April 2024 | Prepared by: Athey Creek Consultants

ENTER PRISE

Novel Uses of Unmanned Aerial Systems (UAS) in Intelligent Transportation Systems (ITS)

ENTERPRISE TRANSPORTATION POOLED FUND STUDY TPF-5(490)

FINAL REPORT

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16. Abstract

The use of UAS (drones) by state departments of transportation (State DOTs) is steadily increasing. The ENTERPRISE Pooled Fund Study completed this project to explore ways to optimize UAS integration with ITS and operations within transportation agencies. The literature search identified more than 30 UAS use cases for ITS and transportation operations that are being used in practice, researched, tested, planned, or considered by State DOTs. A survey of State DOTs revealed that the highest number of responding agencies are using UAS for post-emergency documentation, observing conditions where cameras are not present, traffic data collection for congestion monitoring, on-site incident scene monitoring, and collecting data for before/after studies. Though the stage of implementation varies for each purpose, the use of UAS for ITS and operations appears to be trending beyond research and testing toward being implemented. Details about four successful ITS and transportation operations use cases were gathered. Benefits associated with use of UAS included obtaining views that would not otherwise be possible, improving safety for employees and contractors as they operate drones away from hazardous conditions, and communicating conditions (e.g., emergencies or hazardous situations) to decision makers and the public. Limitations exist with operating UAS when flying drones in unfavorable weather conditions (e.g., cold, sleet, rain) as well as battery life for longer flights and distances.

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Project Champion

Charles Tapp from the Texas Department of Transportation was the ENTERPRISE Project Champion for this effort. The Project Champion serves as the overall lead for the project.

ENTERPRISE Members

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- Texas Department of Transportation
- Wisconsin Department of Transportation

Project Input

ENTERPRISE would like to thank the many state departments of transportation that provided input to the project through an online survey and phone interviews.

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AI	Artificial Intelligence
AK	Alaska
AL	Alabama
DE	Delaware
DOT	Department of Transportation
ENTERPRISE	Evaluating New Technologies for Roads Program Initiatives in Safety and Efficiency
FAA	Federal Aviation Administration
FL	Florida
ICM	Integrated Corridor Management
IL	Illinois
IMAP	Incident Management Assistance Patrol
IPP	Integration Pilot Program
ITS	Intelligent Transportation Systems
KS	Kansas
KY	Kentucky
LMR	Land Mobile Radio
MA	Massachusetts
MD	Maryland
ME	Maine
MO	Missouri
MPH	Miles per Hour
MPO	Metropolitan Planning Organization
MT	Montana

NC	North Carolina
NCDOT	North Carolina Department of Transportation
ND	North Dakota
NDDOT	North Dakota Department of Transportation
NJ	New Jersey
NJDOT	New Jersey Department of Transportation
OK	Oklahoma
PCI	Pavement Condition Index
PFS	Pooled Fund Study
RTK	Real-time Kinematic
SC	South Carolina
SD	Secure Digital
SD	South Dakota
SOP	Standard Operating Procedure
STIC	State Transportation Innovation Council
STOC	Statewide Operations Center
SMART	Strengthening Mobility and Revolutionizing Transportation
State DOTs	State Departments of Transportation
TMC	Traffic Management Center
TPF	Transportation Pooled Fund Study
TX	Texas
UAS	Unmanned Aerial Systems
UT	Utah
USDOT	United States Department of Transportation
WA	Washington State

Executive Summary

The use of unmanned aerial systems (UAS) by state departments of transportation (state DOTs) is steadily increasing. While monitoring road and bridge conditions remains a leading example of how state DOTs are using UAS, the types of uses are rapidly expanding beyond infrastructure monitoring to support many more agency activities. As agencies expand their use of UAS (drones), there is a benefit to exploring ways to optimize UAS for multiple agency functions and services, including integration with ITS and transportation operations.

The Evaluating New Technologies for Roads Program Initiatives in Safety and Efficiency (ENTERPRISE) Pooled Fund Study (PFS) completed this project, "Novel Uses of UAS in ITS," to explore ways to optimize UAS integration with ITS and operations within transportation agencies. The project completed a literature search, conducted a survey of state DOTs, documented case studies highlighting agency uses of UAS for ITS and transportation operations, and summarized key findings. The information gathered will help inform agencies as they consider increasing use of UAS to support transportation operations and ITS activities.

Literature Search

The literature search revealed more than 60 UAS use cases (e.g., special event traffic monitoring, queue observation) that are being used in practice, researched, tested, considered, or planned by state DOTs. More than 30 of these use cases were focused on ITS and transportation operations UAS efforts. These ITS and transportation operations use cases were then organized into nine categories. See Table E.1.

Table E.1 UAS Use Cases: ITS and Transportation Operations

Category	UAS Use Cases from Literature*
#1: Real-time traffic monitoring	• Special event traffic monitoring • Queue observation • Live streaming traffic video where cameras are not available • Congestion assessment
#2: Assess traffic operations strategies and traffic control	• Before/after studies (e.g., for ramp meter installations) • Roundabout assessment • Traffic control assessment • Work zone setup (i.e., ensure work zone elements positioned correctly) • Work zone traffic control documentation
#3: Traffic data collection	• Traffic characterization for monitoring (i.e., obtain traffic counts, speeds, origin-destination flow, density, with real-time analytics) • Traffic flow data collection at intersections (e.g., vehicle counts, classification, speed, trajectory) • Highway speed-sensing (collect speed data for speed limit setting)

Category	UAS Use Cases from Literature*
#4: Traffic incident management	Response and monitoring: • Traffic monitoring, incident scene monitoring • Equip emergency vehicles with UAS to expedite response times Post-incident analysis: • Post-incident review • Collision scene reconstruction and investigation • Incident mapping
#5: Emergency operations	Pre-hazard planning: • Landslide and rockslide prediction, monitoring, mapping Management, monitoring, and response: • Assess and monitor road hazards and emergency situations (e.g., sink holes, fallen rocks, unstable slopes, bridge failures, flooding) • Bridge scour monitoring, damage inspection, and searching operations • First responder situational awareness • Avalanche mitigation • Deploy UAS with visual warnings to alert drivers of upcoming emergencies Post-hazard documentation: • Damage assessment (e.g., rockfalls, storm damage) • Post-incident documentation (e.g., after train derailment)
#6: Road weather management	• Weather forecasting • Prewinter storm brine spreading • Assess drainage issues pre-storm • Snow mapping • Snow plowing activity • Gather situational awareness data on snow, ice, and overland trails
#7: Parking management	• Illegal or unintended parking assessment • Parking lot utilization monitoring
#8: Locate and evaluate ITS assets	• Evaluation of closed-circuit television locations
#9: Communications networks	• Create ad-hoc communications networks (deploy multiple airborne hosts for temporary communications access points, to allow communications at locations where cellular or other communications are not present)

**See Appendix A for details and citations.*

In addition to the UAS use cases that support ITS and transportation operations applications, more than 30 use cases in 17 other (non-ITS) categories (e.g., agriculture and environment assessment, airports/air transportation) were identified, showing the breadth of UAS uses that are being considered, researched, or implemented by transportation agencies. See Appendix A.

Survey

Based on the literature search, survey questions were developed to gather additional information on the use of UAS for ITS and transportation operations purposes from state DOTs. Twenty-one agencies responded to the survey. The following are key findings from the survey responses.

- Agencies reported a wide range of ITS and transportation operations purposes for which they are using UAS. The highest number of responses indicated use of UAS for post-emergency documentation, observing conditions where cameras are not present, traffic data collection for congestion monitoring, on-site incident scene monitoring, and collecting data for before/after studies.
- Though the stage of implementation varies for each purpose, the use of UAS appears to be trending beyond research and testing (toward being implemented) for many of the ITS and transportation operations purposes reported.
- Every survey respondent indicated that they use untethered drones. Only one agency indicated the use of tethered drones for on-site incident scene monitoring and to determine traffic camera heights.
- Respondents noted a very successful outcome with the use of UAS for post emergency documentation, video recording for post-incident debriefing, and observing conditions where camera are not present.
- Improved documentation or data and safety improvement were selected most often as benefits of UAS.
- Battery life and FAA regulations were selected most often as a challenge or limitation.

Case Studies

Four case studies were identified by reviewing survey responses and selecting a diverse set of UAS uses that were reported by the responding agency as having a successful outcome and/or a particularly novel approach (e.g., use of untethered UAS). After selecting case studies for expanded documentation, phone interviews were conducted with each agency to gather additional information about each specific use case, to supplement information collected through the survey.

- Case Study #1: North Dakota DOT – UAS for Supporting Road Weather Events
- Case Study #2: North Carolina DOT – Tethered UAS for On-Site Monitoring
- Case Study #3: Florida DOT – UAS for ITS Equipment Placement
- Case Study #4: New Jersey DOT – UAS Use and Program Evolution

Following are key findings from the case studies:

- Each agency has trained staff within their agency to operate their drones. Staff are trained within the agency and certified through the FAA every two years. A drone pilot license is not required to operate tethered drones.
- Drones typically last 3 to 5 years. If an older drone is used, upgrades are needed to meet FAA requirements. Retired drones are often used for training purposes.

- Starting in December 2025, DOTs will have to follow the American Security Drone Act. This act bars the federal government from using funds to buy drones made in China or certain other countries from December 2025 through 2028. Some agencies are already using American made drones, and others are beginning to research American made drone options.
- Participating agencies reported significant benefits with use of UAS for obtaining views that would not otherwise be possible, improving safety for employees and contractors as they operate drones away from hazardous conditions and communicating conditions (e.g., emergencies or hazardous situations) to decision makers and the public.
- There are challenges with flying drones in unfavorable weather conditions (e.g., cold, sleet, rain) as well as battery life for longer flights and distances.
- Video and photos captured from drones can be viewed in real-time or downloaded after use.
- Agencies reported the use of software platforms to track UAS program information such as drone inventories, pilots, licenses, flights, flight paths, speed, altitude, and to view drone footage.

Overall, the research conducted for this project provided ENTERPRISE member agencies with numerous UAS use cases that are being used in practice, researched, tested, considered, or planned by state DOTs. Further, details about successful ITS and transportation operations use cases were gathered from four state DOTs, demonstrating practices for implementing these use cases for state DOT operations.

Chapter 1: Introduction

The use of unmanned aerial systems (UAS) by state departments of transportation (state DOTs) is steadily increasing. While monitoring road and bridge conditions remains a leading example of how state DOTs are using UAS, the types of uses are rapidly expanding beyond infrastructure monitoring to support many more agency activities. For example, a growing body of research has explored using drones for purposes typically associated with intelligent transportation systems (ITS) and transportation operations, such as:

- Traffic data collection;
- Real-time traffic monitoring;
- Traffic incident management;
- Emergency operations;
- Locating and managing ITS assets;
- Traffic control and traffic operations;
- Road weather management; and
- Parking management.

As agencies expand their use of UAS (drones), there is a benefit to exploring ways to optimize UAS for multiple agency functions and services, including integration with ITS and transportation operations. Information about current use cases such as stage of deployment, level of success, benefits, challenges, and lessons learned, will help inform agencies as they consider increasing use of UAS to support transportation operations and ITS activities.

> **Project Purpose**
>
> To explore ways to optimize UAS integration with ITS and operations within transportation agencies.

The Evaluating New Technologies for Roads Program Initiatives in Safety and Efficiency (ENTERPRISE) Pooled Fund Study (PFS) completed this project "Novel Uses of UAS in ITS" to explore ways to optimize UAS integration with ITS and operations within transportation agencies. The project identified numerous UAS use cases for ITS and transportation operations that are being used in practice, researched, tested, planned, or considered by state DOTs. Further, details about successful ITS and transportation operations use cases were gathered, demonstrating practices for implementing these use cases for state DOT operations.

1.1 Project Approach

This project identified UAS use cases for ITS and transportation operations and gathered additional details from state DOTs who are utilizing UAS for these purposes. The project completed a literature search, conducted a survey of state DOTs, documented case studies highlighting agency uses of UAS for ITS and transportation operations, and summarized key findings. See Figure 1.1 for the project tasks.

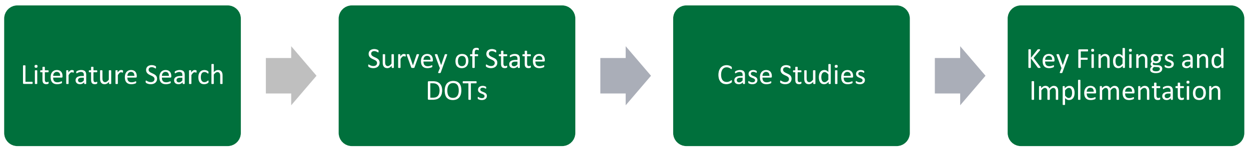

Figure 1.1 Project Tasks

1.2 Report Organization

This report summarizes the research findings and is organized as follows:

- Chapter 2: Literature Search – Presents key findings from the literature search which identified numerous UAS use cases for ITS and transportation operations, as well as non-ITS use cases applicable to transportation agencies.
- Chapter 3: Survey of State DOTs – Provides results from the survey of state DOTs which gathered information about ITS and transportation use cases for UAS, including the stage of implementation, drone type (tethered, untethered), level of success to date, benefits, and challenges.
- Chapter 4: Case Studies – Documents four case studies that provide details about selected UAS use cases supporting ITS and/or transportation operations activities within state DOTs.
  - Case Study #1: North Dakota DOT – UAS for Supporting Road Weather Events
  - Case Study #2: North Carolina DOT – Tethered UAS for On-Site Monitoring
  - Case Study #3: Florida DOT – UAS for ITS Equipment Placement
  - Case Study #4: New Jersey DOT – UAS Use and Program Evolution
- Chapter 5: Key Findings and Implementation – Provides an overview of the project's key findings and suggested implementation.
- References: Provides details about each source reviewed for this project.
- Appendix A: Literature Search UAS Use Cases: Details and Citations – Tabulates the UAS use cases identified from the literature search, including details and citations.
- Appendix B: Survey Questions – Provides the questions from the online survey.
- Appendix C: Survey Responses – Provides the responses from the online survey.
- Appendix D: Survey Responses by Use Case – Provides the responses from the online survey by use case.

Chapter 2: Literature Search

This chapter provides a summary of the literature search completed for this project. The purpose of the literature search was to identify state DOT UAS use cases for ITS and transportation operations. The literature search was the first step in the project and was finalized in October 2023. The literature search focused on resources published from 2018 through October 2023 and included national resources, state and regional research and peer exchanges, and forward-looking research. While this project is focused on UAS for ITS and transportation operations, the search also revealed several use cases that are not typically associated with ITS or transportation operations, demonstrating growing UAS usage by DOTs. More than 30 applicable publications and online resources were reviewed to identify UAS use cases during this literature search task.

2.1 Overview of UAS for ITS

Several instances of ITS and transportation operations uses of UAS by state DOTs were noted in national resources and federal programs. The Uncrewed Aerial Systems & Advanced Air Mobility State of Play for State DOTs, Second Edition (AASHTO, 2022) notes that “State DOTs apply UAS in a variety of day-to-day operations, including asset inspections, emergency response and disaster management, traffic incident management, and diverse project data collection efforts.” Completed in 2020, the United States Federal Aviation Administration (FAA) UAS Integration Pilot Program included three state DOTs as lead participants, with transportation operations use cases being demonstrated by North Carolina DOT (disaster response and recovery operations) and North Dakota DOT (emergency management and operations) (FAA, n.d.). In 2023, the United States Department of Transportation (USDOT) announced Strengthening Mobility and Revolutionizing Transportation (SMART) FY 2022 Grant Awards which includes the Alaska Department of Transportation & Public Facilities’ plans to use UAS to gather situational awareness data on snow, ice, and overland trails (USDOT, n.d.-b).

At the state level, studies have explored and tested UAS for ITS and transportation operations. For example, Michigan DOT has tested UAS for collecting traffic data to support traffic/congestion monitoring (Brooks et al., 2022). See Figure 2.1. In a study published by the Virginia Research Council, a survey of state transportation agencies revealed traffic-related UAS uses (planned or in use) such as traffic data characterization (e.g., types, speeds, counts), first responder situational awareness, roadway emergency alert, illegal or unintended parking assessment, ramp metering assessment, special event traffic monitoring, queue observation, and live streaming traffic video where cameras are not available (Alden et al., 2022).

