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The State of the Practice of UAS Systems in Transportation

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16. Abstract

The objective of this research was to establish the state of the practice of unmanned aircraft system (UAS) applications in the transportation profession, with particular interest in understanding how other state departments of transportation across the United States are using UASs. To accomplish the objective, a survey was conducted among state departments of transportation to understand how they implemented UAS applications in their business. In addition, an exhaustive literature search was conducted to identify applications of UASs in the transportation profession. Based on the above understanding, recommendations were made regarding the development of an internal policy and a standard operating procedure for using UASs, as well as a pilot program consisting of three UAS applications in each division of the Massachusetts Department of Transportation.

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The State of the Practice of UAS Applications in Transportation

Final Report

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Disclaimer

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Massachusetts Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Executive Summary

This study of The State of the Practice of UAS Applications in Transportation was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Unmanned aircraft systems (UASs) are quickly becoming an important topic, and demand for them is currently surging in both the public and private sectors. Within this context, application of UASs in transportation is accelerating. Due to their easy maneuvering, great flexibility, low cost, quick deployment, and on-board sensing, particularly video-capturing capability, UASs are promising in various transportation applications. For example, UASs can be used as airborne traffic surveillance systems to monitor congestion formation and dissipation; they can be quickly deployed to verify highway crashes and provide firsthand information to assist first response and rescue teams; conventional means of bridge inspection can be costly and there are safety concerns for human inspection, while there is less concern and lower cost with using a UAS.

The objective of this research was to establish the state of the practice of UAS applications in the transportation profession, with particular interest in understanding how other state departments of transportation (DOTs) across the United States are using UASs. In order to achieve the objective, a survey was conducted among state DOTs. To lower the barrier to participation without losing details, the survey was conducted in two stages: an initial screening and a follow-up inquiring about further details. In the first stage, the research team asked three simple questions, mainly to inquire if the DOT had applied UASs in its business. A total of 14 state DOTs responded to the survey, among which only six state DOTs indicated having deployed UAS applications. After that initial inquiry, the research team followed up with the six state DOTs with a set of more specific questions to better understand their experience with UAS applications such as obtaining authorization, creating internal policies, developing standard operating procedures, training pilots, and using hardware and software.

In addition to the survey, the research team conducted an exhaustive literature search. Since the information of interest is mainly about transportation, the most relevant database is Transport Research International Documentation (TRID), the Transportation Research Information Services (TRIS) and International Transport Research Documentation (ITRD) database. The research team also extended the search in Google to identify any information left out by the TRID database. The results of the above efforts are elaborated in this report. In addition, applications of UASs in transportation were identified that mainly fall into the following categories: asset management, construction, disaster management, environmental issues, inspection, safety, surveillance, and traffic operations.

While the civil UAS market in the United States has been rapidly expanding in recent years, there is still no comprehensive federal law that provides a firm basis for commercial and

recreational use of UASs. As a result, many state and local governments moved forward and enacted or proposed numerous state laws and local regulations. This literature search shows that state UAS legislation activities are concentrated in 2013–2016. A total of 34 states have passed 79 pieces of legislation during this period. These laws are mainly about resolving issues such as prohibiting certain operations, making certain operations a crime, and defining UAS or related terms.

After reviewing a few cases of best practice in terms of UAS policy, the research team recommended that MassDOT develop an internal policy regarding the use of UASs across all divisions and offices within the organization. Based on these best practices, some specific items were recommended for incorporation in the internal policy. Similarly, specific recommendations were made for MassDOT to develop a standard operating procedure to guide future applications of UASs.

As the first step to a MassDOT-wide UAS program, the research team identified a set of conceptual UAS applications for each division of MassDOT, among which three applications that are likely to be successfully implemented in the short term were recommended for each division to serve as a pilot program.

