, the device and environment used in the testing procedure were identical, with one exception. To emulate an actual data collection scenario, we placed the Tablet with Bluetooth dongle inside a vehicle while the RR3

with Bluetooth adapter was placed on the front right side of the vehicle. Bluetooth adapter height attached to RR3 was varied to observe if height change could improve connectivity while Bluetooth dongle height inside the vehicle remained constant at the height of 5 feet 2 inches. Table 3 results suggest that given the experimental setting, a 20 ft. distance and Bluetooth adapter height of 3.2 ft proved a minimum configuration to establish communication between RR3 and an ODOT agent operating in a vehicle. This finding can be explained primarily as a result of path loss due to the physical obstruction of the vehicle's thick front hull, which negated the good connection at a low height for the Bluetooth adapter.

5. TCMS Android App

Before ODOT can start utilizing the RR3 unit, the organization must first establish its configuration (e.g., number of lanes and other variables). To easily facilitate such services, the TCMS mobile app was designed for use on any Android device (e.g., tablet, phone, and others) with USB On-The-Go (USB OTG) capability. Utilizing this app, an ODOT agent can program and configure RR3 on the fly during the deployment. Details about the TCMS app are provided below.

TCMS app, provides the following functionalities:

- Connect to RR3: By connecting the Android device with RR3 using OTG cable (or wireless interface), the app can send configuration commands to RR3 to start/stop data collection in various modes.
- Get Tasks and Map it: This feature allows collectors to see their tasks (e.g., sites to deploy) and map them on the Google map application.
- Upload Bin Files: The app can upload binary files into the cloud for processing at the server.
- Start Manual Counting: This function permits the collector to do manual counting using the app for validating RR# collected data.

- Upload Manual Counting File: Manually collected data can be uploaded to the server to validate RR3 data.

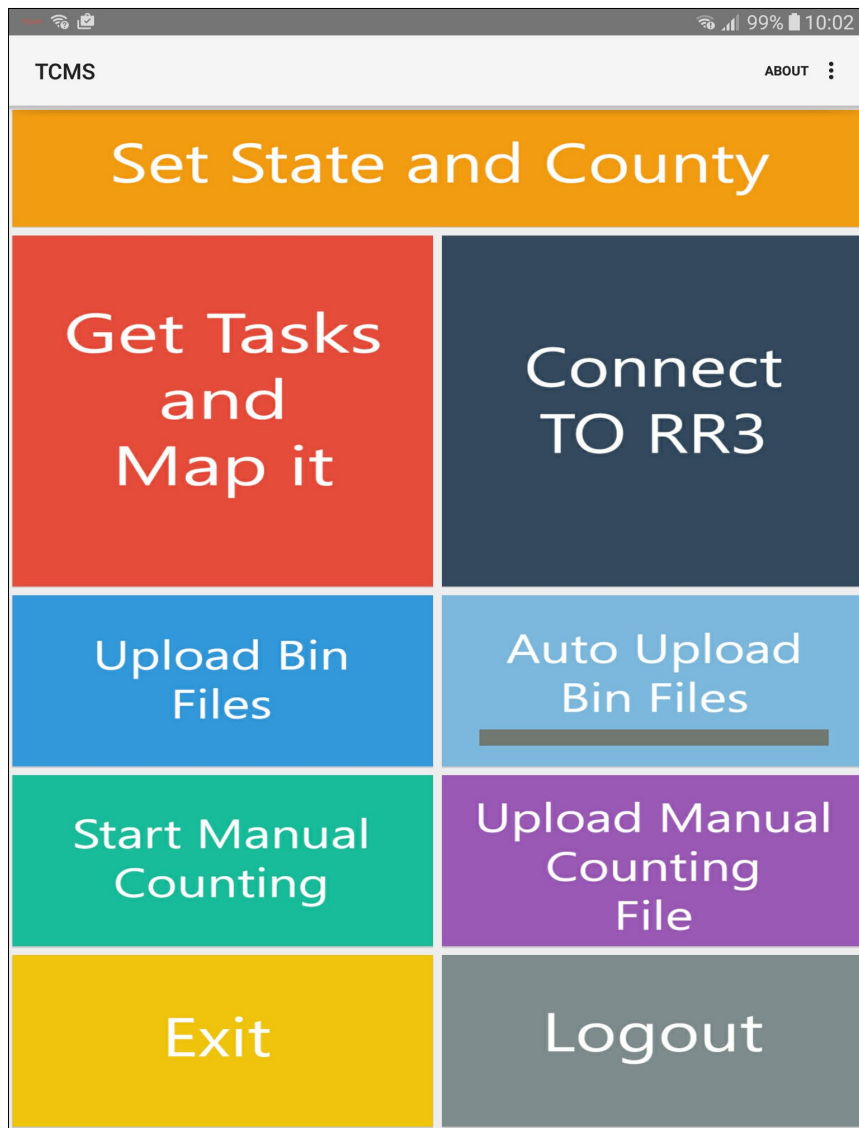


Figure 5. TCMS app main layout.

Figure 5 shows the main screen of the app, where users can see and access all features. The app was carefully designed to simplify use by ODOT's collector agents. During users' initial access to the application, each user must input a local login username of their choice before being redirected to the screen shown in Figure 5, where 'LOGIN' must be selected so that a user can input given credentials. It is likely that the user must then need to set up the state and county from which they will deploy.

5.1 Get Tasks and Map It function

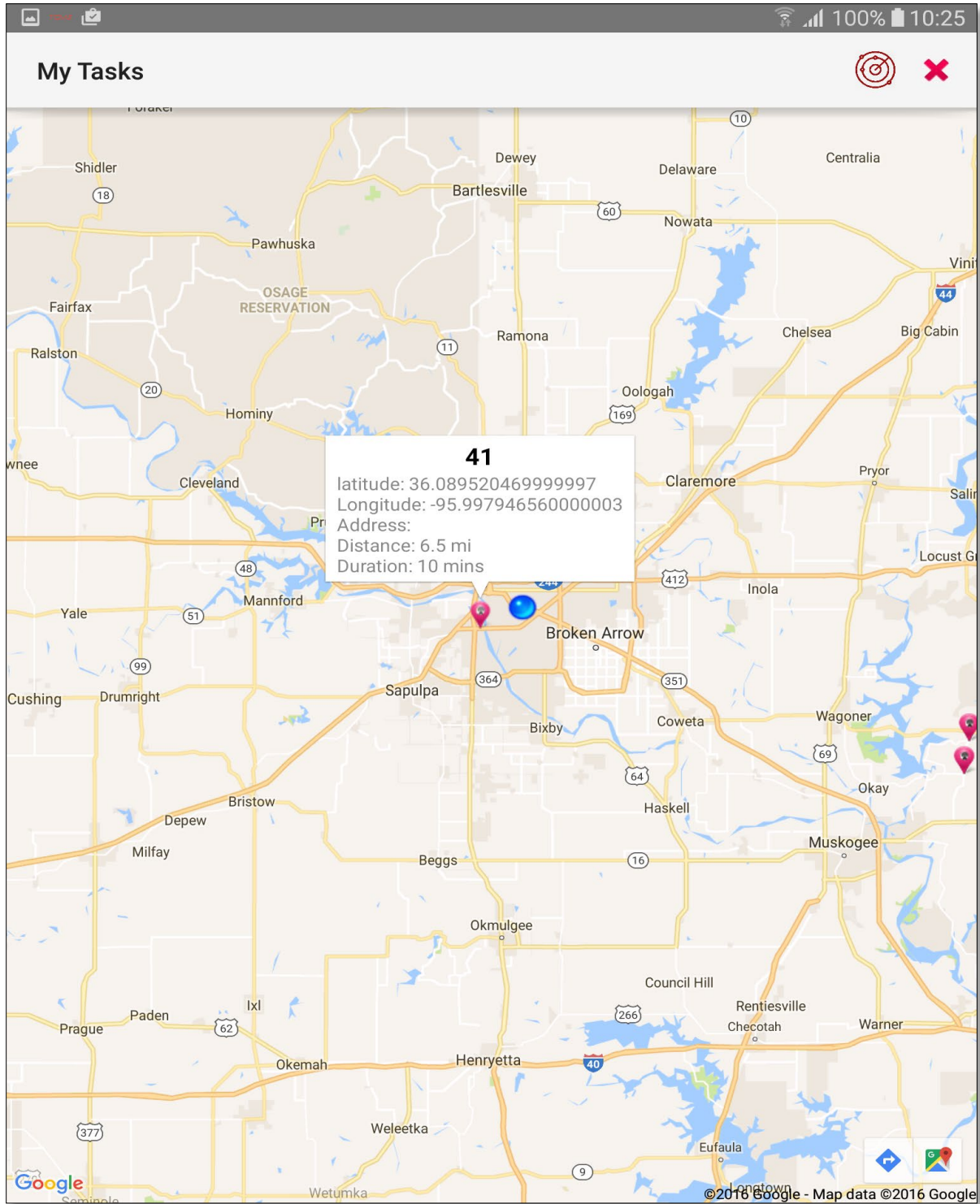


Figure 6. TCMS app, Get and Map My Tasks layout.

To enhance efficiency and organization, a new feature was developed to show users a set of sites on a dynamic map that he/she must visit. Using auto-navigation-system accessibility through Google Maps, a user can optimize his/her trip while deploying or collecting vehicles records from RR3. By selecting the “Get Tasks and Map It” button, a user will be shown a screen with a map. Given that the user has tasks assigned, the map will indicate each task site requiring counter deployment, as shown in Figure 6.

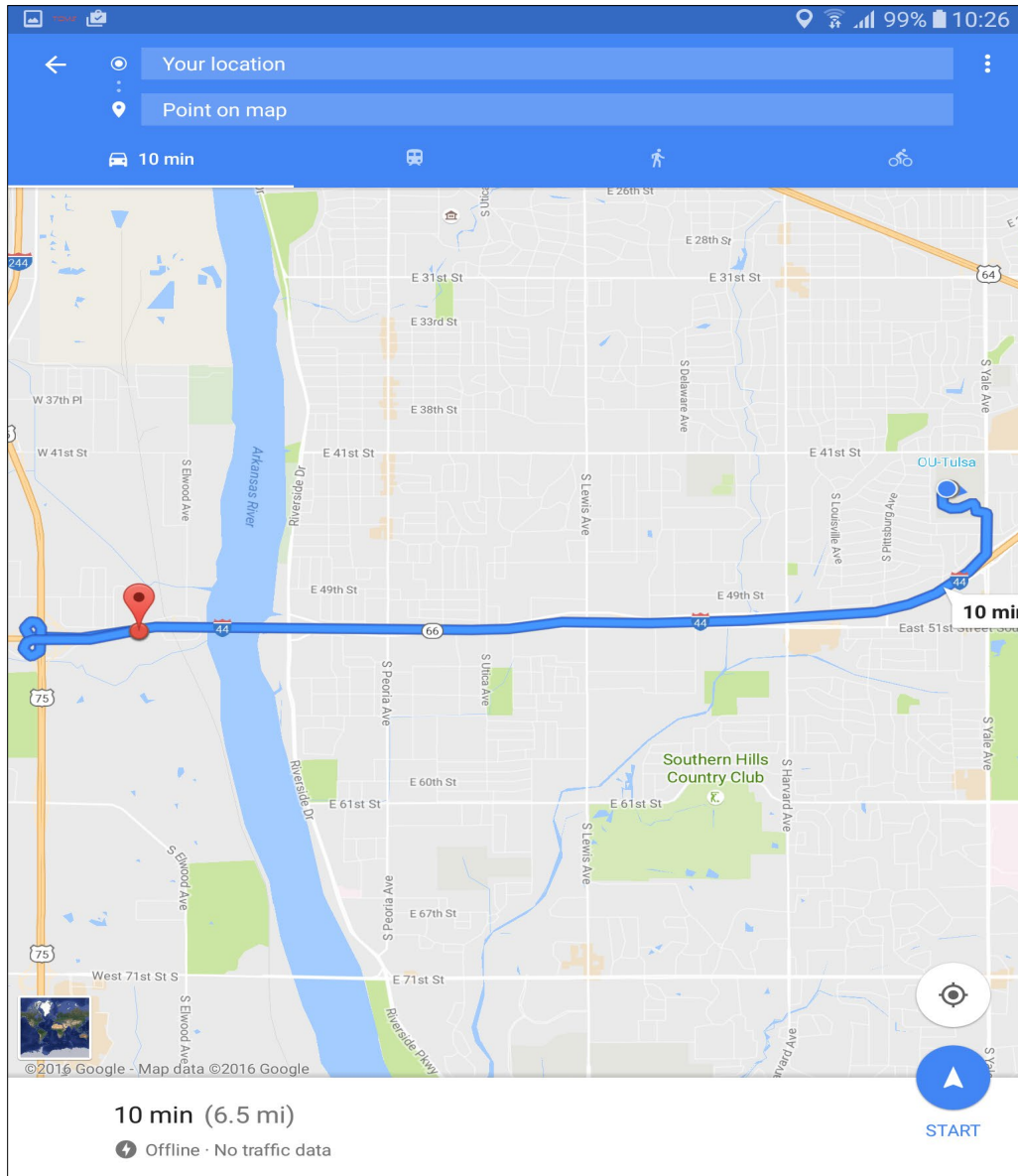


Figure 7. Google Map navigation to task site.

After enabling the location service, a user can verify the distance between his current location and the task location (i.e., deployment site). Selecting the system's navigation button in Google Maps will subsequently show a navigation route to the destination point (See Figure 7).

5.2 RR3 configuration

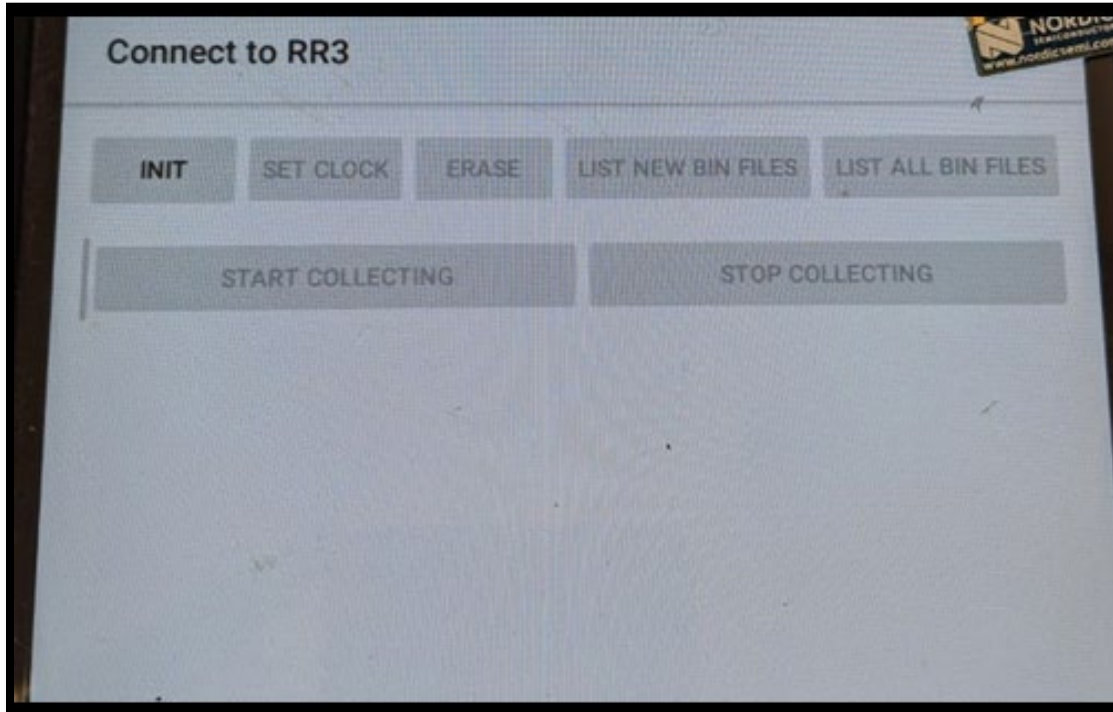


Figure 8. TCMS app, Connect to RR3 layout.