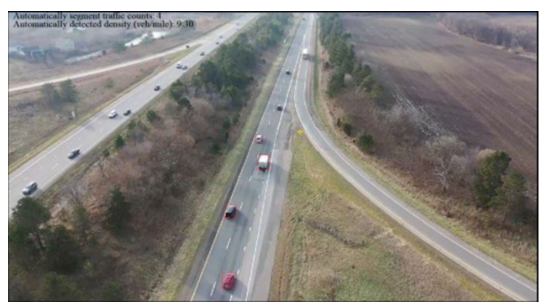

Figure 2.1 Screenshot of processed streaming video with counts and detected density at the top left corner of the image. (Source: Brooks, et al., 2022)

Future ITS-related purposes might involve use of UAS to act as a temporary sign (e.g., to display variable speed limits) or for improved communications connectivity since UAVs can offer a stable communication link due to flight altitude and persistent line-of-sight channel (Saboor et al., 2021).

2.2 Key Findings

The literature revealed more than 60 UAS use cases that are being used in practice, researched, tested, considered, or planned by state DOTs. For each use case identified, the following information (as available from each publication) was tabulated and is provided in Appendix A:

- Use case;
- State DOT(s), if noted;
- Citation;
- Publication's sponsoring agency;
- Publication type; and
- Publication date (year).

Figure 2.2 provides one example of the details provided for each use case.

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Traffic monitoring / traffic analysis	Massachusetts DOT	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021

Figure 2.2 Example Use Case Documentation

For each use case identified in the literature, a UAS category was then assigned by the research team. The following nine (9) categories of UAS use cases for ITS and traffic operations were identified:

- Category #1: Real-time traffic monitoring
- Category #2: Assess traffic operations strategies and traffic control
- Category #3: Traffic data collection
- Category #4: Traffic incident management
- Category #5: Emergency operations
- Category #6: Road weather management
- Category #7: Parking management
- Category #8: Locate and evaluate ITS assets
- Category #9: Communications networks

More than 30 UAS use cases for ITS and transportation operations are listed in Table 2.1, organized into the categories derived from the literature. This list of use cases includes those that are used in practice as well as those that are being researched, tested, planned, or considered by transportation agencies.

Table 2.1 Literatures Search: UAS Use Cases by ITS and Transportation Operations Category

Category	UAS Use Cases from Literature*
#1: Real-time traffic monitoring	• Special event traffic monitoring • Queue observation • Live streaming traffic video where cameras are not available • Congestion assessment
#2: Assess traffic operations strategies and traffic control	• Before/after studies (e.g., for ramp meter installations) • Roundabout assessment • Traffic control assessment • Work zone setup (i.e., ensure work zone elements positioned correctly) • Work zone traffic control documentation
#3: Traffic data collection	• Traffic characterization for monitoring (i.e., obtain traffic counts, speeds, origin-destination flow, density, with real-time analytics) • Traffic flow data collection at intersections (e.g., vehicle counts, classification, speed, trajectory) • Highway speed-sensing (collect speed data for speed limit setting)
#4: Traffic incident management	Response and monitoring: • Traffic monitoring, incident scene monitoring • Equip emergency vehicles with UAS to expedite response times Post-incident analysis: • Post-incident review • Collision scene reconstruction and investigation • Incident mapping
#5: Emergency operations	Pre-hazard planning: • Landslide and rockslide prediction, monitoring, mapping Management, monitoring, and response: • Assess and monitor road hazards and emergency situations (e.g., sink holes, fallen rocks, unstable slopes, bridge failures, flooding) • Bridge scour monitoring, damage inspection, and searching operations • First responder situational awareness • Avalanche mitigation • Deploy UAS with visual warnings to alert drivers of upcoming emergencies Post-hazard documentation: • Damage assessment (e.g., rockfalls, storm damage) • Post-incident documentation (e.g., after train derailment)
#6: Road weather management	• Weather forecasting • Prewinter storm brine spreading • Assess drainage issues pre-storm • Snow mapping • Snow plowing activity • Gather situational awareness data on snow, ice, and overland trails
#7: Parking management	• Illegal or unintended parking assessment • Parking lot utilization monitoring

Category	UAS Use Cases from Literature*
#8: Locate and evaluate ITS assets	• Evaluation of closed-circuit television locations
#9: Communications networks	• Create ad-hoc communications networks (deploy multiple airborne hosts for temporary communications access points, to allow communications at locations where cellular or other communications are not present)

**See Appendix A for details and citations.*

In addition to the UAS use cases that support ITS and transportation operations applications, more than 30 use cases in the following 17 other (non-ITS) categories were identified, showing the breadth of UAS uses that are being considered, researched, or implemented by transportation agencies:

- Agriculture and environmental assessment
- Airports/air transportation
- Asset management
- Construction
- Counter-UAS operations
- Delivery services
- Design survey
- Facility maintenance
- Geologic assessment
- Ground vehicle assistance
- Image collection
- Infrastructure inspection
- Mapping and modeling
- Maritime
- Media/public relations
- Virtual design, construction, project evaluation
- Volumetric analysis

See Appendix A for tables with details for each category, including specific use cases, citations, and state DOT if noted in the literature.

Chapter 3: Survey of State DOTs

Building on findings from the literature search, an online survey was designed to gather input from state DOTs regarding their use of UAS for ITS and transportation operations. The purpose of the survey was to identify current use cases for UAS that support ITS and transportation operations applications, and to identify selected case studies for further documentation through phone interviews.

In October 2023, the survey was distributed to ENTERPRISE member agencies, the American Association of State Highway and Transportation Officials (AASHTO) Council on Aviation, and the AASHTO Committee on Transportation System Operations.

3.1 Survey Respondents

Twenty-one (21) survey responses were received from the following state transportation agencies. See Figure 3.1.

- Alabama (AL) DOT
- Alaska (AK) DOT & Public Facilities
- Delaware (DE) DOT
- Florida (FL) DOT
- Illinois (IL) DOT
- Kansas (KS) DOT
- Kentucky (KY) Transportation Cabinet
- Maine (ME) DOT
- Maryland (MD) State Highway Administration
- Massachusetts (MA) DOT
- Missouri (MO) DOT
- Montana (MT) DOT
- New Jersey (NJ) DOT
- North Carolina (NC) DOT
- North Dakota (ND) DOT
- Oklahoma (OK) DOT
- South Carolina (SC) DOT
- South Dakota (SD) DOT
- Texas (TX) DOT
- Utah (UT) DOT
- Washington State (WA) DOT

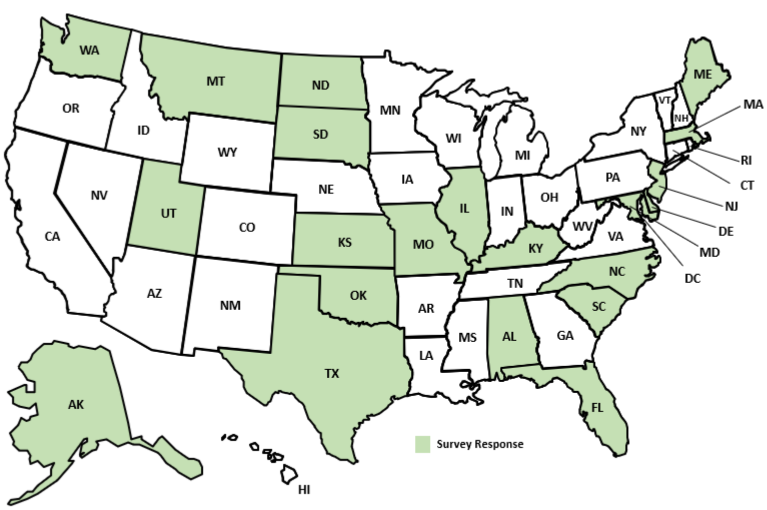

Figure 3.1 Survey Respondents

3.2 Summary of Survey Responses

This section summarizes information gathered from the 21 state transportation agencies that submitted responses to the online survey on the use of UAS for ITS and transportation operations purposes. The purpose of the survey was to identify the degree to which state transportation agencies are utilizing UAS for operations and ITS purposes, and to document additional details about these specific uses. The survey first asked respondents to indicate the ITS or transportation operations purposes for which their agency has used UAS. For each selected purpose, respondents indicated the stage of implementation, drone type (tethered or untethered), level of success, benefits, and challenges. See Appendix B for the survey questions.

The following provides a summary-level compilation of survey responses, noting key observations by reviewing the collective responses to each question. See Appendix C for the complete survey responses by question. See Appendix D for complete survey responses by use case.

UAS for ITS or Transportation Operations Purposes

The first survey question asked “For which of the following intelligent transportation systems (ITS) or transportation operations purposes does your agency use UAS (e.g., tested or implemented)? Select all that apply.” Table 3.1 shows the answer choices (left column), the corresponding number of responses (middle column), and agencies for each ITS or transportation operations purpose (right column).

Agencies reported a wide range of ITS and transportation operations purposes for which they are using UAS. The highest number of responses indicated use of UAS for post-emergency documentation, observe conditions where cameras are not present, traffic data collection for congestion monitoring, on-site incident scene monitoring, and collect data for before/after studies.

Table 3.1 Survey Results: Use of UAS for ITS or Transportation Operations Purposes

Purpose (survey options)	Responses	State Agency
Post-emergency documentation	12	AK, AL, DE, FL, KS, KY, MA, MO, MT, NJ, TX, UT,
Observe conditions where cameras are not present	11	AK, DE, FL, KY, ME, MO, NC, ND, NJ, TX, WA
On-site incident scene monitoring	9	AK, DE, FL, KY, MO, NC, NJ, WA, UT
Traffic data collection for congestion monitoring	9	AK, DE, KY, MA, MO, ND, SC, TX, WA
Collect data for before/after studies	8	AK, KS, KY, MT, ND, SD, TX, UT
Collision scene reconstruction	7	AK, DE, IL, KY, MA, MD, UT
Incident mapping	7	AK, FL, KY, MO, MT, OK, UT
Observe traffic control setup in work zones	7	AK, KY, ND, UT, DE, MO, NJ
Road surface treatment	7	AK, DE, KY, MT, ND, TX, UT
Video recording for post-incident debriefing	7	AK, FL, KS, KY, MO, OK, UT

Purpose (survey options)	Responses	State Agency
Determine sight lines for radio infrastructure	6	AK, DE, FL, KY, MO, TX
Road surface detection (e.g., snow, flood, ice)	6	AK, DE, KS, KY, ND, UT
Determine traffic camera heights	5	FL, KS, KY, ME, ND
Parking lot utilization	3	DE, KS, KY
Illegal or unintended parking assessment	2	KS, KY
None	1	SD
Snow plowing activity monitoring	2	KY, ND
Pedestrian or bicyclist data collection	1	AK
Equip multiple UAS to create ad-hoc communications network	0	N/A
Weather forecasting	0	N/A

When asked to respond with other operations or ITS purposes for which they are using UAS, the following were noted by survey respondents:

- Pavement Condition Index (PCI) (AK)
- Live Streaming to Emergency Operations Centers (FL)
- Reconstruction of signal infrastructure damage (FL)
- Bridge inspection (FL, KS, MO, ND, TX)
- Microwave tower modeling (FL)
- Storm water assessment (KS, ND)
- Communications tower inspection (KS)
- Volumetric determinations (KS, ND)
- 3D modeling roadways and natural disaster (KY)
- LiDAR Surveys (MO) and LiDAR data collection (ND)
- Drone in a Box solution for avalanche and rockslide detection/mitigation (MT)
- Noxious weed detection/classification and treatment (MT)
- Real-time signal timing to support an incident detour due to a crash occurring on a bridge (NC)
- High-mast lighting and ancillary structure inspection (ND)
- Platooning (ND)
- Real-time kinematic (RTK) positioning operations (ND)
- Tunnel and retaining walls (ND)
- Landslides and highway impact observation (ND)
- Erosion (ND, TX)
- We use UAS to do inventory and structural inspections of land mobile radio (LMR) Towers and equipment (OK)
- Survey and mapping for right-of-way (ROW) acquisition (TX)
- Construction progress monitoring (TX)
- Beach dredging monitoring (TX)
- Bird nest surveys (TX)
- 3D modeling (TX)
- Survey and construction (UT)

Stage of Implementation

For each ITS or transportation operations purpose selected in the first question, respondents were asked to indicate the UAS stage of implementation, either “research/testing” or “implemented.” Table 3.2 shows the stage of UAS implementation indicated by respondents for each ITS or transportation operations purpose, along with the state transportation agencies that indicated the response.

Though the stage of implementation varies for each purpose, the use of UAS appears to be trending beyond research and testing (toward being implemented) for many of the ITS and transportation operations purposes reported.

Table 3.2 Survey Results: UAS Stage of Implementation for Each Purpose

Purpose	Research/Testing Responses		Implemented Responses	
Post-emergency documentation	2	FL, TX	10	AK, AL, DE, KS, KY, MA, MO, MT, NJ, UT
Observe conditions where cameras are not present	2	NC, TX	8	AK, DE, FL, KY, ME, MO, ND, NJ
On-site incident scene monitoring	1	NC	7	AK, DE, FL, KY, MO, NJ, UT
Traffic data collection for congestion monitoring	4	AK, MA, SC, TX	4	DE, KY, MO, ND
Collect data for before/after studies	4	AK, KS, MT, TX	4	KY, ND, SC, UT
Collision scene reconstruction	2	DE, MA	5	AK, IL, KY, MD, UT
Incident mapping	2	FL, MT	5	AK, KY, MO, OK, UT
Observe traffic control setup in work zones	1	MO	6	AK, DE, KY, ND, NJ, UT
Road surface treatment	5	AK, DE, KY, MT, TX	2	ND, UT
Video recording for post-incident debriefing	0	-	7	AK, FL, KS, KY, MO, OK, UT
Determine sight lines for radio infrastructure	3	KY, MO, TX	3	AK, DE, FL
Road surface detection (e.g., snow, flood, ice)	2	KS, KY	4	AK, DE, ND, UT
Determine traffic camera heights	2	KS, NC	3	FL, KY, ME
Parking lot utilization	2	KS, KY	1	DE
Illegal or unintended parking assessment	2	KS, KY	0	-
Snow plowing activity monitoring	1	KY	1	ND
Pedestrian or bicyclist data collection	1	AK	0	-

Drone Type

For each ITS or transportation operations purpose selected in the first question, respondents were asked to indicate if the drone used was tethered or untethered. Every survey respondent indicated that their agency uses untethered drones. North Carolina DOT is the only respondent that indicated the use of tethered drones for on-site incident scene monitoring and to determine traffic camera heights.

Outcome with Drone Use

For each ITS or transportation operations purpose selected in the first question, respondents were asked to describe the outcome with the use of the drone. The options to select were “not successful,” “somewhat successful,” “very successful”, or “too early to determine.” Respondents were required to select only one of these options.

None of the respondents indicated that the outcome was “not successful.”

The top 7 UAS purposes selected as “very successful” were:

- Post emergency documentation (9 responses)
- Video recording for post-incident debriefing (7 responses)
- Observe conditions where cameras are not present (7 responses)
- On-site incident scene monitoring (6 responses)
- Collect data for before/after studies (5 responses)
- Collision scene reconstruction (5 responses)
- Observe traffic control setup in work zones (5 responses)

Benefits

For each ITS or transportation operations purpose selected in the first question, respondents were asked to indicate benefits. The options to select were “cost saving,” “time saving,” “safety improvement,” “quality improvement,” and “improved documentation or data.” Respondents were asked to select all that apply.

The following bullets summarize how many responses for each benefit were selected. Improved documentation or data was selected most often as a benefit of using UAS. Details of benefits for each specific purpose (e.g., post emergency documentation) can be found in Appendix C.

- Improved documentation or data (82 responses)
- Safety improvement (75 responses)
- Cost saving (57 responses)
- Quality improvement (56 responses)
- Time saving (53 responses)

One additional benefit noted was the use of UAS to keep employees off the roadway and improve their safety.