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1.0 Introduction and Objective

This study of The State of the Practice of UAS Applications in Transportation was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Within the past few years, civilian demand for unmanned aircraft systems (UASs), commonly referred to as drones, has skyrocketed. Previously only used for military reconnaissance and later for strike programs, UASs have been considered for a variety of civilian tasks, including infrastructure monitoring, precision agriculture, package delivery services, search and rescue operations, photography, and more. Among many public and private sector agencies, transportation agencies are in a unique position to leverage the emerging technology, due to the nature of this profession, the vast demand, and the great benefit in terms of reducing accidents, mitigating congestion, and cost savings. According to a recent survey by the American Association of State Highway and Transportation Officials (AASHTO) *(1)*, 33 state departments of transportation (DOTs) have carried out or are exploring applications of UASs in various aspects of transportation, including inspecting bridges, collecting traffic data, and helping crash clear-up. In early 2016, the California Department of Transportation (Caltrans) anticipated that UAS use by DOTs and other state agencies will become commonplace within a very short period of time. Although the use of UASs requires an understanding of flight, operators could be trained to utilize UASs safely in the workplace.

In order to help MassDOT better achieve its mission and play a leading role in the era of technology revolution, a clear understanding of the state of the practice of UAS applications in transportation, especially among other state DOTs, is critical. The outcome of this study will enable MassDOT to position itself strategically in the near future and devise potential UAS applications that fit the current and long-term goals of the organization.

With the above understanding, the objectives of this research were the following:

- To conduct a literature search on actions taken by other state DOTs regarding their use of UASs.
- To analyze the results of the literature search to include their policy, standard operating procedures, implementation strategy, and best practices.
- To provide a set of options or recommendations for MassDOT with regard to each of the aforementioned areas.
- To determine three options for a UAS pilot program for each MassDOT division and the Massachusetts Bay Transportation Authority (MBTA), with the rationale and priority for each alternative.

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2.0 Research Methodology

The American Association of State Highway and Transportation Officials (AASHTO) conducted a survey *(1)* in March 2016, and found that 33 state departments of transportation (state DOTs) have or are exploring, researching, testing, or using unmanned aerial vehicles (UAVs), commonly referred to as drones and used interchangeably with unmanned aircraft systems (UASs) in this report, to inspect bridges and assist with clearing vehicle crashes, among other innovative applications. Unfortunately, the survey results, if any, are not publicly available. In August 2016, the Kansas Department of Transportation conducted another survey on how other state DOTs are using UASs *(2)*. The survey, consisting of 36 questions, was sent to leaders of other state DOTs. A total of 30 state DOTs responded, among which 11 were considering using UASs, seven were considering purchasing a UAS once regulations allow for commercial use, six had submitted requests for a Certificate of Authorization (COA) exemption from the Federal Aviation Administration (FAA), and four DOTs claimed to be utilizing UAS technology, but none was using UASs in its operations.

To obtain an update and, perhaps, to gain perspectives from a different set of eyes at state DOTs, the research team conducted a survey in September 2016, which was posted on Ask NASAO (National Association of State Aviation Officials) with the help of MassDOT staff. To lower the barrier of participating without losing details, the survey was conducted in the following two stages: initial screening and further details.

In the first stage, the research team asked only three simple questions:

Q1: Does your organization ever use UAS/drones in daily work? If no, that's it. Thank you. If yes, please proceed.
Q2: What do you use UAS/drones for? (Describe your application scenario in a few sentences.)
Q3: Who is the contact for further information on the above application(s)?

A total of 14 state DOTs responded to the survey, among which only six state DOTs indicated Yes (i.e., they have deployed UAS applications).

In the second stage, the research team followed up the six state DOTs with a set of more specific questions:

a) Does your state have a blanket COA (Certificate of Waiver or Authorization)? If not, how do you get authorized for each work effort?
b) Did you create policy documents? If so, can/will you share?
c) Did you create SOPs (standard operating procedures)? If so, can/will you share?
d) Does your organization train all of the drone operators? If not, who does?
e) What types of missions do you fly in each division?
f) Does your organization fly all of the operational missions, or does each division (highway, rail, and aeronautics) have their own trained drone operators?
g) Software questions: Types, applications, etc.

As of the date of publication, only four state DOTs have replied, and their responses are shown in Table 2.1.

