STANDARD OPERATING PROCEDURES

Field Data Collection

I. General

This standard operating procedure provides instructions and lists of equipment required by the field data collection of operational, geometric, and illumination characteristics from innovative intersections through field survey. In addition to regular field survey, drones that are commercially available will also be used to capture high-resolution drone videos to measure and calibrate important operational and safety related parameters for selected intersections. This procedure could be used directly, or modified as needed, by transportation agencies and other practitioners to meet their specific data collection needs.

II. Field Survey Procedures

For the safety analysis discussed in this document, the safety influence area for each intersection is set to be 400 ft (122 m) upstream from the entry/exit point of each approach, and data should be collected within this area. The stop lines can be used to delineate exit and entry points, as shown in Figure 1. For situations where the safety influence areas of two adjacent survey intersections overlap, the edge of the influence area on the approach between the two intersections should be set at the half-way point. Intersection geometric characteristics data such as number of lanes, lane width, and angles between two adjacent approaches etc. should be collected by field survey, and instructions regarding the collection of each data type are provided below.



Figure 1. Location of Entry and Exit points at Roundabouts and Conventional Intersections

A. Required Equipment

- Compass
- GPS device
- Traffic safety vest for every crew member
- Survey-crew-ahead safety signs
- Two traffic cones
- Metered wheel
- 25 feet tape measure
- Laser distance meter (Bosch GLM 50)
- Laser target card
- Laser enhancement glasses

B. Field Data Collection

1. Intersection Location

It is necessary to record the latitude and longitude information of selected reference points within each intersection surveyed so that they can be geocoded in the analysis process. At least three reference points are required to locate one intersection and these points should be within the intersection's safety influence area. The latitude and longitude values can be obtained from Google Maps[®] and they should be recorded as decimal degrees.

2. Lane Width Measurement

In order to avoid entering into active travel lanes, a Bosh GLM 50 laser distance meter and a laser target card are used for lane width measurement. For data collection during daytime, a pair of laser enhancement glasses is also used to enhance the visibility of the red beam laser in sunlight. The lane width of each intersection approach should be measured within the safety influence area defined earlier.

• Undivided Roadway Lane Width Measurement

Use the laser meter and the laser target card to measure the entire road width from one edge of the pavement to the other.

Step 1: One crew member holds the laser meter on one side of the road while another crew member holds the laser target card on the other side.

Step 2: The crew member with the laser meter beams the laser across the travel lanes towards the target card. Since the laser might cause damage to human eyes, it is important that the crew member who is holding the target card does not look at the laser meter.

Step 3: Read and record the width of the road displayed on the meter screen. Then divide the measured distance by the number of lanes on that approach to obtain the width of each lane.

• Divided Roadway Lane Width Measurement

For roadways with wide median, use the laser meter and the laser target card to only measure the width of incoming approach lanes.

Step 1: One crew member holds the laser meter on the edge of pavement next to the shoulder while another crew member stands at a safe location inside the roadway median and holds the laser target card on the other edge of the pavement next to the median.

Step 2: The crew member with the laser meter beams the laser across the travel lanes towards the target card.

Step 3: Read and record the width of the road displayed on the meter screen. Then divide the measured distance by the number of incoming travel lanes on that approach to obtain the width of each lane.

3. Intersection Geometric Layout

Step 1: Choose the basic intersection layout from Figure 2 based on the intersection type. The basic layouts provided are for 4-leg intersections, users can cross out or add legs depending on the actual number of legs the selected intersections have.



Figure 2. Basic Layout of Conventional Intersection (Left) and Roundabout (Right)

Step 2: Indicate the true North direction with a North Arrow on the intersection layout.

Step 3: Assign directions to each intersection leg based on the direction of vehicles entering the intersection on that approach, and label the approach directions on the layout. For example, the Northbound (NB) approach is the one on which vehicles traveling towards the intersection are heading Northbound.

Step 4: Number the intersection legs clockwise starting from SB and record the name of each leg based on the corresponding street names.

Step 5: Observe and record the approach geometric characteristics based on the intersection type. For roundabout approaches, record the number of travel lanes, lane width, roadway functional class, the angle to the upstream approach, the presence of splitter island, roundabout ahead warning sign, yield sign, speed limit sign and horizontal curve. For conventional intersection approaches, record the number of travel lanes for each turning movement within the safety influence area, lane width, roadway functional class, posted speed limit, presence of horizontal curve, intersection ahead warning sign and shoulder width.

