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Road Agencies Take to the Air

The World Road Association, with the support of the Federal Highway Administration, explored the use of unmanned aerial systems internationally.

From Canada to Tanzania, transportation agencies are using unmanned aerial systems (UASs), also known as drones, to collect data, design and construct road infrastructure, inspect bridges, monitor roads for avalanche and mudslide dangers, identify flood damage risks in urban areas, reconstruct crash scenes, and monitor traffic and road conditions. Public agencies, under pressure to reduce costs and to be adaptable, are turning to drones as one means of improving operations, safety, and efficiency.

To understand the role of UASs in transportation, the World Road Association (PIARC) funded an international study on the use of drones, led by the Federal Highway Administration (FHWA). The research resulted in the publication of *A Report on the Use of Unmanned Aerial Systems (UASs) to Remotely Collect Data for Road Infrastructure*, which is available on the PIARC and FHWA websites. In addition, PIARC and FHWA conducted a webinar on April 16, 2018, to help disseminate the results of the report.

The UAS Study

World Road Association Secretary General Patrick Mallejacq explains the role of his organization in the drone research:

"PIARC is a nonprofit, nonpolitical organization headquartered in Paris, France, with 121 member countries and more than 1,000 technical experts. We sponsor special projects to conduct critical research studies like this one exploring the use of unmanned aerial systems internationally."

FHWA Executive Director Thomas D. Everett, adds:

"Over the past couple of years, we have seen a rapid growth in the highway industry's use of this technology, both in construction and maintenance. All kinds of data can be collected. The opportunities for using drones in planning, design, construction, operations, and maintenance of highways seem endless."

U.S. Department of Transportation
Federal Highway Administration

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The final report on the UAS study provides an overview of various applications around the world.

"The research was an effort to capture the lessons learned by early adopters," says FHWA Wyoming Division Administrator Bryan Cawley, who led FHWA's contributions to the study.

"It provides recommendations to agencies that are considering—or who might benefit from—using drones as part of their operations. The goal is to help PIARC members leverage the experience of others to expedite the deployment and mainstreaming of this technology."

The research process included a literature review and a survey questionnaire distributed to public agencies around the globe. The final report highlighted 10 case studies that span several real-life applications, such as highway construction and monitoring, emergency response, traffic monitoring, mapping, and law enforcement. The research synthesized the results of the case studies, which were a mixture of academic research and real-world applications from Canada, Iran, Tanzania, and the United States.

Ten Real-Life Applications from Around the World

Highway Construction, Inspection, and Asset Monitoring

- Utah DOT's Use of Geospatial Technology for Design and Construction of State Route 20
- Evaluating the Use of Unmanned Aerial Vehicles for Bridge Inspection
- Bridge Component Inspection Using UAS
- An Automated Asphalt Pavement Inspection using UAS
- Monitoring the Condition of Gravel/Unpaved Roads with UAS

Emergency Response

- The Use of Small UAS by the Washington State DOT for Avalanche Monitoring

Traffic Monitoring

- Monitoring Driver Adaptation to a Two-Lane Roundabout with UAS
- Surface Transportation Surveillance from Unmanned Aerial Vehicles

Mapping

- Using UAS for Urban Mapping and Flood Prevention in Dar es Salaam

Law Enforcement

- Evaluating the Use of UAS for Transportation Purposes - Crash Scene Reconstruction Technologies

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UAS Overview

The U.S. Federal Aviation Administration defines a UAS as a system that includes the unmanned aircraft and the associated support equipment for its operation. In addition to the aircraft, the basic components of a UAS are its payload, human operator, ground control station, data and telemetry links, and navigation system.

Unmanned aircraft. Often referred to as the "platform," the unmanned aircraft consists of the airframe, motor(s), and fuel. The aircraft are broadly classified as rotary and fixed wing. They come in various shapes and sizes, ranging from inexpensive mini drones to expensive, large fixed wings.

Payload. This component refers to anything that can be carried by a drone, including a variety of passive or active sensors such as infrared, hyperspectral, radar, and thermal sensors. In some cases, geospatial professionals attach remote sensing equipment to the aircraft, such as lightweight video and red-green-blue cameras. Some UASs can carry heavier payloads, such as LiDAR sensors. Because of this payload versatility, a UAS can economically collect a variety of remote sensing data.