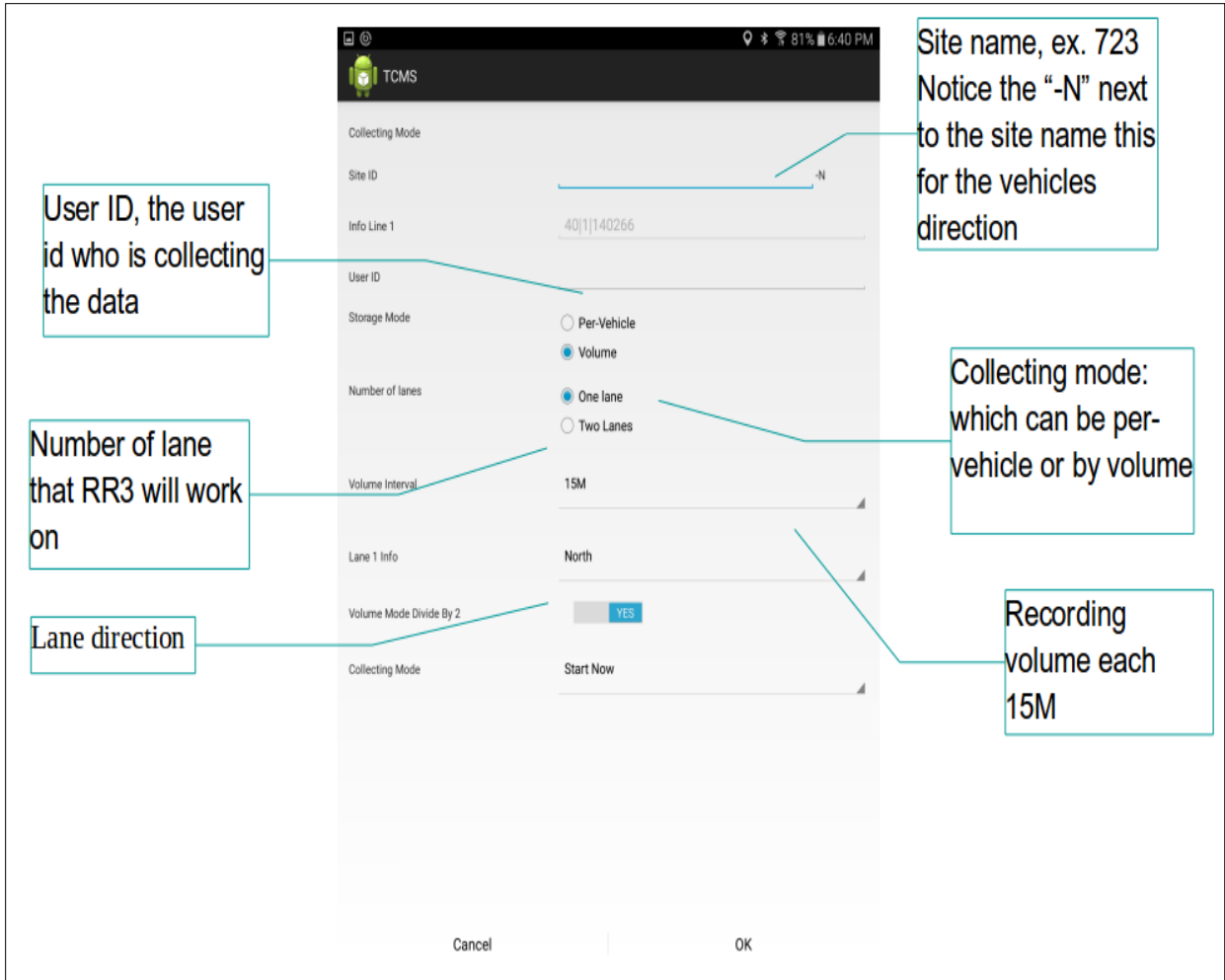


Figure 9. RR3 configuration screen, for Start Collecting function.

The setup and configuration functionality were developed to permit ODOT’s agents to program RR3 on the fly. First, the connection between RR3 and Tablet must be established. After the user selects “Connect TO RR3,” they must select ‘init’ button, as shown in Figure 8. Doing so will establish connection between RR3 and the Tablet. Next, the user selects the Start Counting button, which will subsequently redirect the user to the configuration screen, shown in Figure 9. This screen displays various configuration options and modes. Including:

- **Site ID:** Required field representing site name, (e.g., 723). Note that state and county should already be entered. If not, a message will prompt the user to insert this information.
- **Info line 1:** Auto-filled field containing state, county, and GPS locations.

- **User ID**: Field representing ID of person deploying the system.
- **Storage mode**: RR3 supports vehicle counting or vehicle classification; user should choose between per-vehicle for classification and volume for counting. Note that per-vehicle classification is not yet implemented.)
- **Number of lanes**: Option allowing choice of one or two lanes; RR3 classifies no more than two lanes.
- **Volume interval**: Functionality enabling frequency data saved to memory, with recommended default value of 15 minutes.
- **Lane 1 info**: Information representing flow direction (North, East, West, South and Total), given that one lane is selected.
- **Volume mode divided by 2**: Option set to yes when two road tubes are used with RR3 on one lane; total number of vehicles should be divided by 2.

Setting all configuration options and selecting the OK button will initiate RR3 counting. The “STOP COLLECTING” button can be used to stop RR3. All binary output files generated by RR3 must be fetched for uploading to the server later. A function for transferring binary files from RR3 to the Android app was developed and can be initiated by selecting the “Get Bin files” button, as shown in Figure 8.

5.3 Upload and process binary file

The proposed system depends on storing, archiving, and processing all RR3 output files in the OU-Tulsa network cloud. Two modes are available for uploading binary files. The first is auto upload, wherein the app detects internet connection availability for sending binary files to the server. The second is manually uploading binary files to the server. In this mode a user can choose one binary file at a time for upload. Feedback to the user reports uploaded binary file status and detected vehicle count. Alternatively, several binary files can be uploaded at once to the server at once; however, no feedback is reported to the user. Auto upload mode can be enabled by selecting the “Auto upload bin files” button, as shown in Figure 5. When uploading a file to the server, the app will first verify if the binary file has already been uploaded. If not, the file is uploaded before

it transmits a message to that effect. Note that a single binary file cannot be uploaded to the server more than once.

5.4 Deployment of sites not in database

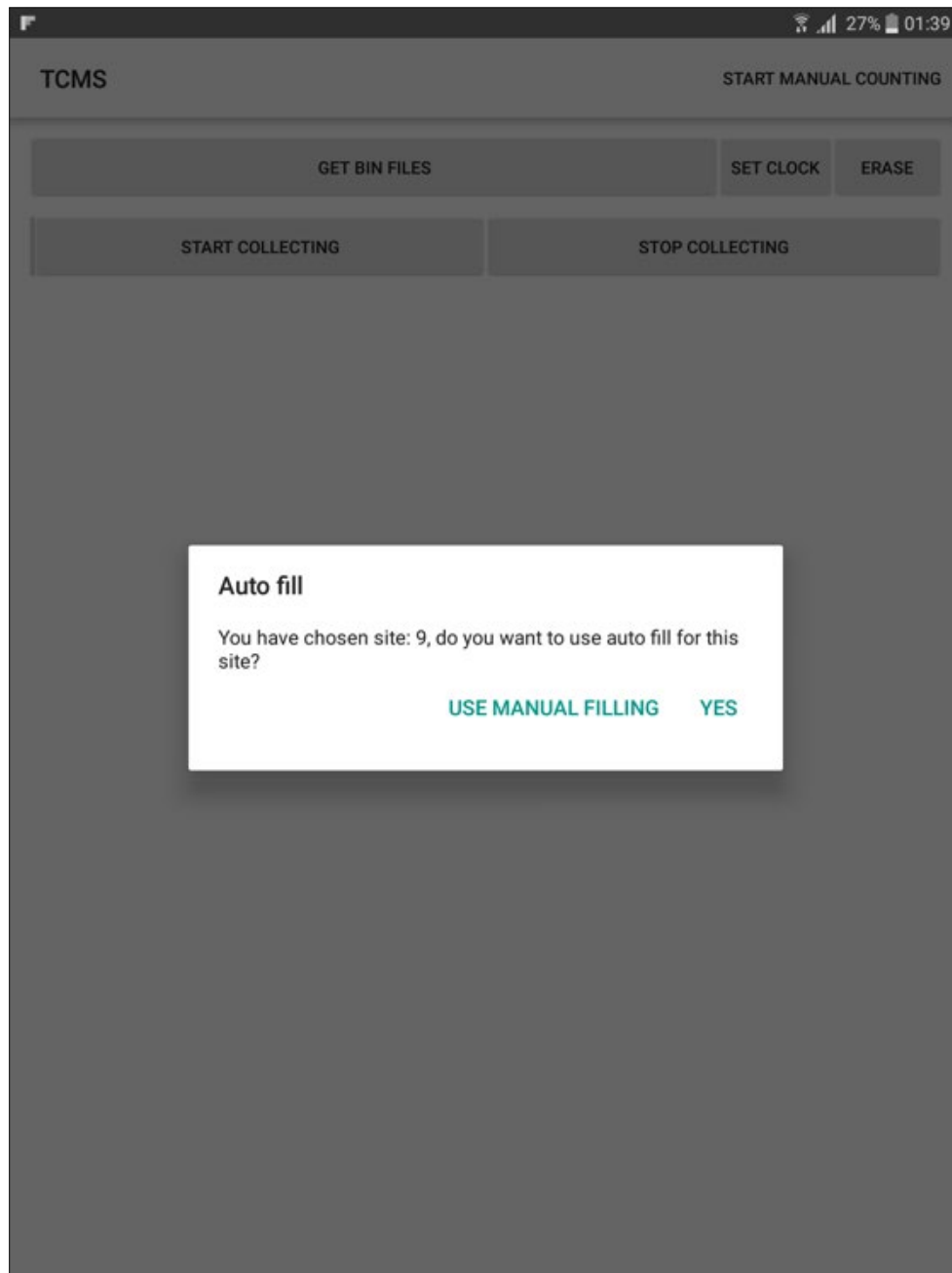


Figure 10. Manual site configuration option.

The app allows a user to choose a site from which to collect data from RR3 through the use of a manual rather than auto-fill setting. The user can also set state and county manually. A dialog was also added to ask user whether he/she prefers auto-fill (e.g., site name, state, county, and site location) or manual-fill (See the dialog box shown in Figure 10).

This method allows a user to deploy RR3 equipment in a different, yet nearby task-specific site location stored in the database. New deployment site GPS coordinates that are different from those in the TCMS database, will be uploaded to the server and recorded in the database as the actual data collection site. The new location should be limited to 1000ft linear distance from the task specific site. If the new location is further than a 1000ft, the app will consider the deployment site as new and record it as such in the server.

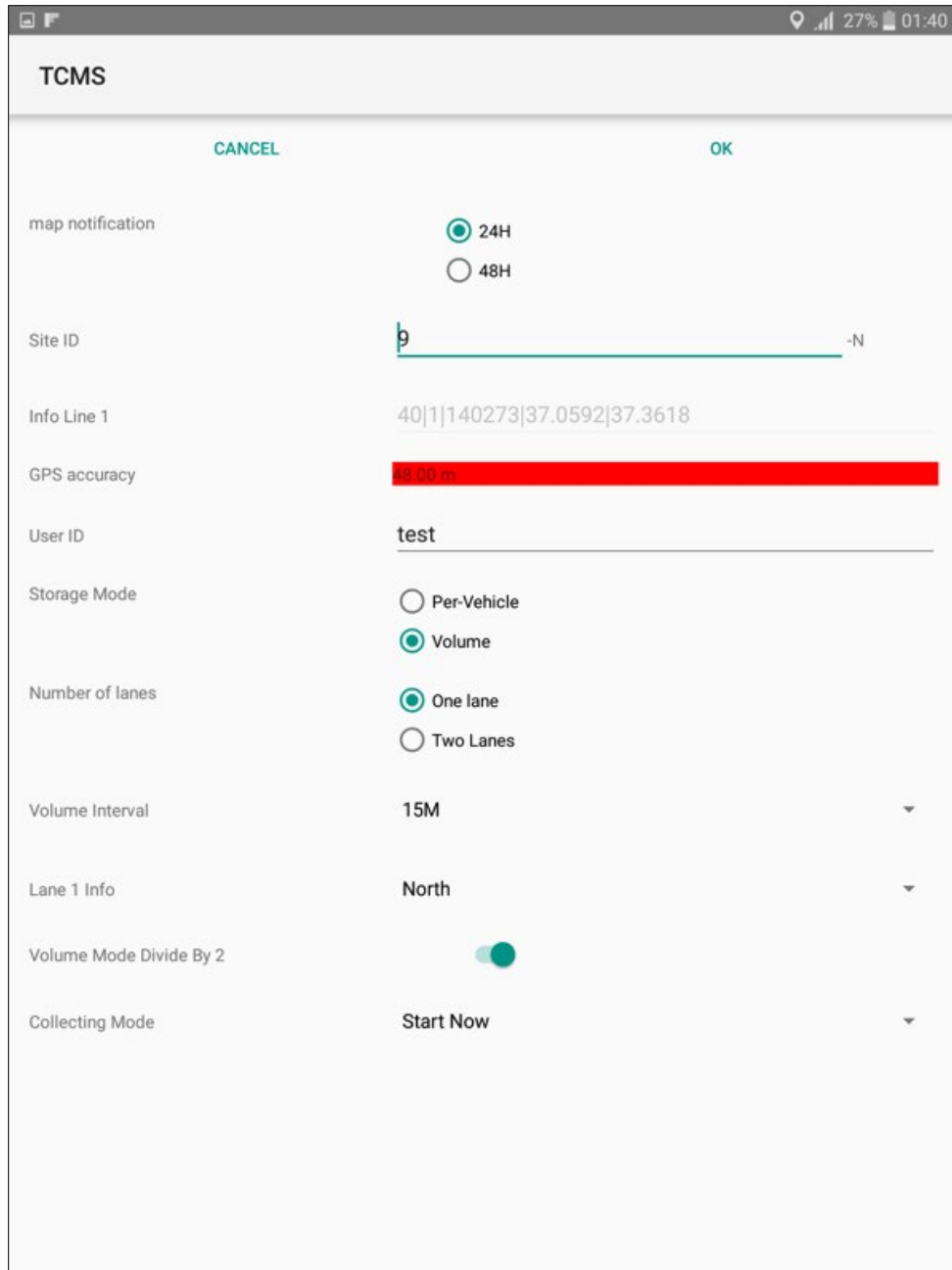


Figure 11. Inaccurate GPS indication (error is less than 40 meters).

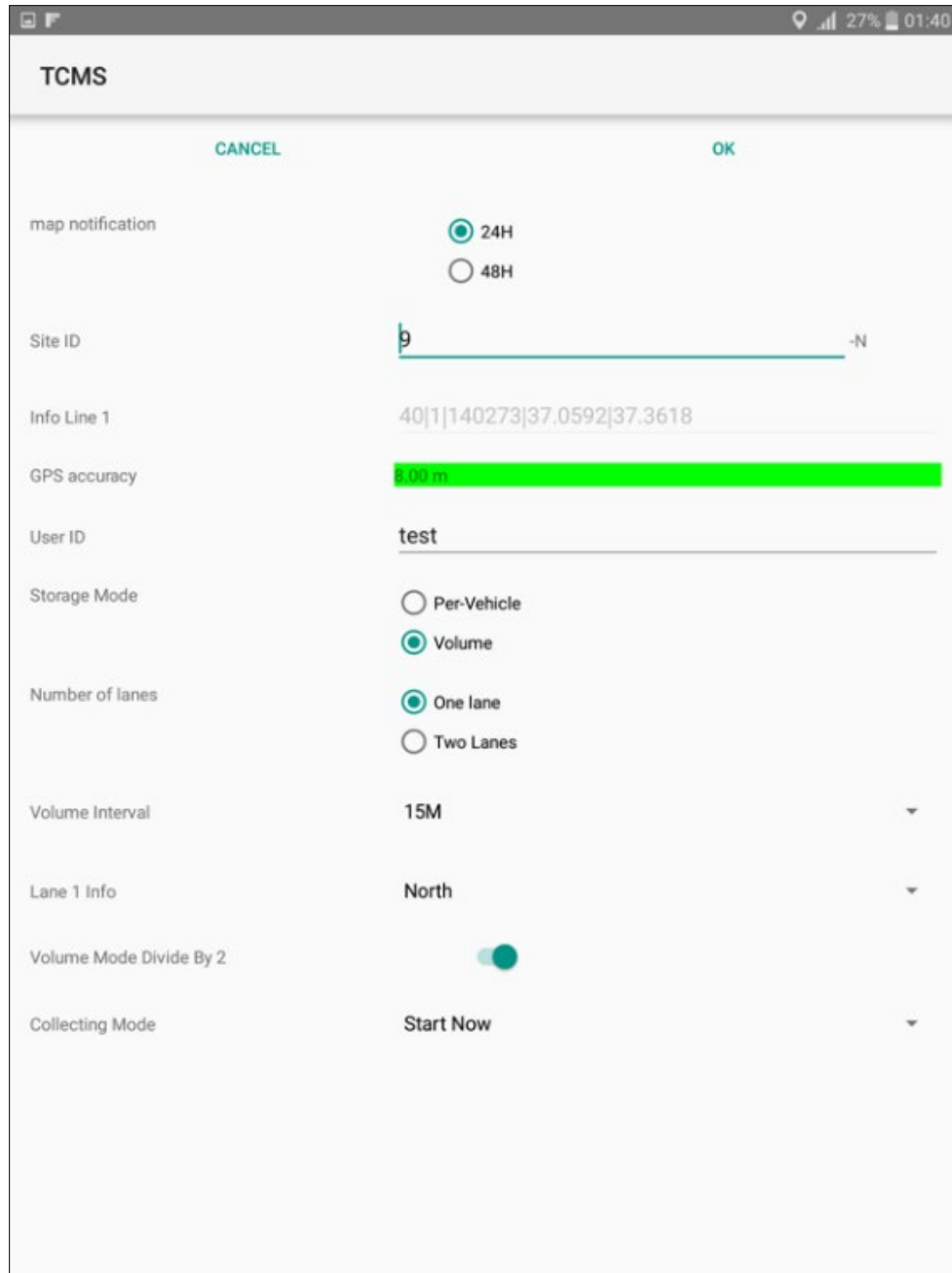


Figure 12. Accurate GPS location (error is less than 8 meter).

