STANDARD OPERATING PROCEDURES

Drone Video Data Analysis

I. General

Due to the successful application of computer-vision techniques on high-resolution drone video data to extract quantitative operational and safety parameters from roundabouts in previous research projects, it is reasonable to believe that this method has the potential to enter routine service and make important contributions to transportation system management and design by both reducing data collection costs and increasing parameter measurement accuracy. To help state DOTs effectively use high-resolution drone video collection and computer-vision data reduction as a part of normal data collection activities, this standard operating procedure provides guidelines to extract quantitative measurements of traffic conditions (e.g., traffic volumes, vehicle trajectories, etc.) from roundabouts and other innovative intersections through analysis of videos collected by a drone-mounted camera. The video data analysis will be conducted in the DataFromSky TrafficSurvey Viewer™ (DFS Viewer) software, a desktop application that can detect objects, trajectories, and interactions based on raw data from videos. Users are also encouraged to explore other functions provided in DFS Viewer to produce quantitative measurements of traffic conditions based on specific data analysis needs.

II. Standardized Drone Video Dataset

For automatic processing of drone captured video data, the TrafficSurvey Viewer™ developed by DataFromSky® will be used. There are certain requirements regarding the video data collection process and video formats that should be satisfied to ensure the accuracy of extracted traffic parameters.

A. Drone Video Recording Guidelines

For drone video recording, previous field tests found that if the view angle of the drone camera is above 55 degrees (at which point the drone's altitude is larger than the distance between the drone's projection on the ground and the intersection center), then there is a significant drop of vehicle localization accuracy, as shown in Figure 1. Therefore, for the most reliable vehicle localization results, the ideal drone position should be directly above the intersection to minimize the dynamic and static occlusion between individual objects. If the safety regulations or other unexpected conditions make it impossible to hover the drone directly above the intersection, fly the drone to the nearest possible place above the center of the intersection to get a near bird's eye view.

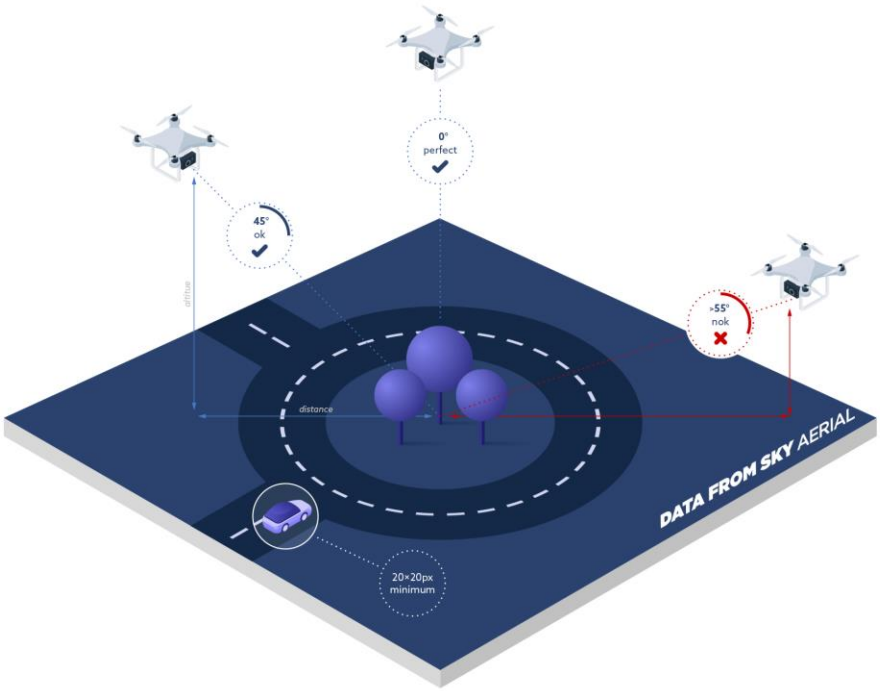

Figure 1. The incidence angle of the drone should be below 55 degrees

Source: DataFromSky®

During recording, it is recommended to keep the drone's position and camera parameter settings unchanged to increase the precision of automatic video analysis. Based on the experiences from previous research projects, the ideal condition to fly the drone for field data collection is in clear skies with winds below 8 MPH. High ambient wind speeds above 15 MPH can cause the drone to dither in its position, which could result in the views of captured videos constantly shifting, making

it impossible for automatic vehicle trajectory extraction without correction for the shift. Figure 2 shows a comparison of vehicle trajectories identified from drone video data captured under high wind and low wind conditions.

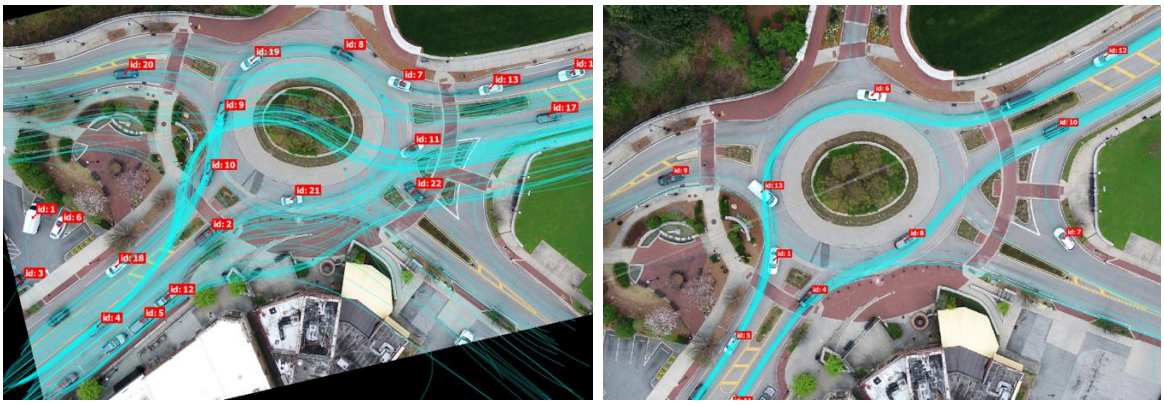

Figure 2. Vehicle Trajectory Data Extracted from Drone Videos Captured under High Wind Condition (left) vs. Low Wind Condition (right)

When recording vehicle operations within an intersection, pilots should make sure that vehicles or other noteworthy objects should be visibly identifiable within the camera frame. Avoiding parasitic optical phenomena (such as glare or lens flare caused by bright light sources) in the video recordings is also important for accurate data processing. For high-quality recordings, it is also better to use a camera with ultra-wide range lens instead of fisheye lens, which can cause high distortion at image margins.