Table 2.1: Responses to the second-stage questions from state DOTs using UASs

	CDOT	**KYTC**	**SCDOT**	**ALDOT**	**MNDOT**	**WSDOT**
a)	Yes	Yes + 333	No, but 9 other cases	No response	No response	No
b)	Developing	User manual	Operating manual	-	-	Internal policy
c)	Developing	N/A	Operating manual	-	-	No
d)	DOA: COA Others: Operating manual	DOA for itself	UAS distributor	-	-	Outside training
e)	Rockfall	Surveying	Mapping	-	-	Traffic, bridge inspection
f)	Division	DOA for itself	DOA for itself	-	-	Division
g)	Not yet	Pix4D	N/A	-	-	N/A

Note: CDOT – Colorado DOT; KYTC – Kentucky Transportation Cabinet;
SCDOT – South Carolina DOT; ALDOT – Alabama DOT;
MNDOT – Minnesota DOT; WSDOT – Washington DOT

In addition to the above efforts, the research team extended the search for the use of UASs in state DOTs to online databases. Since the information of interest is mainly about transportation, the most relevant database is TRID, the TRIS and ITRD database. The research team first focused the search on projects of state DOTs that were related to small unmanned aircraft system (sUAS) applications. The search yielded only limited results, since only a few state DOTs are active in this area. The search was then expanded to incorporate drone applications in transportation that were not necessarily state DOT efforts and more general applications of drones that may have impacts in transportation. The research team also extended the search in Google to identify any information that is not yet registered in the TRID database. The results of this search are presented in Chapter 3.

3.0 Results

This chapter presents the major findings of the state DOT survey and literature search.

3.1 Application Survey Results

Several sUAS activities are identified at the United States Department of Transportation (USDOT). The FAA finalized its rule (Part 107) of operation and certification of sUASs *(3)* in June 2016. The new rule is in effect as of August 29, 2016. The rule offers safety regulations for sUASs to carry out non-hobbyist operations, with the goal of minimizing risks to other aircraft and people and property on the ground. The FAA provides two ways for sUAS operators who want to fly outside the requirements of the above rule: Certificate of Waiver and Section 333. As part of the FAA's privacy education campaign, the agency will issue new guidance to local and state governments on drone privacy issues. This effort builds on the "privacy best practices," whose purpose is "to outline and describe voluntary Best Practices that UAS operators could take to advance UAS privacy, transparency and accountability for the private and commercial use of UAS" *(4).* The USDOT has supported a few research projects on applications of UASs, including research on monitoring the condition of unpaved roads with remote sensing and other technology by South Dakota State University, commercial remotely sensed imagery for disaster response and recovery by University of Vermont, research on advanced imaging of transportation infrastructure using UASs by University of Alaska, and research on the development of a UAS operational data collection concept by University of North Dakota.

At the state level, the research team found sUAS-related activities in 25 state DOTs. Some state DOTs actually applied or tested sUASs, some funded sUAS-related research projects, and some carried out other sUAS-related activities, such as supporting information, task groups, and envisioned uses. Meanwhile, the research team also identified some sUAS activities that were outside of state DOTs but still applied in transportation, e.g., research projects funded by the Transportation Research Board (TRB) and regional transportation centers. In summary, sUASs have been found useful in the following categories: asset management, construction, disaster management, environmental issues, inspection, safety, surveillance, and traffic operations. Further details are elaborated in the following subsections.

While the civil UAS market in the United States has been rapidly expanding in recent years, there is still no comprehensive federal law that provides a firm basis for commercial and recreational use of UASs. Many state and local governments moved forward and enacted or proposed numerous state laws and local regulations. In order to streamline the legislative process and avoid confusion between laws and regulations enacted or proposed by different levels of government, it is important to understand the superiority of federal laws and the ultimate responsibility of the FAA over the National Airspace. On the other hand, it would be helpful if state and local governments provide support to federal efforts by assuming some responsibilities. As a result, the cooperative effort may include: (a) federal: focus on national safety and general operational standards; (b) state government: focus on privacy and safety regulations in addition to federal law; and (c) local government: focus on privacy/restricted fly in addition to federal and state laws. The research team's review showed that state UAS legislation activities were concentrated in the period of 2013–2016. A total of 34 states passed 79 pieces of legislation during this period. These laws in general prohibit certain operations, make certain operations a crime, and define UAS or related terms.