New site coordinates are logged using tablet GPS. An accuracy at TCMS parameters configuration page with meters and color scale is displayed (See Figures 11 and 12). The app will capture actual deployment location rather than the information in the server database, and then report the data to the server. User must wait until GPS accuracy is accurate before commencing data collection.

5.5 Off-line operation and site deployment tracking

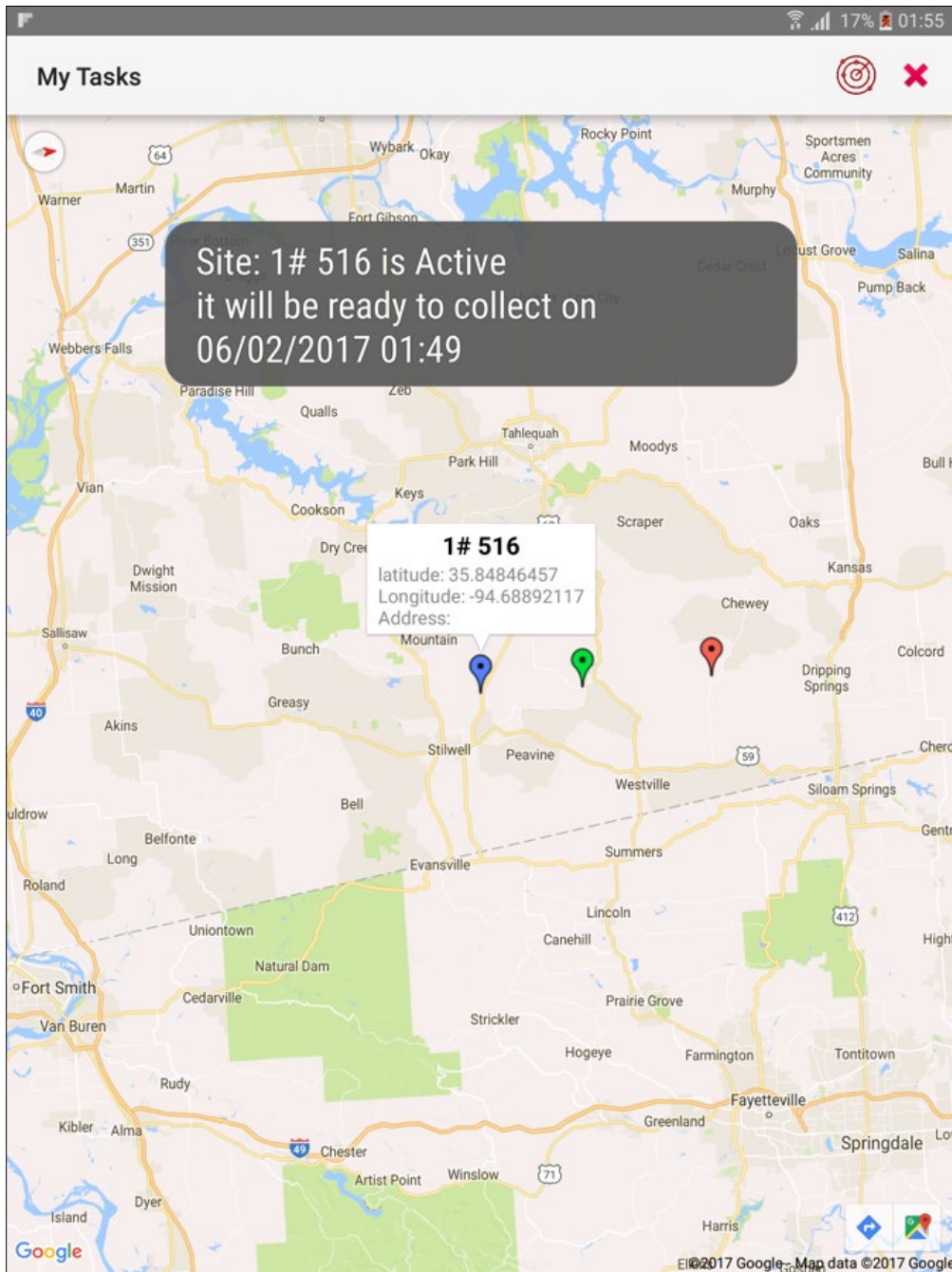


Figure 13. Display sites on map after deployment using local management structure.

Once RR3 equipment is deployed onsite, the app monitors time of deployment and informs user when data collection is complete, and equipment can be removed. Deployment tracking continues whether tablet is online/offline or if cellular coverage is not available (See Figure 13).

A management structure was added into the app for user to locally manage his/her tasks without the need for server connectivity or cellular coverage. After user requests and receives his/her tasks from the server, the app synchronizes tasks into a local structure.

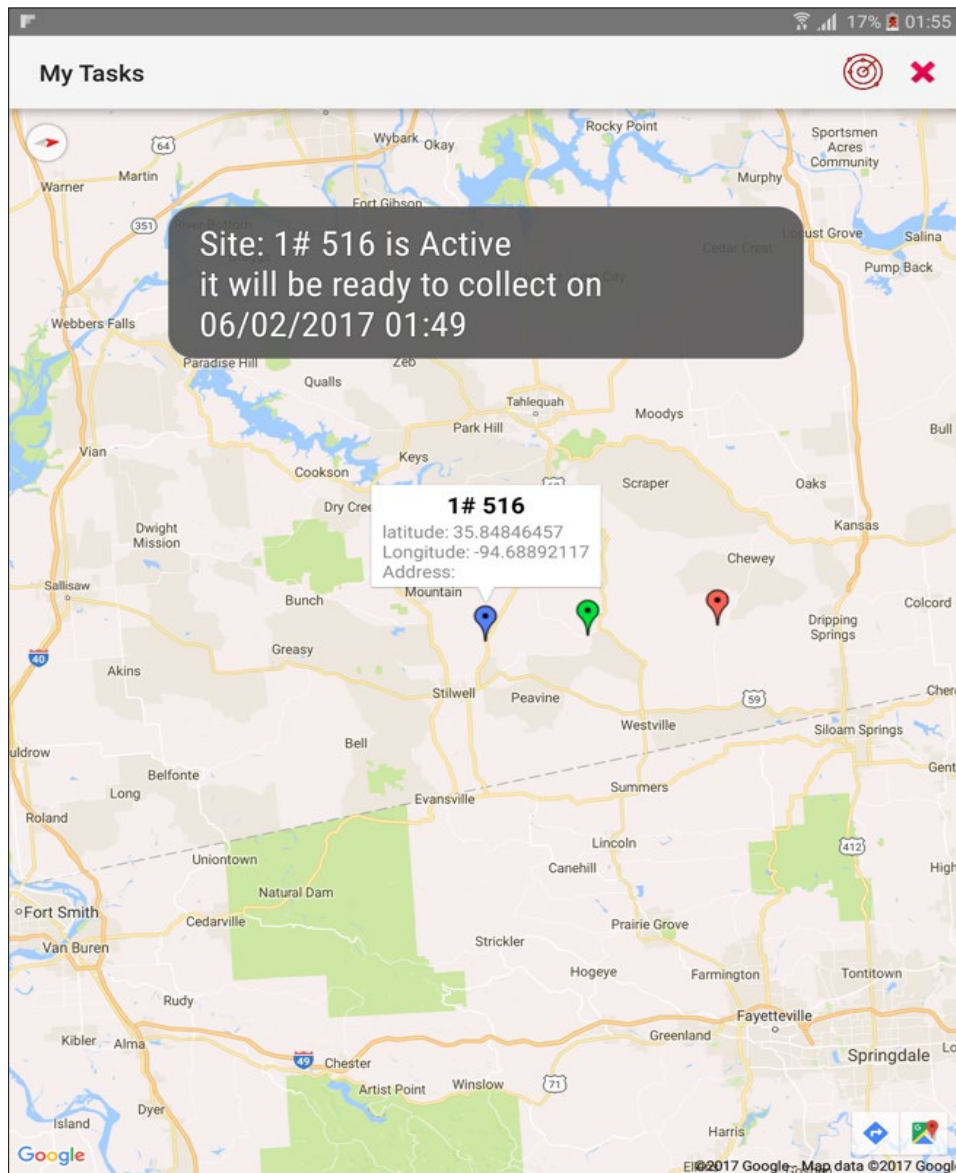


Figure 14. Site deployment status (active) information display.

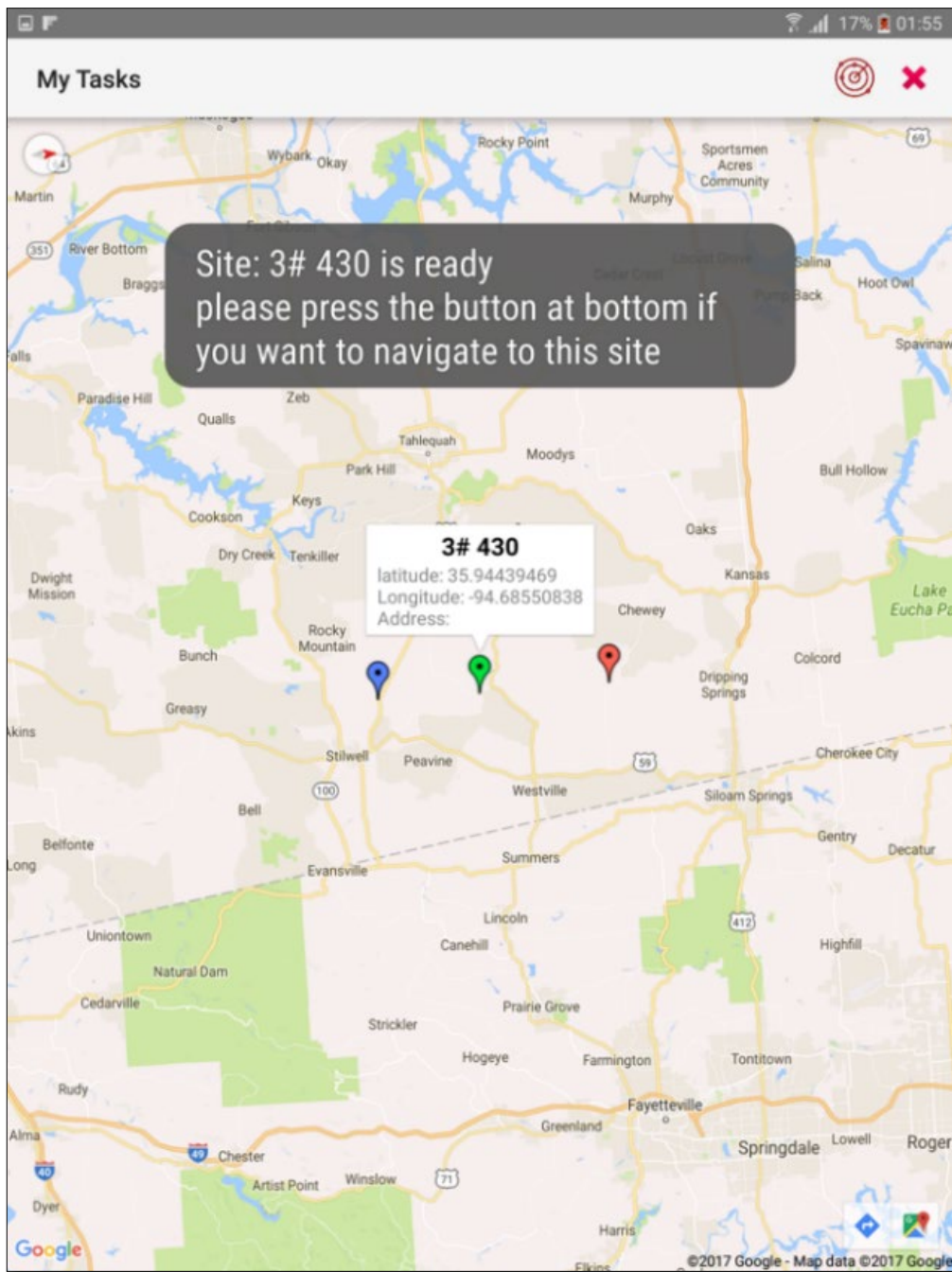


Figure 15. Site deployment status (Ready) information display

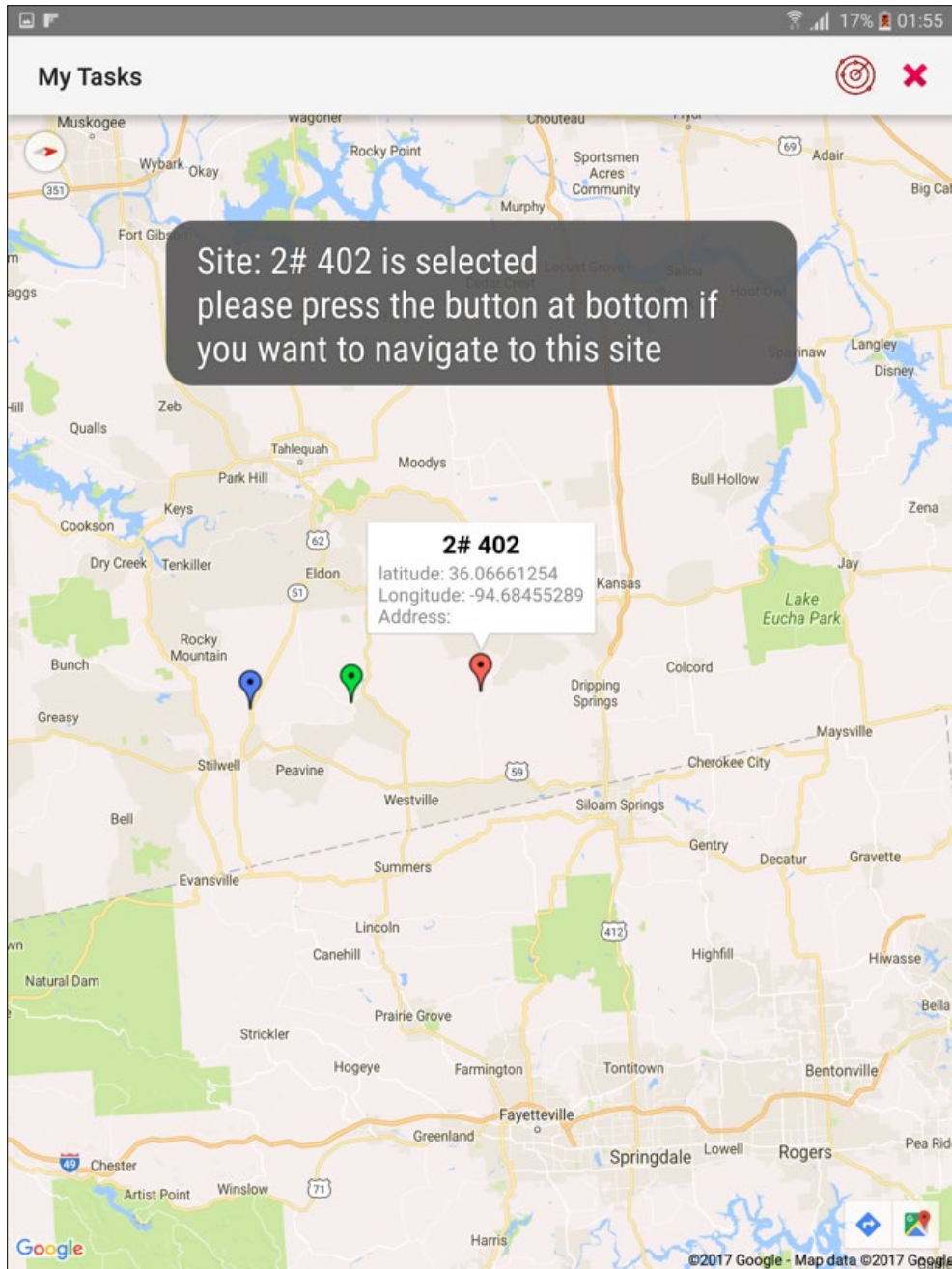


Figure 16. Site is selected for deployment.