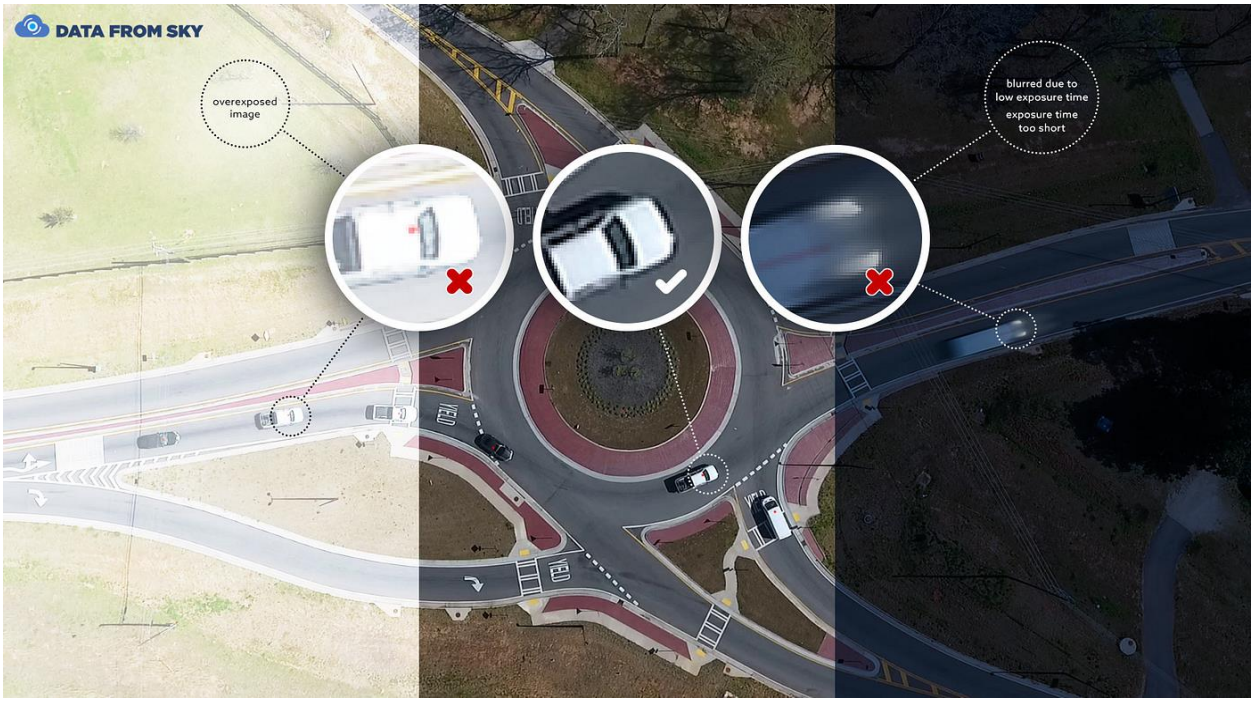

Figure 3. Three situations – not ok: too bright (left), ok: ideal (center), not ok: blurred due to low exposure time (right)

Source: DataFromSky®

B. Video Quality Requirements

For automatic video analysis, resolution is a key determinant of object detection and classification. The minimal size of an object for correct detection and classification is 30 * 30 pixels, and a recommended size is between 30 * 30 pixels and 150 * 150 pixels within the intersection. For objects within a distance of less than or equal to 394 ft (120 m) at oblique angles, FULL HD (1920 * 1200) resolution will be sufficient. While for objects that are at a distance between 394 ft and 984 ft (300 m) at oblique angles, 4K video resolution is required.

In addition to resolution, bitrate settings can also influence video quality. For FULL HD videos coded with the H264 coding format, the bitrate should be at least 10 Mbit/s. And for 4K videos coded with H264, a minimum of 20 Mbit/s is necessary.

For best results, it is recommended to upload videos in their original format with a framerate around 25 FPS. It should be noted that videos with resolution below 512 * 512 are not supported by the software system.

In terms of video formats, the software can process most of the existing video encoding formats including MP4, AVI, MPEG, WMV, etc. The system also supports most existing video codes like H.262, H.263, H.264, other MPEG-4 video codecs, etc.

III. DataFromSky™ TrafficSurvey Viewer Functions

DataFromSky™ TrafficSurvey Viewer is a license-free software that provides computer vision services for fully automated vehicle identification and trajectory extraction based on traffic videos. Some of the basic functions provided in the software are:

- Visualize detected objects and their trajectories within the processed video
- Classification of objects up to 16 categories
- Origin-Destination matrix (OD matrix)
- Turning movement counts (TMCs)
- Calculation of headways
- Gap time, time to follow data
- Safety analysis (time to collision, post encroachment time, heavy breaking)
- Current speed, acceleration, deceleration of any object
- Color recognition
- License plates detection (optional)
- Position of the object within each millisecond of the video
- Interactions of objects within the video - distance measurement

- Travel and occupancy times
- Configurable gates for vehicle counting
- Configurable virtual lanes, traffic regions, or action regions
- Capacity evaluation

To download the DataFromSky Viewer™ software, users can use this link and start the installation process following the provided guidelines.

IV. Data Analysis Procedures

The data analysis procedures of captured drone video data include uploading videos to DFS Viewer for object identification and trajectory extraction, then geocoding and configuring the processed video files based on specific data analysis needs, and exporting the corresponding data for further advanced analysis to measure traffic operational and safety parameters within the selected intersections.

A. Process Drone Videos through DFS Viewer™

To gain access to the video data analysis, users will have to create an account first by signing up on the website ai.datafromsky.com. Then users can use this account to upload the captured drone videos to the DataFromSky AERIAL™ platform to conduct video analysis. The analysis of objects detection and trajectory extraction will be performed in the background, users can check the processing status in their personal accounts under the Tasks section.