Challenges or Limitations

For each ITS or transportation operations purpose selected in the first question, respondents were asked to indicate any challenges or limitations. The options to select were “cannot operate above traffic,” “battery life (i.e., time in air),” “privacy,” “FAA regulation,” “registration and liability requirements,” “technical expertise,” and “funding.” Respondents were asked to select all that apply.

The following bullets summarize how many responses for each challenge were selected. Battery life overall was selected most often as a challenge and privacy was selected the least often as a challenge. Details of challenges or limitations for each specific purpose (e.g., post emergency documentation) can be found in Appendix C.

- Battery life (42 responses)
- FAA regulation (32 responses)
- Funding (24 responses)
- Cannot operate above traffic (18 responses)
- Technical expertise (13 responses)
- Registration and liability requirements (7 responses)
- Privacy (4 responses)

Weather (e.g., wind speed, cold temperatures, rain) was also noted as a huge factor by a couple of respondents as a challenge with UAS.

Chapter 4: Case Studies

This chapter provides a summary of the case studies documented for this project. The case studies were identified by reviewing survey responses and selecting a diverse set of UAS uses that were reported by the responding agency as having a successful outcome and/or a particularly novel approach (e.g., use of untethered UASs). After selecting the following case studies for expanded documentation, phone interviews were conducted with each agency to gather additional information about each specific use case, to supplement information collected through the survey.

- Case Study #1: North Dakota DOT – UAS for Supporting Road Weather Events
- Case Study #2: North Carolina DOT – Tethered UAS for On-Site Monitoring
- Case Study #3: Florida DOT – UAS for ITS Equipment Placement
- Case Study #4: New Jersey DOT – UAS Use and Program Evolution

The following details gathered from each case study are included on the following pages.

- Brief overview of their agency's UAS program.
- Details of the drones they own and operate.
- Uses of the drones focused on the case study purpose.
- Benefits of using drones.
- Challenges or limitations with using drones.
- Process used to view drone photos or video photos.
- Future uses of drones.
- Contact information.

Case Study #1

North Dakota DOT
UAS for Supporting Road Weather Events

UAS Program

The North Dakota DOT (NDDOT) UAS program was initiated through legislative action which led to participation in the Federal Aviation Administration (FAA) Integration Pilot Program (IPP) in the summer of 2018. However, NDDOT was not allowed to buy drones (aircraft) through this legislation. NDDOT partnered with a private company that had access to operate drones over people and for urban infrastructure inspection which was the focus of the NDDOT IPP project. During this pilot project, an example of flying a drone over people was during a tailgating event at North Dakota State University. The drone had covers over the propellers to provide additional protection during this flight over people. NDDOT also engaged with 146 FAA employees as part of its participation in the IPP.

Through the state legislative session in 2019, NDDOT was approved to buy drones. NDDOT started buying drones in August 2019.

Each of NDDOT's eight districts has a drone. There are 50 drone pilots statewide. They have other duties in addition to being drone pilots. NDDOT pays for a boot camp for staff to be trained and become certified though the FAA. Certification lasts for two years. NDDOT also has the ability in certain situations to hire contracted drone pilot staff, if needed, through a third-party credentialing process.

NDDOT had three approved waivers from FAA: operations over people with the parachute, night navigation (with strobe to see three miles), and beyond visual line of sight operations for floods. NDDOT is currently in the next version of the IPP after its initial 3 years which is looking beyond line of sight and focusing on inspection of infrastructure.

The agency monitors drone flights through an off-the-shelf software program with an online dashboard and logbook. The platform contains an inventory of drones, licenses, pilots, flights, flight paths, speed, altitude, and photos collected.

Drone Details

NDDOT overall has 25 operational drones. The majority of the drones are DJI MAVIC 2 and DJI MAVIC 3. The MAVIC 3 drones have been in use since March/April 2023.

These drones last approximately three years. If an older drone is used, upgrades are needed to meet FAA requirements (e.g., remote ID).

NDDOT uses a parachute developed by ParaZero on its drones. The parachute is utilized to bring a drone down safely if needed.

The NDDOT owns one larger drone (cost @ $23,000) that is able to carry the payload of a LiDAR system. The drone (UAS) LiDAR system is used in construction (e.g., pre-survey work). The NDDOT has a plane, with LiDAR capability as well, however using LiDAR on a drone is more cost effective on smaller, remote projects.

NDDOT does not use any tethered drones.

Starting in December 2025, the DOT will have to follow the American Security Drone Act. This act bars the federal government from using funds to buy drones made in China or certain other countries from December 2025 through December 2028. The NDDOT is starting to look at American made drone options. From a cost perspective, there may be less expensive American made drones available on the market, but the annual software cost could be higher.

Drone Uses

The 25 drones owned and operated by NDDOT are used all over the state (not dependent on type of road) to provide a better vantage point. Use of drones for road treatment materials stockpile inventory and weather-related events are described below:

- *Inventory Stockpiles:* Since 2020, drones have been used to inventory stockpiles (e.g., sand and salt used for road surface treatment) and determine a quantity of materials. NDDOT uses Botlink and Pix4D to measure quantities. Real-time kinematic (RTK) technology is used for measuring these quantities. Points are marked, measurements are taken, and a 3D model is developed to provide the stockpile quantities. Currently the accuracy is within 5%, however the goal is to be 1% accurate. As accuracy increases, it will be more trusted by contractors and will help the DOT with budgeting, quantities, and forecasting.
- *Monitor Snow on Roadways:* NDDOT has used a drone to investigate the condition of a roadway before sending out snowplows. See Figure 4.1.
- *Washouts/Landslides/Ice Jams and Highway Impact Observation:* Drones have been used to observe washouts, slides (e.g., pavement or where there is a hill), and ice jams. See Figure 4.1.
- *Flood Monitoring:* Drones are used during floods and are especially critical at locations where access is not possible. See Figure 4.1.
- *Community Outreach:* The drone footage in some situations is provided to the public through websites and local media, providing critical information during weather events and throughout emergency management efforts.

Figure 4.1 Drone Photos: Snow on Roadway, Ice Jam, and Flooding (Source: NDDOT)

Other uses of drones in NDDOT have included monitoring an intersection or roundabout with known issues, high-mast lighting and ancillary structure inspections, platooning, bridge inspections, tunnel and retaining walls inspections, erosion and stormwater control, traffic data collection for congestion monitoring, collecting data for before/after studies, observing traffic control setup in work zones, and observing conditions where cameras are not present.

Benefits

NDDOT noted the following benefits from drone use.

- Drones have improved safety (e.g., not have to close a lane for inspecting)
- Quality improvement
- Improved documentation or data

In addition, a major benefit to using drones is being able to obtain a significantly better vantage point (i.e., “birds eye view”) while keeping employees away from dangerous conditions such as severe weather, flooded roads, slides, and confined spaces.

Challenges and Limitations

The following were noted as challenges and limitations with drone use.

- Weather is a major factor that can limit drone use. There are challenges with flying drones in the cold, sleet, rain, moisture, and high winds. For example, a drone cannot fly in freezing rain.
- In addition, cold temperatures adversely impact battery life. In regular conditions a battery may last 23 to 25 minutes, and in cold temperatures this may decrease to 10 minutes. Some drones do have heated batteries that can increase the duration of battery life.
- Batteries are a limitation for longer distances. Multiple drone batteries are typically needed for each mission, along with a power source to charge the batteries for multiple flights that are often needed to gather information. Drones have an under 55-pound payload, so adding battery capacity to the drone itself may not be possible within the payload limitation.

Process for Viewing Drone Photos and Video

The photos and videos from drones are downloaded through a cellular hub hot spot (available in a few minutes) or at a NDDOT facility. The capability to provide the information in real-time exists, but it is not used by NDDOT. It is a much simpler process through a download of information.

The drone footage in some situations is pushed to the public through websites and local media which in some cases have received over a million views and stopped calls to NDDOT.

Future Plans

In the future NDDOT would like to program drones and use artificial intelligence (AI) to fly the 80 mile I-29 corridor to determine if the road is clear after a snow event. More than one drone would be needed for this purpose. NDDOT would also like to incorporate AI in other aspects in the future such as ancillary inspection of billboards and bridges (e.g., crack comparison).

NDDOT is currently working with the Northern Plains UAS Test Site and the state's VANTIS network to improve the ability to gather data in larger segments, such as during search and recovery after storms, and on beyond visual line of sight efforts.

Contact

Russ Buchholz, North Dakota DOT

Case Study #2

North Carolina DOT
Tethered UAS for On-site Monitoring

UAS Program

Figure 4.2 Photo of the Fotokite (Source: NCDOT STIC Grant Final Report)

North Carolina DOT (NCDOT) has sufficient camera coverage on most interstates; however, rural areas have limited camera coverage to provide situational awareness during incidents. To address this issue, NCDOT initially worked with the NC State Highway Patrol (NCSHP) to purchase five drones, purchased at $25,000 each. NCSHP focused on using these drones, also known as unmanned aircraft systems (UAS,) for their crash reconstruction investigations. In return, NCSHP would provide NCDOT with live footage of the traffic queue for situational awareness.

NCDOT also considered adding poles with cameras on their Incident Management Assistance Patrol (IMAP) vehicles, but the weight was over the maximum capacity of an IMAP vehicle, and the pole height was too low to adequately observe conditions in the field. NCDOT explored untethered drones as an option, and decided not to pursue those because of the requirement for a FAA drone certification (Part 107 FAA Certification).

NCDOT piloted tethered UAS as an option since operating one does not require a FAA Certification if flown below 150 feet, and therefore IMAP supervisors could operate the drones. NCDOT received a $50,000 State Transportation Innovation Council (STIC) Grant to assess two types of tethered drones (Fotokite (See Figure 4.2) and MAVIC-2 with a V-line tether). For more information on the pilot study, please see the report: NCDOT STIC Grant Final Report: Safety Service Patrol Technology Pilot Project.

UAS operator training includes a tethered drone checklist developed in partnership with the NCDOT Division of Aviation. NCDOT's Incident Management program also includes standard operating procedures (SOPs) for tethered drone use.

Drone Details

To operate the tethered Fotokite and MAVIC-2, both systems need to be stationary, placed on the ground, and stable.

The Fotokite moves up to 150 feet vertically in the air, with the gimbal-mounted dual camera capable of panning left or right. The Fotokite system also includes thermal visioning. The drone needs a power source, and, in this case, it was plugged into the IMAP vehicle via a high-powered inverter. On one occasion, the drone was in the air for 7 to 8 hours providing live-stream of a long-term lane closure. If the Fotokite drone loses power, it will begin to shut down and land on its ground station.

The MAVIC-2 needs a battery source to operate or it can also be directly connected to the IMAP truck via a power inverter. The system includes 6-pack rechargeable batteries that will power the UAS for approximately 12 hours on battery power, or longer if using vehicle power. This drone, when operated with a V-line tether, can move vertically, and left to right.

Drone Uses

Tethered drones are useful in rural areas or other areas where there is limited camera coverage. Urban areas typically have sufficient camera coverage, and tethered drones would not be necessary except in situations when a camera is not working, or the view is blocked by trees. For example, NCDOT deployed a tethered drone at a location where a camera was not working to support viewing conditions during a bridge strike on I-95. NCDOT was able to utilize Integrated Corridor Management (ICM) strategies to reroute traffic. NCDOT used the tethered drone to monitor the situation, which helped DOT staff in adjusting signal timings on the arterial roadway. See Figure 4.3.

Figure 4.3 Drone Footage (Source: NCDOT)

NCDOT has contracted with consulting firms to use drones for multiple purposes, including camera height determination.

Benefits

NCDOT noted the following benefits of tethered drone use.

- Improved safety with real-time traveler information
- Improved situational awareness of on-scene support
- Time savings

Challenges and Limitations

NCOT noted the following challenges with tethered drone use.

- Tethered drones are constrained by the line of sight (operator to the drone). An IMAP supervisor had to always remain close to the tethered drone.
- There were concerns about the drone falling around traffic if it lost power (MAVIC-2).
- The IMAP supervisor had to place their vehicles with the tethered drones in a location that provided the best coverage of back-of-queue monitoring. This was not always the best location for the IMAP supervisor to support the incident.
- Large no-fly areas around North Carolina airports affect the locations where tethered drones can be flown.

Process for Viewing Drone Photos and Video

The Fotokite system uses a video application dashboard within the video management system to stream live video. This system generates a QR code, provided to the Statewide Transportation Operations Center (STOC) and those on scene, to view the live footage. For the MAVIC-2 tethered drone, IMAP supervisors could only share the video via Microsoft Teams, which the STOC accessed.

NCDOT does not record videos.

Future Plans

Since the pilot project, NCDOT has used the two tethered drones in limited situations. The NCDOT plans to continue to use the drone with incidents with no camera coverage. They are also looking into other situations with their regions could use the drones to support incident management in other ways, like special events.

Equipping each IMAP vehicle with a tethered drone could potentially add $30,000 to each truck. Since the cost is high, NCDOT is looking at other options to provide situational awareness, including dash cameras.

Contact

Dominic Ciaramitaro, North Carolina DOT

Case Study #3

Florida DOT
UAS for ITS Equipment Placement

UAS Program

Florida DOT (FDOT) a few years ago utilized UAS pilots from consultants for various uses, however during hurricane events there were issues with consultants gaining necessary access to restricted areas and providing the drone footage to FDOT. To avoid these constraints, FDOT progressed into creating a UAS department where trained and licensed FDOT staff can operate drones. Currently FDOT has a trained drone pilot in each district.

Drone Details

Most drones used by FDOT are untethered. The agency recently implemented tethered drones. One of the larger drones has GPS and AI. FDOT has procured a weather resistant UAS that flies in full downpour and up to 55 MPH wind.

Drone Uses

FDOT has utilized drones to determine traffic camera placements and heights. On I-10 where the 200-mile stretch of roadway has rural areas and hills, drones were used to determine camera spacing and pole heights to ensure there was coverage for the entire corridor. Traffic Management Center (TMC) staff are involved, utilizing drone results along with engineering judgement to finalize camera placements.

Drones are also used to inspect the 350-foot radio towers around the state annually. If during the year there are issues with an antenna (e.g., high-rise building blocks a signal) a drone is used to re-engineer line of sight. See Figure 4.4.

Figure 4.4 Drone Footage (Source: FDOT)

Other uses of the drones include stockpile inventory, observing conditions where cameras are not present, video recording for post-incident debriefing, incident mapping, post-emergency documentation, on-site incident scene monitoring, reconstruction of signal infrastructure damage, bridge inspection, and microwave tower modeling. During emergencies, drones are used to collect and transmit images to the governor's office to communicate the event conditions and response efforts. Drones are also used for traffic management during crashes (e.g., if a camera goes out) to obtain a 360-degree view. A common platform (DiVAS) is used to share the resulting footage with first responders.

Benefits

FDOT noted the following benefits from drone use.

- Quality improvement
- Improved documentation or data
- Cost saving
- Time saving

Challenges and Limitations

The following were noted as challenges with drone use.

- Flight restrictions can limit success if restrictions are in place at the same time FDOT has a need for drone footage.
- Battery life

Process for Viewing Drone Photos and Video

Video from the drones is streamed live during emergencies and for incident management. If cellular towers are down, satellite is used to transmit the live stream. A pilot can also download and transfer footage near a DOT network.

Figure 4.5 Screenshot of Dashboard to View Photos and Videos (Source: FDOT)

The Skydio 2 video aggregation platform is used by FDOT. A dashboard is used to view certified pilots and to view the photos and video from each mission. FDOT controls access to the footage, both internal and external to the agency. See Figure 4.5.

Live video collected by drones is not recorded, per FDOT legislation.

Future Plans

Based on new regulations, FDOT has transitioned to use of American made drones.

Contact

Kenneth Shiver, Florida DOT

Case Study #4

New Jersey DOT
UAS Use and Program Evolution

UAS Program

The New Jersey Department of Transportation (NJDOT) is considered a public operator of UAS/drone technology. Currently, NJDOT operates under a blanket public Certification of Waiver or Authorization (COA), which allows them to operate drones in Class G airspace (uncontrolled) airspace at or below 400 feet, self-certification of the UAS pilot, and the option to obtain emergency COAs under special circumstances.