A map will display all sites deployed and actively collecting data. Color coding aids in quick recognition: red (not deployed), blue (active), green (read), as shown in Figures 14, 15, and 16.

5.6 Manual counting

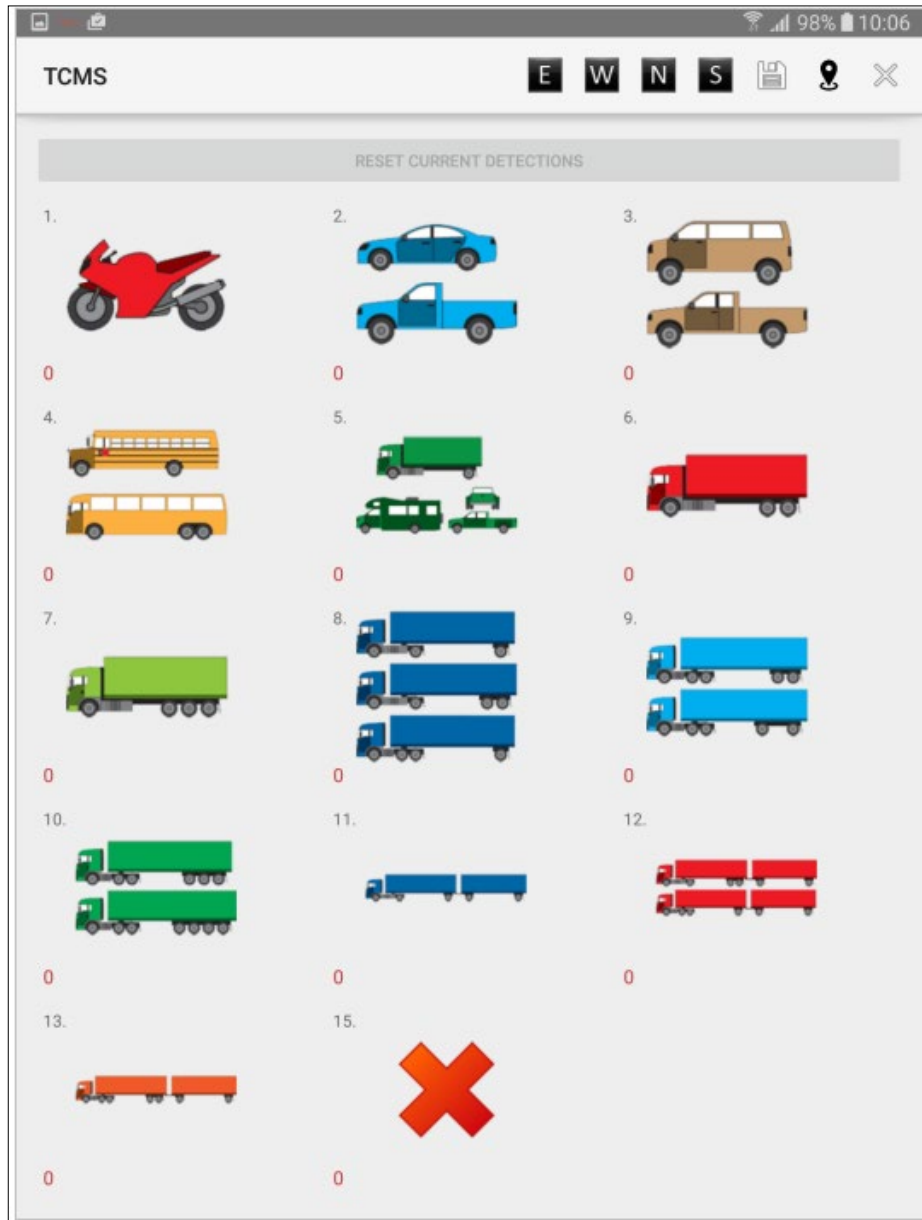


Figure 17. Manual counting layout.

To measure RR3 counting accuracy, a manual counting tool was developed for ODOT agents to manually count highway traffic during short period deployment and then perform a comparison between the manually counted and RR3 detected vehicles. Figure 17 depicts the tool layout for manual vehicle counting and classification. The tool

generates a .TXT file with manually collected data. Note that the file can be uploaded using the “Upload manual counting file” function, as illustrated previously in Figure 5.

6. TCMS Back-end Servers

Table 4. Server Specifications.

Processor	Intel Xeon CPU E5-2640 @2.50GHz (2 processors)
Memory (RAM)	48.0 GB
Operating System	Microsoft Windows Server 2008 Enterprise
System Type	64 Bit
Disk Space	500 GB

A cloud-based system was built to receive, process, and archive collected traffic data using a server setup and configured in the OU-Tulsa network. The server hosts and runs web services for processing traffic data, as well as a database designed for storing collected data. Table 4 shows deployed server specifications. Back-end server-side components are detailed in the following section.

6.1 Database Structure

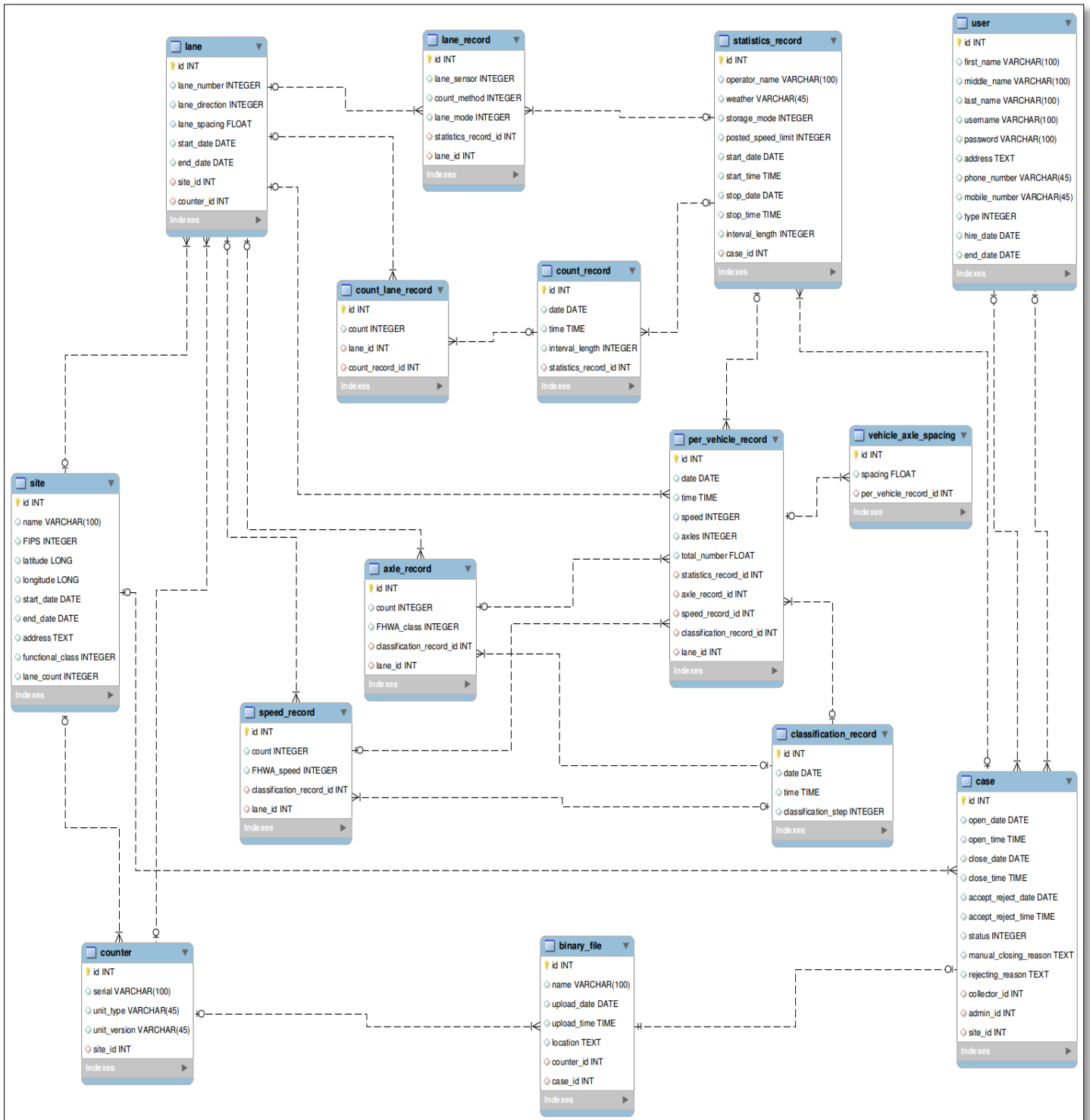


Figure 18. TCMS Database Schema

A database was designed to serve as a structured storage place for processing collected data. The structure was developed to meet best-practice standards, offering consideration for relationships between entities and normalizing design for eliminating data redundancy (See Figure 18). The database was implemented using MySQL—a free and open source database engine with high performance and reliability. Figure 18 illustrates the schema divided into tables, representing five primary system modules:

- **Site**: Each site is represented by its location and number of lanes indicated with direction. The entity consists of two tables, namely site and lane.
- **Counting/classification units**: “Counter” table represents information about each counter (e.g., serial number, location, site deployed). The table has a one-to-many relationship with “site” table.
- **Cases**: Each case represents data collection for one site for a specific period. For example, given that a collector sets up RR3 to record vehicles for 24H, after which the collection can be represented as a site case study for RR3 (i.e., “case” table). Note that the case has a relationship with most tables (e.g., site, binary_file, and others).
- **Binary output file**: When RR3 completes recording, the output file is stored in a binary format. When uploading the file to the server and leveraging the TCMS Android app, the server commences the process for extracting count or classification records. Information is represented in the following tables: binary_file, statistics_record, per_vehicle_record, classification_record, count_record, count_lane_record, lane_record and vehicle_axle_spacing.
- **Users**: A user table has been created to manage and store user information and to provide authentication and security for accessing the web service.

6.2 Server website

6.2.1 Dashboard interface

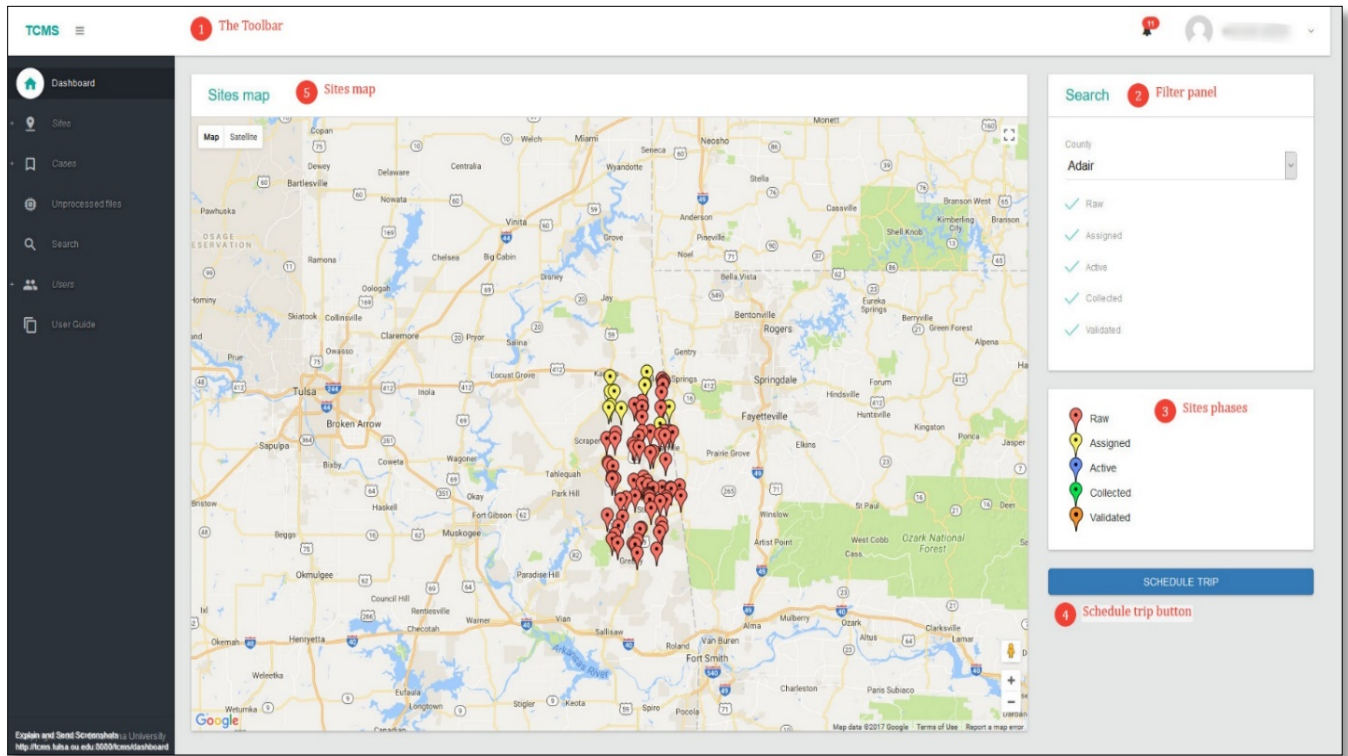


Figure 19. TCMS Web service dashboard

The dashboard is the main interface for displaying a map containing colored marker for each site (See Figure 19). The map illustrates an up-to-date status for each site position in Oklahoma counties. Each site has a five-state life cycle: raw, assigned, deployed, collected, and validated. See description for these cycles below.

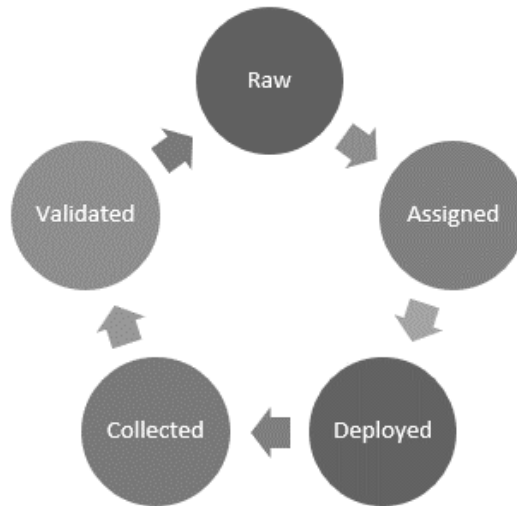


Figure 20. Site life cycle

By coloring site markers on the map, administrators can distinguish between sites, determine if they are deployed/collected, and quickly see if a site has been assigned to a collector. Site phases include:

- Raw: No tasks assigned (red marker)
- Raw: Downtown OKC (pink marker)
- Assigned: Assigned to collector for deployment (yellow marker)
- Deployed: Collector (blue marker)
- Collected: Collected and uploaded site data (green marker)
- Validated: Reviewed and validated (orange marker)
- No Access: Site can't be reached (black marker)
- Temporary unavailable (gray marker)

Sites start in a raw state, not assigned to a collector. After collector is assigned, the site becomes yellow, indicating an “assigned” state. After a collector deploys a counter in the assigned site, the indicator turns blue, indicating a “deployed” status. Next, a green (“collected”) site indicates that a collector is uploading the binary file associated with the deployed site to the server. Given that an administrator validates the collected data by accepting it, the site turns orange.