Once the analysis is complete, an email will be sent to users with instructions and a link to download the processed results. The results are presented in the form of a tracking log, which is a data package containing information about traffic analysis scenes and detected or annotated vehicle trajectory data. It should be noted that since each tracking log is tied to the original video data, to view or edit a tracking log, users will need to open it in the software with the original video files opened as well.

B. Geo-Registration

To extract accurate speed or distance data, geo-registration is required for each tracking log as everything in the original processed files is measured in units relative to the footage resolution. This step can be performed in the DFS Viewer based on known latitude and longitude information of at least four reference points selected within the video frame. Some examples of reference points include corners of splitter islands or yield signs within roundabouts. The steps to conduct geo-registration of a tracking log are illustrated as follows:

1. Open the tracking log through DFS Viewer, select Tracking Log -> Manual Geo-Registration, as shown in Figure 4. Then follow the instructions provided in the Manual Geo-registration Wizard window (Figure 5) to select the region of interest.

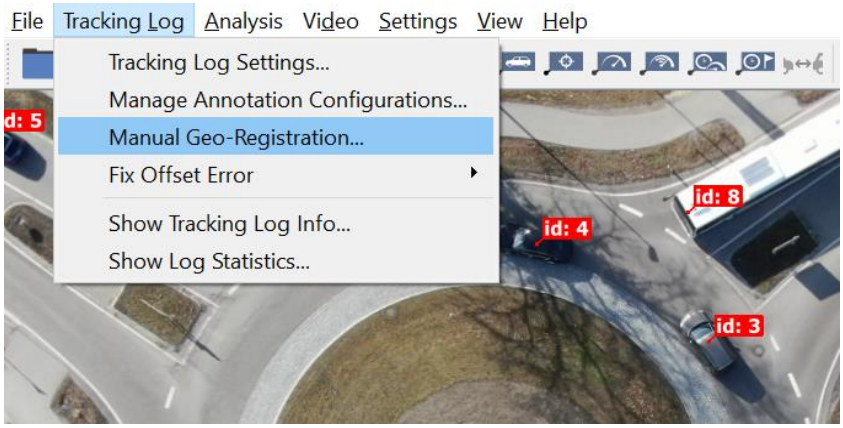

Figure 4. Conduct Geo-registration in DFS Viewer

Source: DataFromSky®

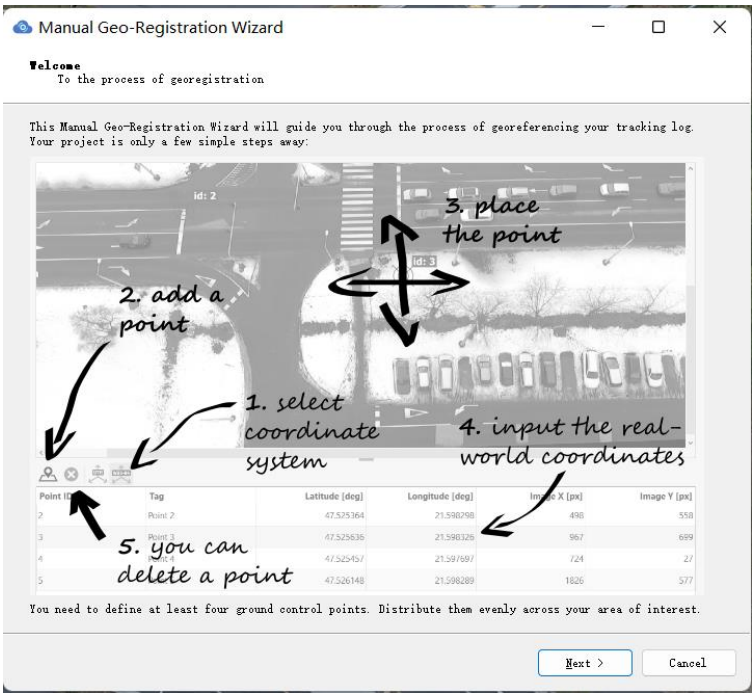

Figure 5. Manual Geo-Registration Wizard in DFS Viewer®

2. Draw blue polygons on the region of interest within which objects will be identified and analysis will be conducted. Figure 6 presents a typical example of identified region of interest within a roundabout.

Figure 6. Regions of Interest Marked by Blue Polygons

3. Set at least 4 reference points near places where objects are expected to be detected, then obtain the real-world coordinates of selected reference points either from Google Maps® or in-situ measurement, and input the coordinates information either in UTM or WGS-84 system. Reference points should be visually distinct and stationary, some common examples include roadway signs, edges of pavement markings, etc. within the intersection.

Figure 7. Reference Points Selected within a Roundabout

4. Confirm the geo-registration process with the Finish button and save the tracking log for subsequent analysis.

If the recorded videos are relatively unstable, users can also consider requesting the commercial service provided by DFS to conduct geo-registration at each frame with special stabilization of the video to minimize the impacts of camera movement.

C. Video Files Configuration

DFS Viewer allows users to set up their own annotation configurations of tracking log files to measure and extract traffic parameters through virtual gates and regions based on vehicle trajectory data. Inside a tracking log file, users can select Tracking Log –> Manage Annotation Configurations to open the configurations window, as shown in Figure 8.

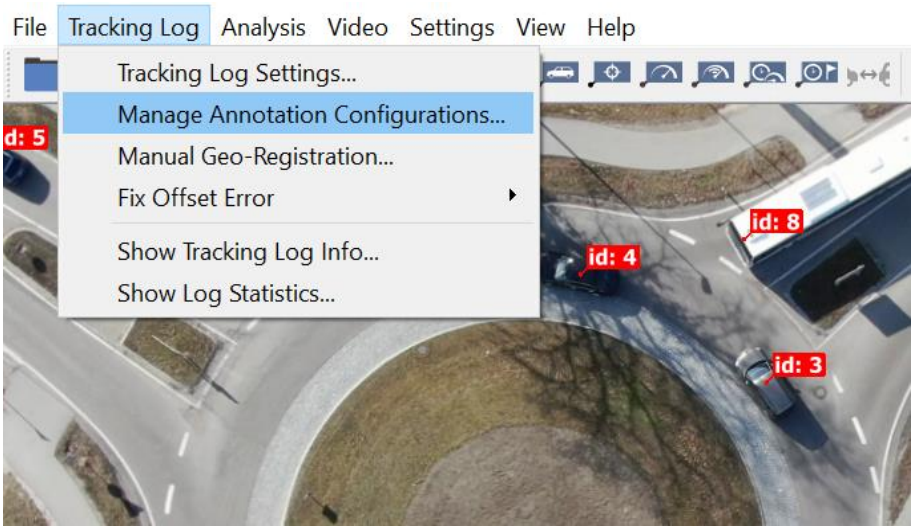

Figure 8. Manage Annotation Configurations of the Tracking Log

Source: DataFromSky®

To create a new annotation configuration for specific data analysis needs, users can clone the existing configuration, select the newly cloned one as active, and click the Edit button to modify the configuration, as shown in Figure 9. During the configuration process, users can set gates, lanes, action regions, traffic regions, and anonymization regions based on analysis requirements. Once the configuration is finished, simply confirm the annotation redefinition, and apply it to the video scene.