Operator. One or more human operators are necessary to supervise the safe and efficient operation of the unmanned aircraft. Operators might include a pilot, a payload operator, and a spotter.

This is a multi-rotor or quadcopter UAS, which is more suitable for inspecting enclosed and tight areas.

Source: Ehang.com

This is a fixed wing UAS, which is more suited to inspecting and mapping large areas.

Source: Sensefly.com

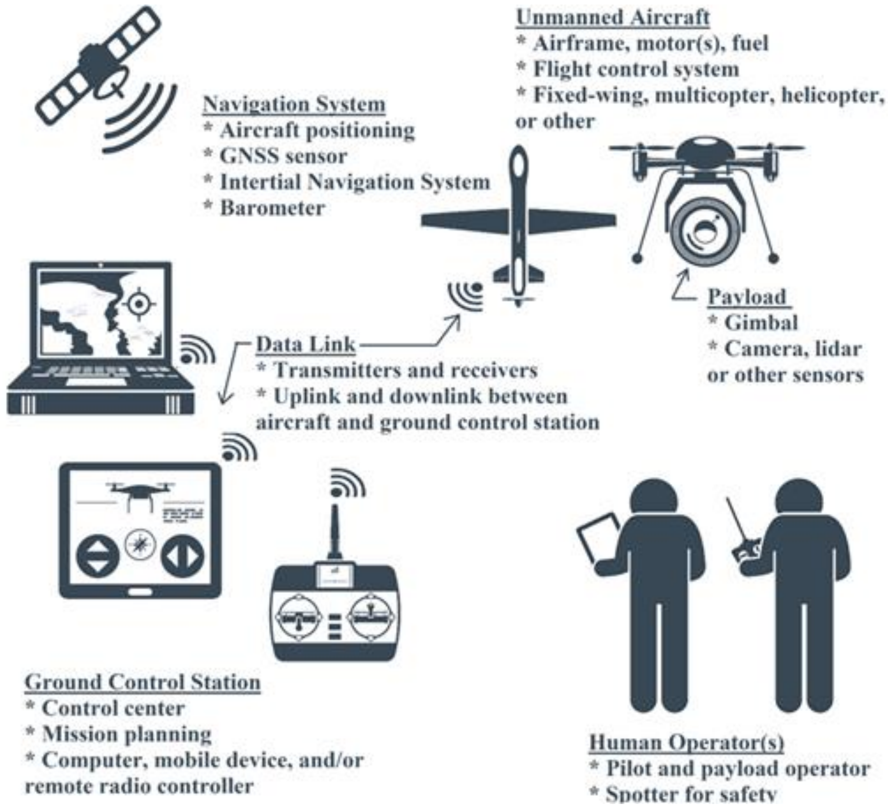
Ground control station. The ground control center typically includes a laptop, mobile device, or remote radio controller.

Data link. The data link is the transmission system between the ground control station and the operator. The operator uses a wireless uplink to transmit the mission plans to the aircraft prior to takeoff and a downlink to return information on the performance of the aircraft and the data from the sensors.

Navigation system. The navigation system enables the operator to monitor the aircraft's position, as well as its velocity, altitude, and possibly other variables, in real time.

"Because the technology is advancing rapidly," says Cawley, "the report recommends that, before each project, agencies evaluate available technology to select the one that is most suitable."

Basic Components of a UAS



Source: Dan Gillins

Regulations, Legislation, and Licensing

Regulations governing the use of UASs vary geographically, but drones typically are categorized based on size, weight, and sometimes usage—whether they are being employed commercially or recreationally. For any project involving a UAS, researching the restrictions governing use is advisable, especially given that regulations are changing rapidly.

In the United States, for example, the Federal Aviation Administration (FAA) oversees the safety and integrity of aircraft. For commercial uses of UASs, the agency requires the operator to obtain a remote pilot airman certificate. In addition, operators must pass Transportation Security Administration vetting, along with other requirements. Further, any aircraft weighing more than 55 pounds (25 kilograms) must be registered online and undergo preflight safety checks.