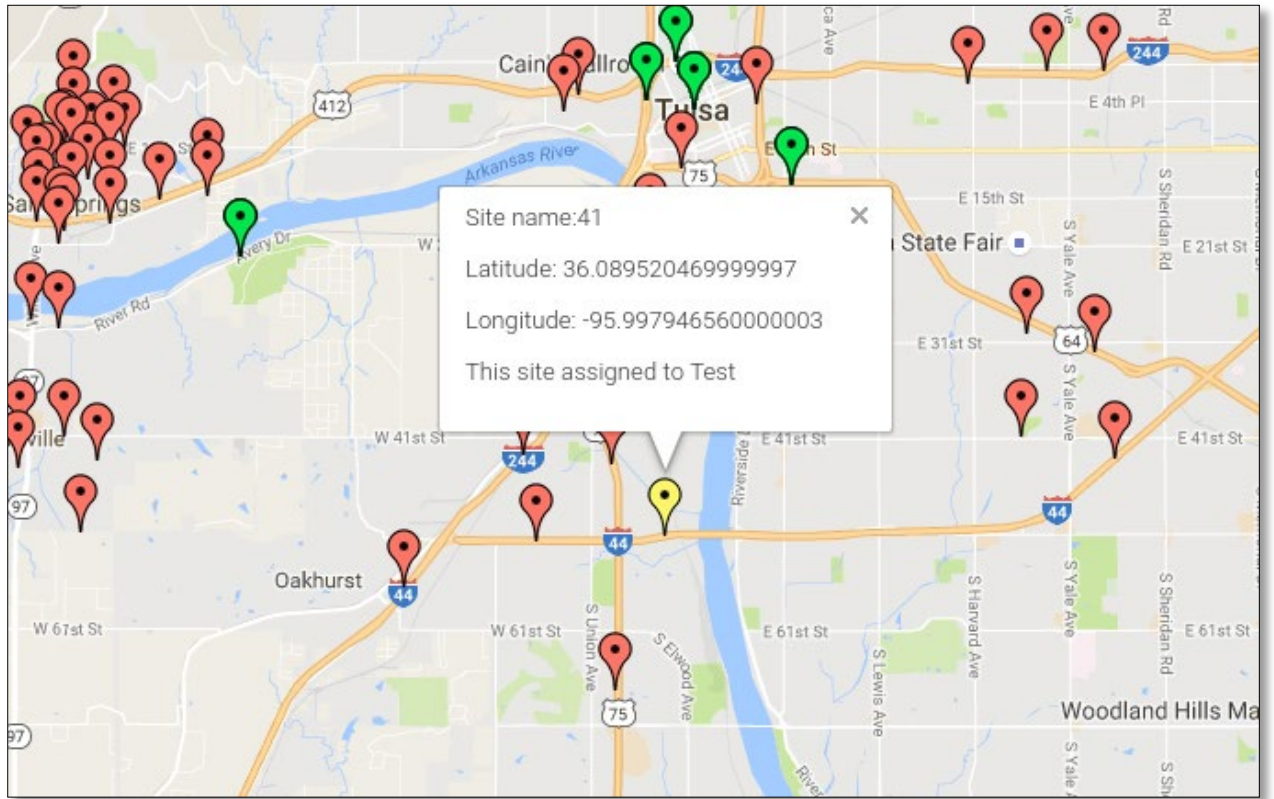


Figure 21. Example of sites with various status indicators.

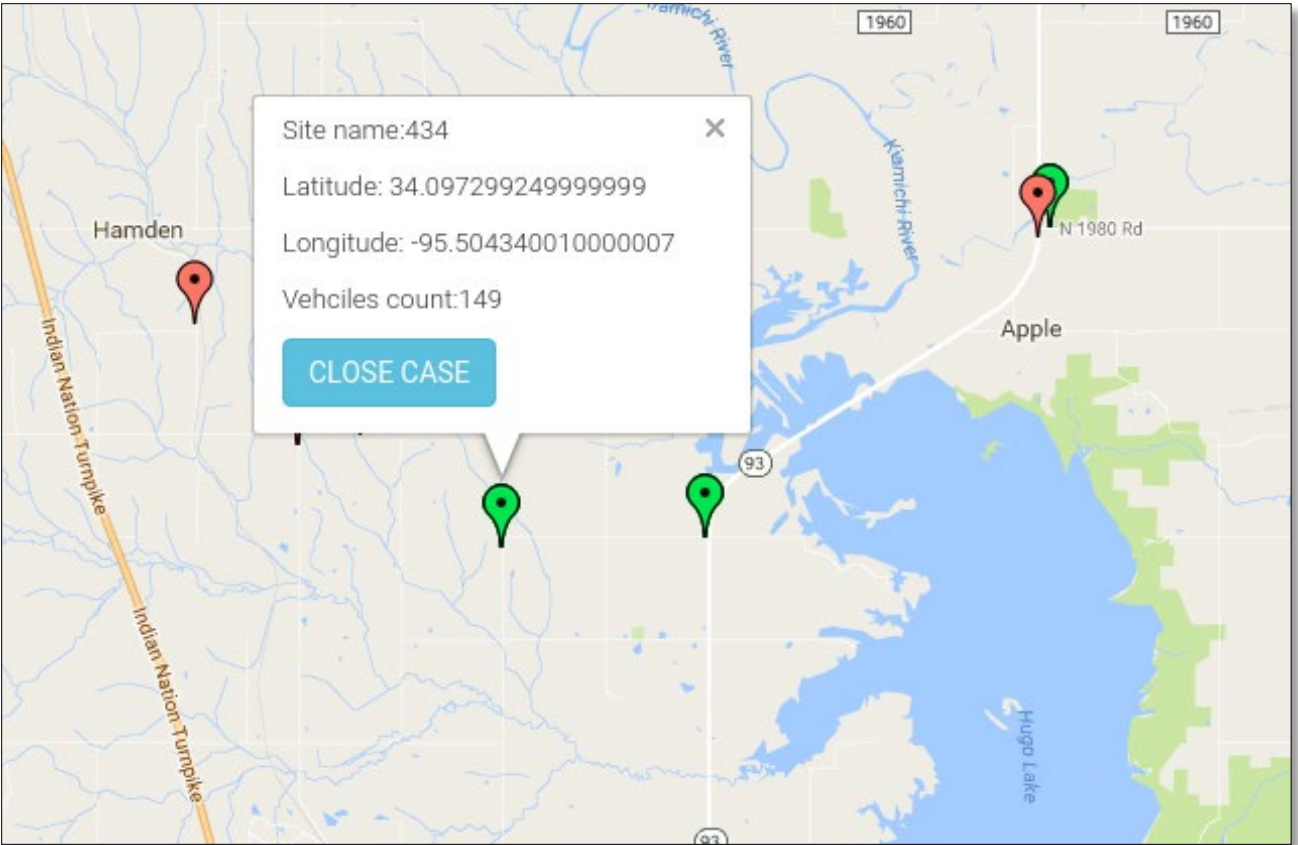


Figure 22. Example of site with deployed and collected data status.

Figure 21 shows sites with a variety of status indicators. For example, when selecting a yellow-colored site, information (e.g., collector name assigned to the site) will be displayed. When selected a green site (i.e., closed case), a message with button will be displayed, indicating that the user should check the collected data, as shown in Figure 22.

6.2.1.1 Trip scheduler

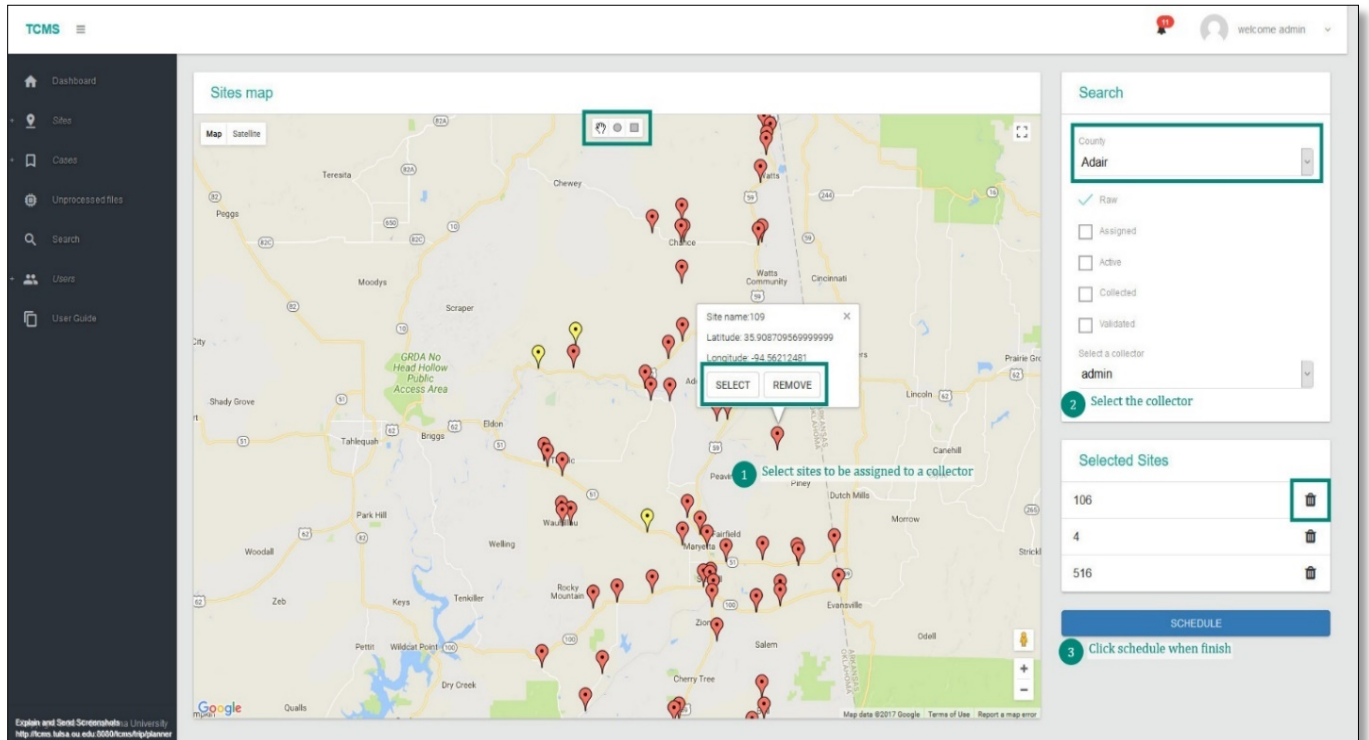


Figure 23. Schedule trip interface

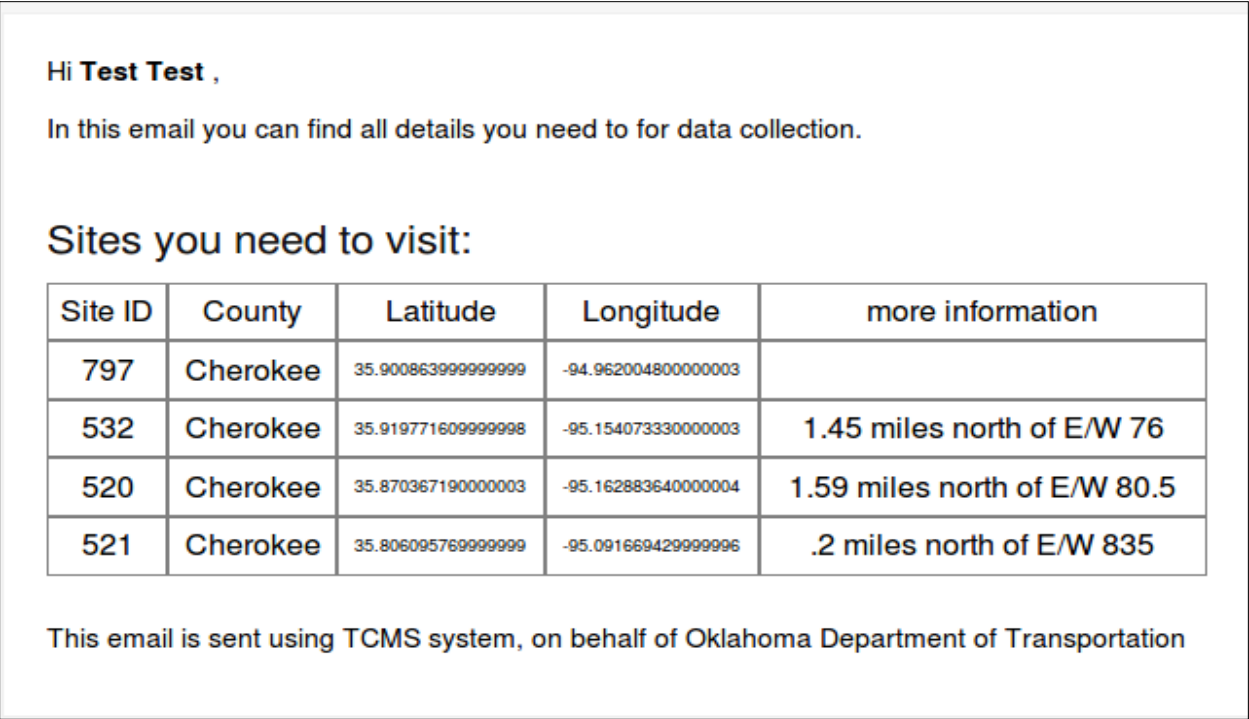


Figure 24. An email of scheduled tasks.

TCMS provides an interface for scheduling and assigning sites to collectors for data collection, as illustrated in Figure 23. Sites can be assigned to a collector by either selecting them individually or using the drawing tool from the top of the maps to select multiple sites. After scheduling a trip, an email containing necessary trip information will be sent to the selected collector. Figure 24 provides an example of an email trip plan. In addition to the email, all scheduled tasks will be sent to the collector’s Android device after the user selects the “Get tasks” button, as detailed in Section 5.1. Recall that when selecting sites for deployment, the color of the map indicator will change to yellow.

6.2.2 Dashboard Active Site

The dashboard displays all current and active sites. Sites are placed on a Google map with proper locations.

6.2.3 Dashboard Assignments

The dashboard displays all current assigned sites. Sites are placed on a Google map with proper location and different colors indicating the assignees.

6.2.4 Sites

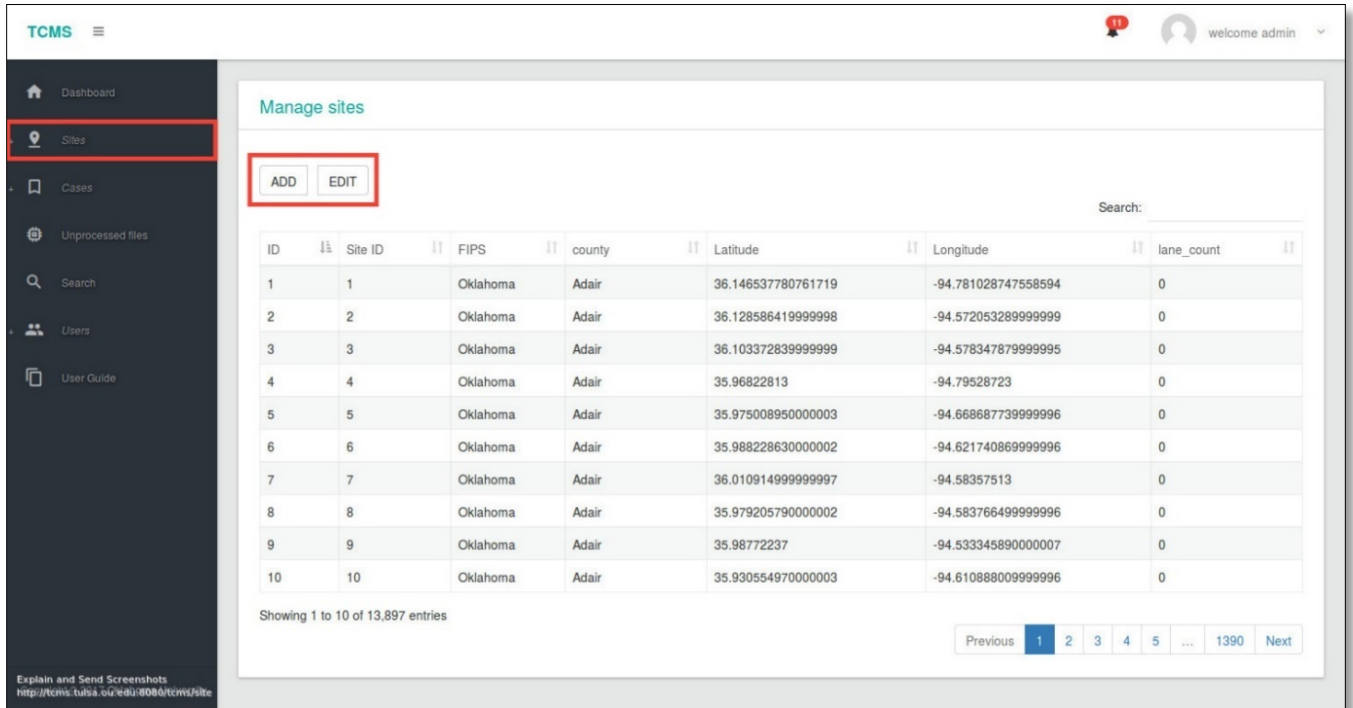


Figure 25. Manage site web interface.