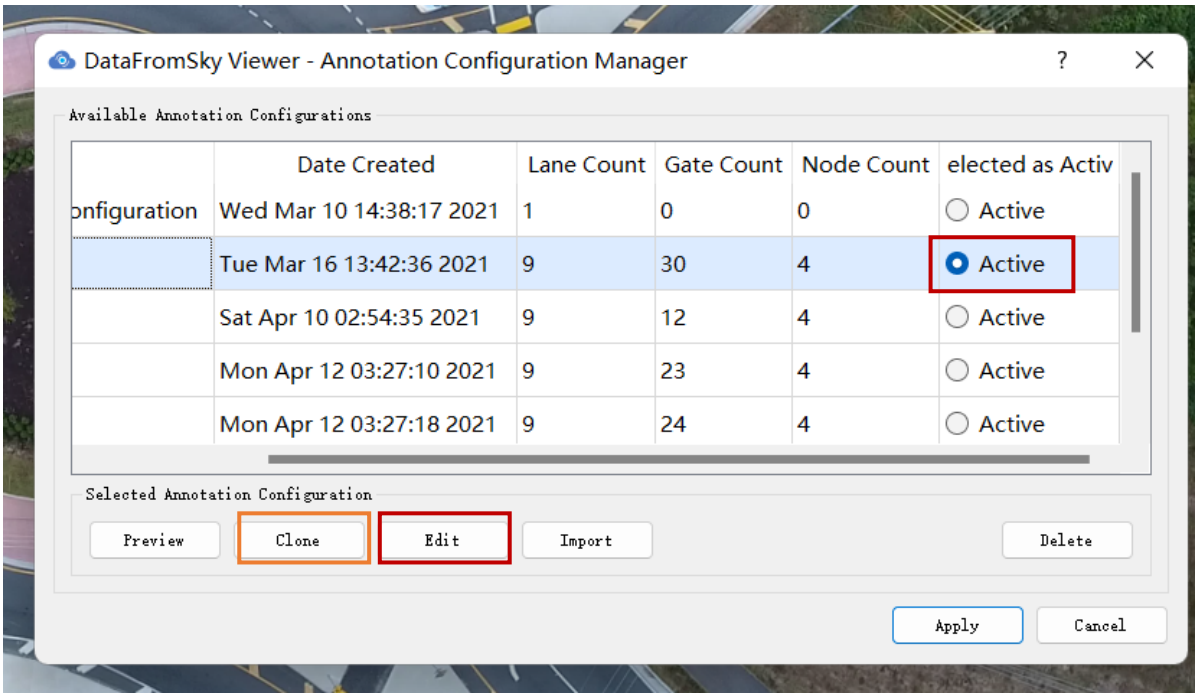

Figure 9. Edit or Activate the Annotation Configurations of the Tracking Log

- **Traffic Gates**

Traffic gates are virtual lines that can be used to count different types of objects that pass the gates in one or both directions. They are in the form of a line consisting of straight segments connecting points, thus, they require at least 2 specified points to create. Once a gate is created, users will need to set the characteristics of the gate, and the steps involved in the gate setup process are:

1. **Choose the gate type.** There are three types of gates available, namely entry gates, exit gates, and neutral gates. Entry gates (green) are usually placed in the entrance of each intersection approach together with exit gates (red) placed in the exit of each approach to provide Origin-Destination information. Neutral gates (blue) can be set at any place of interest within the identified region to record vehicle gate crossing events.

2. **Specify the gate direction.** The gate direction can be set to only record vehicles passing in the specified direction, and will be displayed as a small arrow on the gate. The direction can either be set to positive, negative, or bidirectional depending on users' data analysis needs.

3. **Adjust the angular sensitivity.** The sensitivity of the gates can also be adjusted based on the angle of passing objects.

4. **Select the allowed objects.** The types of objects that can be tracked by the gates include car, medium vehicle, heavy vehicle, etc. Users can select what types of objects to be recorded in the gate annotation window.

5. **Set the gate tag.** The gate tag is used to identify the gate, and will be displayed in the configured tracking log file.