Step 6: If the selected intersection is a roundabout, users are also required to measure and record the inscribe circle diameter and the presence of raised central island.

Step 7: Observe and record the presence of any abutting properties within the safety influence area, as well as the presence of any potential lighting source(s) other than the purposefully built streetlights (e.g., gas station, stores, house decorations etc.) within the intersection.

4. Intersection Safety Countermeasure

In addition to the geometric layouts, all the safety countermeasures employed within the intersection safety influence area should be recorded too. These countermeasures include roadway medians, rumble strips, median barriers, transverse markings, roadside safety barriers, etc., which can be applied to all kinds of intersections. Additionally, for roundabouts, the safety treatments for central island like truck aprons, reflective chevron signs, plants should be considered as well. For each countermeasure, the specific type, dimensions, and locations should be recorded. Users can refer to **Error! Reference source not found.** for typical examples of each type of safety countermeasures.

5. Intersection Pedestrian Facility

To analyze pedestrians' impacts on intersection safety and traffic operations, the collected dataset should include the presence of pedestrian facilities within the safety influence area. Common pedestrian facilities include marked/raised/paved crosswalk, refuge island, sidewalk, and pedestrian crossing sign. Similar to safety countermeasures, the detailed types, dimensions and locations of each pedestrian facility should be recorded.

6. Data Recording

Step 1: To record the observed intersection geometric characteristics data, users can use the data reporting form provided in Figure 3. Figure 4 shows an example of the reporting form filled during one of the previous field surveys. Users are encouraged to add or delete the items listed in the form based on specific data collection needs.

Step 2: Users can scan the completed data forms along with the intersection geometric layout sketches to store the collected dataset, or extract the information from the forms and input into a spreadsheet within 24 hours of field survey.

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	Transverse Markings on Approach	7	Check	X	X	×		1
	Rumble Strips across Approach Lane	8	Check	×	X	X	L	1
	Rumble Strips on Median Line	8	Check	X	X	×	L	1
l	Rubmble Strips along Shoulder	8	Check	X	X	X		1
•	Roadside Safety Barrier		Check	X	X	X	L	1
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Figure 4. Example of Filled Data Reporting Form

C. Safety Guidelines

- It is important for survey crew members to wear a traffic safety vest at all times. The vest must be put on before surveyors set off from their base to the selected intersection site(s). The vest must be worn on top of all other clothing.
- The survey must be carried out by at least two surveyors; One can serve as a lookout to warn of potential hazards while the other does the main survey work.
- Crew members should not enter the active travel lane at any time since there is no measurement that will require crew members to be in the active travel lane.

III. Drone Data Collection Procedures

A. Required Equipment

- DJI Inspire[™] 2 drone
- Intelligent flight batteries
- Gimbal and Zenmuse[™] X5S camera
- Flashlight
- Metered wheel
- Traffic safety vest for every crew member
- Survey-crew-ahead safety signs
- Two traffic cones

B. Before Departure to the Field

- Ensure that there is no event near the selected intersection site that will generate large crowds because drones must not be flown over a large crowd.
- Check for Notice to Airmen (NOTAM) for the vicinity of the site and local weather forecast. Field trips should proceed only under good weather conditions when there is no rain/snow/fog, the temperatures are within the range of -4 to 104 °F and wind speeds do not exceed 15 MPH. For best results, wind speeds should not exceed 8 MPH.
- Check the FAA's B4UFLY App to ensure that the survey location is not within a restricted air space or has not been designated as a temporary no fly zone.
- Ensure that the remote controller and all the Intelligent Flight Batteries are fully charged.
- Ensure the DJI GO 4 app or DJI GS PRO app and the aircraft's firmware have been upgraded to the latest version.

- Ensure that the gimbal is detached from the drone during travel to and from the site.
- Ensure that no member of the team is under the influence of alcohol or drugs, and is not fatigued or impacted by emotional or psychological stress.
- Ensure that all crew members wear the traffic safety vests before going to the field.

C. Preflight

• Drive to the survey site and find a parking place that is located at a sufficient distance from the intersection site but in a location such that the drone pilot can always have a clear line of sight to both the drone and the surveyed intersection. This is to ensure the field data collection process won't distract drivers and/or influence driver behavior. Some field setup locations used in the previous studies include adjacent parking lots, right-of-way reservations around the roads, and driveways of residential buildings (with permission of the owners). Figure 5 shows a setup location selected in a parking lot near the surveyed roundabout site.



Figure 5. Example of Setup Location Near a Roundabout

• Ensure that all propellers are in good condition. Do not use aged, chipped, or broken propellers.