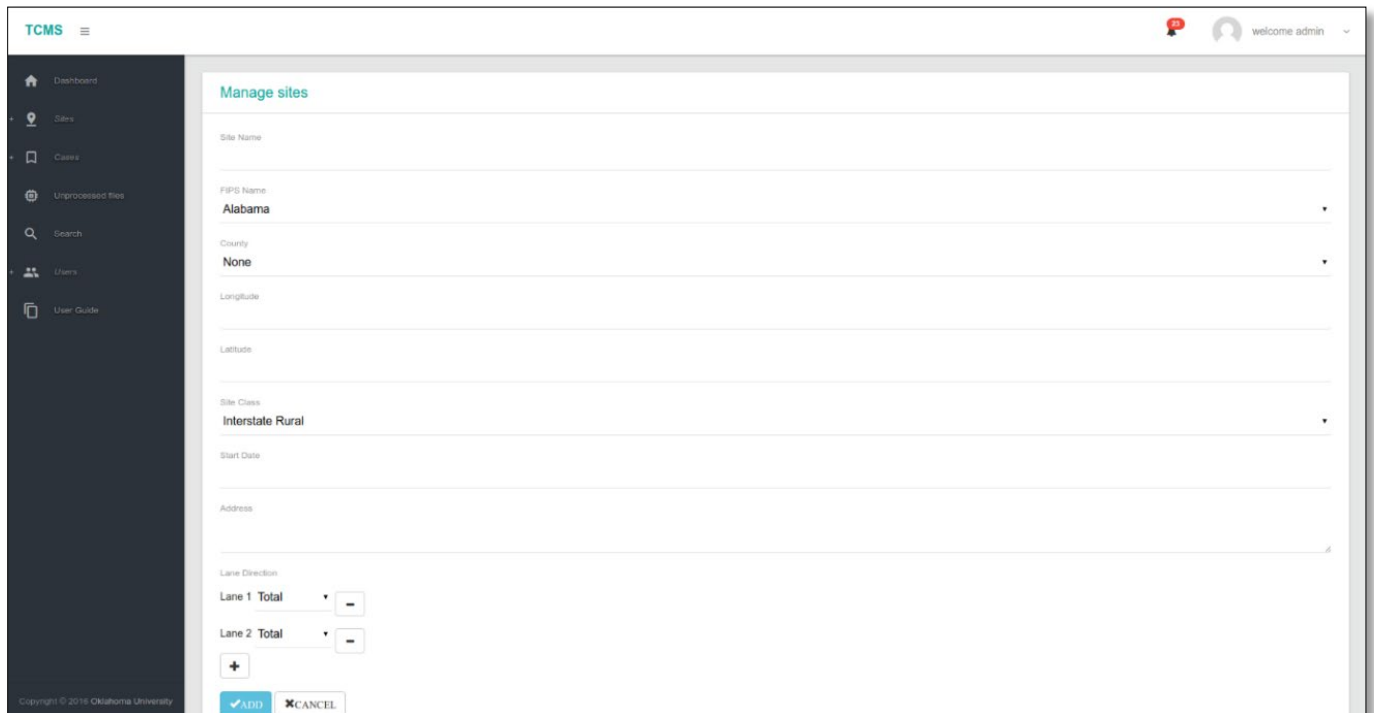


Figure 26. Add new site web interface.

Manage sites service allows an administration board to add or modify sites. Figure 25 shows the interface of 'Sites' services in which existing sites can be edited or new sites can be added. Given that the "Add" button is selected, the screen will resemble the layout in Figure 26. After adding a site, the service will ensure that the new site is not a duplicate.

6.2.5 Cases

6.2.5.1 Manage Cases

Each case represents data collection for one site for a specific period. For example, if a collector sets up RR3 to record vehicles for 24 hours, then the collection can be represented as a case for the site that RR3 is working on. The output binary file can subsequently be uploaded and processed using "case module" services.

The screenshot displays the 'Active Cases' management interface in the TCMS system. The interface includes a sidebar with navigation options and a main content area with a table of active cases. A 'DELETE ACTIVE CASE' button is located at the top left of the table area. The table has columns for ID, Site ID, State, County, Deployment Date, and Deployed by. The data is as follows:

ID	Site ID	State	County	Deployment Date	Deployed by
14597	543	Oklahoma	Caddo	2019-03-26 09:53:46	Curtis Atwell
14598	454	Oklahoma	Caddo	2019-03-26 09:44:27	Curtis Atwell
14599	438	Oklahoma	Caddo	2019-03-26 09:33:08	Curtis Atwell
14601	564	Oklahoma	Caddo	2019-03-26 09:16:25	Curtis Atwell
14603	554	Oklahoma	Caddo	2019-03-26 08:56:52	Curtis Atwell
14604	449	Oklahoma	Caddo	2019-03-26 09:06:15	Curtis Atwell
14605	555	Oklahoma	Caddo	2019-03-26 08:48:30	Curtis Atwell
14641	550	Oklahoma	Cimarron	2019-04-09 00:01:01	General Admin
14642	445	Oklahoma	Cimarron	2019-04-09 00:19:10	General Admin
14645	25	Oklahoma	Adair	2019-04-15 18:37:05	General Admin

Showing 1 to 10 of 13 entries

Navigation: Previous 1 2 Next

Figure 27. Manage Cases layout (Active Cases).

Closed Cases

Merge Directions

ACCEPT REJECT DETAILS CHANGE DIRECTION COUNTS HISTORY

Search: _____

Case ID	Site Name	Direction	County	Deployment Date	Stop Counting Date	Upload Date	Count	Deployed By
13157	43	Total	Kay	2019-03-25 15:42:00	2019-03-26 15:45:00	2019-03-26 15:47:14	3260	Jerry Pendley
13146	537	Total	Caddo	2019-03-25 14:46:00	2019-03-26 15:06:00	2019-03-26 15:07:29	97	Curtis Atwell
13155	549	Total	Caddo	2019-03-25 15:19:00	2019-03-26 15:37:00	2019-03-26 15:37:57	252	Curtis Atwell
13156	558	Total	Caddo	2019-03-25 15:27:00	2019-03-26 15:44:00	2019-03-26 15:45:01	327	Curtis Atwell
13162	560	Total	Caddo	2019-03-25 16:36:00	2019-03-26 16:43:00	2019-03-26 16:44:15	53	Curtis Atwell
13159	551	Total	Caddo	2019-03-25 15:56:00	2019-03-26 16:04:00	2019-03-26 16:05:17	203	Curtis Atwell
13149	550	Total	Caddo	2019-03-25 14:58:00	2019-03-26 15:17:00	2019-03-26 15:18:11	85	Curtis Atwell
13160	539	Total	Caddo	2019-03-25 16:13:00	2019-03-26 16:17:00	2019-03-26 16:18:42	101	Curtis Atwell
13165	545	Total	Caddo	2019-03-25 17:08:00	2019-03-26 17:14:00	2019-03-26 17:14:42	140	Curtis Atwell
13166	553	Total	Caddo	2019-03-25 17:21:00	2019-03-26 17:25:00	2019-03-26 17:25:40	86	Curtis Atwell

Showing 1 to 10 of 22 entries 1 row selected

Previous 1 2 3 Next

Figure 28. Manage Cases layout (Closed Cases).

The Manage Cases service is utilized after a collector has deployed a site counter. The service records information about the collection site (e.g., who is collecting data, collection start time, site GPS location). This service is important for providing real-time tracking information for each site on the map. Given that a site is deployed, its status will automatically change on the dashboard to “Deployed,” and its color will change to blue. All deployed sites are listed under the Active Cases section in the Manage Cases interface, as shown in Figure 27. Given that the deployed site has a location different from that stored in the database, a new GPS location will be stored in a temporary site location, and the temporary new location, will be compared with the original one in an attempt to increase site location accuracy and make the deployment process easier. Figure 27 indicates that ODOT will also have the option to delete Active Cases by selecting the corresponding rows and deleted then selecting the Delete Active Case button.

Figure 28 displays a section of the Manage Cases service with all closed cases (i.e., cases in which counting has ended after deployment period ended). The information on the interface includes Site ID, Site Name, Direction, County, Deployment Dates, Counts,

and the Collector Agent's Name. An administrator can choose to Accept or Reject the information or select Details and Count History to ensure successful collection before deciding to accept or reject the data.

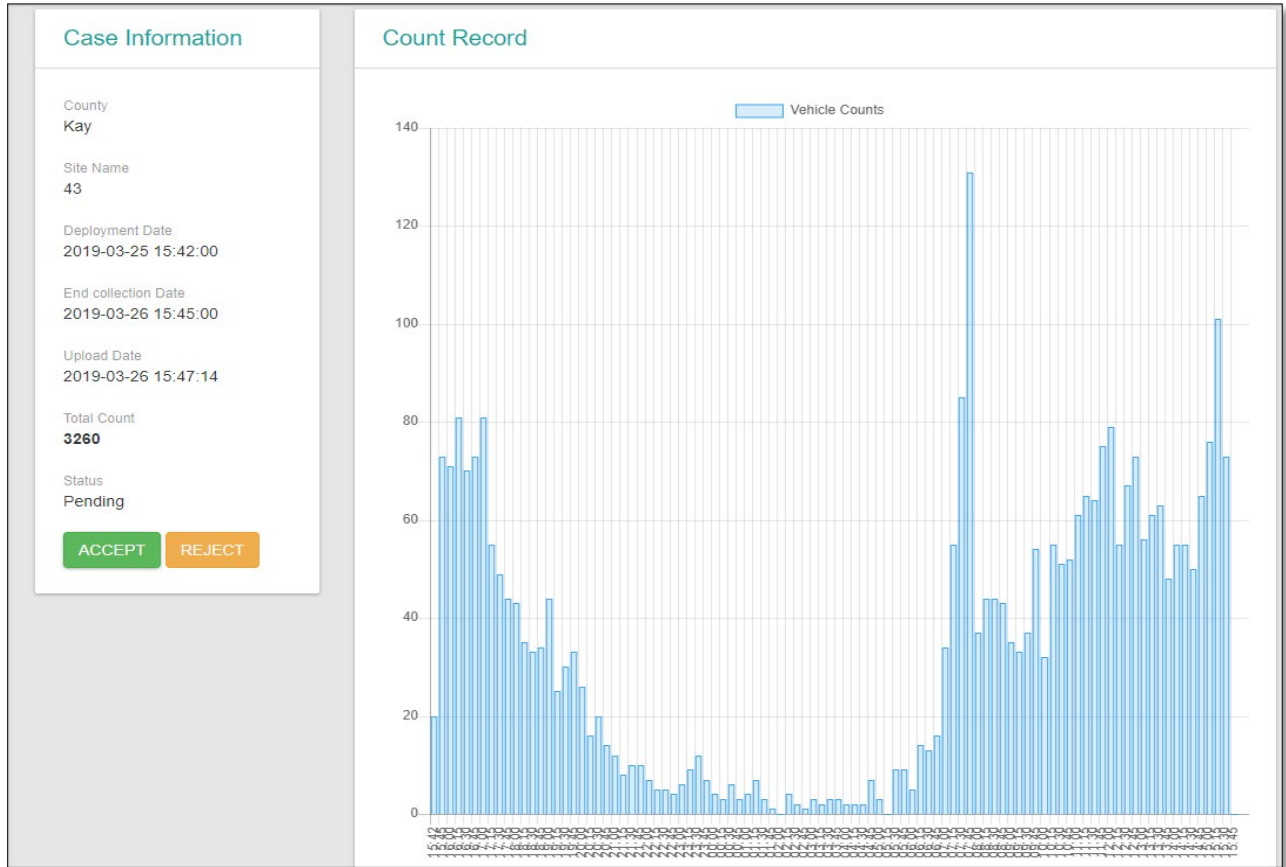


Figure 29. Details of a Closed Case.

Site Counts History:				
Site Name	County	Direction	Date	Count
43	Kay	Total	October 24 2016	3505
43	Kay	Total	March 21 2016	3475
43	Kay	Total	July 02 2013	3533
43	Kay	Total	February 04 2013	3622
43	Kay	Total	April 28 2008	10984
43	Kay	Total	March 03 2008	3981
43	Kay	Total	October 25 2006	3402
43	Kay	Total	September 20 2006	4745
43	Kay	Total	April 12 2006	4422
43	Kay	Total	February 06 2006	3901

Figure 30. Counts History of Closed Case.

Figure 27 show that selecting the Detail button will result in the layout featured in Figure 29. This figure describes a plot of traffic count as a variable of time, which in turn offers traffic distribution during the period at the site. This information is not only beneficial in terms of traffic analysis as a function of time feature, but also aids the administrator in deciding whether the distribution is appropriate for case acceptance. Figure 30, it is a result of clicking on the Counts History button (See Figure 28). It also portrays previous deployment count, which can then be used as a benchmark for deciding whether the recently closed case should be accepted or not.

It is important to note that any case study can be rejected or accepted based on counted number of vehicles provided by the collected binary files. When rejecting a case, a prompt box will be displayed for documenting reason for rejection, and the same site will be reassigned to the collector for repeating collection. An explanation listing the rejected site and detailing the reasoning behind the decision will be emailed. When accepting a case, the site will display Validated (i.e., orange color on the dashboard). An accepted (i.e., validated) site will remain validated for one year, and then return to raw status for recollection.

6.2.5.2 Create Case

Open case

County: Adair ▼

Site: 508 ▼

✓ OPEN
✗ CANCEL

Figure 31. Create Case.

The server is equipped with an option for collecting agents/admins to create a new case for new deployments. By selecting Create Case under the header Cases on the dashboard interface (See Figure 19) will change to layout to the Create Case page, as shown in Figure 31.

Sites Issues

Search:

DELETE ISSUE

County	Site	Location	Issue Date	Issue Type	Note	User	Image
Marshall	407	33.94113313791766 , -96.7611485773092	2018-08-20	Construction		David Busby	Click here
Okmulgee	665	35.439706654362527 , -95.98664048535339	2018-08-20	Other	Parking On Both Sides	Aaron Cooper	N/A
Okmulgee	439	35.49039611707026 , -95.84036830272541	2018-08-20	Other	Road Ends at residents	Aaron Cooper	Click here
Okmulgee	657	35.44198395310834 , -96.00372597954993	2018-08-20	No access (private drive or road closed permanently)	School Grounds and blocked off with chain.	Aaron Cooper	Click here
Ottawa	505	36.87265692834332 , -94.85392862820618	2018-08-21	No access (private drive or road closed permanently)	road closed	Jerry Pendley	Click here
Ottawa	747	36.87267557133089 , -94.85388478509292	2018-08-21	No access (private drive or road closed permanently)	road closed	Jerry Pendley	Click here
Ottawa	24	36.87267537359272 , -94.85410757700213	2018-08-21	Construction	bridge replacement, completion date is December 2018	Jerry Pendley	N/A
McClain	52	35.01362094158591 , -97.36006030642585	2018-08-21	Construction	new pavement	Curtis Atwell	N/A
Okmulgee	672	35.45833759490842 , -95.95980462356012	2018-08-21	Other	same site as 36	Aaron Cooper	N/A
Pittsburg	126	34.92483547180349 , -95.50928591794091	2018-08-21	Road Closed		David Busby	Click here

Showing 1 to 10 of 164 entries

Previous
1
2
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4
5
...
17
Next

Figure 32. Sites Issue.



Figure 33. An example of issue.

Under subcategory Cases on the left side of the main dashboard interface (See Figure 19), an issues site is displayed to indicate where collector agents have recorded issues that prevented them from successful deployment (See Figure 32). Issues are described, and often an image is attached (See Figure 33).