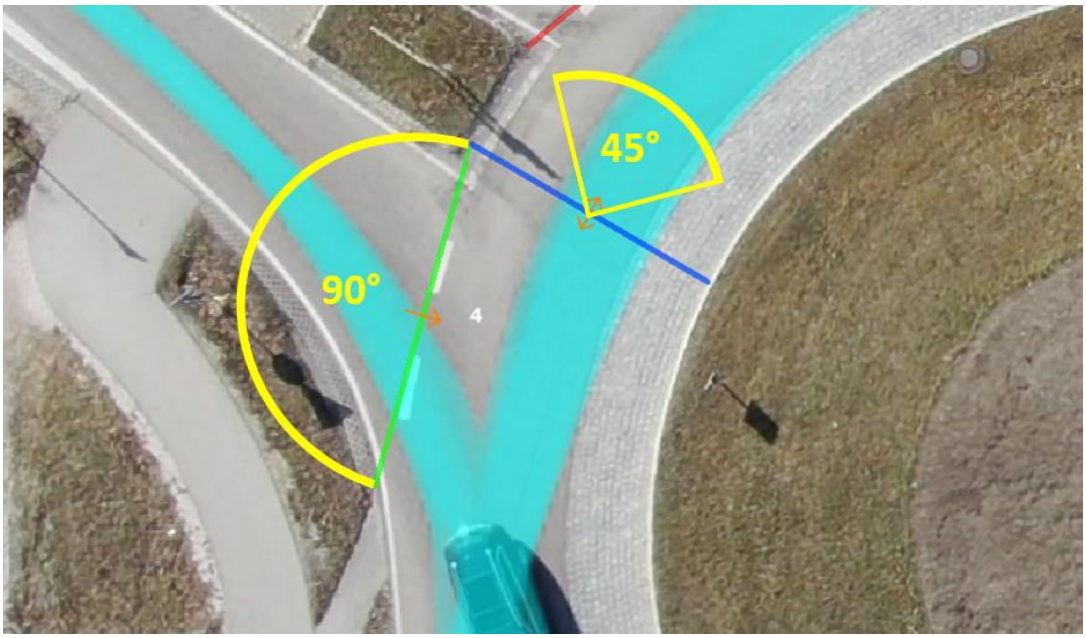

Figure 10. Set up Traffic Gates in One Intersection Approach

Source: DataFromSky®

Once all the gates are set up at desired locations within the video frame, confirm the gate settings with the Finish Editing button and apply the new configuration to the video analysis scene. The created gates can always be modified later by moving or removing the points in the configuration edit window and reapply it to the scene. The display formats of the traffic gates can be changed by clicking 'View' -> 'Show Traffic Gates' or 'Switch Gate Label', as shown in Figure 11.

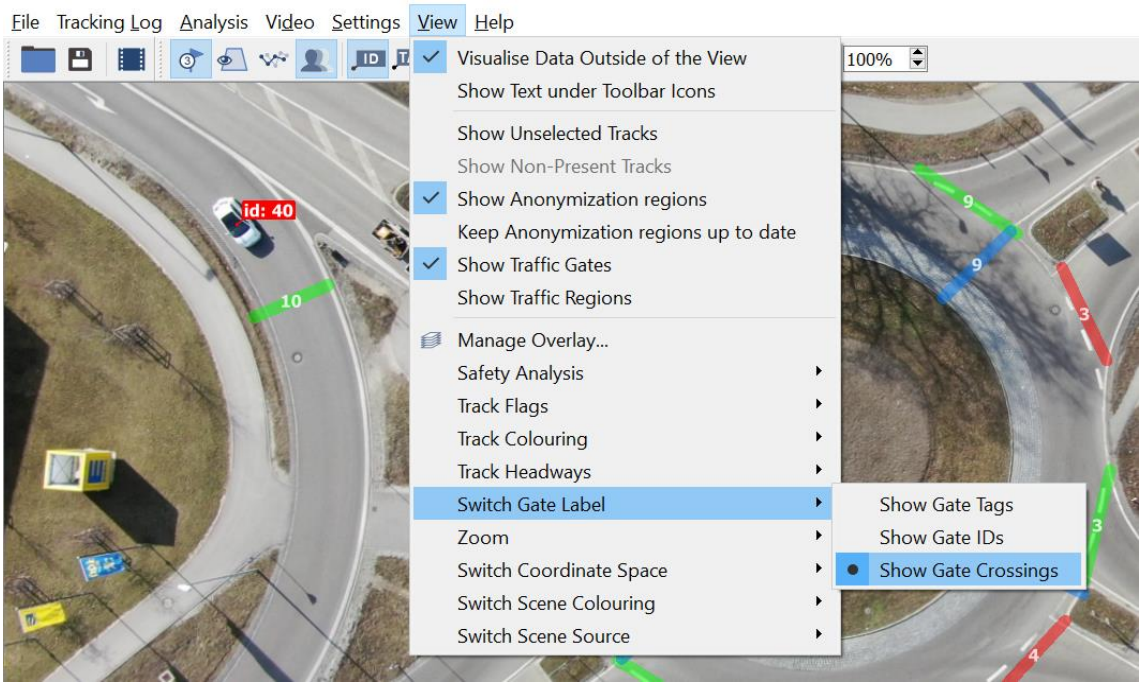

Figure 11. Modify Display Format of Traffic Gates

Source: DataFromSky®

- **Action Regions**

Action regions can be used to detect the presence and traveling speeds of objects within a certain area of the scene view. To define an action region, simply follow the steps below:

1. **Create an action region.** Click on the Add Action Region button or right-click in the scene view and select Add Action Region, then draw a polygon to define the action region. The action region will be displayed in an orange polygon after three points have been added.

2. **Edit an action region.** To move the already placed points of the defined action region, simply drag the points to desired locations. The points can also be removed by right-clicking and selecting Remove Control Point. Once the editing of an action region is done, press the Finish Editing button in Main Toolbar.

3. **Set presence alert.** Check the enabled button next to Presence Alert to display and record a presence alert whenever an object enters the defined action regions. Users can also select object types for which the presence alert will be displayed and recorded.

4. **Set speeding alert.** Check the enabled button next to the Speeding Alert to display and record a speeding alert whenever a vehicle exceeds a set speed within the defined action regions. Users can select maximum speed for individual objects as well.