The website of UAV Systems International (www.uavsystemsinternational.com/drone-laws-by-country/) provides UAS laws and rules from around the world. The information available on this website should be used for reference only. For the most up-to-date rules and regulations, project managers should search for information directly from the governing agency in their region.

Real-World Applications

The report's real-life examples are drawn from around the world, although much of the research was done in the United States.

Those from the United States include the use of drones for design and construction of a State Road in Utah, bridge and component inspections in Minnesota, avalanche monitoring in Washington State, crash scene reconstruction, monitoring of the condition of gravel and unpaved roads, and traffic surveillance.

Worldwide, various countries studied the use of drones. Iran researched automated inspection of asphalt pavements, Canada monitored driver behavior and adaptation to a two-lane roundabout, and Tanzania created detailed urban maps for one of its cities, Dar es Salaam.

Urban mapping. Formerly the capital of Tanzania, Dar es Salaam is a rapidly urbanizing city of 4.5 million people. More than two-thirds of the population live in unplanned settlements with inadequate infrastructure. The World Bank is working with the local government on a variety of development projects, but their team lacks accurate, up-to-date geographic data (orthoimagery) because satellite imagery is unavailable and prohibitively expensive. Using a fixed wing drone, the project team collected more than 20,000 aerial images from an area of 55 square miles (142 square kilometers). The team then used the images to produce 3-D elevation models, which identify buildings and roads vulnerable to flooding. The map detail of the city is also proving useful for first responders. According to a speaker on a video shown during the webinar, a UAS that cost less than $2,000 provided a dataset worth $50,000.

Roadway construction monitoring. When the Utah Department of Transportation (DOT) used geospatial tools and a UAS for data collection for topographic mapping of a highway construction project on State Route 20, the agency saw a total savings of $82,672 compared to traditional methods. The UAS offered a more time-efficient means of surveying and geographic mapping and provided better photos of the construction progress over time, helping to complete the work 25 days ahead of schedule. The project scope involved adding climbing lanes to a steep hillside and included the use of small UASs for calculating earthwork quantities during construction. Because the FAA prohibits flights over moving vehicles and people, the team offset the flights from the roadway, but overlapped flights to cover the roadway. In addition, the flights landed as they reached each crossroad and then resumed on the far side.

Bridge inspection. A study by the Minnesota DOT, and a similar project in Michigan, found that photographs of bridge components taken by small rotary drones are valuable for visual inspection of delamination and for creating 3-D renderings. The Minnesota project team found that UASs can be effective for improving inspections and reducing costs and as a tool for interim and special inspections. Using drones can reduce the time spent near traffic and thus improve safety for inspection personnel. The Minnesota team found that UASs are more suitable as a tool for inspections of larger bridges, but some advantages were found for inspecting short span bridges and large culverts. Defects can be identified and viewed with a level of detail equivalent to a close-up photo for areas that are not easily accessible. The

ability to direct cameras upward and to fly the UAS without a GPS signal are important features when flying under bridges. A UAS could be used either as the sole means of conducting an inspection, or as a tool used in conjunction with other methods. Minnesota dealt with privacy concerns by carefully following regulations and being transparent.

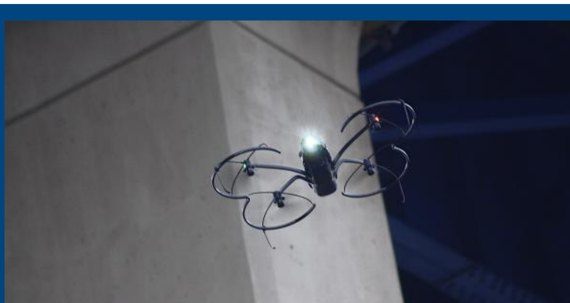
Pre-construction land surveying. UASs can provide important pre-inspection information for planning large-scale inspections. Information on bridge clearances, rope access anchor points, and general conditions can be obtained easily with a UAV and can aid in the planning of an inspection.

Automated asphalt pavement inspection. UAS equipment, including sensors, GPS, and high-resolution cameras, can cost a few hundred thousand dollars as compared to millions for traditional ground vehicles. UASs also can perform surveys much faster than vans, as drones have the ability to scan large and wide areas in a single pass. Using sophisticated algorithms, inspection teams can correctly identify various kinds of cracking defects such as fatigue, longitudinal, and transverse cracks.