6.2.6 Uploaded Files

6.2.6.1 Uploading Binary File Service

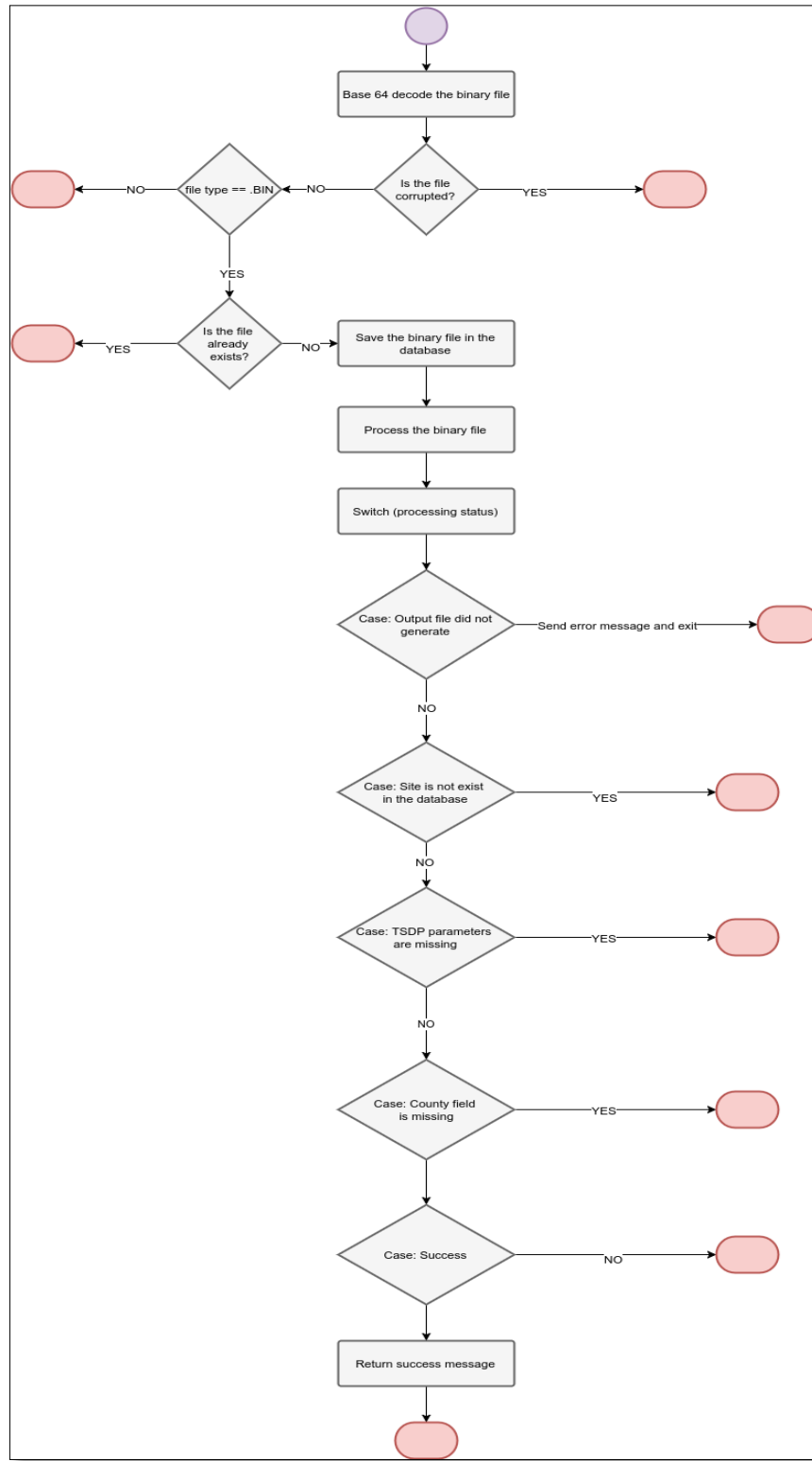


Figure 34. Upload and process binary file.

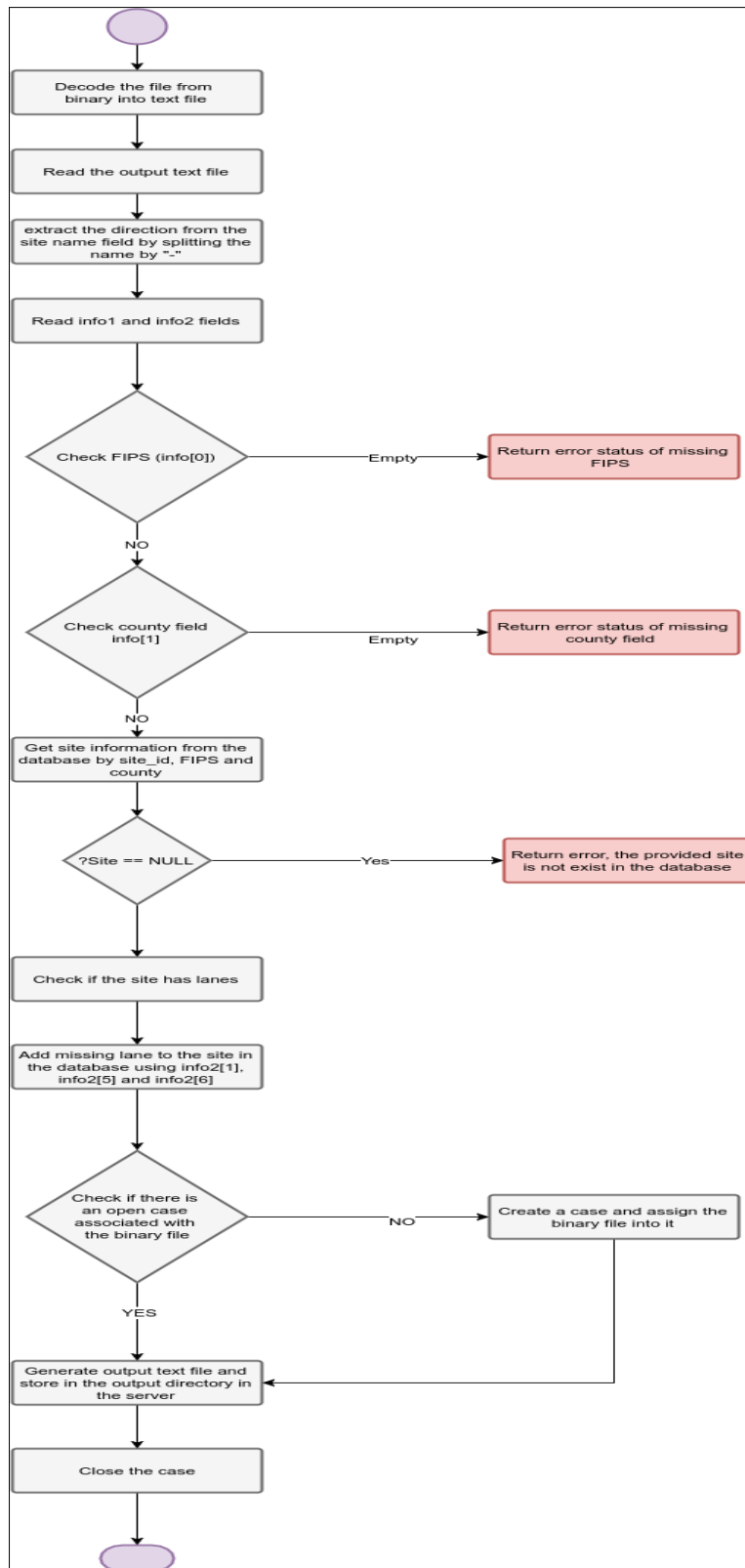


Figure 35. Process binary file service.

TCMS provides a service permitting Android app to upload collected binary files for processing and archiving purposes. See Figure 34 for a flow chart diagram. The service first starts by investigating if the binary file is valid or corrupted. Next, the service decodes the binary file into a text file, making it readable and ready for analysis. Figure 35 depicts details of the process file service. In general, each file should contain the following information: site name, FIPS, and county. Without these, the file would return “error,” and the binary file will be uploaded and listed under the unprocessed files interface. Given that a binary file is successfully uploaded, the case associated with the upload will be closed and ready for review—to either accept or reject the case, as shown in Figure 28.

6.2.6.2 Unprocessed Binary Files

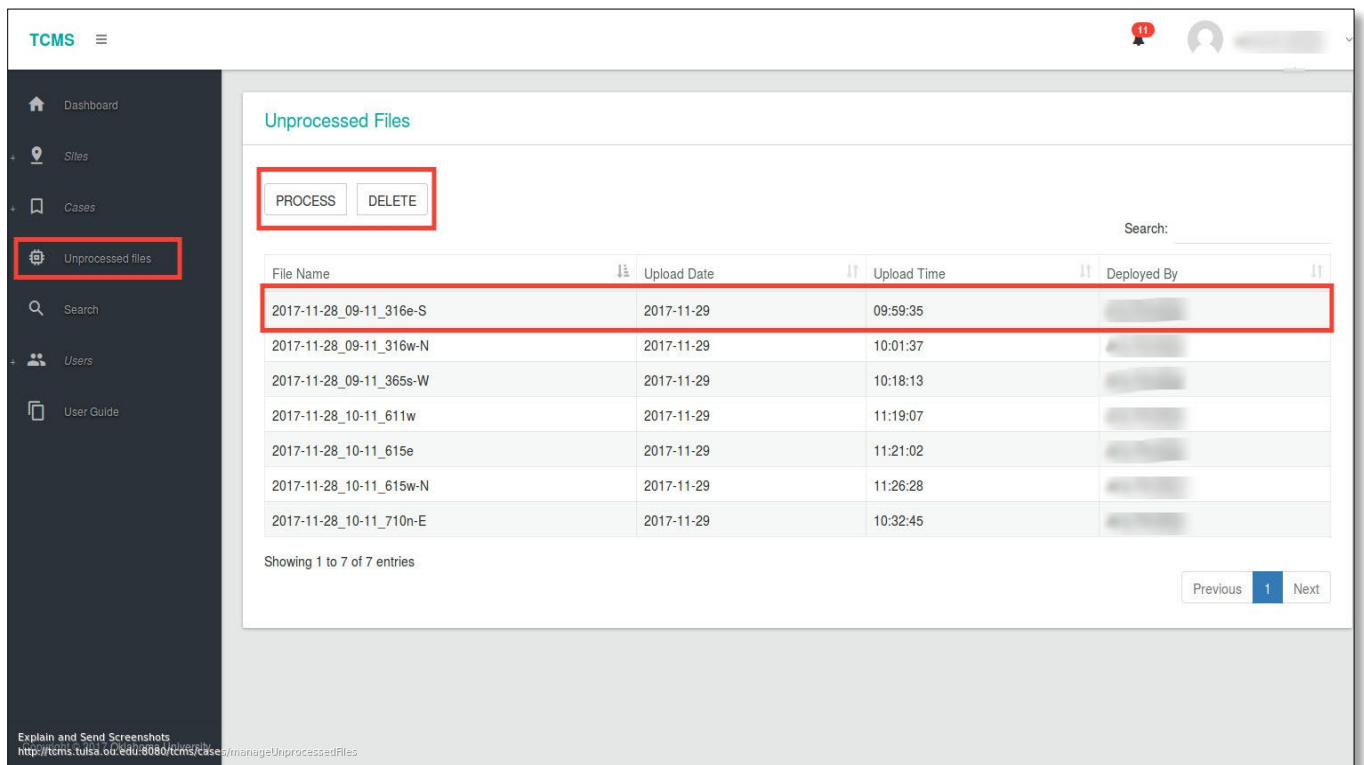


Figure 36. Unprocessed Binary Files.

Given that the uploaded binary file has a missing value (e.g., site does not exist in the database) the binary file must be processed manually. Figure 36 illustrates the unprocessed binary interface.

After selecting the “Process” button, the server will start processing the binary file to validate missing values and prompt another interface to fill out missing data. For example, if the uploaded binary file represents a site that does not exist in the database, the interface will redirect the administrator to add the missing site and autofill the missing site information (e.g., latitude, longitude, site name, ..., and more).

6.2.6.3 Notifications system

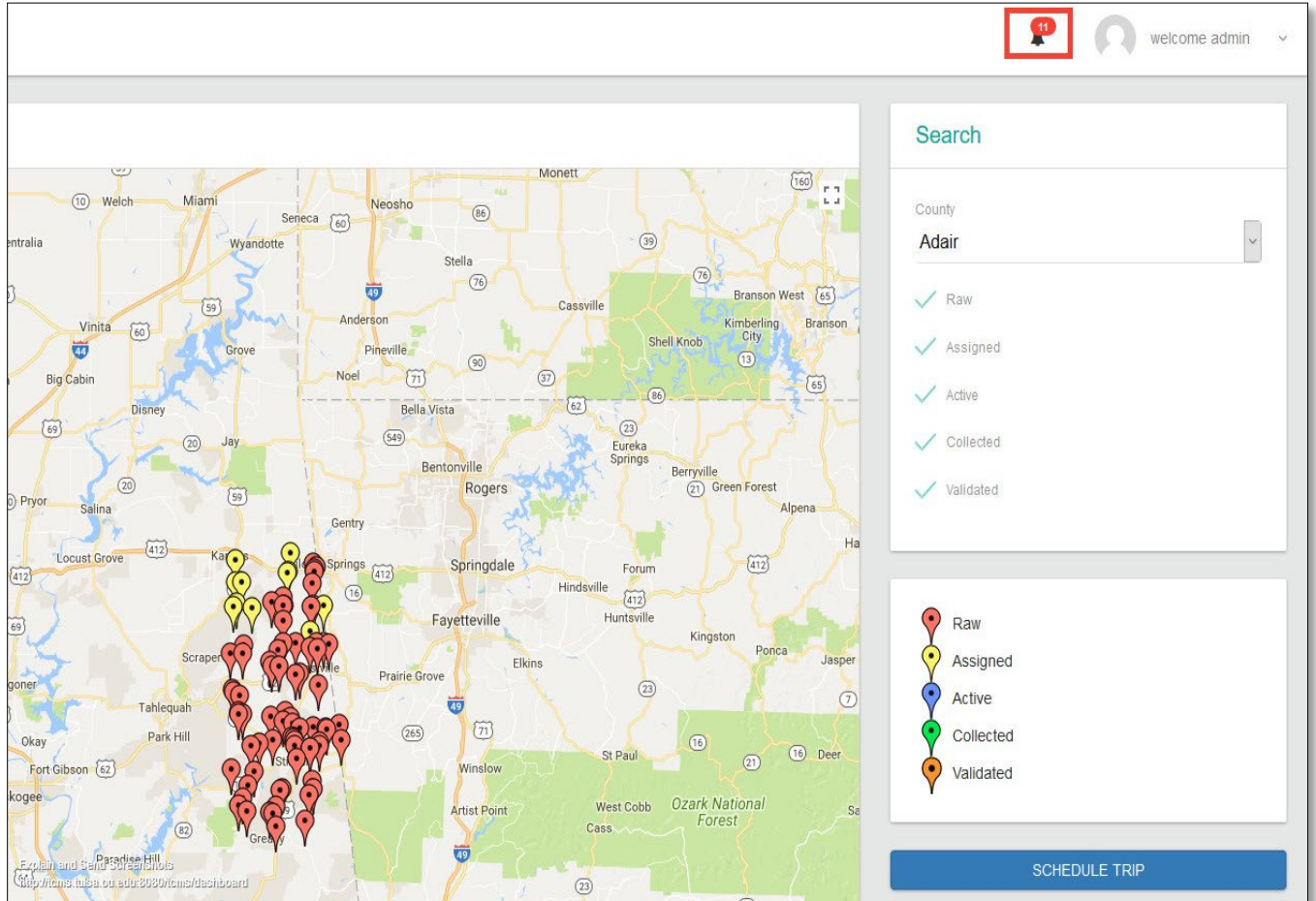


Figure 37. Notification bar.

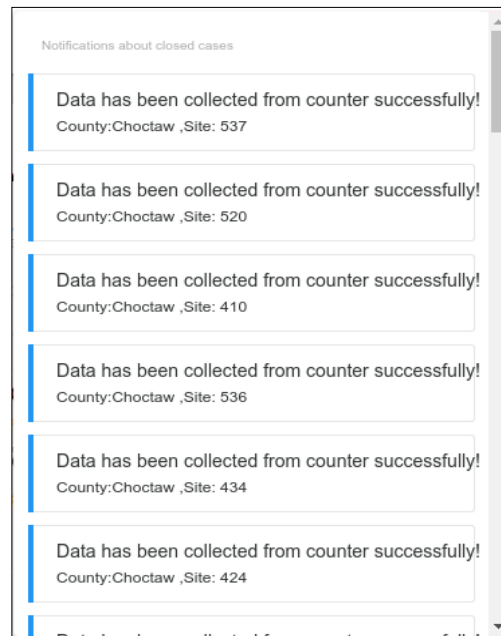


Figure 38. Examples of notifications.

For collectors to notify the ODOT administration board, a notification module was developed for sending different types of notifications and helping manage cases on time/follow up with collectors. Two types of notifications are generated:

- Valid binary file is uploaded, which indicates a case is closed and ready for review
- Given that a binary file and accompanying problem is uploaded, a file can be processed manually from “unprocessed files” page.

Figures 37 and 38 show an example of notifications for closed cases that require reviewed. After selecting one notification, the user will be redirected to the case review page to accept or reject the case (See Figure 28). All notifications can be accessed from the toolbar on the top of the web interface.