- Check to ensure that the gimbal can rotate freely before powering it on.
- Ensure that the lens cover of the camera is off, and the lens is clean and free of stains.
- Ensure that the Micro SD card has enough available data space.
- Ensure that the camera settings match the standard specifications for flight. The standard specifications are listed in Table 1.

Standard Zenmuse X58 Specificatio	ns for Roundabout Video Recording
Parameters	Labeled Settings
Camera Mode	Auto (400 ft)
Resolution	20.8 megapixels
Exposure Value	Manual (take images at -3, -2, and +2)
ISO Setting	3200
White Balance	Default
Auto Focus	Enabled
Shooting Mode	Single Shot (enabled)
Shutter Speed	Auto
Aperture	Manual (take images at 4 and 5)
Color Mode	Black and White

Table 1. Zenmuse X5S Camera Standard Specifications for Flight

- Assemble the DJI Inspire[™] 2 drone by inserting the batter pair, attaching propellers, mounting the gimbal and camera and inserting the Micro SD card. Then power the drone on. The assembling process is discussed in detail in the 'Procedures for operating the DJI INSPIRE[™] 2 drone' SOP.
- Prepare the remote controller by connecting it to the mobile device, launch the DJI GO 4 app on the mobile device, enter camera view and then tap "Linking Remote Controller" button to connect it to the drone.

- Check the flight mode switch on the remote controller and ensure the drone is set to P-mode (Positioning).
- Rotate each propeller to ensure that it moves freely without touching any part of the drone. Be aware of the sharp edges of the propellers.
- Check that the propellers and motors are installed correctly and firmly before every flight.
- All crew members must stay clear of propellers or motors when they are spinning. The aircraft must only be touched by hand while it is powered off.
- Observe the surroundings and develop an emergency landing plan in case the drone cannot return to the takeoff point.
- Ensure that the drone is placed in a flat open area, and its' takeoff and landing positions are clear of overhead power lines and/or tree branches.
- Ensure that Wi-Fi on any mobile device is turned off to avoid causing interference to the remote controller.
- Use a high beam flashlight to inspect and ensure that the planned takeoff and landing path do not have any overhead power cables that may otherwise not be very visible at night.
- Ensure the Aircraft Status Bar in the DJI GO 4 app indicates 'Ready to Go (GPS)' or 'Ready to Go (Vision)' in flying indoors. If so, the drone is ready to take off.

D. During Flight

The DJI Inspire[™] 2 drone attached with Zenmuse X5S[™] camera can be used to capture both image and video data to measure and calibrate geometric and operational related parameters for different types of intersections. Due to the differences in the required operation and flight time between the two types of data collection, the operating procedures of both image and video data collection will be discussed. Depending on the specific data collection needs, users can follow the corresponding procedures provided below.

1. Video Data Collection Procedures

Intersection geometric characteristics (e.g., lane configuration, the presence of safety countermeasures, etc.) and operational data (e.g., vehicle trajectories, traveling speed, etc.) can be extracted from the high-resolution video data recorded by the drone.

Step 1: Scroll the Left Dial ([1] in **Error! Reference source not found.**) of the remote controller to tilt the camera down by 90 degrees to have a top-down view of the intersection. The camera angle in degrees will be displayed on the Gimbal Slider ([9] in **Error! Reference source not found.**) in the DJI GO 4 app.



Figure 6. Remote Controller Diagram

Step 2: Fly the drone to the center of the intersection at an altitude of 390-395 ft above ground level (AGL), just shy of the maximum allowable height of 400 ft AGL, to ensure that the video could capture both the intersection center as well as a significant portion of each intersection approach.

Step 3: Set the camera at a minimum resolution of 1080P at 30 frames-per-second to ensure video qualities in which traffic is seen as a smooth rather than "glitchy" movement of vehicles. This is also required for the subsequent drone video data analysis. A typical high-resolution image taken by the drone camera is shown in Figure 7.



Figure 7. Example of High-resolution Image of One Roundabout Taken by the Drone Camera

Step 4: Record videos of vehicle operation within the intersections. Users can either press the Video Recording Button ([2] in **Error! Reference source not found.**) on the remote controller once to start recording videos, then press it again to stop recording. Or tap the Shutter/Record Switch ([6] in **Error! Reference source not found.**) to activate video recording mode, and then tap the Shutter/Record button ([8] in **Error! Reference source not found.**) once to start recording, and tap it again to stop recording. For each intersection, two video recordings of approximately 10 to 15 minutes duration should be made. The video length is influenced by the drone battery usage speed and the battery power required for a safe landing. It is recommended to start landing procedures when the battery level drops to 25 - 30%.