Unpaved road condition monitoring. Transportation personnel can use data collected by a UAS for generating 3-D models for measuring the depth of ruts and potholes, and for identifying corrugation.

Avalanche monitoring. Drones have proved efficient for both triggering controlled avalanches and providing an infrastructure overview after avalanches. Pilot testing by the Washington State DOT observed that sturdier, fixed wing aircraft worked best for more difficult weather conditions. In addition to surveying conditions after an avalanche, a UAS can survey after a mudslide, tunnel collapse, or other event.

Traffic monitoring. UASs can provide valuable footage at high-incident locations to facilitate analysis of traffic patterns and for problem solving.



The manufacturer of the drone shown with LED lighting at the Blatnik Bridge in Duluth, MN, advertises its ability to switch between capturing video and still and thermal imagery during the same flight, without landing to change cameras.

Source: MnDOT

A drone at a border bridge between North Dakota and Minnesota in Neilsville, MN.

Source: MnDOT

Canadian researchers used low-cost cameras and UAS technology to observe a challenging roundabout facility and analyze motorist behavior. They found that the aerial angle offered by the UAS provided advantages over mounting a camera on a nearby building. Other research by Ohio State University found that UASs can provide valuable footage of a variety of facilities, including freeways, intersections, and parking lots, as well as footage of traffic flows.

Crash scene analysis. Tests by Michigan authorities found that a UAS, even with a low-resolution camera, provided useful imagery of crash scenes, although not at the level of detail needed to make quantitative measurements. With a higher resolution camera, as demonstrated by a project undertaken by the Bloomfield Township Police Department, UASs can provide rapid and low-cost aerial images of crash scenes with enough accuracy to support the reconstruction of crash scenes based on quantitative measurements from the images.

Advantages

Compared with traditional methods of collecting data, the study found that drones have high potential for the transportation sector. The reasons involve five factors:

- Low cost
- Ready availability off the shelf, with customizing as required
- Quick turnaround in data download and efficiency
- Ability to access remote locations
- Enhanced safety for humans

Specific advantages depend on the type of use. The study examined the advantages of UAS use in bridge inspections, automated asphalt

UAS Advantages Versus Traditional Approaches

UAS Bridge Inspections	Aerial Work Platform Advantages
• Low capital and maintenance costs • Increased safety of inspector and the public • No bridge weight restrictions • No lane closures required • Less mobilization time and cost	• Ability for inspector to be within arm's reach of bridge components • More reliable as inspector can touch and feel the components • Ability to perform nondestructive tests • Continuous uninterrupted inspection for long hours
UAS Automated Asphalt Pavement Inspections	**Ground Vehicle Advantages**
• Low initial cost due to in-house operation • Distress survey is faster as UASs can scan wide areas in a single pass • Data can be collected more frequently due to low cost	• High accuracy • Use in urban scenario, as its imagery is not blocked by traffic • More data coverage • Continuous data collection for an extended period
UAS Unpaved Road Condition Monitoring	**Manual Visual Inspection Advantages**
• Low data collection cost • More frequent surveys possible • Minimum lane closure • Re-measurement possible from collected data without an additional field visit • Ability to create an accurate 3-D model for potholes, rutting, corrugation, etc.	• High winds do not affect the data quality • Does not require image processing • Low initial cost

pavement inspections, and unpaved road condition monitoring.

Challenges

The study found certain challenges associated with the use of UASs. One is finding ample storage for the huge amount of data collected from a UAS. One contractor uses a separate server just for drone data. Other users employ external hard drives or storage in the cloud.

In addition, standardized data-sharing specifications are lacking in the current guidelines within road administrations. Their availability would facilitate using UASs to their full potential.

Further, safety concerns exist when operating in populated areas. The current generation of UASs has obstacle-avoidance systems to prevent crashing into structures, but a system capable of preventing a crash in a situation where a UAS loses control could greatly reduce the risk to the public.

Also, some low-end UASs have limited battery life and thus flight time, typically varying between 15 and 30 minutes. A longer battery life certainly will improve overall efficiency.