The inception for the program was born in 2017 and the program started in 2018. NJDOT utilized the FJWA State Transportation Innovation Council (STIC) Incentive program (See: STIC Incentive Projects (FY 2014-2022) | Federal Highway Administration (dot.gov) that provides $100,000 to each state yearly. Some of these funds were used to hold a training workshop as well as a peer exchange with other state DOTs.

As the program started, the different areas within NJDOT were asked how drones could support them. The drones were used initially for traffic counts and for unique congested areas.

The program is in the process of purchasing drone “go bags” for emergency response that include all necessary equipment for deploying a drone and will be capable of feeding live video from an incident scene into the Department’s traffic management centers. There are three regions at NJDOT (North, Central, and South) and three regional Incident and Emergency Management Coordinators. Each regional office will have 2 drones. Six (6) “go bags” will be purchased to support the regions.

In NJDOT, drone pilots become certified through a rigorous and time-intensive process which has been developed by NJDOT and conforms with state and federal regulations. NJDOT drone pilot certification is a three-part curriculum that includes two days of classroom preparation for the FAA Part 107 Small UAS Pilot Certification; two days of practical training which includes learning best practices, becoming familiar with the fleet of various drones and gaining hands-on flight experience; and passing a competency evaluation by planning and conducting a comprehensive flight mission.

There are 30 trained pilots to fly missions at NJDOT and they are recertified every 2 years. Drone flight requests from trained DOT staff can be made online.

The following is additional information about NJDOT’s Program.

- Innovation Spotlight: NJDOT UAS Program
- Drone Technology at NJDOT
- Executive Branch of New Jersey State Government: Statewide information Security Manual
- NJDOT Technology Transfer: UAS

Drone Details

NJDOT UAS Program currently operate with 11 drones:

- 1- Parrot Anafiai
- 2 -DJI Inspire 2
- 1- DJI Inspire 3
- 1- DJI M30
- 1- DJI M300
- 2- DJI Mavic 3
- 2- Skydio X2
- 1- Skydio X2E

Five drones have been retired and are now used for education and research.

Drone Uses

NJDOT's UAS/drone program receives mission requests from at least 38 divisions and has been able to demonstrate feasibility and benefits for a dozen different types of state transportation operations, including:

- Structural inspections
- Real-time construction project monitoring
- Traffic incident management
- Emergency management activities
- Aerial 3D mapping
- Traffic congestion assessments

UAS are used on interstates, state highways, urban areas, and rural areas.

Drones are not utilized for monitoring work zones on a programmatic basis. However, live stream videos from drones have been used by traffic operations and command posts to assess traffic congestion during construction (see Figure 4.6). Drones were also used during a long-term work zone outside of the Lincoln Tunnel to monitor traffic conditions during a major rehabilitation project in 2017.

In the Camden area, a construction interchange location experienced a structural issue to heavy rain (2021). Drones were used to view the damage to the roadway to work with the contractor on the response. The footage was used in townhall meetings.

Drones have also been used to observe and monitor conditions during landslides (2023). See Figure 4.7.

Figure 4.7 Screenshot of Live Stream Videos from Drones to Assess Traffic Congestion During Construction (Source: Innovation Spotlight: NJDOT UAS Program)

Figure 4.6 Screenshot of Drone Footage – Rockfall along I-287 (Source: Innovation Spotlight: NJDOT UAS Program)

A wide variety of drones have been used for responses to flood events in New Jersey. The drones on-site provide photos and video of the area to better assess emergency response.

Requests for drones continue to increase, for example the DOT's landscaping area is using drones for initiating pollination reviews and studies. Safety inspections are also conducted at airports that provide owners with footage for use as they apply for safety grants. Other uses are by local MPOs to view projects pre and post construction. Drones have also been used for areas where a rail line is converted into a trail to provide images to the local community.

Benefits

NJDOT noted the following benefits from drone use.

- Improved documentation or data.
- NJDOT has found that the use of UAS/drone technology when conducting structural inspections has increased safety benefits, as well as clarity. The high-quality cameras equipped to the drones provide highly accurate images of the areas in need of inspection.
- A major benefit of drone use is the ability to operate safely during emergency situations and dangerous conditions. For example, during a significant rain event that caused a mudslide,

NJDOT was able to gain situational awareness to assist with response efforts, communicate with the public, and to observe geotechnical conditions to assist with mitigating the impacts.

Challenges and Limitations

The following were noted as challenges with drone use.

- There are challenges with flight restrictions in New Jersey with numerous, densely located airports in the area. DOT staff work closely with the FAA to apply for waivers and maintain working relationships.
- Laws prohibit drones from flying over a highway. In addition, some municipalities do not want drones to operate in their area.
- Drones used by the DOT and by recreational drone users are currently regulated by the same laws, so there are challenges for the DOT when regulation is based on recreational use of drones.

Process for Viewing Drone Photos and Video

Video is downloaded once the drone completes its mission on Secure Digital (SD) cards. In the future NJDOT is designing their aircraft to provide continuous live video streams for TMC operators to view conditions. There are challenges with adding video for viewing on NJDOTs secure network. NJDOT currently records video from its traffic cameras on a 7-day rolling basis. The Department will need to make the determination whether or not video footage from UAS will fall into the same category.

Future Plans

NJDOT plans deploy drone “kits” that will be located around the state, to function like a portable camera. The agency is also working to transmit footage to the TMC in real-time.

Contacts

Sal Cowan and Kimbrali Davis, New Jersey DOT

Chapter 5: Key Findings and Implementation

The ENTERPRISE Pooled Fund Study completed this project "Novel Uses of UAS in ITS" to explore ways to optimize UAS integration with ITS and operations within transportation agencies. The project identified numerous UAS use cases for ITS and transportation operations that are being used in practice, researched, tested, planned, or considered by state DOTs. Further, details about four successful ITS and transportation operations use cases were gathered, demonstrating practices for implementing these use cases for state DOT operations.

5.1 Key Findings

This section highlights key findings found in the literature search, survey, and case studies.

Literature Search

The literature search revealed more than 60 UAS use cases (e.g., special event traffic monitoring, queue observation) that are being used in practice, researched, tested, considered, or planned by state DOTs. More than 30 of these use cases were focused on ITS and transportation operations UAS efforts. These ITS and transportation operations use cases were then organized into nine categories. See Table 5.1.

Table 5.1 UAS Use Cases: ITS and Transportation Operations

Category	UAS Use Cases from Literature*
#1: Real-time traffic monitoring	• Special event traffic monitoring • Queue observation • Live streaming traffic video where cameras are not available • Congestion assessment
#2: Assess traffic operations strategies and traffic control	• Before/after studies (e.g., for ramp meter installations) • Roundabout assessment • Traffic control assessment • Work zone setup (i.e., ensure work zone elements positioned correctly) • Work zone traffic control documentation
#3: Traffic data collection	• Traffic characterization for monitoring (i.e., obtain traffic counts, speeds, origin-destination flow, density, with real-time analytics) • Traffic flow data collection at intersections (e.g., vehicle counts, classification, speed, trajectory) • Highway speed-sensing (collect speed data for speed limit setting)
#4: Traffic incident management	Response and monitoring: • Traffic monitoring, incident scene monitoring • Equip emergency vehicles with UAS to expedite response times Post-incident analysis: • Post-incident review • Collision scene reconstruction and investigation • Incident mapping

Category	UAS Use Cases from Literature*
#5: Emergency operations	Pre-hazard planning: • Landslide and rockslide prediction, monitoring, mapping Management, monitoring, and response: • Assess and monitor road hazards and emergency situations (e.g., sink holes, fallen rocks, unstable slopes, bridge failures, flooding) • Bridge scour monitoring, damage inspection, and searching operations • First responder situational awareness • Avalanche mitigation • Deploy UAS with visual warnings to alert drivers of upcoming emergencies Post-hazard documentation: • Damage assessment (e.g., rockfalls, storm damage) • Post-incident documentation (e.g., after train derailment)
#6: Road weather management	• Weather forecasting • Prewinter storm brine spreading • Assess drainage issues pre-storm • Snow mapping • Snow plowing activity • Gather situational awareness data on snow, ice, and overland trails
#7: Parking management	• Illegal or unintended parking assessment • Parking lot utilization monitoring
#8: Locate and evaluate ITS assets	• Evaluation of closed-circuit television locations
#9: Communications networks	• Create ad-hoc communications networks (deploy multiple airborne hosts for temporary communications access points, to allow communications at locations where cellular or other communications are not present)

**See Appendix A for details and citations.*

In addition to the UAS use cases that support ITS and transportation operations applications, more than 30 use cases in 17 other (non-ITS) categories (e.g., agriculture and environment assessment, airports/air transportation) were identified, showing the breadth of UAS uses that are being considered, researched, or implemented by transportation agencies. See Appendix A.

Survey

Based on the literature search, survey questions were developed to gather additional information on the use of UAS for ITS and transportation operations purposes from state DOTs. Twenty-one agencies responded to the survey. The following are key findings from the survey responses.

- Agencies reported a wide range of ITS and transportation operations purposes for which they are using UAS. The highest number of responses indicated use of UAS for post-emergency documentation, observing conditions where cameras are not present, traffic data collection for congestion monitoring, on-site incident scene monitoring, and collecting data for before/after studies.

- Though the stage of implementation varies for each purpose, the use of UAS appears to be trending beyond research and testing (toward being implemented) for many of the ITS and transportation operations purposes reported.
- Every survey respondent indicated that they use untethered drones. Only one agency indicated the use of tethered drones for on-site incident scene monitoring and to determine traffic camera heights.
- Respondents noted indicated a very successful outcome with the use of UAS for post emergency documentation, video recording for post-incident debriefing, and observing conditions where cameras are not present.
- Improved documentation or data and safety improvement were selected most often as benefits of UAS.
- Battery life and FAA regulations were selected most often as a challenge or limitation.

Case Studies

Four case studies were identified by reviewing survey responses and selecting a diverse set of UAS uses that were reported by the responding agency as having a successful outcome and/or a particularly novel approach (e.g., use of untethered UAS). After selecting case studies for expanded documentation, phone interviews were conducted with each agency to gather additional information about each specific use case to supplement information collected through the survey.

- Case Study #1: North Dakota DOT – UAS for Supporting Road Weather Events
- Case Study #2: North Carolina DOT – Tethered UAS for On-Site Monitoring
- Case Study #3: Florida DOT – UAS for ITS Equipment Placement
- Case Study #4: New Jersey DOT – UAS Use and Program Evolution

Following are key findings from the case studies:

- Each agency has trained staff within their agency to operate their drones. Staff are trained within the agency and certified through the FAA every two years. A drone pilot license is not required to operate tethered drones.
- Drones typically last 3 to 5 years. If an older drone is used, upgrades are needed to meet FAA requirements. Retired drones are often used for training purposes.
- Starting in December 2025, DOTs will have to follow the American Security Drone Act. This act bars the federal government from using funds to buy drones made in China or certain other countries from December 2025 through 2028. Some agencies are already using American made drones, and others are beginning to research American made drone options.
- Participating agencies reported significant benefits with use of UAS for obtaining views that would not otherwise be possible, improving safety for employees and contractors as they operate drones away from hazardous conditions, and communicating conditions (e.g., emergencies or hazardous situations) to decision makers and the public.
- There are challenges with flying drones in unfavorable weather conditions (e.g., cold, sleet, rain) as well as battery life for longer flights and distances.

- Video and photos captured from drones can be viewed in real-time or downloaded after use.
- Agencies reported the use of software platforms to track UAS program information such as drone inventories, pilots, licenses, flights, flight paths, speed, altitude, and to view drone footage.

5.2 Implementation

The research resulted in several resources that ENTERPRISE member agencies can use to information staff about the ITS and transportation operations uses of UAS including:

- Literature search summary (Chapter 2)
- Survey of transportation agencies (Chapter 3)
- Case Studies (Chapter 4)

Transportation agencies can implement the results of this research in several ways. Recommended implementation steps could include the following actions:

1. Distribute the report to UAS program staff at ENTERPRISE agencies as well as others within the agency that request UAS support.

2. Review the resources found through the literature search in Appendix A to understand the wide range of unique UAS use cases being used in practice or being researched, tested, considered, or planned by transportation agencies.

3. Review the four successful ITS and operational case studies of UAS to help agencies understand the details of operational and ITS uses, including types of drones used for specific purposes, benefits, challenges, and lessons learned.

4. As ENTERPRISE members learn from these research findings and understand their agencies' most likely use cases, ENTERPRISE could consider conducting a follow-up project to seek and document case studies for additional specific ITS and operations use cases, beyond the four case studies that were created for this project. For example, focusing on UAS uses for work zone management or parking management.

Overall, the research conducted for this project provided ENTERPRISE member agencies with numerous UAS use cases that are being used in practice, researched, tested, considered, or planned by state DOTs. Further, details about successful ITS and transportation operations use cases were gathered from four state DOTs, demonstrating practices for implementing these use cases for state DOT operations.

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Appendix A
Literature Search UAS Use Cases: Details and Citations

UAS Use Cases: Details and Citations

The following tables provide UAS use cases that are being in practice or being researched, tested, considered, or planned by transportation agencies. For each use case, the following information (as available from each publication) is tabulated:

- Use case;
- State DOT(s), if noted;
- Citation;
- Publication's sponsoring agency;
- Publication type; and
- Publication date (year).

It is important to note that this compilation of use cases does not comprehensively indicate the stage of implementation. This is because in many publications, the stage of implementation was not explicitly stated. Further, because the publications reviewed date back to 2018, the stage of implementation for any given agency use case may have changed since the date of the publication.