3.2 Recommendations on Policy and Standard Operating Procedures

The research team reviewed operator's manuals, internal policies, and other documents developed by other state DOTs, and summarized their best practices in terms of UAS policy and standard operating procedures. Based on the research team's findings, a set of specific recommendations was made for MassDOT to consider when developing its own UAS policy and standard operating procedures. The research team also suggested an implementation strategy to create a MassDOT/MBTA-wide UAS implementation program in Section 4.0. The research team's recommendations are elaborated in the following subsections.

3.2.1. Recommendations on the Policy of Using UASs

The research team recommended that MassDOT develop an internal policy regarding the use of UASs across all divisions and offices within the organization. Based on the research team's understanding of the best practices available, it is recommended that the internal policy incorporate the following items to start.

UAS Operation Management
MassDOT may consider naming or creating a unit to be in charge of UAS flight operations and maintenance within the organization. Responsibilities of key personnel of the unit need to be well defined.

Use of UASs
It is necessary to clarify appropriate and inappropriate use of UASs. For example, personal uses are inappropriate, while business use must be clearly defined with purpose of use, justification, and compliance with federal, state, and local regulations. Note that Massachusetts currently does not have UAS-related legislation. A procedure is needed to outline the steps to follow in order to carry out business use, including how to initiate the request, file an application, review process, approval, and execution.

UAS Procurement
A policy is needed to specify the appropriate process of buying the equipment and associated sensors and software.

Contracting for UAS Services

A policy is needed to specify the appropriate process to contract for UAS service, if such service is not to be provided from within MassDOT.

Training

A policy is needed to specify the requirements for key personnel such as pilots and visual observers, as well as how they obtain the necessary training and how their training is evaluated. Sometimes, UAS vendors may provide training and associated documents. For example, SenseFly eBee training documentation contains a 16-hour, six-module training involving office training, field-based training, advanced techniques and maintenance, etc.

Privacy Issues

A policy is needed to protect individual privacy and personal information. The policy needs to specify how to properly collect, process, use, disclose, store, and dispose of data obtained from the UAS platform (such as aerial images, videos, and 3D models) without violating privacy rules. For example, good practices of addressing privacy issues and public concerns can be to inform others of intended use of UASs, to allow people to watch when one is operating UASs or collecting and saving the data collected using UASs, to limit the use and sharing of covered data, to secure covered data, and to monitor and comply with evolving federal, state, and local UAS laws.

Communications and Community Engagement

A general policy is needed on interaction with the media and press, and a preferred method of communication is called for when there is a need to deal with external relationships.

Resources for Safe Use of UASs

It is a good practice to compile relevant resources regarding legal and safe use of UASs, including federal laws, state regulations, and responsibilities of involved parties.

3.2.2. Recommendations on the Standard Operating Procedures of UASs

The research team recommended that MassDOT develop standard operating procedures to guide future applications of UASs. Based on the best practices available, the research team recommended that the standard operating procedures incorporate the following items to start.

Business Decision

A procedure is needed to define the process of business decisions on the use of UASs. For example, who is eligible to initiate an application? How does one file an application? Which parties are involved in reviewing an application? What criteria are used to approve an application?

Authorization and Airworthiness

A procedure is necessary to guide the process to obtain authorization and airworthiness for an intended UAS use. For example, how does one obtain airspace use authorizations (public and civil) from the FAA? How does one obtain authorizations at the state level, such as qualifications and permits? How does one obtain authorizations at the local level, such as owner's permits to use properties and facilities?

Operator Qualification
A guideline is needed to provide the necessary training for UAS operators and to evaluate the outcomes of the training process. The guideline may include issues such as roles, qualifications, and responsibilities of trainers and trainees, requirements and selection of training and testing facilities, obtaining and holding approval and compliance documents, and training topics.