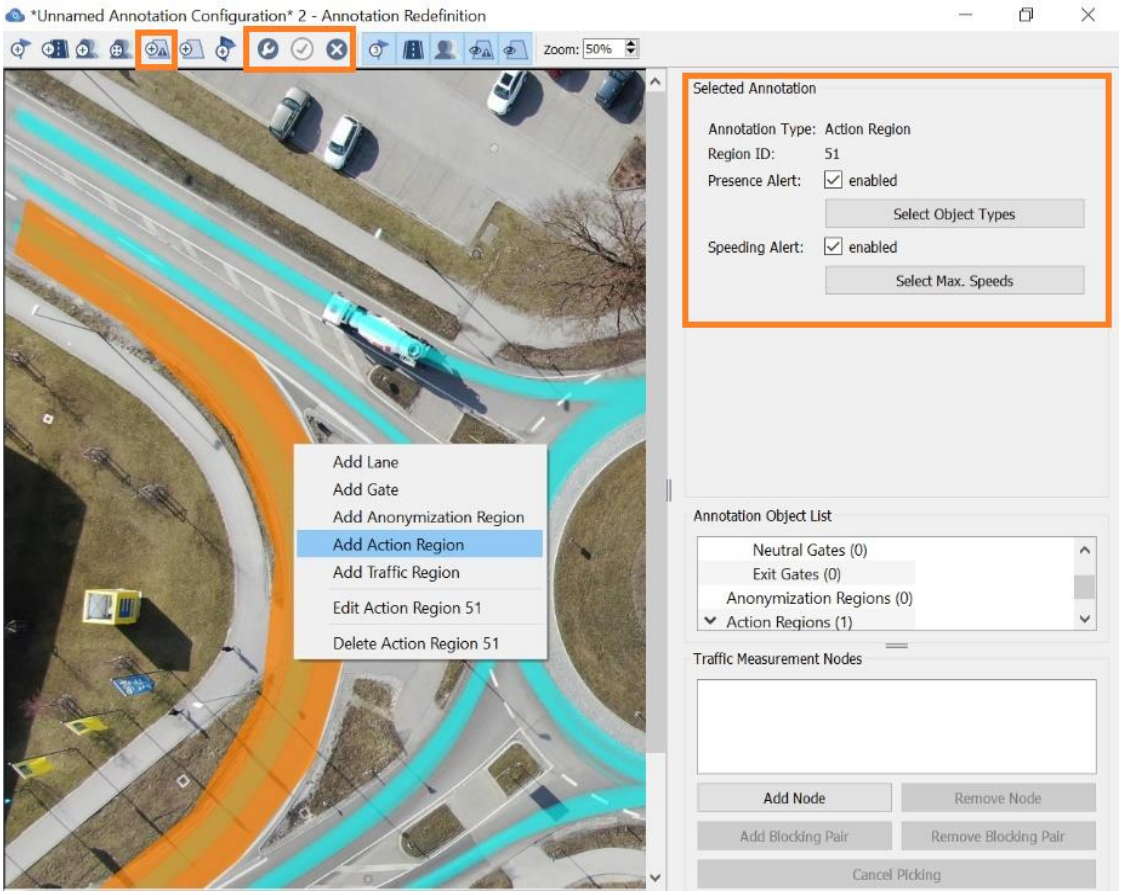

Figure 12. Set up an Action Region (Orange Area) in One Intersection Approach

Source: DataFromSky®

- **Traffic Regions**

Traffic regions can be used to extract operating information like average speed, acceleration, etc. of each object or detect stationary vehicles within a certain area of the scene view.

1. **Create a traffic region.** Click on the Add Traffic Region button from the main menu or right-click in the scene view and select Add Traffic Region, then draw a polygon to define the traffic region, which will be displayed in green.

2. **Set allowed types.** Click the Select Object Types button next to the Allowed Types to choose which types of objects the traffic region will detect.

3. **Set the maximum stationary vehicle speed.** Input the number to set the maximum stationary vehicle speed below which the vehicle is considered as stationary.

4. **Set the minimum stationary vehicle spell.** Input the number to set the minimum stationary vehicle spell for how long at least the vehicle must be below the maximum stationary vehicle speed to be considered as stationary.

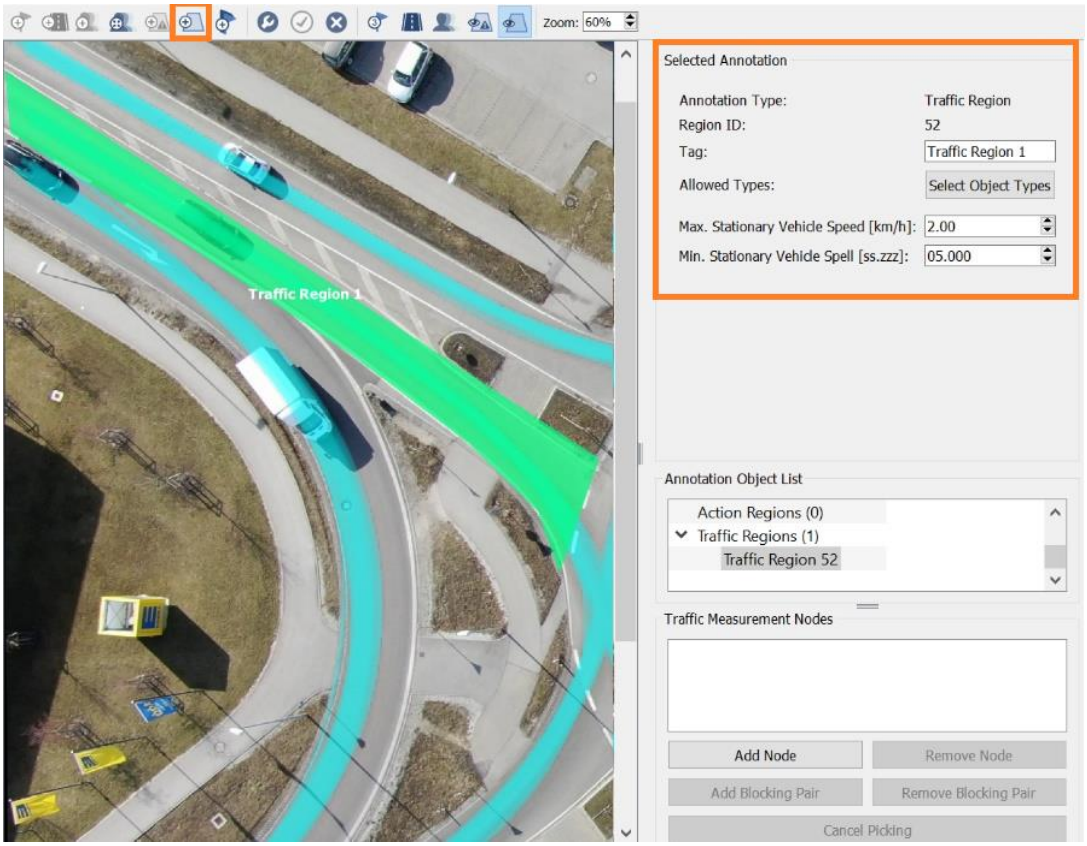

Figure 13. Set up a Traffic Region (Green Area) in One Intersection Approach

Source: DataFromSky®

D. Data Export

After setting up the annotation configuration for the tracking log file, users can conduct operational and safety analysis based on the identified object trajectory data and export the corresponding results in DFS Viewer. The procedures to export raw trajectory data and gate/region crossing events data are discussed below.

1. Trajectory Data

The raw trajectory data of each detected object can be exported into a .CSV file and information such as position, speed, acceleration, etc. can be calculated to every millisecond of the video based on the extracted trajectories. To get the raw trajectory data, go to the toolbar and click Analysis -> Export Trajectories to CSV File or click the icon on the main toolbar.