ITS and Operations Use Cases

Table A.1 Literature Search: Real-time Traffic Monitoring

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Traffic maintenance		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Special event traffic monitoring		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Queue observation		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Live streaming traffic video where cameras are not available		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Traffic monitoring and management	Ohio DOT	Helmicki et al., 2021	Ohio DOT	Research Report	2021
Traffic monitoring / traffic analysis	Massachusetts DOT	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021
Traffic Congestion Assessment	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Traffic Monitoring	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Traffic monitoring	Utah DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Traffic Congestion Assessment	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-

Table A.2 Literature Search: Assess Traffic Operations Strategies and Traffic Control

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Work zone traffic control documentation	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Work zone setup (ensure work zone elements are positioned correctly)	Iowa DOT	Iowa's News Now, 2023	Iowa News Now	News Article	2023
Ramp metering assessment		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Roundabout assessment		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Traffic control assessment		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Transportation operations and studies (e.g., before/after traffic studies for ramp meter installations)	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021

Table A.3 Literature Search: Traffic Data Collection / Congestion Assessment

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Traffic characterization (type, speed, count, etc.)		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Traffic flow data collection (vehicle counts, vehicle classification, speed, trajectory) at intersections	Virginia DOT	Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Traffic monitoring/operations (obtain traffic counts, origin-destination flow, and density, with real-time analytics)	Michigan DOT	Brooks et al., 2022	Michigan DOT	Research Report	2022
Traffic management (traffic data collection, traffic flow monitoring, qualitative assessment congested interchanges, etc.)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Traffic data collection (i.e., collect volume and speed data)		Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Highway speed-sensing applications (i.e., collect speed data for speed limit setting purposes)	Massachusetts DOT (research)	Knodler et al., 2019	Massachusetts DOT	Research Report	2019

Table A.4 Literature Search: Traffic Incident Management

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Incident scene monitoring	Iowa DOT	Iowa's News Now, 2023	Iowa News Now	News Article	2023
Post-incident review (use drone footage to review road setup and responder actions)	Iowa DOT	Iowa's News Now, 2023	Iowa News Now	News Article	2023
Incident mapping		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Incident management		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Traffic Incident Management (e.g., real-time traffic surveillance, simulation models calibration, vehicle and traffic conditions quantification, and semi-automated video and image annotation)	Michigan	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Collision Scene Reconstruction and Investigation	North Carolina	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Traffic Incident Management	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Equipping emergency vehicles with UAS to expedite response time	Utah DOT (possible future)	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Collision reconstruction	North Carolina DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Traffic Incident Management	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-
Accident reconstruction	North Carolina State Highway Patrol	USDOT, n.d.-b	USDOT	Informational Document	-

Table A.5 Literature Search: Emergency Operations

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Rockfall assessment	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Emergency relief events	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Roadway emergency alert (deployable UAS that utilize visual warnings to alert drivers of upcoming emergencies on the roadway)		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Landslide assessment		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
First responder situational awareness (emergency event where first responders deploy a UAS to gain situational awareness before arriving to the scene)		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Assessment of road hazards (sink hole, road weather, fallen rocks, etc.)		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Emergency operations pre-hazard monitoring (prewinter storm brine spreading, drainage issues pre-storm, etc.)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Emergency operations post-hazard monitoring (bridge scour monitoring, damage inspection, searching operations, etc.)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Emergency management (highway incidents, railway, flooding, bridge failure, etc.)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Emergency response monitoring (monitoring situations such as unstable slopes and rockslides)	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Post-incident documentation (e.g., after train derailment)	Washington State Patrol	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Emergency response and recovery	Vermont Agency of Transportation	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021
Landslide and Rockslide Prediction and Monitoring	Colorado, California, Vermont	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Storm Damage Assessment	North Carolina, Texas	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Emergency services (i.e., obtain post-disaster information for emergency	Massachusetts DOT (research)	Knodler et al., 2019	Massachusetts DOT	Research Report	2019

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
response and disaster damage assessment					
Rockfall sites	Montana DOT	Tritsch, 2019	FHWA	Peer Exchange Summary Report	2019
Emergency Response Assessment	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Quick Clear Operations/Emergency Management	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Landslide monitoring / landslide mapping	Utah DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Emergency response	Utah DOT (possible future)	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Avalanche mitigation	Utah DOT (possible future)	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Disaster response and recovery operations	North Carolina DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Emergency management operations	North Dakota DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Emergency Response Assessment	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-
Documentation following train derailment	Washington State DOT	USDOT, n.d.-b	USDOT	Informational Document	-

Table A.6 Literature Search: Road Weather Management

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Weather Forecasting		Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Snow Mapping (support improved snow removal efforts)		Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Snow plowing activity	Montana DOT	Tritsch, 2019	FHWA	Peer Exchange Summary Report	2019

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Gather situational awareness data on snow, ice, and overland trails	Alaska DOT & Public Facilities (planned)	USDOT, n.d.-c	USDOT (FY 22 SMART Grant)	Informational Document	-

Table A.7 Literature Search: Parking Management

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Illegal or unintended parking assessment		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Parking Lot Utilization Monitoring	Arizona, Colorado, Delaware	Fischer et al., 2020	FHWA	Research / Desk Scan	2020

Table A.8 Literature Search: Locate and Evaluate ITS Assets

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Evaluation of closed-circuit television locations		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022

Table A.9 Literature Search: Communications Networks

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Ad-hoc communications network (multiple airborne hosts for temporary comm's access points deployed in a daisy chaining manner to allow comm's where there may be no cellular or other comm's)		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022

Non-ITS Use Cases

Table A.10 Literature Search: Agriculture and Environmental Assessment

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Wetland mitigation	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Wetland mitigation	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Subaquatic vegetation monitoring		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Environmental surveys (e.g., vegetation inspection, wildlife management)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Plant health	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Herbicide spray applications	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Precision agriculture	Kansas DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-

Table A.11 Literature Search: Airports/Air Transportation

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Airport obstruction survey		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Aeronautics (e.g., 5010 obstacle mapping)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Airport safety and runway inspections	Kansas DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-

Table A.12 Literature Search: Asset Management

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Asset management	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Identification, Assessment, and Inventorying of Roadway Assets	Ohio, Vermont	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Asset and property management - LiDAR for asset management	Utah DOT (possible future)	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018

Table A.13 Literature Search: Construction

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Quantity calculations	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Construction inspection	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Construction documentation (prosecution and progress, project quantities)	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Construction inspection	Michigan DOT	Brooks et al., 2022	Michigan DOT	Research Report	2022
Highway Construction: Perform routine quality inspection	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022
Highway Construction: Perform work safety inspection	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022
Highway Construction: Measure stockpiles	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022
Highway Construction: Monitor work progress	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022
Highway Construction: Inspect and document erosion and sediment control	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022
Highway Construction: Provide arterial surveying	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022
Highway Construction: Mapping (3D modeling) of construction	Multiple states	Turkan et al., 2022	NCHRP	Research Report	2022

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Construction inspection (e.g., aerial site surveys, real time construction monitoring, etc.)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Construction monitoring	Ohio DOT	Helmicki et al., 2021	Ohio DOT	Research Report	2021
Construction inspection	Connecticut DOT	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021
Construction monitoring	Montana DOT	Tritsch, 2019	FHWA	Peer Exchange Summary Report	2019
Real-time Construction Project Monitoring	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Construction Monitoring	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Real-time Construction Project Management	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-

Table A.14 Literature Search: Counter-UAS Operations

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Counter-UAS operations to enforce illicit use of UAS by bad actors	Utah DOT (possible future)	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018

Table A.15 Literature Search: Delivery Services

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Product deliveries		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Medical specimen delivery	North Carolina DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Food delivery	North Carolina DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-

Table A.16 Literature Search: Design Survey

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
LiDAR UAS for design survey	Michigan DOT	Brooks et al., 2022	Michigan DOT	Research Report	2022
Planning survey (e.g., conceptual design, transportation corridor design)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Surveying and mapping	New Hampshire DOT	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021

Table A.17 Literature Search: Facility Maintenance

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Facility maintenance	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023

Table A.18 Literature Search: Geologic Assessment

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Earth movement	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Erosion Research	Minnesota, California, North Carolina	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Geohazard Modeling and Monitoring	Colorado DOT	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Geologic Mapping		Fischer et al., 2020	FHWA	Research / Desk Scan	2020

Table A.19 Literature Search: Ground Vehicle Assistance

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Ground vehicle assistance (UAS assist with navigation of ground vehicles whether manned or autonomous)		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022

Table A.20 Literature Search: Image Collection

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Event photography	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021
Videography and Photography	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Thermal imagery	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Aerial Photography/GIS	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018

Table A.21 Literature Search: Infrastructure Inspection

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Supplemental bridge inspections	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Light towers inspections	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Infrastructure inspection	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
In-service structure inspection	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Bridge and bridge deck inspection		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Overhead sign inspections		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Bridge inspection	Michigan DOT	Brooks et al., 2022	Michigan DOT	Research Report	2022
Physical infrastructure inspection (e.g., bridges, tunnels, railways, roadways, drainage systems,	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
trenches, high mast light poles, traffic signs, and barriers)					
Bridge and facility inspection	Ohio DOT	Helmicki et al., 2021	Ohio DOT	Research Report	2021
Inspections	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Bridge inspection	Maine DOT	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021
Traffic Signal Inspection		Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Bridge Inspection	Alabama, California, Connecticut, Florida, Idaho, Kentucky, Michigan, Minnesota	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Confined Space Inspection (wells, tunnels, pump stations, bridge beams and pier towers)	Minnesota	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Railroad Inspection (explored use)	Vermont, North Carolina	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
High Mast Light Pole Inspection	New Jersey	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Bridge and rail inspections	Massachusetts DOT (research)	Knodler et al., 2019	Massachusetts DOT	Research Report	2019
Assessment of roadway pavement conditions	Massachusetts DOT (research)	Knodler et al., 2019	Massachusetts DOT	Research Report	2019
Bridge inspection	Minnesota DOT	Tritsch, 2019	FHWA	Peer Exchange Summary Report	2019
Structural Inspections	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
High Mast Light Pole Inspections	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Exterior/interior Inspections	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Structures/Facilities Inspections	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Structure inspections (delamination, deck mapping, etc.)	Utah DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Light tower inspections	Kansas DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Power line inspections	Kansas DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Power line inspections	North Dakota DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Bridge inspections	North Dakota DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-
Structural Inspections	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-
Bridge inspection	Minnesota DOT	USDOT, n.d.-b	USDOT	Informational Document	-
Bridge inspection	Michigan DOT	USDOT, n.d.-b	USDOT	Informational Document	-

Table A.22 Literature Search: Mapping and Modeling

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Aerial mapping	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Aerial mapping	Ohio DOT	Helmicki et al., 2021	Ohio DOT	Research Report	2021
Aerial mapping/photogrammetry	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
2D/3D mapping	Washington State DOT	Leingang & Ryan, 2021	16th Annual Western States Forum	Conference Presentation	2021
Aerial 3D Corridor Mapping	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
3D Reality Modeling	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Aerial 3D Corridor Mapping	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-
3D Reality Modeling	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-

Table A.23 Literature Search: Maritime

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Maritime (e.g., channel dredging)	New Jersey DOT	Agrawal et al., 2021	FHWA/New Jersey DOT	Research Report	2021

Table A.24 Literature Search: Media / Public Relations

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Public engagement	Iowa DOT	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Public relations	South Dakota DOT (possible/interest)	Wheeler & Mallela, 2023	FHWA	Peer Exchange Summary Report	2023
Public outreach and engagement	Rhode Island DOT	Mallela et al., 2021	New England Transportation Consortium	Research Report	2021
Communications/Promotional Videos	Ohio DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Joint media operations	North Dakota DOT	FAA, n.d.	Federal Aviation Administration	UAS Integration Pilot Program Summary	-

Table A.25 Literature Search: Virtual Design, Construction, and Project Evaluation

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Monitoring engineering design		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Project evaluation		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Virtual Design and Construction		Fischer et al., 2020	FHWA	Research / Desk Scan	2020

Table A.26 Literature Search: Volumetric Analysis

Use Case	State DOT, if noted	Citation	Sponsoring Agency	Publication Type	Publication Date
Earthwork and stockpile volume determination		Alden et al., 2022	Virginia Transportation Research Council	Research Report	2022
Estimate Pond Capacity	Colorado	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Estimate Aggregate Mound Volume	Michigan	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Volume Estimation for Damaged Roadways	Vermont	Fischer et al., 2020	FHWA	Research / Desk Scan	2020
Stockpile measurements	Montana DOT	Tritsch, 2019	FHWA	Peer Exchange Summary Report	2019
Landfill Volume Calculations	New Jersey DOT	Quinton & Regan, 2018	FHWA	Peer Exchange Summary Report	2018
Landfill volume calculations	New Jersey DOT	USDOT, n.d.-b	USDOT	Informational Document	-

Appendix B
Survey Questions

ENTERPRISE: UAS for ITS

Contact Information

1. Please provide your contact details. This information will be used if additional information or clarification is needed from this survey.

Name:

Agency:

Email:

ENTERPRISE: UAS for ITS

UAS Use

* 2. For which of the following intelligent transportation systems (ITS) or transportation operations purposes does your agency use UAS (e.g., tested or implemented)? Select all that apply.

- [ ] Traffic data collection for congestion monitoring
- [ ] Pedestrian or bicyclist data collection
- [ ] Collect data for before/after studies
- [ ] Observe traffic control setup in work zones
- [ ] Observe conditions where cameras are not present
- [ ] On-site incident scene monitoring
- [ ] Video recording for post-incident debriefing
- [ ] Collision scene reconstruction
- [ ] Incident mapping
- [ ] Weather forecasting
- [ ] Road surface treatment
- [ ] Road surface detection (e.g., snow, flood, ice)
- [ ] Snow plowing activity monitoring
- [ ] Post-emergency documentation
- [ ] Parking lot utilization
- [ ] Illegal or unintended parking assessment
- [ ] Equip multiple UAS to create ad-hoc communications network
- [ ] Determine traffic camera heights
- [ ] Determine sight lines for radio infrastructure
- [ ] None

Please describe any other ITS or transportation operations UAS purposes your agency has used or is testing that is not listed above.

ENTERPRISE: UAS for ITS

UAS Implementation and Outcomes

For each ITS or transportation operations UAS use case identified in Question #2, please respond to the following questions.

3. What is the stage of implementation?

	Research/testing	Implemented
Traffic data collection for congestion monitoring	○	○
Pedestrian or bicyclist data collection	○	○
Collect data for before/after studies	○	○
Observe traffic control setup in work zones	○	○
Observe conditions where cameras are not present	○	○
On-site incident scene monitoring	○	○
Video recording for post-incident debriefing	○	○
Collision scene reconstruction	○	○
Incident mapping	○	○
Weather forecasting	○	○
Road surface treatment	○	○
Road surface detection (e.g., snow, flood, ice)	○	○
Snow plowing activity monitoring	○	○
Post-emergency documentation	○	○
Parking lot utilization	○	○
Illegal or unintended parking assessment	○	○
Equip multiple UAS to create ad-hoc communications network	○	○
Determine traffic camera heights	○	○
Determine sight lines for radio infrastructure	○	○

Comments (Please identify which UAS use case(s) your comment refers to):

4. What type of drone is typically used?

	Tethered	Untethered
Traffic data collection for congestion monitoring	○	○
Pedestrian or bicyclist data collection	○	○
Collect data for before/after studies	○	○
Observe traffic control setup in work zones	○	○
Observe conditions where cameras are not present	○	○
On-site incident scene monitoring	○	○
Video recording for post-incident debriefing	○	○
Collision scene reconstruction	○	○
Incident mapping	○	○
Weather forecasting	○	○
Road surface treatment	○	○
Road surface detection (e.g., snow, flood, ice)	○	○
Snow plowing activity monitoring	○	○
Post-emergency documentation	○	○
Parking lot utilization	○	○
Illegal or unintended parking assessment	○	○
Equip multiple UAS to create ad-hoc communications network	○	○
Determine traffic camera heights	○	○
Determine sight lines for radio infrastructure	○	○

Comments (Please identify which UAS use case(s) your comment refers to):

5. Which of the following best describes your agency's outcome with use of UAS for this purpose?

	Not successful	Somewhat successful	Very successful	Too early to determine
Traffic data collection for congestion monitoring	◯	◯	◯	◯
Pedestrian or bicyclist data collection	◯	◯	◯	◯
Collect data for before/after studies	◯	◯	◯	◯
Observe traffic control setup in work zones	◯	◯	◯	◯
Observe conditions where cameras are not present	◯	◯	◯	◯
On-site incident scene monitoring	◯	◯	◯	◯
Video recording for post-incident debriefing	◯	◯	◯	◯
Collision scene reconstruction	◯	◯	◯	◯
Incident mapping	◯	◯	◯	◯
Weather forecasting	◯	◯	◯	◯
Road surface treatment	◯	◯	◯	◯
Road surface detection (e.g., snow, flood, ice)	◯	◯	◯	◯
Snow plowing activity monitoring	◯	◯	◯	◯
Post-emergency documentation	◯	◯	◯	◯
Parking lot utilization	◯	◯	◯	◯
Illegal or unintended parking assessment	◯	◯	◯	◯
Equip multiple UAS to create ad-hoc communications network	◯	◯	◯	◯
Determine traffic camera heights	◯	◯	◯	◯
Determine sight lines for radio infrastructure	◯	◯	◯	◯

Comments (Please identify which UAS use case(s) your comment refers to):

ENTERPRISE: UAS for ITS

UAS Benefits and Limitations

6. What benefits have resulted from using UAS for each purpose? Select all that apply.

	Cost saving	Time saving	Safety improvement	Quality improvement	Improved documentation or data
Traffic data collection for congestion monitoring	☐	☐	☐	☐	☐
Pedestrian or bicyclist data collection	☐	☐	☐	☐	☐
Collect data for before/after studies	☐	☐	☐	☐	☐
Observe traffic control setup in work zones	☐	☐	☐	☐	☐
Observe conditions where cameras are not present	☐	☐	☐	☐	☐
On-site incident scene monitoring	☐	☐	☐	☐	☐
Video recording for post-incident debriefing	☐	☐	☐	☐	☐
Collision scene reconstruction	☐	☐	☐	☐	☐
Incident mapping	☐	☐	☐	☐	☐
Weather forecasting	☐	☐	☐	☐	☐
Road surface treatment	☐	☐	☐	☐	☐
Road surface detection (e.g., snow, flood, ice)	☐	☐	☐	☐	☐
Snow plowing activity monitoring	☐	☐	☐	☐	☐
Post-emergency documentation	☐	☐	☐	☐	☐
Parking lot utilization	☐	☐	☐	☐	☐
Illegal or unintended parking assessment	☐	☐	☐	☐	☐
Equip multiple UAS to create ad-hoc communications network	☐	☐	☐	☐	☐
Determine traffic camera heights	☐	☐	☐	☐	☐
Determine sight lines for radio infrastructure	☐	☐	☐	☐	☐

Please describe any additional benefits and which UAS use case(s) it refers to.

