MINNESOTA IT SERVICES

Smart Bridges – The Future Is Here

State of Minnesota: Minnesota IT Services

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Executive Summary

Minnesota has more than 20,800 bridges that require regular inspections and maintenance. Minnesotans cross those bridges more than 56.8 million times every day. Bridges are important components of our transportation system serving critical public needs. Federal law mandates periodic inspections to verify the structural integrity of bridges and plan for their maintenance, rehabilitation, and eventual replacement.

The architectural integrity of bridges is a primary focus for the Minnesota Department of Transportation (MnDOT) Bridge Office. Traditional inspection methods are expensive, time-consuming, pose personal safety risks for inspectors, and often cause traffic slow-downs and road hazards.

New technologies like inspection drones mean new opportunities to improve lives for Minnesotans. MnDOT began a multi-phased project in 2015 to research how we could leverage advancements in drone technology to ensure the safety and integrity of bridge architecture while lowering the risk to MnDOT inspectors and motorists. Each project phase built on the findings of the previous one and incorporated advancements in drone technology and FAA regulations.

The latest phase of a multi-phased project – Unmanned Aircraft Systems (UAS) - Metro District Bridge Inspection Implementation – was completed in 2021. The results showed that drone bridge inspections will lower costs, provide better quality data and asset management, improve safety for bridge inspectors and travelers, save tax dollars, and reduce traffic delays.

The long-term research explored different types of drones, their performance, and comparisons to hands-on inspections. Evaluations focused on drone capabilities to visualize, record and capture imagery for live, real-time reviews by multiple stakeholders, and compliance with existing Federal Aviation Administration (FAA) regulations. Drones rely on high-tech optical sensors to stabilize themselves in flight. Obstacle-avoidance features coupled with sophisticated high-resolution cameras allow multi-directional image captures of bridge structures. MnDOT researchers generated high-quality visual data and created 3D models of structures for inspection, repairs, maintenance, design, and load ratings for the life of the bridge.

This phased approach allowed Minnesota to collect the data needed over multiple years to show decision-makers that the project was worthy of investment based on our safety analysis, cost analysis, and data deliverables. MnDOT's use of cloud-based tools expanded data capacity exponentially. As a result of the project, MnDOT acquired 33 new drones and began to develop a proficient fleet for statewide use. Over the next two years, MnDOT teams are poised to perfect 3D modeling skills that will provide even greater benefits.

Why it matters: Inspection drones, 3D models, and augmented reality headsets can improve the quality of Minnesota's bridge inspections and improve worker safety.

Addressing Risks with Technology

MnDOT's Bridge Office started looking into drones for bridge inspection in 2015 by way of a research project. Recent news had focused on farmers using drones to monitor their crops. The teams posed this question: Could that technology help address the risks associated with traditional inspections? MnDOT embarked on this research journey with the goals of more access, better data, and safer methods.

Four phases of research on drones for bridge inspection have been completed, with each phase building on the last. A safety analysis was conducted in Phase 2, and a cost analysis was performed in Phase 3. This data supported the addition of implementing drones and 3D models as part of our work scope.

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How Drone Inspections Work

Drone inspections work well to inspect large bridges, ones in open areas, and those that need lane closures and specialized access equipment. Drones collect data faster than humans and do that almost entirely autonomously as they fly with only directional input from a pilot. They utilize sensors and input from GPS, an inertial measurement unit (IMU), compass, and cameras to gather high-quality visuals.

Drones can provide important pre-inspection information such as clearances, rope access anchor points, and current and general conditions for planning large-scale and emergency inspections.

Drones used in conjunction with thermal sensors can be an effective way to detect concrete delamination and can be done by flying adjacent to traffic lanes without closing the bridge to traffic.