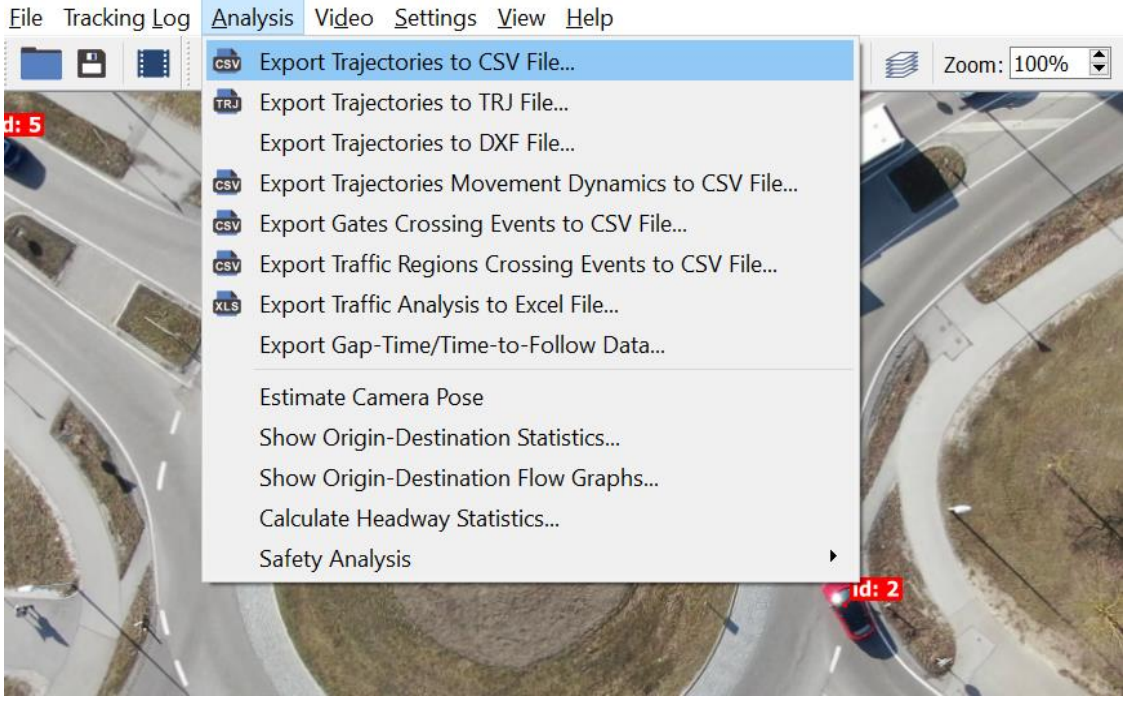

Figure 14. Export Raw Trajectory Data in DFS Viewer

Source: DataFromSky®

The first eight columns of the extracted file contain information about the object track ID and object type, the entry gate ID and entry time, the exit gate ID and exit time, as well as the total

travel distance (m) and average speed (km/h). Then a set of columns with data related to object position - x [deg], y [deg], Speed [km/h], Tangential acceleration [ms^{-2}], Lateral acceleration [ms^{-2}], Traveling time [s], Angle [rad], and Traffic regions (list) are repeated for each frame of the video.

2. Gate Crossing Event Data

The gate crossing events data can be used to conduct analysis including O-D matrix, gap time, time to follow, or average speed of the objects between two gates and others. To export information about one specific gate, choose the gate in section Traffic Analysis Objects and click Show in section Detailed Info, then click Export button to export the crossing event information to .CSV format for subsequent analysis, as shown in Figure 15.

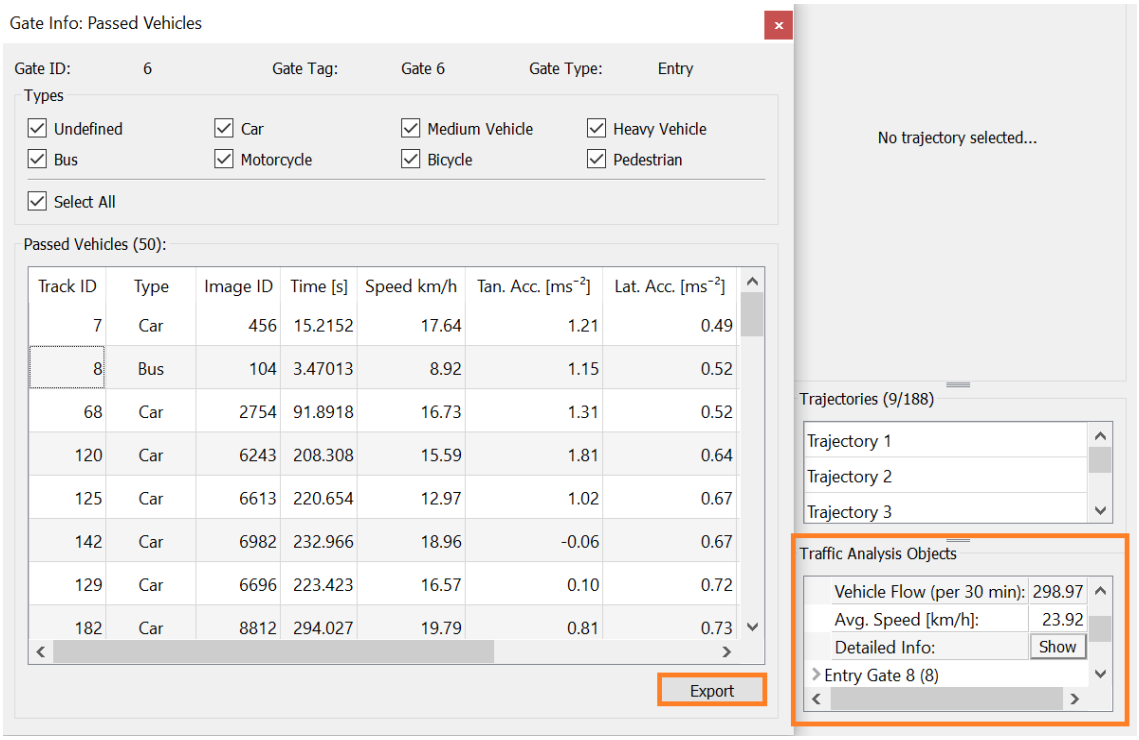

Figure 15. Export Crossing Events Information for One Specific Gate

Source: DataFromSky®

To get the crossing events for all gates, simply go to the toolbar, click Analysis -> Export Gate Crossing Events to CSV File, as indicated in Figure 16, and the extracted file will be downloaded

to a selected local folder. The information contained in the extracted data includes Gate ID, Track ID and Type, Image ID and Time [s], Speed, Tan. Acc. [ms^{-2}], Lat. Acc [ms^{-2}], Headway [s] and Headway [m]. Additionally, more advanced analysis can be conducted based on traffic gates, such as OD matrix, turning movement counts, safety analysis, and gap-acceptance behavior analysis, etc.