7. What are the challenges or limitations with using UAS for each purpose? Select all that apply.

	Cannot operate above traffic	Battery life (i.e., time in air)	Privacy	Federal Aviation Administration (FAA) regulation	Registration and liability requirements	Technical expertise	Funding
Traffic data collection for congestion monitoring	☐	☐	☐	☐	☐	☐	☐
Pedestrian or bicyclist data collection	☐	☐	☐	☐	☐	☐	☐
Collect data for before/after studies	☐	☐	☐	☐	☐	☐	☐
Observe traffic control setup in work zones	☐	☐	☐	☐	☐	☐	☐
Observe conditions where cameras are not present	☐	☐	☐	☐	☐	☐	☐
On-site incident scene monitoring	☐	☐	☐	☐	☐	☐	☐
Video recording for post-incident debriefing	☐	☐	☐	☐	☐	☐	☐
Collision scene reconstruction	☐	☐	☐	☐	☐	☐	☐
Incident mapping	☐	☐	☐	☐	☐	☐	☐
Weather forecasting	☐	☐	☐	☐	☐	☐	☐
Road surface treatment	☐	☐	☐	☐	☐	☐	☐
Road surface detection (e.g., snow, flood, ice)	☐	☐	☐	☐	☐	☐	☐
Snow plowing activity monitoring	☐	☐	☐	☐	☐	☐	☐
Post-emergency documentation	☐	☐	☐	☐	☐	☐	☐
Parking lot utilization	☐	☐	☐	☐	☐	☐	☐
Illegal or unintended parking assessment	☐	☐	☐	☐	☐	☐	☐
Equip multiple UAS to create ad-hoc communications network	☐	☐	☐	☐	☐	☐	☐
Determine traffic camera heights	☐	☐	☐	☐	☐	☐	☐
Determine sight lines for radio infrastructure	☐	☐	☐	☐	☐	☐	☐

Please describe any additional limitations and which UAS use case(s) it refers to.

ENTERPRISE: UAS for ITS

Additional Information

8. Please provide any additional information that may be relevant to your agency's use of UAS for ITS and transportation operations purposes.

Appendix C
Survey Responses

Q1: Please provide your agency.

- Alabama DOT (AL)
- Alaska DOT&PF (AK)
- Delaware DOT (DE)
- Florida DOT (FL)
- Illinois DOT (IL)
- Kansas DOT (KS)
- Kentucky Transportation Cabinet (KY)
- Maine DOT (ME)
- Maryland State Highway Administration (MD)
- Massachusetts DOT (MA)
- Missouri DOT (MO)
- Montana DOT (MT)
- New Jersey DOT (NJ)
- North Carolina DOT (NC)
- North Dakota DOT (ND)
- Oklahoma DOT (OK)
- South Carolina DOT (SC)
- South Dakota DOT (SD)
- Texas DOT (TX)
- Utah DOT (UT)
- Washington State DOT (WA)

Q2: For which of the following intelligent transportation systems (ITS) or transportation operations purposes does your agency use UAS (e.g., tested or implemented)? Select all that apply.

Purpose	Number of Responses	State Agency
Post-emergency documentation	12	AK, AL, DE, FL, KS, KY, MA, MO, MT, NJ, TX, UT
Observe conditions where cameras are not present	11	AK, DE, FL, KY, ME, MO, NC, ND, NJ, TX, WA
On-site incident scene monitoring	9	AK, DE, FL, KY, MO, NC, NJ, UT, WA
Traffic data collection for congestion monitoring	9	AK, DE, KY, MA, MO, TX, ND, SC, WA
Collect data for before/after studies	8	AK, KS, KY, MT, ND, SD, TX, UT
Collision scene reconstruction	7	AK, DE, IL, KY, MA, MD, UT
Incident mapping	7	AK, FL, KY, MO, MT, OK, UT
Observe traffic control setup in work zones	7	AK, DE, KY, MO, ND, NJ, UT,
Road surface treatment	7	AK, DE, KY, MT, ND, TX, UT
Video recording for post-incident debriefing	7	AK, FL, KS, KY, MO, OK, UT
Determine sight lines for radio infrastructure	6	AK, DE, FL, KY, MO, TX
Road surface detection (e.g., snow, flood, ice)	6	AK, DE, KS, KY, ND, UT
Determine traffic camera heights	5	FL, KS, KY, ME, ND
Parking lot utilization	3	DE, KS, KY
Illegal or unintended parking assessment	2	KS, KY
None	1	SD
Snow plowing activity monitoring	2	KY, ND
Pedestrian or bicyclist data collection	1	AK

Purpose	Number of Responses	State Agency
Equip multiple UAS to create ad-hoc communications network	0	N/A
Weather forecasting	0	N/A

Please describe any other ITS or transportation operations UAS purposes your agency has used or is testing that is not listed above. (13 responses)

- Pavement Condition Index (PCI) (Alaska DOT&PF)
- Live Streaming to Emergency Ops Centers. Recon of signal infrastructure damage, bridge inspection, microwave tower modeling. (Florida DOT)
- We are just beginning the UAS program in the Highway side of our DOT. We plan on doing many of these but just getting pilots and using state police for the above for crash recon with UAS. (Illinois DOT)
- Bridge inspection; storm water assessment; comms tower inspection; volumetric determinations. (Kansas DOT)
- Most of these are collected in other, better ways. (Kansas DOT)
- 3D modeling roadways and natural disaster. (Kentucky Transportation Cabinet)
- Bridge Inspection and LiDAR Surveys. (Missouri DOT)
- Drone in a Box solution for avalanche and rockslide detection/mitigation.
  Noxious weed detection/classification and treatment using UAS. (Montana DOT)
- Real time signal timing to support an incident detour due to a crash occurring on a bridge. Traffic was routed off the freeway (via ramp), across the highway, and back onto the freeway (via ramp). (North Carolina DOT)
- High-mast lighting and ancillary structure inspections, platooning, measuring quantities of stockpiles (salt, sand, fill work, etc.), bridge inspections, real-time kinematic (rtk) positioning operations, LiDAR data collection, tunnel and retaining walls, landslides and highway impact observation, erosion and stormwater control. (North Dakota DOT)
- We use UAS to do Inventory and Structural Inspections of LMR Towers and equipment.
  DPS uses the UAS to Map Incidents for faster clearance of incidents. (Oklahoma DOT)
- Survey and mapping for ROW acquisition, construction progress monitoring, beach dredging monitoring, erosion monitoring, bird nest surveys, 3D modeling, bridge inspection. (Texas DOT)
- Survey and Construction. (Utah DOT)

Q3: What is the stage of implementation (research/testing or implemented)?

Purpose	Number of Responses			
	Research/Testing		Implemented	
Post-emergency documentation	2	FL, TX	10	AK, AL, DE, KS, KY, MA, MO, MT, NJ, UT
Observe conditions where cameras are not present	2	NC, TX	8	AK, DE, FL, KY, ME, MO, ND, NJ
On-site incident scene monitoring	1	NC	7	AK, DE, FL, KY, MO, NJ, UT
Traffic data collection for congestion monitoring	4	AK, MA, SC, TX	4	DE, KY, MO, ND

Purpose	Number of Responses			
	Research/Testing		Implemented	
Collect data for before/after studies	4	AK, KS, MT, TX	4	KY, ND, SC, UT
Collision scene reconstruction	2	DE, MA	5	AK, IL, KY, MD, UT
Incident mapping	2	FL, MT	5	AK, KY, MO, OK, UT
Observe traffic control setup in work zones	1	MO	6	AK, DE, KY, ND, NJ, UT
Road surface treatment	5	AK, DE, KY, MT, TX	2	ND, UT
Video recording for post-incident debriefing	0	N/A	7	AK, FL, KS, KY, MO, OK, UT
Determine sight lines for radio infrastructure	3	KY, MO, TX	3	AK, DE, FL
Road surface detection (e.g., snow, flood, ice)	2	KS, KY	4	AK, DE, ND, UT
Determine traffic camera heights	2	KS, NC	3	FL, KY, ME
Parking lot utilization	2	KS, KY	1	DE
Illegal or unintended parking assessment	2	KS, KY	0	N/A
Snow plowing activity monitoring	1	KY	1	ND
Pedestrian or bicyclist data collection	1	AK	0	N/A
Equip multiple UAS to create ad-hoc communications network	0	N/A	0	N/A
Weather forecasting	0	N/A	0	N/A

Comments. Please identify which UAS use case(s) your comment refers to. (4 responses)

- Again through our state police. (Illinois DOT)
- Used to assess possible locations for traffic cameras at a proposed highway alignment. Specific lines-of-sight and an overall viewshed were investigated. (Kansas DOT)
- Used by Department of Public Safety only. (Oklahoma DOT)
- Before and After evaluations for intersection improvements for safety. (South Carolina DOT)

Q4: What type of drone is typically used (tethered or untethered)?

Purpose	Number of Responses			
	Tethered		Untethered	
Post-emergency documentation	0	N/A	12	AK, AL, DE, FL, KS, KY, MA, MO, MT, NJ, TX, UT
Observe conditions where cameras are not present	1	NC	9	AK, DE, FL, KY, ME, MO, ND, NJ, TX
On-site incident scene monitoring	1	NC	7	AK, DE, FL, KY, MO, NJ, UT
Traffic data collection for congestion monitoring	0	N/A	8	AK, DE, KY, MA, MO, ND, SC, TX

Purpose	Number of Responses			
	Tethered		Untethered	
Collect data for before/after studies	0	N/A	8	AK, KS, KY, MT, ND, SC, TX, UT
Collision scene reconstruction	0	N/A	7	AK, DE, IL, KY, MA, MD, UT
Incident mapping	0	N/A	7	AK, FL, KY, MO, MT, OK, UT
Observe traffic control setup in work zones	0	N/A	7	AK, DE, KY, MO, ND, NJ, UT
Road surface treatment	0	N/A	7	AK, DE, KY, MT, ND, TX, UT
Video recording for post-incident debriefing	0	N/A	7	AK, FL, KS, KY, MO, OK, UT
Determine sight lines for radio infrastructure	0	N/A	6	AK, DE, FL, KY, MO, TX
Road surface detection (e.g., snow, flood, ice)	0	N/A	6	AK, DE, KS, KY, ND, UT
Determine traffic camera heights	1	NC	4	FL, KS, KY, ME
Parking lot utilization	0	N/A	3	DE, KS, KY
Illegal or unintended parking assessment	0	N/A	2	KS, KY
Snow plowing activity monitoring	0	N/A	2	KY, ND
Pedestrian or bicyclist data collection	0	N/A	1	AK
Equip multiple UAS to create ad-hoc communications network	0	N/A	0	N/A
Weather forecasting	0	N/A	0	N/A

Comments. Please identify which UAS use case(s) your comment refers to. (3 responses)

- Tethered Drones are new to our UAS Fleet at FDOT. We are testing. (Florida DOT)
- We used DJI Mavic 2 Enterprise drones until recently. We now use mostly domestic-made drones. (Kansas DOT)
- Used by Department of Public Safety only. (Oklahoma DOT)

Q5: Which of the following best describes your agency's outcome with use of UAS for this purpose?

Purpose	Number of Responses							
	Not Successful		Somewhat Successful		Very Successful		Too early to determine	
Post-emergency documentation	0	N/A	2	FL, MO	9	AK, AL, DE, KS, KY, MA, MT, NJ, UT	1	TX
Observe conditions where cameras are not present	0	N/A	2	MO, NC	7	AK, DE, FL, KY, ME, ND, NJ	1	TX

Purpose	Number of Responses							
	Not Successful		Somewhat Successful		Very Successful		Too early to determine	
On-site incident scene monitoring	0	N/A	2	MO, NC	6	AK, DE, FL, KY, NJ, UT	0	N/A
Traffic data collection for congestion monitoring	0	N/A	1	MA	4	DE, KY, ND, SC	3	AK, MO, TX
Collect data for before/after studies	0	N/A	0	N/A	5	KS, KY, ND, SC, UT	3	AK, MT, TX
Collision scene reconstruction	0	N/A	0	N/A	5	AK, KY, MA, MD, UT	1	IL
Incident mapping	0	N/A	1	FL	4	AK, KY, OK, UT	2	MO, MT
Observe traffic control setup in work zones	0	N/A	1	UT	5	AK, DE, KY, ND, NJ	1	MO
Road surface treatment	0	N/A	2	DE, ND	1	UT	4	AK, KY, MT, TX
Video recording for post-incident debriefing	0	N/A	0	N/A	7	AK, FL, KS, KY, MO, OK, UT	0	N/A
Determine sight lines for radio infrastructure	0	N/A	0	N/A	3	AK, DE, FL	3	KY, MO, TX
Road surface detection (e.g., snow, flood, ice)	0	N/A	1	KS	4	AK, DE, ND, UT	1	KY
Determine traffic camera heights	0	N/A	0	N/A	4	FL, KS, KY, ME	1	NC
Parking lot utilization	0	N/A	1	DE	1	KS	1	KY
Illegal or unintended parking assessment	0	N/A	0	N/A	1	KS	1	KY
Snow plowing activity monitoring	0	N/A	0	N/A	1	ND	1	KY
Pedestrian or bicyclist data collection	0	N/A	0	N/A	0	N/A	1	AK
Equip multiple UAS to create ad-hoc communications network	0	N/A	0	N/A	0	N/A	0	N/A
Weather forecasting	0	N/A	0	N/A	0	N/A	0	N/A

Comments. Please identify which UAS use case(s) your comment refers to. (2 responses)

- Flight Restrictions and timing are impact factors that limit some success. (Florida DOT)
- Used by Department of Public Safety only. (Oklahoma DOT)

Q6: What benefits have resulted from using UAS for each purpose? Select all that apply.