Flight Planning
A guideline is necessary to specify who is in charge of flight planning and what considerations should be incorporated in the flight planning process.

Pre-Flight Procedure
The pre-flight procedure may include the following details: (1) required crew: e.g., a qualified pilot-in-command and visual observer; (2) flight planning checklist; (3) weather check; (4) programming flight and landing; (5) aircraft inspection checklist; (6) technical review; and (7) safety review.

Flight Procedure
The flight procedure may include the following details: (1) pre-launch checklist; (2) taking off procedure; (3) flying procedure; (4) maintaining connection; (5) checking status; (6) dynamically modifying flight plan; and (7) landing and recovery.

Post-Flight Procedure
The post-flight procedure may include the following details: (1) post-flight checklist; (2) cleaning, maintaining, and storage, including scheduled inspection and maintenance, replacement schedule for parts and components, unscheduled maintenance, checklist of maintenance items, battery log, and maintenance log; (3) data management, including retrieving, processing, disclosure, and storage to address privacy issues; and (4) reporting and logging.

Emergency/Accident Procedure
The emergency/accident procedure may incorporate a set of rules to deal with emergencies and accidents such as radio fail-safe, loss of control link, battery fail-safe, GPS fail-safe, fail-safe for other system component malfunctions, inclement weather, emergency landing, and emergency/accident reporting.

3.2.2. Recommendations on UAS Pilot Program Options

As the first step to a MassDOT-wide UAS program, the research team identified a set of conceptual UAS applications for each division of MassDOT. The team's recommendation was based on the results of the literature synthesis and state DOT survey. The following are three specific UAS applications recommended for each division of MassDOT as a pilot program.

Highway Division

1. Traffic and Safety Engineering – Bridge Inspection

The Traffic and Safety Engineering Section is responsible for overseeing the traffic engineering activities for MassDOT to ensure that the roadway and bridge construction and maintenance program complies with federal, state, and local engineering standards and the Commonwealth of Massachusetts General Laws.

To reduce the risks of bridge cracking and collapsing, the FHWA requires states to perform a detailed visual inspection and inventory of all federal-aid highway system bridges once every two years. Conventional means of bridge inspection involve the use of platform trucks, bucket trucks, or under-bridge inspection vehicles for inspectors to access and view necessary bridge elements, methods that are time-consuming and dangerous. UAS technology provides a cost-effective and safe method for remotely performing visual inspections and inventorying of bridges. UASs are capable of flying a pre-programmed flight path and can carry high-resolution digital cameras and/or other sensors. During flights, operators can view live video from the camera on a monitor or through live video goggles. In addition, digital imagery collected during flights can be mosaicked, geo-referenced, and converted into 3D point clouds for detailed spatial inventorying.

2. Construction – Construction Site Inspection

Another example of application of the same nature is construction site inspection. There are significant economic and environmental benefits to keeping highways and other types of facilities operational and construction sites safe. UASs can potentially be used as aerial image and data capture devices viable for inspecting and monitoring construction and large infrastructure projects.

3. District Offices – Roadway Asset Management

District Offices are responsible for monitoring roadway conditions and traffic control devices. A fast and low-cost data collection method such as the employment of UASs is particularly useful in managing unpaved roads and incorporating their conditions in decision support systems.

Rail and Transit Division

1. Rail Track and Right-of-Way Inspection

Rail track and right-of-way inspection is intended to identify deficiencies, estimate maintenance costs, and assure the safety of the traveling public on rail services. The use of UASs will reduce the costs and minimize time associated with these inspections. Use of UASs also will improve safety by reducing exposure of track and right-of-way maintenance personnel to potentially hazardous situations common with traditional rail track and right-of-way inspection methods.

2. Confined-Space Inspection

Confined spaces such as tunnels, pump stations, and wells constitute unfriendly working environments that are often dangerous or inaccessible to workers. The use of UASs to conduct confined-space inspection is expected to significantly reduce the risk to personnel by not requiring human entry for confined-space inspections. In addition, such technology provides high-quality, high-definition (HD), repeatable inspection imagery faster than traditional techniques such as rope access and scaffolding. Moreover, it allows UAS operators to rapidly access confined spaces, and inspection imagery is relayed to the inspector during the flight and stored for detailed playback to get near-firsthand understanding of the condition of the internal structure.