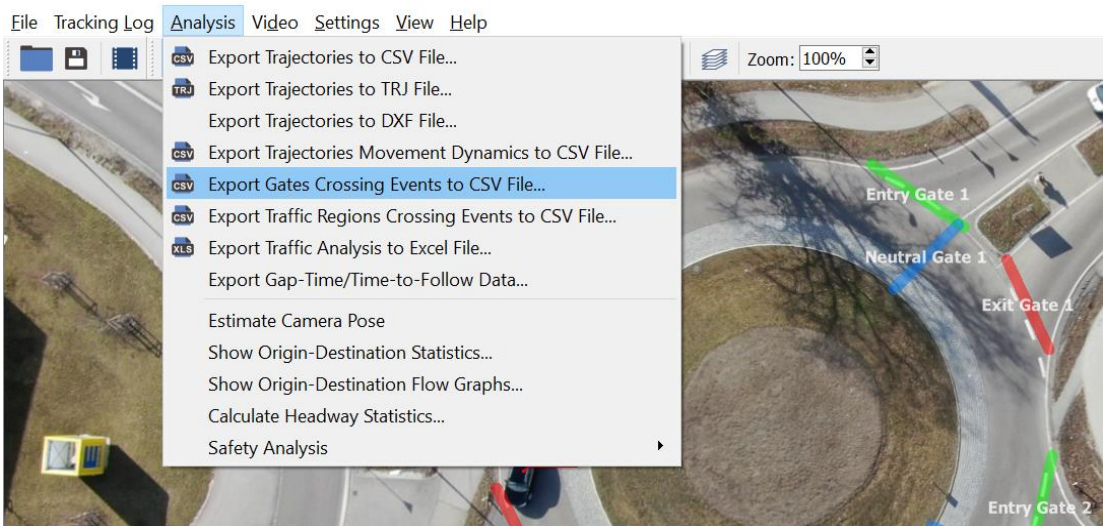

Figure 16. Export Crossing Events Information for All Gate

Source: DataFromSky®

3. Traffic Region Crossing Event Data

To export data from the defined traffic regions, go to the toolbar and click Analysis -> Export Traffic Regions Crossing Events to .CSV File. For each object identified within the traffic region, the extracted data include Traffic region ID, Track ID and object type, Entry time [s] and Exit time [s] of the object, Average speed [km/h], Average tangential acceleration [ms^{-2}], Average lateral acceleration [ms^{-2}], and Average total Acceleration [ms^{-2}] within the defined traffic region, as well as the Total stationary time [s], and Longest stationary time [s] measured within the traffic region.

Procedure Checklist of Drone Video Data Analysis

Procedure Checklist of Drone Video Data Analysis		
General Information	Project Number:	Comments
	Date:	
	Time:	
	Recorder:	
Standardized Drone Video Dataset Collection		**Check**
Drone Video Recording Guidelines	Ensure the drone position to be the nearest possible place above the center of the intersection to minimize the dynamic and static occlusion between individual object	
	Keep the drone's position and camera parameter settings unchanged to increase the precision of automatic video analysis	
	Avoid flying drones under the condition of high ambient winds with speed being above 15 MPH	
	Ensure vehicles or other noteworthy objects are visibly identifiable within the camera frame during the data collection process	
	Avoid parasitic optical phenomena (such as glare or lens flare caused by bright light sources) in the video recordings	
	Use a camera with ultra-wide range lens to avoid high distortion at image margins	
Video Quality Requirements	The recommended size of the captured object is between 30 * 30 pixels and 150 * 150 pixels within the intersection	
	4K video resolution is required for objects that are at a distance between 394 ft and 984 ft (300 m) at oblique angles	
	The bitrate should be at least 10 Mbit/s for FULL HD videos coded with the H264 coding format while for 4K videos coded with H264, a minimum of 20 Mbit/s is necessary	
	Videos are recommended to be uploaded in their original format with a framerate around 25 FPS	
Drone Video Data Analysis		**Check**
Process drone videos through DFS Viewer™	Create a user account by signing up on the website ai.datafromsky.com	

	Use the created account to upload the captured drone videos to the DataFromSky AERIAL™ platform to conduct video analysis	
	Download the corresponding tracking log files once the video processing is complete	
Geo-Registration	Open the tracking log through DFS Viewer, select Tracking Log -> Manual Geo-Registration	
	Draw blue polygons on the region of interest within which objects will be identified and analysis will be conducted	
	Set at least 4 reference points near places where objects are expected to be detected, then input the real-world coordinates of selected reference points either in UTM or WGS-84 system	
	Confirm the geo-registration process with the Finish button and save the tracking log for subsequent analysis	
Video Files Configuration	Select Tracking Log –> Manage Annotation Configurations to open the configurations window	
	Create traffic gates in the configuration to count different types of objects that pass the gates in one or both directions if needed	
	Create action regions to detect the presence and traveling speeds of objects within a certain area of the scene view if needed	
	Create traffic regions to extract operating information of each object or detect stationary vehicles within a certain area of the scene view if needed	
Analysis Results Export	Go to the toolbar and click Analysis -> Export Trajectories to CSV File or click the icon on the main toolbar to get the raw trajectory data if needed	
	Go to the toolbar and click Analysis -> Export Gate Crossing Events to CSV File to obtain the crossing events for all gates if needed	
	Go to the toolbar and click Analysis -> Export Traffic Regions Crossing Events to .CSV File to export vehicle speed and stationary time data from the defined traffic regions	
Operator Signature		