Purpose	Number of responses									
	Cost saving		Time saving		Safety improvement		Quality improvement		Improved documentation or data	
Post-emergency documentation	6	AK, DE, KY, MO, TX, UT	7	DE, FL, KS, KY, MO, MT, UT	9	AK, KS, KY, MA, MO, MT, NJ, TX, UT	8	DE, FL, KS, KY, MA, MO, NJ, UT	11	AK, AL, DE, FL, KS, KY, MO, MT, NJ, TX, UT
Observe conditions where cameras are not present	5	AK, KY, ND, NJ, TX	5	FL, KY, MO, ND, NJ	7	AK, DE, FL, KY, MO, NC, TX	5	DE, FL, KY, ME, MO	8	AK, FL, KY, MO, NC, ND, NJ, TX
On-site incident scene monitoring	4	AK, DE, KY, UT	4	DE, KY, MO, UT	7	AK, DE, FL, KY, MO, NC, UT	5	DE, KY, MO, NJ, UT	7	AK, FL, KY, MO, NC, NJ, UT
Traffic data collection for congestion monitoring	5	AK, KY, MA, ND, TX	5	DE, KY, MA, MO, ND	7	AK, DE, KY, MO, ND, SC, TX	1	KY	5	AK, KY, MO, ND, TX
Collect data for before/after studies	6	AK, KS, KY, MT, TX, UT	3	KY, MT, UT	5	AK, KY, SC, TX, UT	5	KS, KY, ND, SC, UT	6	AK, KS, KY, ND, TX, UT
Collision scene reconstruction	4	AK, IL, KY, UT	5	IL, KY, MA, MD, UT	6	AK, DE, IL, KY, MA, UT	4	DE, IL, KY, UT	5	AK, IL, KY, MD, UT
Incident mapping	6	AK, KY, MO, MT, OK, UT	6	FL, KY, MO, MT, OK, UT	7	AK, FL, KY, MO, MT, OK, UT	4	FL, KY, MO, UT	6	AK, KY, MO, MT, OK, UT
Observe traffic control setup in work zones	3	AK, KY, ND	2	KY, ND	6	AK, DE, KY, MO, ND, UT	4	DE, KY, MO, UT	6	AK, KY, MO, ND, NJ, UT
Road surface treatment	4	AK, MT, TX, UT	2	MT, UT	4	AK, DE, TX, UT	3	DE, ND, UT	4	AK, ND, TX, UT
Video recording for post-incident debriefing	3	AK, KY, OK	4	KY, MO, OK, UT	6	AK, FL, KY, MO, OK, UT	5	FL, KS, KY, MO, UT	6	AK, FL, KS, KY, MO, UT
Determine sight lines for radio infrastructure	6	AK, DE, FL, KY, MO, TX	4	DE, FL, KY, MO	4	AK, KY, MO, TX	4	DE, FL, KY, MO	6	AK, DE, FL, KY, MO, TX

Purpose	Number of responses									
	Cost saving		Time saving		Safety improvement		Quality improvement		Improved documentation or data	
Road surface detection (e.g., snow, flood, ice)	2	AK, ND	2	DE, ND	3	AK, DE, ND	2	DE, KS	3	AK, KS, ND
Determine traffic camera heights	2	KS, KY	3	KS, KY, NC	1	KY	3	FL, KY, ME	4	FL, KS, KY, NC
Parking lot utilization	0	N/A	1	DE	1	KS	1	KS	2	DE, KS
Illegal or unintended parking assessment	0	N/A	0	N/A	1	KS	1	KS	1	KS
Snow plowing activity monitoring	0	N/A	0	N/A	0	N/A	1	ND	1	ND
Pedestrian or bicyclist data collection	1	AK	0	N/A	1	AK	0	N/A	1	AK
Equip multiple UAS to create ad-hoc communications network	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
Weather forecasting	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A

Please describe any additional benefits and which UAS use case(s) it refers to. (2 responses)

- Primarily using UAS to keep employees off the roadway and improve their safety. (Missouri DOT)
- Used by Department of Public Safety only. (Oklahoma DOT)

Q7: What are the challenges or limitations with using UAS for each purpose? Select all that apply.

Purpose	Number of Responses													
	Cannot operate above traffic		Battery life (i.e., time in air)		Privacy		FAA regulation		Registration and liability requirements		Technical expertise		Funding	
Post-emergency documentation	2	KS, MA	7	AK, KS, MA, MO, MT, TX, UT	1	MA	7	FL, KS, MA, MO, NJ, TX, UT	2	KS, MO	2	DE, MO	3	AK, DE, UT

Purpose	Number of Responses													
	Cannot operate above traffic		Battery life (i.e., time in air)		Privacy		FAA regulation		Registration and liability requirements		Technical expertise		Funding	
Observe conditions where cameras are not present	0	N/A	6	AK, FL, MO, NC, ND, TX	0	N/A	6	DE, FL, ME, MO, NJ, TX	1	MO	2	DE, MO	3	AK, DE, NC
On-site incident scene monitoring	0	N/A	4	AK, MO, NC, UT	0	N/A	5	DE, FL, MO, NJ, UT	1	MO	1	MO	4	AK, DE, NC, UT
Traffic data collection for congestion monitoring	5	KY, MA, MO, ND, TX	7	AK, KY, MA, MO, ND, SC, TX	1	MA	4	MA, MO, ND, TX	1	MO	1	MO	2	AK, DE
Collect data for before/after studies	1	KS	5	AK, KS, ND, SC, TX	0	N/A	2	KS, UT	0	N/A	1	TX	2	AK, UT
Collision scene reconstruction	1	MA	4	AK, MA, MD, UT	2	DE, MA	4	DE, MA, MD, UT	0	N/A	2	DE, MD	3	AK, DE, UT
Incident mapping	1	MO	4	AK, FL, MO, UT	1	FL	3	FL, MO, UT	1	MO	1	MO	2	AK, UT
Observe traffic control setup in work zones	3	DE, MO, ND	3	AK, MO, ND	0	N/A	4	MO, ND, NJ, UT	1	MO	1	MO	3	AK, DE, UT
Road surface treatment	2	DE, TX	4	AK, MT, ND, UT	0	N/A	2	DE, UT	0	N/A	2	DE, TX	3	AK, DE, UT
Video recording for post-incident debriefing	1	KS	4	AK, KS, MO, UT	0	N/A	4	FL, KS, MO, UT	1	MO	1	MO	2	AK, UT
Determine sight lines for radio infrastructure	0	N/A	2	AK, MO	0	N/A	2	FL, MO	1	MO	2	DE, MO	2	AK, DE

Purpose	Number of Responses													
	Cannot operate above traffic		Battery life (i.e., time in air)		Privacy		FAA regulation		Registration and liability requirements		Technical expertise		Funding	
Road surface detection (e.g., snow, flood, ice)	1	KS	4	AK, KS, ND, UT	0	N/A	3	DE, KS, UT	0	N/A	1	DE	3	AK, DE, UT
Determine traffic camera heights	1	KS	0	N/A	0	N/A	2	FL, ME	0	N/A	1	NC	0	N/A
Parking lot utilization	1	KS	1	KS	0	N/A	1	KS	1	KS	0	N/A	1	DE
Illegal or unintended parking assessment	1	KS	1	KS	0	N/A	1	KS	1	KS	0	N/A	0	N/A
Snow plowing activity monitoring	0	N/A	2	KY, ND	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
Pedestrian or bicyclist data collection	0	N/A	1	AK	0	N/A	0	N/A	0	N/A	0	N/A	1	AK
Equip multiple UAS to create ad-hoc communications network	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
Weather forecasting	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A

Please describe any additional limitations and which UAS use case(s) it refers to. (5 responses)

- Data Size is a limitation for field events. (Florida DOT)
- Weather and under structures. (Illinois DOT)
- Case study was done in an urban area, so several visual observers were used to coordinate with traffic and other operational considerations. Study was a success and saved time and money. (Kansas DOT)
- Observe conditions/onsite monitoring - since we used tethered UAS on our IMAP vehicles, our vehicles needed to be placed in a location that would provide the best coverage of the incident location and back of queue information. This was not always the best location for IMAP to support. (North Carolina DOT)
- Weather is a huge factor - wind speed, cold temps, rain. Additional payload - sensor and camera capabilities. (North Dakota DOT)

Q8: Please provide any additional information that may be relevant to your agency's use of UAS for ITS and transportation operations purposes. (7 responses)

- We will begin investigating feasibility of tethered UAS for traffic incident management efforts in rural areas outside of traditional field deployed device coverage in FY 24. (Alabama DOT)
- Collaboration with other entities is super helpful even outside of normal transportation issues. Cross training is a great way to learn more capabilities of resources. (Florida DOT)
- Will continue to push for use of UAS for the agency. (Illinois DOT)
- Agency uses UAS for bridge inspections, channel repair projects, quarry inspections, traffic camera height determinations, highway project planning, evaluating bridge deck conditions, and other applications. Most ITS applications listed in this survey are done by other means. Glad to discuss further if needed. (Kansas DOT)
- MDT's UAS program is still in its infancy but growing rapidly. MDT has had an official UAS program for just over a year (9/1/2022 being the official program start date). MDT has a little over 60 Part 107 certified pilots, with approximately 25 aircraft in its fleet. MDT has established an "interagency UAS working group" that includes all Montana state agencies that operate UAS to discuss various UAS related issues, activities, and strategies for data sharing & dissemination to alleviate redundant data collection efforts between agencies. (Montana DOT)
- Beyond Visual Line of Sight - being able to gather data in larger segments, search and recovery after storms, etc. This is something we are currently working on with our Northern Plains UAS Test Site and the state's VANTIS network. Again, batteries / power for longer distances is a concern. (North Dakota DOT)
- Used by Department of Public Safety only. As part of ODOT's TIM's Program. (Oklahoma DOT)

Appendix D
Survey Responses by Use Case

Use case: Post-emergency documentation

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	12	-	AK, AL, DE, FL, KS, KY, MA, MO, MT, NJ, TX, UT
Stage of implementation (out of 12 responses)			
Research/Testing	2	17%	FL, TX
Implemented	10	83%	AK, AL, DE, KS, KY, MA, MO, MT, NJ, UT
Type of drone typically used			
Tethered	0	0%	-
Untethered	12	100%	AK, AL, DE, FL, KS, KY, MA, MO, MT, NJ, TX, UT
Agency's outcome with use of UAS for this purpose (out of 12 responses)			
Not Successful	0	0%	-
Somewhat Successful	2	17%	FL, MO
Very Successful	9	75%	AK, AL, DE, KS, KY, MA, MT, NJ, UT
Too early to determine	1	8%	TX
Benefits resulting from using UAS for this purpose (out of 12 responses)			
Cost saving	6	50%	AK, DE, KY, MO, TX, UT
Time saving	7	58%	DE, FL, KS, KY, MO, MT, UT
Safety improvement	9	75%	AK, KS, KY, MA, MO, MT, NJ, TX, UT
Quality improvement	8	67%	DE, FL, KS, KY, MA, MO, NJ, UT
Improved documentation or data	11	92%	AK, AL, DE, FL, KS, KY, MO, MT, NJ, TX, UT
Challenges or limitations with using UAS for this purpose (out of 10 responses)			
Cannot operate above traffic	2	20%	KS, MA
Battery life (i.e., time in air)	7	70%	AK, KS, MA, MO, MT, TX, UT
Privacy	1	10%	MA
FAA regulation	7	70%	FL, KS, MA, MO, NJ, TX, UT
Registration and liability requirements	2	20%	KS, MO
Technical expertise	2	20%	DE, MO
Funding	3	30%	AK, DE, UT

Use case: Observe conditions where cameras are not present

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	11	-	AK, DE, FL, KY, ME, MO, NJ, NC, ND, TX, WA
Stage of implementation (out of 10 responses)			
Research/Testing	2	20%	NC, TX
Implemented	8	80%	AK, DE, FL, KY, ME, MO, ND, NJ
Type of drone typically used (out of 10 responses)			
Tethered	1	10%	NC
Untethered	9	90%	AK, DE, FL, KY, ME, MO, ND, NJ, TX
Agency's outcome with use of UAS for this purpose (out of 10 responses)			
Not Successful	0	0%	-
Somewhat Successful	2	20%	MO, NC
Very Successful	7	70%	AK, DE, FL, KY, ME, ND, NJ
Too early to determine	1	10%	TX
Benefits resulting from using UAS for this purpose (out of 10 responses)			
Cost saving	5	50%	AK, KY, ND, NJ, TX
Time saving	5	50%	FL, KY, MO, ND, NJ
Safety improvement	7	70%	AK, DE, FL, KY, MO, NC, TX
Quality improvement	5	50%	DE, FL, KY, ME, MO
Improved documentation or data	8	80%	AK, FL, KY, MO, NC, ND, NJ, TX
Challenges or limitations with using UAS for this purpose (out of 9 responses)			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	6	67%	AK, FL, MO, NC, ND, TX
Privacy	0	0%	-
FAA regulation	6	67%	DE, FL, ME, MO, NJ, TX
Registration and liability requirements	1	11%	MO
Technical expertise	2	22%	DE, MO
Funding	3	33%	AK, DE, NC

Use case: Traffic data collection for congestion monitoring

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	9	-	AK, DE, KY, MA, MO, ND, SC, TX, WA
Stage of implementation (out of 8 responses)			
Research/Testing	4	50%	AK, MA, SC, TX
Implemented	4	50%	DE, KY, MO, ND
Type of drone typically used (out of 8 responses)			
Tethered	0	0%	-
Untethered	8	100%	AK, DE, KY, MA, MO, ND, SC, TX
Agency's outcome with use of UAS for this purpose (out of 8 responses)			
Not Successful	0	0%	-
Somewhat Successful	1	13%	MA
Very Successful	4	50%	DE, KY, ND, SC
Too early to determine	3	37%	AK, MO, TX
Benefits resulting from using UAS for this purpose (out of 8 responses)			
Cost saving	5	63%	AK, KY, MA, ND, TX
Time saving	5	63%	DE, KY, MA, MO, ND
Safety improvement	7	88%	AK, DE, KY, MO, ND, SC, TX
Quality improvement	1	13%	KY
Improved documentation or data	5	63%	AK, KY, MO, ND, TX
Challenges or limitations with using UAS for this purpose (out of 8 responses)			
Cannot operate above traffic	5	63%	KY, MA, MO, ND, TX
Battery life (i.e., time in air)	7	88%	AK, KY, MA, MO, ND, SC, TX
Privacy	1	13%	MA
FAA regulation	4	50%	MA, MO, ND, TX
Registration and liability requirements	1	13%	MO
Technical expertise	1	13%	MO
Funding	2	25%	AK, DE

Use case: On-site incident scene monitoring

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	9	-	AK, DE, FL, KY, MO, NJ, NC, UT, WA
Stage of implementation (out of 8 responses)			
Research/Testing	1	13%	NC
Implemented	7	87%	AK, DE, FL, KY, MO, NJ, UT
Type of drone typically used			
Tethered	1	13%	NC
Untethered	7	87%	AK, DE, FL, KY, MO, NJ, UT
Agency's outcome with use of UAS for this purpose (out of 8 responses)			
Not Successful	0	0%	-
Somewhat Successful	2	25%	MO, NC
Very Successful	6	75%	AK, DE, FL, KY, NJ, UT
Too early to determine	0	0%	-
Benefits resulting from using UAS for this purpose (out of 8 responses)			
Cost saving	4	50%	AK, DE, KY, UT
Time saving	4	50%	DE, KY, MO, UT
Safety improvement	7	88%	AK, DE, FL, KY, MO, NC, UT
Quality improvement	5	63%	DE, KY, MO, NJ, UT
Improved documentation or data	7	88%	AK, FL, KY, MO, NC, NJ, UT
Challenges or limitations with using UAS for this purpose (out of 7 responses)			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	4	57%	AK, MO, NC, UT
Privacy	0	0%	-
FAA regulation	5	71%	DE, FL, MO, NJ, UT
Registration and liability requirements	1	14%	MO
Technical expertise	1	14%	MO
Funding	4	57%	AK, DE, NC, UT

Use case: Collect data for before/after studies

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	8	-	AK, KS, KY, MT, ND, SC, TX, UT
Stage of implementation (out of 8 responses)			
Research/Testing	4	50%	AK, KS, MT, TX
Implemented	4	50%	KY, ND, SC, UT
Type of drone typically used (out of 8 responses)			
Tethered	0	0%	-
Untethered	8	100%	AK, KS, KY, MT, ND, SC, TX, UT
Agency's outcome with use of UAS for this purpose (out of 8 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	5	63%	KS, KY, ND, SC, UT
Too early to determine	3	37%	AK, MT, TX
Benefits resulting from using UAS for this purpose (out of 8 responses)			
Cost saving	6	75%	AK, KS, KY, MT, TX, UT
Time saving	3	38%	KY, MT, UT
Safety improvement	5	63%	AK, KY, SC, TX, UT
Quality improvement	5	63%	KS, KY, ND, SC, UT
Improved documentation or data	6	75%	AK, KS, KY, ND, TX, UT
Challenges or limitations with using UAS for this purpose (out of 6 responses)			
Cannot operate above traffic	1	17%	KS
Battery life (i.e., time in air)	5	83%	AK, KS, ND, SC, TX
Privacy	0	0%	-
FAA regulation	2	33%	KS, UT
Registration and liability requirements	0	0%	-
Technical expertise	1	17%	TX
Funding	2	33%	AK, UT