6.2.7 TCMS Search Engine

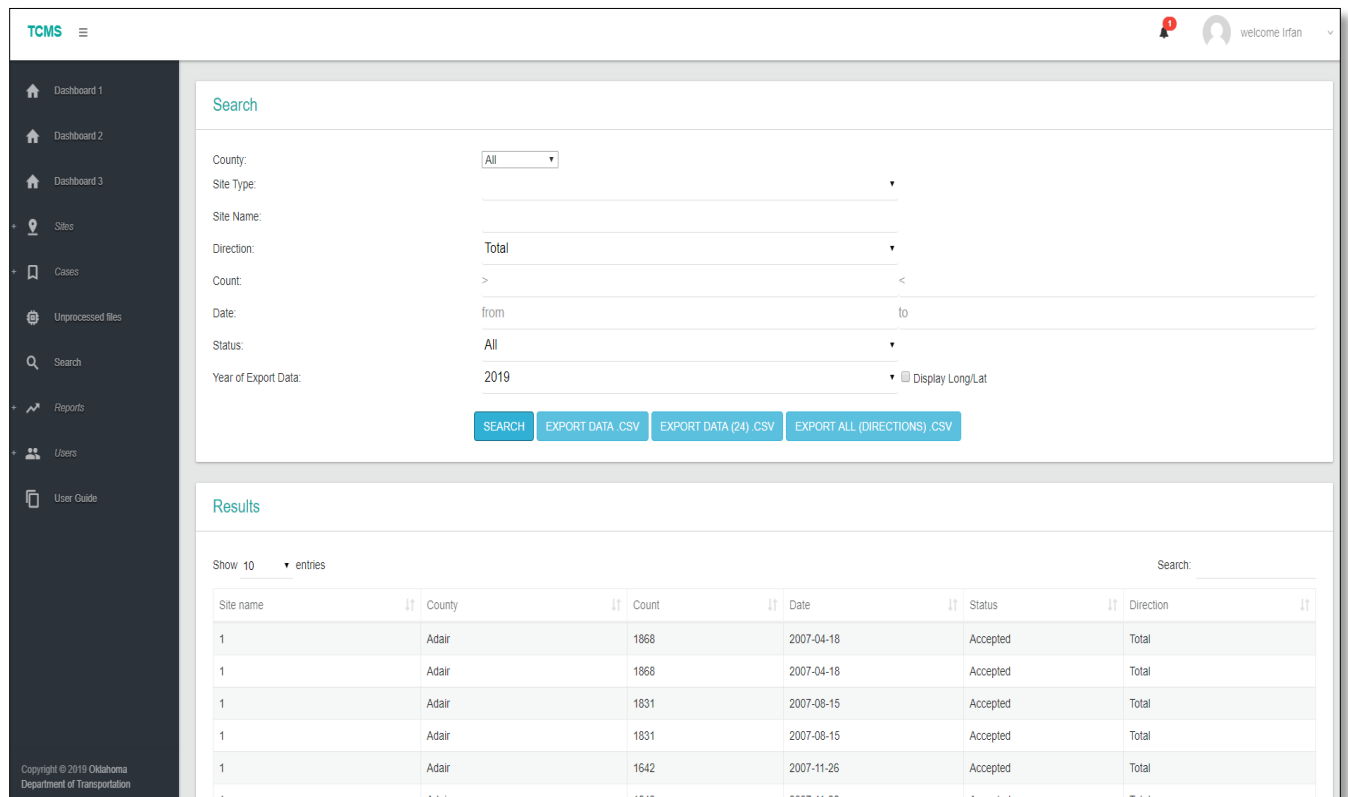


Figure 39. Search interface.

TCMS web interface provides a search engine for searching and filtering cases using different criteria. The Figure 39 illustrates the search interface. A case can be searched using various criteria:

- County
- Site name
- Direction: (Total direction, East, West, South, and North)
- Count: range of count for searching
- Date: range of date for data collection
- Status: (All, pending, accepted, rejected)
- Year of Export Data: Year csv data file is exported to user.

The tool returns all cases that meet selected search criteria as shown in Figure 40.

6.2.7.1 Log Services

TCMS records several types of action in a log file located within the database. The log module records the following events:

1. A task assigned to a collector
2. A site deployed by a collector
3. Site data collected by a collector
4. Collector sent binary file to the server
5. Case rejected
6. Case accepted
7. Collector received tasks
8. Collector uploaded manual counting file

Log records contain the following information:

- User ID: Identification number for collector or user initiating the action
- Site number: Site name for recorded event (e.g., site is deployed)
- Case number
- Event type
- Recorded event date and time

6.2.8 Reports

6.2.8.1 Count Report

The screenshot displays the TCMS Count Report interface. At the top left, the logo 'TCMS' is visible. The top right corner shows a notification bell with a red '1' and a user profile for 'welcome Irfan'. The main content area is titled 'Search Criteria' and is divided into three sections: 'SEARCH SITES', 'MULTI SITES', and 'COUNT DATA CRITERIA'. The 'SEARCH SITES' section includes fields for Site Type, Site Name, Direction, Address, and Site Route. The 'MULTI SITES' section includes fields for County (set to 'None'), From, TO, and Radius (Mile). A checkbox for 'Non-Contiguous Sites' is also present. The 'COUNT DATA CRITERIA' section includes 'From' and 'TO' date pickers (both set to 2019), and checkboxes for 'Monthly Data (Chart)', 'Daily Data (Chart)', 'Count For 24 Hours' (checked), and 'Count All'. A blue 'GENERATE REPORT' button is located at the bottom center of the form.

Figure 40. Count Report Interface.

The dashboard side interface shown in Figure 19 explains that the Reports category provides various measures of collected data statistical and frequency counts. The first available report is the Count Report, as shown in Figure 40. The available search engine is equipped with filters, such as Site Information, data criteria, and multiple sites option.

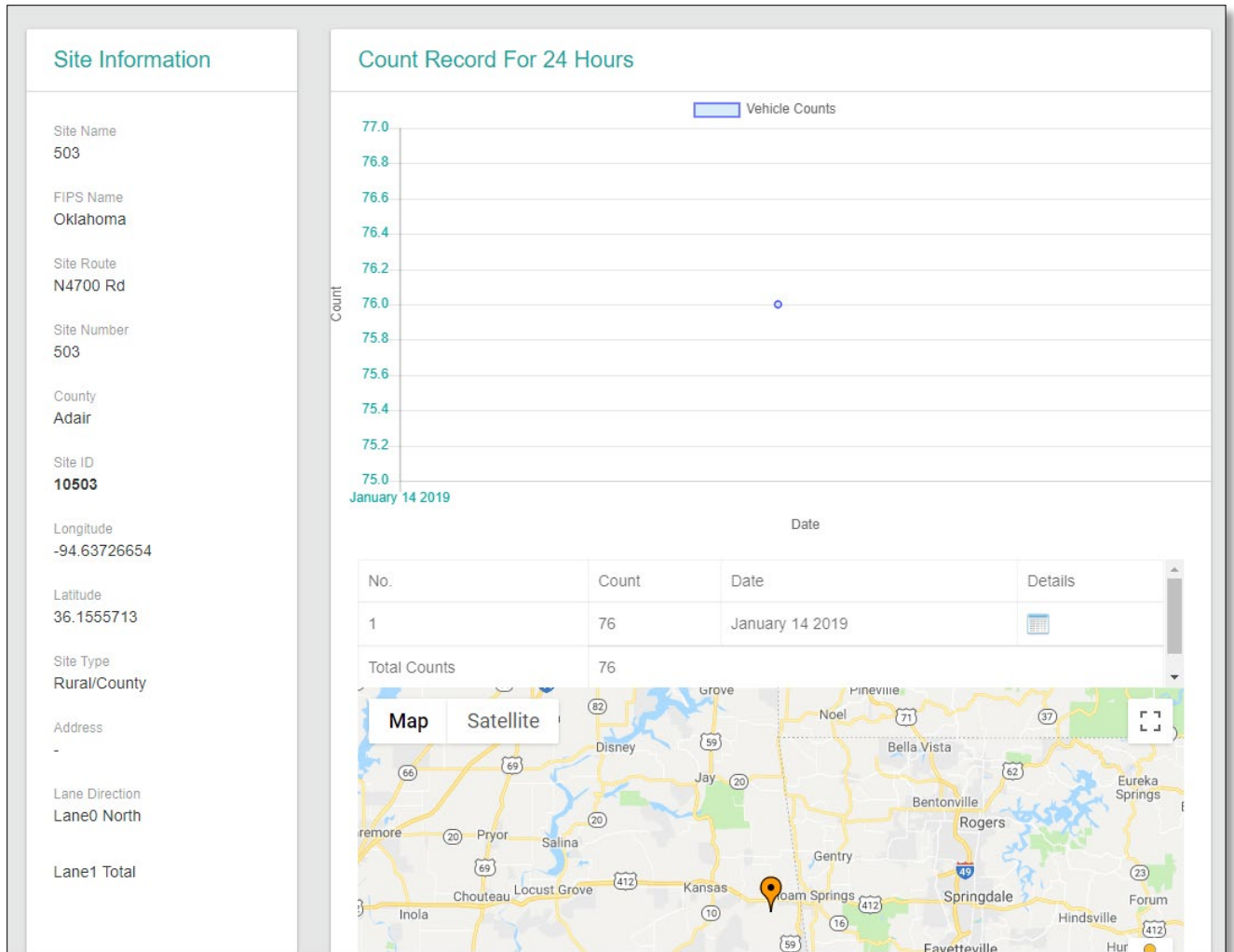


Figure 41. Generated Count Report Details.

Once search criteria have been filled and the Generate Report button is selected (See Figure 40), a table of results matching search criteria is shown. Furthermore, each result confirms an extension of details, which if selected will result in the layout shown in Figure 41. This layout illustrates a count plot with date and google map pin for indicating selected site of accessed report.

6.2.8.2 Progress Report

Search Criteria

Collector Name: _____

- Hazem Refai
- David Busby
- Curtis Atwell

- Jerry Pendley
- Aaron Cooper

From: 2018 ▼

TO: 2019 ▼

Month: February ▼

Average Travel Time Between Sites
 Average Time Per Deployment
 Weekly

Total Mileage Driven

GENERATE REPORT

Figure 42. Progress Report Search Filter.

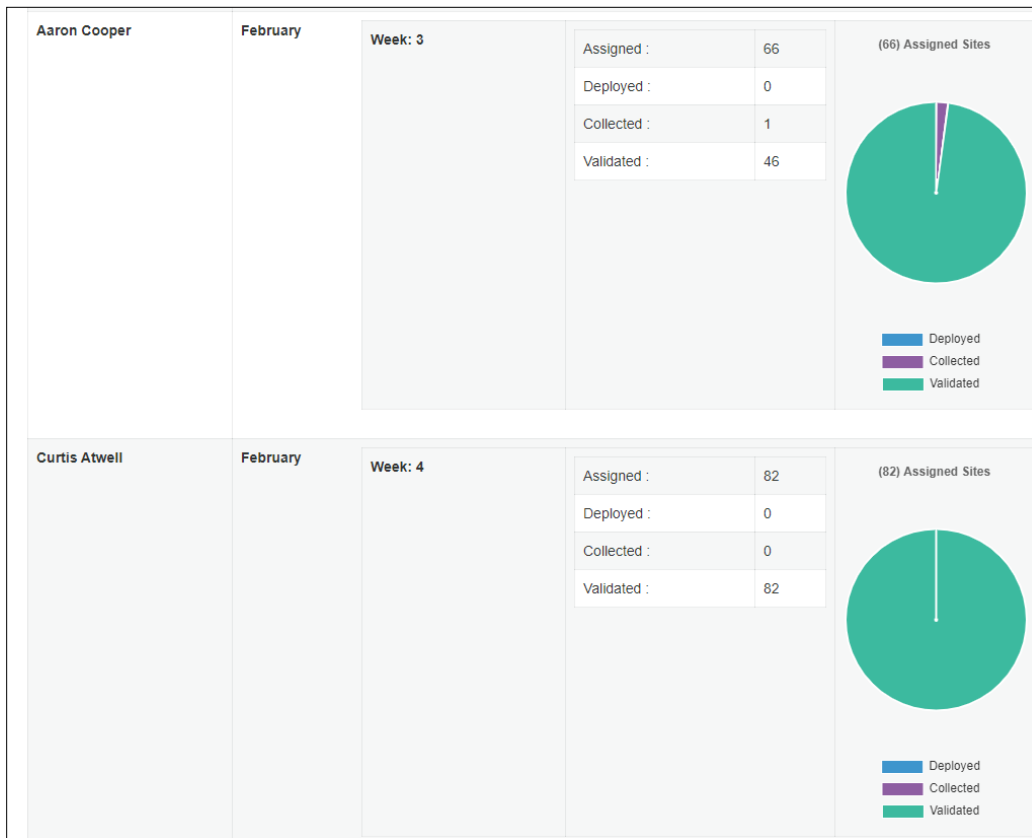


Figure 43. Generated Progress Report.

Subcategory Progress Report is visible in Figure 42 and is positioned under the Reports category located on main dashboard sidebar. The search filter encompasses Collector's name and date duration. After search criteria have been filled and the generate button has been selected, search results will appear (See Figure 43). The report shows deployment results in terms of total deployed, collected, and validated collection.

6.2.8.3 Displacement Report

Search Criteria

County: Adair Site Name: _____

Site ID: _____ Site Type: _____

Bin Size : Bin 1 From Date: _____ TO Date: _____

GENERATE REPORT

Figure 44. Displacement Report.

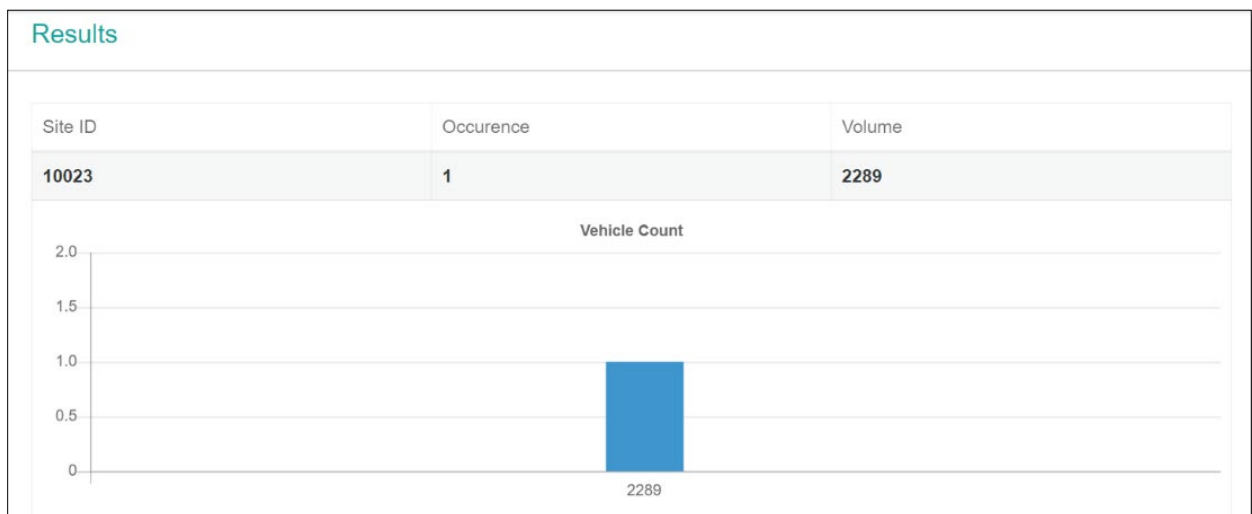


Figure 45. Generated Displacement Report.

The Displacement Report located under the Report category on the interface provides a summary and bar chart related to data collection and traffic volume collected during a specific occurrence. Figure 44 shows the report included with search criteria for filtering and locating the appropriate location, site information, and date, among other information. Once search criteria selected, results shown in Figure 45 will be displayed.

6.3 Email server

TCMS emails notification to collectors when assigning sites for data collection. Given that a case is rejected, an email is sent to the collector indicating data collection for the rejected site. An email server was installed and configured on the TCMS server in the Tulsa campus network for sending emails from TCMS. The installed email server is Mailserver, which is a free and open source e-mail server for supporting common e-mail protocols (e.g., IMAP, SMTP and POP3) and is integrated with TCMS web service for sending emails to collector's email.

7. Conclusion

For many years ODOT has used an exclusively manual process for collecting and entering temporary vehicle data (e.g., vehicle count, site information, device used, collection date and time, ODOT operator, and other vital data) into a computer database. This process is slow and inefficient, costing time and unnecessary workforce hours. Furthermore, mistakes in data entry are possible throughout the arduous task, as human error is inevitable. In this report we proposed a framework that replaces manual data handling with an automated system aimed at reducing such human error. The proposed framework uses an inexpensive portable sensor for necessary vehicle counting and classification. Additionally, an Android app was designed and developed for easy, on-site sensor calibration to aid in fetching collected data from the sensor and sending it to the server in the cloud for processing and presenting data. The novel system is currently functioning with access to the web server is solely reserved for authorized user from ODOT. ODOT agents have tested the system at Tulsa, OK sites. Overall, the framework promises to automate most tasks required for counting and classifying vehicles. Given that the proposed wireless interface is fully developed and integrated into the framework, operation time will be reduced, and the collection process will be simplified. ODOT administrative and managerial tasks can be positively affected by applying additional data mining and machine-learning techniques to various collected data.

8. References

[1]. <http://diamondtraffic.com/product/RoadRunner3>