Figure 8. Touch Interface of DJI GO 4 App

Step 5: Tap the playback button ([11] in **Error! Reference source not found.**) to review recorded videos. Press the same button again to return to the camera view. The recorded videos will be saved in the inserted Micro SD card.

2. Collect Image Data (Geometric and illumination characteristics data collection)

Intersection geometric characteristics (e.g., lane configuration, the presence of safety countermeasures, etc.) and operational data (e.g., vehicle trajectories, traveling speed, etc.) can be extracted from the high-resolution video data recorded by the drone.

Step 1: Scroll the Left Dial ([1] in **Error! Reference source not found.**) of the remote controller to tilt the camera down by 90 degrees to have a top-down view of the intersection.

Step 2: Fly the drone to a desired altitude based on the data collection needs to include all the interested information in the camera frame. Do not fly above the maximum allowable altitude of 400 ft AGL. The app will give out warnings when the drone altitude exceeds 395 ft AGL.

Step 3: Change the camera settings based on the required image qualities by tapping the Photography Configurations and Parameter Settings button ([10] in **Error! Reference source not found.**) to set exposure modes, ISO, shutter, photo styles, and auto exposure values of the camera.

Step 4: Take images of the selected intersection. Users can either press the Shutter Button ([3] in **Error! Reference source not found.**) to take a photo, and multiple photos will be taken with a continuous press if burst mode is activated. Or tap the Shutter/Record Switch ([6] in **Error! Reference source not found.**) to select shutter, then tap the Shutter/Record button ([8] in **Error! Reference source not found.**) to take photos. There are five shooting modes available: Single Shooting, Multiple Mode, AEB (Auto Exposure Bracketing), Timed Shot, and RAW Burst Mode. The default mode is Single Shooting, and the shooting mode can be changed via the DJI GO 4 app.

Step 5: Tap the playback button ([11] in **Error! Reference source not found.**) to review captured images. Press the same button again to return to the camera view. The captured images will be saved in the Micro SD card.

3. Safety Guidelines

- The altitude of the drone should never exceed 400 ft AGL.
- In case of an emergency landing or loss of power that causes a free-fall crash of the drone, crew members should not attempt to catch the drone because the rotating propellers are dangerous and can cause significant harm.
- The pilot and observer(s) must maintain visual line of sight to the drone at all times.
- The pilot must not answer any incoming phone calls or use their mobile device while operating the drone.

- In the instance of low battery warning or dangerous wind speed warning, land the drone immediately at a safe location.
- Do not remove the Micro SD card while the drone is powered on.

E. Post Flight

- The gimbal and camera should be removed before transforming the drone from Landing Mode to Travel Mode. Detach the gimbal from the drone and put both in secure travel mode before departing to base or to another measurement location.
- Power off the drone and pick up the aircraft only after it is powered off.
- Power off the remote controller and disconnect the mobile device, then put all the equipment back into the drone box.
- Download the captured images or videos from the Micro SD card onto an external storage device or laptop.
- Do not connect the aircraft system to any USB interface that is older than version 2.0.

Procedure Checklist of Field Data Collection

	Procedure Checklist of Field Data Collection	
	Project Number:	Comments
Constal Information	Date:	
General Information	Time:	
	Recorder:	
	Required Equipment	Check
	A compass	
	A GPS device	
	Traffic safety vest for every survey crew member	
7.110	Survey-crew-ahead safety signs	
Field Survey Equipment	Two traffic cones	
Equipment	A measuring wheel	
	A 25 feet tape measure	
	A laser distance meter (Bosch GLM 50) and laser target card	
	DJI INSPIRE [™] 2 Drone	
	TB50 Intelligent Flight Batteries® (1 set for each flight)	
	DJI INSPIRE [™] 2 Remote Controller	
	1550T Quick Release Propellers (2 red and 2 white)	
Drone Data Collection	Zenmuse X5S™ camera	
Equipment	A 16 GB Micro SD card	
	A mobile device with DJI GO TM 4 app installed	
	Traffic safety vest for every survey crew member	
	Survey-crew-ahead safety signs	
	Two traffic cones	
	Flashlight (for nighttime data collection)	
	Field Survey	Check
Record Intersection Location	Select at least three reference points within each intersection surveyed and record the latitude and longitude information of each selected reference points	
Measure Lane Width	Use a Bosh GLM 50 laser distance meter and a laser target card for lane width measurement	