Use case: Observe traffic control setup in work zones

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	7	-	AK, DE, KY, MO, NJ, ND, UT
Stage of implementation (out of 7 responses)			
Research/Testing	1	14%	MO
Implemented	6	86%	AK, DE, KY, ND, NJ, UT
Type of drone typically used (out of 7 responses)			
Tethered	0	0%	-
Untethered	7	100%	AK, DE, KY, MO, ND, NJ, UT
Agency's outcome with use of UAS for this purpose (out of 7 responses)			
Not Successful	0	0%	-
Somewhat Successful	1	14%	UT
Very Successful	5	71%	AK, DE, KY, ND, NJ
Too early to determine	1	14%	MO
Benefits resulting from using UAS for this purpose (out of 7 responses)			
Cost saving	3	43%	AK, KY, ND
Time saving	2	29%	KY, ND
Safety improvement	6	86%	AK, DE, KY, MO, ND, UT
Quality improvement	4	57%	DE, KY, MO, UT
Improved documentation or data	6	86%	AK, KY, MO, ND, NJ, UT
Challenges or limitations with using UAS for this purpose (out of 6 responses)			
Cannot operate above traffic	3	50%	DE, MO, ND
Battery life (i.e., time in air)	3	50%	AK, MO, ND
Privacy	0	0%	-
FAA regulation	4	67%	MO, ND, NJ, UT
Registration and liability requirements	1	17%	MO
Technical expertise	1	17%	MO
Funding	3	50%	AK, DE, UT

Use case: Incident mapping

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	7	-	AK, FL, KY, MO, MT, OK, UT
Stage of implementation (out of 7 responses)			
Research/Testing	2	29%	FL, MT
Implemented	5	71%	AK, KY, MO, OK, UT
Type of drone typically used (out of 7 responses)			
Tethered	0	0%	-
Untethered	7	100%	AK, FL, KY, MO, MT, OK, UT
Agency's outcome with use of UAS for this purpose (out of 7 responses)			
Not Successful	0	0%	-
Somewhat Successful	1	14%	FL
Very Successful	4	57%	AK, KY, OK, UT
Too early to determine	2	29%	MO, MT
Benefits resulting from using UAS for this purpose (out of 7 responses)			
Cost saving	6	86%	AK, KY, MO, MT, OK, UT
Time saving	6	86%	FL, KY, MO, MT, OK, UT
Safety improvement	7	100%	AK, FL, KY, MO, MT, OK, UT
Quality improvement	4	57%	FL, KY, MO, UT
Improved documentation or data	6	86%	AK, KY, MO, MT, OK, UT
Challenges or limitations with using UAS for this purpose (out of 4 responses)			
Cannot operate above traffic	1	25%	MO
Battery life (i.e., time in air)	4	100%	AK, FL, MO, UT
Privacy	1	25%	FL
FAA regulation	3	75%	FL, MO, UT
Registration and liability requirements	1	25%	MO
Technical expertise	1	25%	MO
Funding	2	50%	AK, UT

Use case: Road surface treatment

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	7	-	AK, DE, KY, MT, ND, TX, UT
Stage of implementation (out of 7 responses)			
Research/Testing	5	71%	AK, DE, KY, MT, TX
Implemented	2	29%	ND, UT
Type of drone typically used (out of 7 responses)			
Tethered	0	0%	-
Untethered	7	100%	AK, DE, KY, MT, ND, TX, UT
Agency's outcome with use of UAS for this purpose (out of 7 responses)			
Not Successful	0	0%	-
Somewhat Successful	2	29%	DE, ND
Very Successful	1	14%	UT
Too early to determine	4	57%	AK, KY, MT, TX
Benefits resulting from using UAS for this purpose (out of 6 responses)			
Cost saving	4	67%	AK, MT, TX, UT
Time saving	2	33%	MT, UT
Safety improvement	4	67%	AK, DE, TX, UT
Quality improvement	3	50%	DE, ND, UT
Improved documentation or data	4	67%	AK, ND, TX, UT
Challenges or limitations with using UAS for this purpose (out of 6 responses)			
Cannot operate above traffic	2	33%	DE, TX
Battery life (i.e., time in air)	4	67%	AK, MT, ND, UT
Privacy	0	0%	-
FAA regulation	2	33%	DE, UT
Registration and liability requirements	0	0%	-
Technical expertise	2	33%	DE, TX
Funding	3	50%	AK, DE, UT

Use case: Video recording for post-incident debriefing

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	7	-	AK, FL, KS, KY, MO, OK, UT
Stage of implementation (out of 7 responses)			
Research/Testing	0	0%	-
Implemented	7	100%	AK, FL, KS, KY, MO, OK, UT
Type of drone typically used (out of 7 responses)			
Tethered	0	0%	-
Untethered	7	100%	AK, FL, KS, KY, MO, OK, UT
Agency's outcome with use of UAS for this purpose (out of 7 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	7	100%	AK, FL, KS, KY, MO, OK, UT
Too early to determine	0	0%	-
Benefits resulting from using UAS for this purpose (out of 7 responses)			
Cost saving	3	43%	AK, KY, OK
Time saving	4	57%	KY, MO, OK, UT
Safety improvement	6	86%	AK, FL, KY, MO, OK, UT
Quality improvement	5	71%	FL, KS, KY, MO, UT
Improved documentation or data	6	86%	AK, FL, KS, KY, MO, UT
Challenges or limitations with using UAS for this purpose (out of 5 responses)			
Cannot operate above traffic	1	20%	KS
Battery life (i.e., time in air)	4	80%	AK, KS, MO, UT
Privacy	0	0%	-
FAA regulation	4	80%	FL, KS, MO, UT
Registration and liability requirements	1	20%	MO
Technical expertise	1	20%	MO
Funding	2	40%	AK, UT

Use case: Collision scene reconstruction

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	7	-	AK, DE, IL, KY, MA, MD, UT
Stage of implementation (out of 7 responses)			
Research/Testing	2	29%	DE, MA
Implemented	5	71%	AK, IL, KY, MD, UT
Type of drone typically used (out of 7 responses)			
Tethered	0	0%	-
Untethered	7	100%	AK, DE, IL, KY, MA, MD, UT
Agency's outcome with use of UAS for this purpose (out of 6 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	5	83%	AK, KY, MA, MD, UT
Too early to determine	1	17%	IL
Benefits resulting from using UAS for this purpose (out of 7 responses)			
Cost saving	4	57%	AK, IL, KY, UT
Time saving	5	71%	IL, KY, MA, MD, UT
Safety improvement	6	86%	AK, DE, IL, KY, MA, UT
Quality improvement	4	57%	DE, IL, KY, UT
Improved documentation or data	5	71%	AK, IL, KY, MD, UT
Challenges or limitations with using UAS for this purpose (out of 5 responses)			
Cannot operate above traffic	1	20%	MA
Battery life (i.e., time in air)	4	80%	AK, MA, MD, UT
Privacy	2	40%	DE, MA
FAA regulation	4	80%	DE, MA, MD, UT
Registration and liability requirements	0	0%	-
Technical expertise	2	40%	DE, MD
Funding	3	60%	AK, DE, UT

Use case: Road surface detection (e.g., snow, flood, ice)

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	6	-	AK, DE, KS, KY, ND, UT
Stage of implementation (out of 6 responses)			
Research/Testing	2	33%	KS, KY
Implemented	4	67%	AK, DE, ND, UT
Type of drone typically used (out of 6 responses)			
Tethered	0	0%	-
Untethered	6	100%	AK, DE, KS, KY, ND, UT
Agency's outcome with use of UAS for this purpose (out of 6 responses)			
Not Successful	0	0%	-
Somewhat Successful	1	17%	KS
Very Successful	4	67%	AK, DE, ND, UT
Too early to determine	1	17%	KY
Benefits resulting from using UAS for this purpose (out of 4 responses)			
Cost saving	2	50%	AK, ND
Time saving	2	50%	DE, ND
Safety improvement	3	75%	AK, DE, ND
Quality improvement	2	50%	DE, KS
Improved documentation or data	3	75%	AK, KS, ND
Challenges or limitations with using UAS for this purpose (out of 5 responses)			
Cannot operate above traffic	1	20%	KS
Battery life (i.e., time in air)	4	80%	AK, KS, ND, UT
Privacy	0	0%	-
FAA regulation	3	60%	DE, KS, UT
Registration and liability requirements	0	0%	-
Technical expertise	1	20%	DE
Funding	3	60%	AK, DE, UT

Use case: Determine sight lines for radio infrastructure

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	6	-	AK, DE, FL, KY, MO, TX
Stage of implementation (out of 6 responses)			
Research/Testing	3	50%	KY, MO, TX
Implemented	3	50%	AK, DE, FL
Type of drone typically used (out of 6 responses)			
Tethered	0	0%	-
Untethered	6	100%	AK, DE, FL, KY, MO, TX
Agency's outcome with use of UAS for this purpose (out of 6 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	3	50%	AK, DE, FL
Too early to determine	3	50%	KY, MO, TX
Benefits resulting from using UAS for this purpose (out of 6 responses)			
Cost saving	6	100%	AK, DE, FL, KY, MO, TX
Time saving	4	67%	DE, FL, KY, MO
Safety improvement	4	67%	AK, KY, MO, TX
Quality improvement	4	67%	DE, FL, KY, MO
Improved documentation or data	6	100%	AK, DE, FL, KY, MO, TX
Challenges or limitations with using UAS for this purpose (out of 4 responses)			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	2	50%	AK, MO
Privacy	0	0%	-
FAA regulation	2	50%	FL, MO
Registration and liability requirements	1	25%	MO
Technical expertise	2	50%	DE, MO
Funding	2	50%	AK, DE

Use case: Determine traffic camera heights

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	5	-	FL, KS, KY, ME, NC
Stage of implementation (out of 5 responses)			
Research/Testing	2	40%	KS, NC
Implemented	3	60%	FL, KY, ME
Type of drone typically used (out of 5 responses)			
Tethered	1	20%	NC
Untethered	4	80%	FL, KS, KY, ME
Agency's outcome with use of UAS for this purpose (out of 5 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	4	80%	FL, KS, KY, ME
Too early to determine	1	20%	NC
Benefits resulting from using UAS for this purpose (out of 5 responses)			
Cost saving	2	40%	KS, KY
Time saving	3	60%	KS, KY, NC
Safety improvement	1	20%	KY
Quality improvement	3	60%	FL, KY, ME
Improved documentation or data	4	80%	FL, KS, KY, NC
Challenges or limitations with using UAS for this purpose (out of 4 responses)			
Cannot operate above traffic	1	25%	KS
Battery life (i.e., time in air)	0	0%	-
Privacy	0	0%	-
FAA regulation	2	50%	FL, ME
Registration and liability requirements	0	0%	-
Technical expertise	1	25%	NC
Funding	0	0%	-

Use case: Parking lot utilization

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	3	-	DE, KS, KY
Stage of implementation (out of 3 responses)			
Research/Testing	2	67%	KS, KY
Implemented	1	33%	DE
Type of drone typically used (out of 3 responses)			
Tethered	0	0%	-
Untethered	3	100%	DE, KS, KY
Agency's outcome with use of UAS for this purpose (out of 3 responses)			
Not Successful	0	0%	-
Somewhat Successful	1	33%	DE
Very Successful	1	33%	KS
Too early to determine	1	33%	KY
Benefits resulting from using UAS for this purpose (out of 2 responses)			
Cost saving	0	0%	-
Time saving	1	50%	DE
Safety improvement	1	50%	KS
Quality improvement	1	50%	KS
Improved documentation or data	2	100%	DE, KS
Challenges or limitations with using UAS for this purpose (out of 2 responses)			
Cannot operate above traffic	1	50%	KS
Battery life (i.e., time in air)	1	50%	KS
Privacy	0	0%	-
FAA regulation	1	50%	KS
Registration and liability requirements	1	50%	KS
Technical expertise	0	0%	-
Funding	1	50%	DE

Use case: Snow plowing activity monitoring

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	2	-	KY, ND
Stage of implementation (out of 2 responses)			
Research/Testing	1	50%	KY
Implemented	1	50%	ND
Type of drone typically used (out of 2 responses)			
Tethered	0	0%	-
Untethered	2	100%	KY, ND
Agency's outcome with use of UAS for this purpose (out of 2 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	1	50%	ND
Too early to determine	1	50%	KY
Benefits resulting from using UAS for this purpose (out of 1 response)			
Cost saving	0	0%	-
Time saving	0	0%	-
Safety improvement	0	0%	-
Quality improvement	1	100%	ND
Improved documentation or data	1	100%	ND
Challenges or limitations with using UAS for this purpose (out of 2 responses)			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	2	100%	KY, ND
Privacy	0	0%	-
FAA regulation	0	0%	-
Registration and liability requirements	0	0%	-
Technical expertise	0	0%	-
Funding	0	0%	-

Use case: Illegal or unintended parking assessment

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	2	-	KS, KY
Stage of implementation (out of 2 responses)			
Research/Testing	2	100%	KS, KY
Implemented	0	0%	-
Type of drone typically used (out of 2 responses)			
Tethered	0	0%	-
Untethered	2	100%	KS, KY
Agency's outcome with use of UAS for this purpose (out of 2 responses)			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	1	50%	KS
Too early to determine	1	50%	KY
Benefits resulting from using UAS for this purpose (out of 1 response)			
Cost saving	0	0%	-
Time saving	0	0%	-
Safety improvement	1	100%	KS
Quality improvement	1	100%	KS
Improved documentation or data	1	100%	KS
Challenges or limitations with using UAS for this purpose (out of 1 response)			
Cannot operate above traffic	1	100%	KS
Battery life (i.e., time in air)	1	100%	KS
Privacy	0	0%	-
FAA regulation	1	100%	KS
Registration and liability requirements	1	100%	KS
Technical expertise	0	0%	-
Funding	0	0%	-

Use case: Pedestrian or bicyclist data collection

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	1	-	AK
Stage of implementation			
Research/Testing	1	100%	AK
Implemented	0	0%	-
Type of drone typically used			
Tethered	0	0%	-
Untethered	1	100%	AK
Agency's outcome with use of UAS for this purpose			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	0	0%	-
Too early to determine	1	100%	AK
Benefits resulting from using UAS for this purpose			
Cost saving	1	100%	AK
Time saving	0	0%	-
Safety improvement	1	100%	AK
Quality improvement	0	0%	-
Improved documentation or data	1	100%	AK
Challenges or limitations with using UAS for this purpose			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	1	100%	AK
Privacy	0	0%	-
FAA regulation	0	0%	-
Registration and liability requirements	0	0%	-
Technical expertise	0	0%	-
Funding	1	100%	AK

Use case: Weather forecasting

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	0	-	-
Stage of implementation			
Research/Testing	0	0%	-
Implemented	0	0%	-
Type of drone typically used			
Tethered	0	0%	-
Untethered	0	0%	-
Agency's outcome with use of UAS for this purpose			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	0	0%	-
Too early to determine	0	0%	-
Benefits resulting from using UAS for this purpose			
Cost saving	0	0%	-
Time saving	0	0%	-
Safety improvement	0	0%	-
Quality improvement	0	0%	-
Improved documentation or data	0	0%	-
Challenges or limitations with using UAS for this purpose			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	0	0%	-
Privacy	0	0%	-
FAA regulation	0	0%	-
Registration and liability requirements	0	0%	-
Technical expertise	0	0%	-
Funding	0	0%	-

Use case: Equip multiple UAS to create ad-hoc communications network

Question	Use Case Responses		
	#	%	States
Agencies who use UAS for this purpose	0	-	-
Stage of implementation			
Research/Testing	0	0%	-
Implemented	0	0%	-
Type of drone typically used			
Tethered	0	0%	-
Untethered	0	0%	-
Agency's outcome with use of UAS for this purpose			
Not Successful	0	0%	-
Somewhat Successful	0	0%	-
Very Successful	0	0%	-
Too early to determine	0	0%	-
Benefits resulting from using UAS for this purpose			
Cost saving	0	0%	-
Time saving	0	0%	-
Safety improvement	0	0%	-
Quality improvement	0	0%	-
Improved documentation or data	0	0%	-
Challenges or limitations with using UAS for this purpose			
Cannot operate above traffic	0	0%	-
Battery life (i.e., time in air)	0	0%	-
Privacy	0	0%	-
FAA regulation	0	0%	-
Registration and liability requirements	0	0%	-
Technical expertise	0	0%	-
Funding	0	0%	-