3. Park-and-Ride Lots Survey

Park-and-ride lots are parking lots near public transportation facilities that allow commuters and other travelers to leave their vehicles and take buses, trains, light rail, or carpool to continue their trips. Due to their locations and convenience, some lots may be more popular than others, resulting in unbalanced use of park-and-ride lots and, consequently, congestion, not only to these facilities but also to surface streets nearby. UAS technology can be deployed to survey these lots and obtain real-time feedback of their usage, especially during rush hour. Based on the information collected, transportation agencies may dynamically adjust parking fees and/or transit schedules as incentives to encourage full utilization of park-and-ride facilities.

Aeronautics Division

1. Airport Inspection

Airport inspection is conducted to identify infrastructure deficiencies and to assure infrastructure safety. The use of UASs is intended to reduce costs and minimize the time required to conduct such inspections. Use of UASs will also increase safety by reducing the need for operations personnel to physically access tall structures, such as control towers, terminals, hangars, and communication and navigation towers.

2. Airport Perimeter Control

Airport perimeter control is intended to improve security at the airport by reducing the probability of unlawful penetration into its territory. Use of UASs will also facilitate faster response if such intrusion does occur and will improve coordination of efforts to localize potential intruders by providing a live video stream to security and airport administration, management, and operations staff.

3. Obstruction Evaluation/Airport Airspace Analysis

Obstruction evaluation and airport airspace analysis are intended to help to identify potential aeronautical hazards in advance to prevent or minimize the adverse impacts to the safe and efficient use of navigable airspace. Use of UASs will help to reduce both costs and time associated with such evaluations.

The preceding recommendations are made for consideration by MassDOT based on the research team's preliminary study of current practices and a basic understanding of MassDOT's mission and needs. Note that better choices may be updated with more feedback from and interaction with staff at MassDOT.

Also note that, at this stage, the research team focused only on identifying potential use cases and making recommendations. Further details of recommended applications, such as demand analysis, suitable technologies, operational procedures to carry out these applications, and internal policy to guide the implementation of these applications, will be addressed in future research.

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4.0 Implementation and Technology Transfer

The recommended implementation strategy incorporates the following three phases.

Phase I (this study): The outcomes incorporate a solid understanding of UAS applications among state DOTs, some recommendations on UAS policy, standard operating procedures, best practices of UASs, and a set of potential applications proposed for each division of MassDOT.

Phase II: The Phase II study is expected to continue the efforts of Phase I. The outcome of this phase will be a UAS pilot program across MassDOT, with a draft internal policy, draft standard operating procedures, and detailed design and recommended UAS technology, to support a set of intended applications selected from those proposed in Phase I.

Phase III: The results of Phase II pave the road to Phase III, which will specify all the tasking required to create a MassDOT/MBTA-wide UAS implementation program over a period of two to three years.

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5.0 Conclusions

The research team's survey of state DOTs and literature search regarding applications of UASs in transportation demonstrate that UAS technology has received great interest in transportation agencies. The team's research shows that half of the state DOTs have activities either directly or indirectly related to UAS applications, and 33 state DOTs have expressed interest in or plan to deploy UAS applications.

However, incommensurate with the excitement of deployment, there are a lack of general guidelines and operating procedures to carry out these applications consistently across departments and agencies. Those state DOTs that have deployed UAS applications are mostly in the process of developing their own policies and operating procedures that are customized to their specific needs.

With success stories and best practices in other state DOTs, it is advantageous for MassDOT to explore UAS applications now, in an effort to reduce cost and increase efficiency. The next phase in this line of effort can be the implementation of the recommended pilot program involving UAS applications in each division of MassDOT. A detailed design of the pilot program is anticipated before carrying out field tests. Meanwhile, the development of internal policies and standard operating procedures are necessary to provide guidelines for successful implementation of the pilot program.

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