	Choose the basic intersection layout from the provided list based on the intersection type	
	Indicate the true North direction with a North Arrow on the intersection layout	
	Label the approach directions on the layout	
Record Intersection Geometric Layout	Number the intersection legs clockwise starting from SB and record the name of each leg based on the corresponding street names	
	Observe and record the approach geometric characteristics in the data reporting form based on the intersection type	
	Observe and record the presence of any abutting properties within the safety influence area	
Record Intersection Safety Countermeasures	Record all the safety countermeasures and pedestrian facilities employed within the intersection safety influence area	
	Wear a traffic safety vest on top of all other clothing at all times	
Safety Guidelines	The survey crew should consist at least two people	
	Do not enter any active travel lanes at any time	
	Do not enter any active travel lanes at any time Drone Data Collection	Check
	Do not enter any active travel lanes at any time Drone Data Collection Ensure that there is no event near the selected intersection site that will generate large crowds	Check
	Do not enter any active travel lanes at any time Drone Data Collection Ensure that there is no event near the selected intersection site that will generate large crowds Check for Notice to Airmen (NOTAM) for the vicinity of the site and local weather forecast	Check
	Do not enter any active travel lanes at any time Drone Data Collection Ensure that there is no event near the selected intersection site that will generate large crowds Check for Notice to Airmen (NOTAM) for the vicinity of the site and local weather forecast Check the FAA's B4UFLY App to ensure that the survey location is not within a restricted air space or has not been designated as a temporary no fly zone	Check
Before departure	Do not enter any active travel lanes at any time Drone Data Collection Ensure that there is no event near the selected intersection site that will generate large crowds Check for Notice to Airmen (NOTAM) for the vicinity of the site and local weather forecast Check the FAA's B4UFLY App to ensure that the survey location is not within a restricted air space or has not been designated as a temporary no fly zone Ensure that the remote controller and all the Intelligent Flight Batteries are fully charged	Check
Before departure	Do not enter any active travel lanes at any time Drone Data Collection Ensure that there is no event near the selected intersection site that will generate large crowds Check for Notice to Airmen (NOTAM) for the vicinity of the site and local weather forecast Check the FAA's B4UFLY App to ensure that the survey location is not within a restricted air space or has not been designated as a temporary no fly zone Ensure that the remote controller and all the Intelligent Flight Batteries are fully charged Ensure the DJI GO 4 app and the aircraft's firmware have been upgraded to the latest version	Check
Before departure	Do not enter any active travel lanes at any time Drone Data Collection Ensure that there is no event near the selected intersection site that will generate large crowds Check for Notice to Airmen (NOTAM) for the vicinity of the site and local weather forecast Check the FAA's B4UFLY App to ensure that the survey location is not within a restricted air space or has not been designated as a temporary no fly zone Ensure that the remote controller and all the Intelligent Flight Batteries are fully charged Ensure the DJI GO 4 app and the aircraft's firmware have been upgraded to the latest version Ensure that the gimbal is detached from the drone during travel to and from the site	Check

	Ensure that all crew members wear the traffic safety vests before going to the field	
Drone Operation	Refer to the Procedure Checklist of Operating the DJI INSPIRE™ 2 Drone	
	Scroll the Left Dial of the remote controller to tilt the camera down by 90 degrees to have a top-down view of the intersection	
	Fly the drone to a desired altitude based on the data collection needs to include all the interested information in the camera frame	
Image/Video Dete	For video recordings, set the camera at a minimum resolution of 1080P at 30 frames-per-second to ensure video qualities	
Collection	Capture images/ videos of vehicle operation within the intersections by either pressing the Shutter Button/ Video Recording Button on the remote controller or tap the Shutter/Record Switch in the app to switch between image/ video mode and then tap the Shutter/Record button to take a picture or start recording	
	Tap the playback button to review captured images or videos	
	Download the captured images or videos from the Micro SD card onto an external storage device or laptop	
	The altitude of the drone should never exceed 400 ft AGL	
	In case of an emergency landing or loss of power that causes a free-fall crash of the drone, crew members should not attempt to catch the drone because the rotating propellers can cause significant harm	
Sofaty Cuidelines	The pilot and observer(s) must maintain visual line of sight to the drone at all times	
Safety Guidennes	The pilot must not answer any incoming phone calls or use their mobile device while operating the drone	
	In the instance of low battery warning or dangerous wind speed warning, land the drone immediately at a safe location	
	Do not remove the Micro SD card while the drone is powered on	

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