Finally, more extensive studies need to be done over a diverse region to validate performance in terms of accuracy and efficiency.

Recommendations

The report concludes that the use of UASs is more cost-effective than traditional methods in the following areas: bridge inspections, asset inventories and maintenance monitoring, preconstruction surveys (both green- and brown-field projects), construction monitoring, automated asphalt pavement inspections, monitoring the condition of unpaved and gravel roads, traffic monitoring, urban mapping, law enforcement for the reconstruction of crash scenes, and avalanche monitoring.

The areas where the use of drones is particularly recommended for low- and medium-income countries include bridge inspections, automated asphalt pavement inspections, unpaved and gravel road monitoring, and urban mapping.

While the technology is still under development, road authorities, manufacturers, and international organizations should set interoperability standards for global data integration.

Cawley concludes, "UASs have proved to be more cost-effective and safer than traditional methods. A UAS is often fast and nimble, allowing remote access that would otherwise be difficult or impossible."

Recommended Project Process for UAS Use

The report recommends a general process for new users of projects involving UASs. The process consists of three broad phases: preliminary, intermediate, and final. Users can adapt the process and further develop it for each region or specific project. Note that the process applies whenever a decision has been made to use UASs for data collection.

Recommended Project Process for Using UASs

Preliminary Steps

1. First and foremost step is to check if your country legally allows the use of UASs, as some countries do not allow UAS operations.
2. Familiarize yourself with the rules and regulations and licensing requirements of the national and local governments.
3. Make sure the project area falls within the allowed airspace for UAS operation, and fulfills all other requirements set by the governing authority, for example safe distance from public, airports, heliports, urban areas, built-up areas, etc.
4. Gather the project requirements such as type of data to be collected, that is, imagery, elevation, digital photos, thermal and infrared images, LiDAR, etc.
5. Once the project requirements are set, next step is to evaluate the UASs available in the industry and select the one(s) best suited for the job within the available budget.
6. Select the payloads as required.
   Estimate project costs in detail and compare with business-as-usual scenario.

Intermediate Steps

1. Select the project team, define their roles and responsibilities clearly based on their experience and expertise.
2. Within the project area, select a sample area to perform a pilot project to better understand and evaluate the potential of UASs without huge financial risk.
3. Develop a communication plan, outlining main point of contact, mode of communication (cell phones, radios, walkie talkies, etc.).
4. Develop an emergency plan describing the personnel and equipment available to respond to anticipated emergencies, including incidents and accidents, or medical emergencies.
5. If required, coordinate roadway closure, detour, and alternate access route for emergency vehicles.
6. Select the date and time for the UAS operation and communicate it to all parties involved, most important, the aviation department.

Final Steps

1. Set up the equipment, perform necessary checks to make sure all equipment is working fine.
   (Having a checklist is handy.)
2. Set up traffic closures and detours as required, and have emergency team ready on site.
3. Perform the flight operation and collect all necessary data.
4. If possible, check the data for completeness and quality before leaving the site. This helps avoid any re-flying operation.
5. Secure the data by uploading it to the server, cloud, and/or external hard drive as applicable.
6. Process and analyze the data as required and compare with the project requirements outlined initially.
7. Evaluate the project. If results from this pilot project are satisfactory, apply the same process for the entire project.
   Otherwise, modify the process based on lessons learned.

Final Notes

It is advisable to exercise due diligence while evaluating the available options for UAS projects. Organizations should evaluate UASs on a case-by-case basis, as there is no one-size-fits-all solution in the market. Although some older UAS technology might still be usable for certain projects, the fast-changing nature of the industry and its data collection attachments warrant a fresh evaluation for each project.

Still, UASs hold promise for many highway applications. The survey respondents for this research expressed satisfaction with their use of UASs, and more than 90 percent of respondents are planning additional work involving unmanned aircraft.

In view of these positive responses, road administrations and other organizations might consider updating their operations and maintenance protocols to include guidelines on the use of geospatial technology and UASs. Updated protocols could ensure that drones are considered for appropriate uses, given their potential advantages.

Clearly, unmanned aerial systems are opening a whole new transportation world.

For more information, see https://www.piarc.org/en/publications/.

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