High-Tech Turn for Bridge Inspections

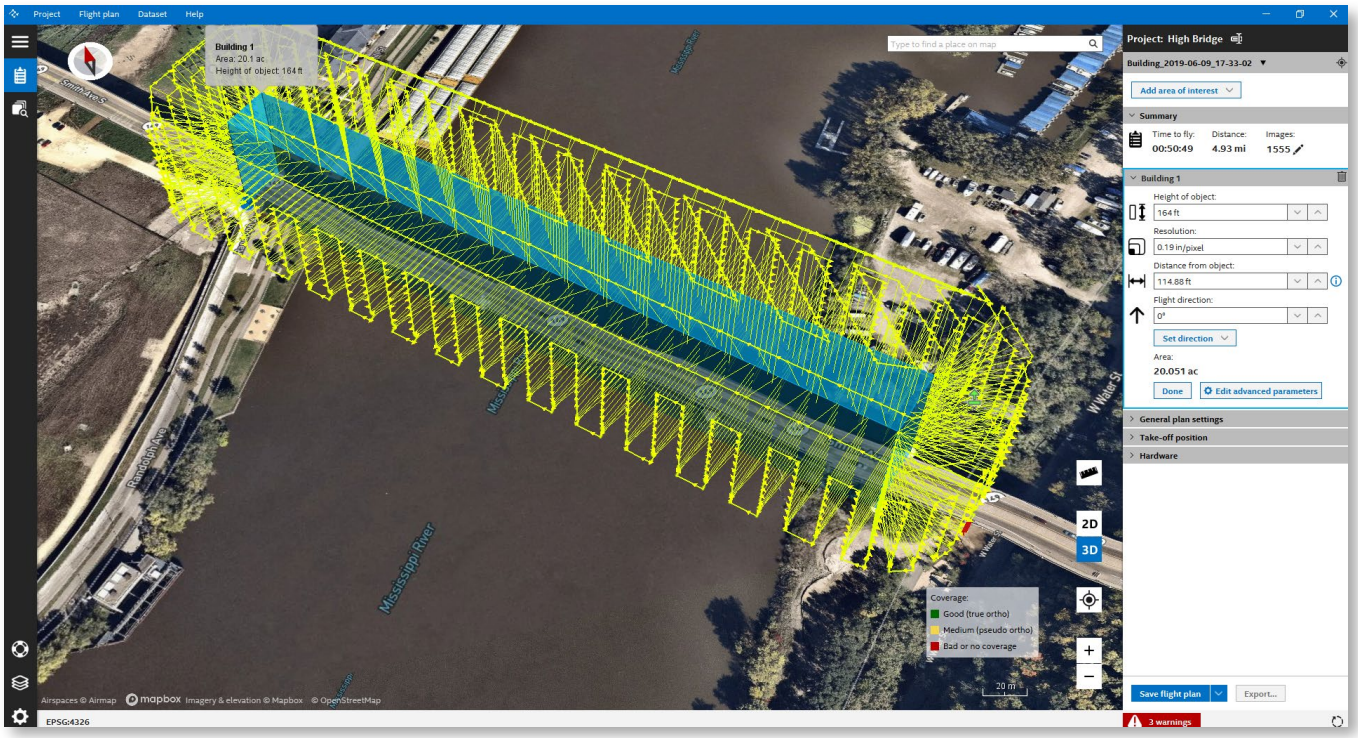
Drones may have been around for a while, but not inspection-specific drones. Inspection-specific drones are designed with cameras to look in all directions, be operated without the use of GPS (global positioning software), and have the ability to get really close to bridge architecture. Inspection-specific drones were starting to be developed in 2016. They are ideal for creating 3D models of structures for use across construction, inspection, maintenance, design, and load ratings for the life of the bridge. The 3D model represents a visual living document of the bridge's life span where all notes, photos, documents, condition states, and everything about the bridge will reside.

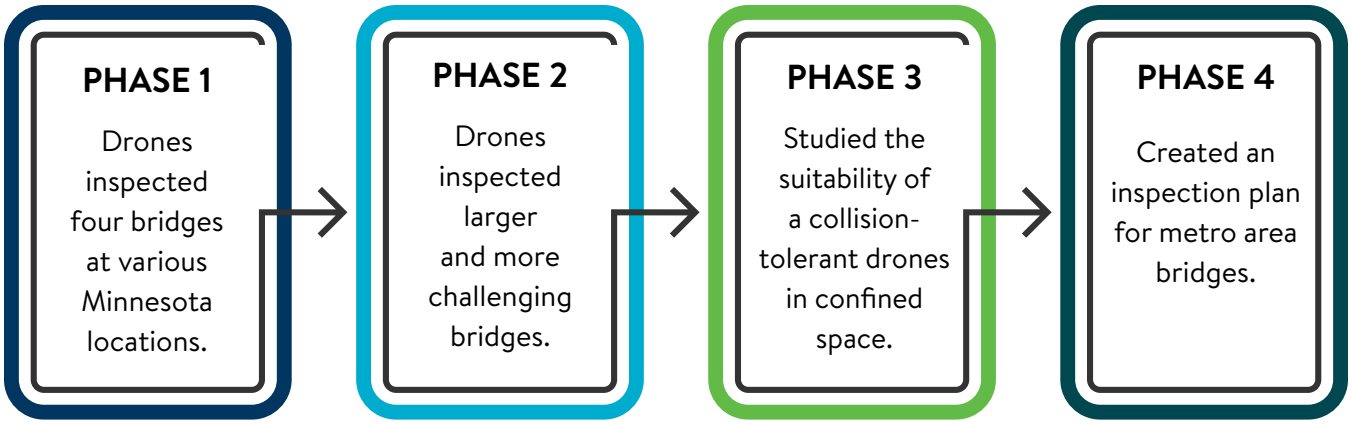
The National Bridge Inspection Standards (NBIS) sets minimum requirements for bridge inspections including inspector qualifications, inspection intervals, and inspection procedures. MnDOT's research aimed to discover whether drone inspections could meet or exceed those requirements.

The multi-year project explored relevant technology, including reality modeling software, drone hardware, artificial intelligence, and autonomous flights, eventually helping MnDOT develop expertise for the successful use of drone inspections. It also included developing cloud infrastructure to house and integrate data.

In phase 3, MnDOT focused on the value of data collected during the inspection, and on finding ways to process the data into improved, actionable inspection deliverables. The final inspection plan identified bridges best suited for drone use with a risk-based priority list and developed parameters (that include average-daily-traffic, bridge type and conditions, etc.) for standard inspection operations.

The project also helped develop a Safety and Operation Manual for drone use in the metro district that has been shared with other states along with all of the research and statistics.





Stitching Data: Blending Technologies

Data stitching is the process of combining different sets of related data into one common destination. There, the data can be merged, aggregated, summarized, and processed in many different ways to provide deep insights. MnDOT quickly realized that data integrations would be key to developing drone bridge inspection technology.

MnDOT's Bridge Office and a project consultant worked with the vendor to develop software for the Microsoft Hololens 2 to perform virtual inspections using mixed reality with Microsoft Azure Remote Rendering. A 3D reality model can be loaded on a Hololens headset, and the user can view the virtual bridge in a hologram, can take measurements, add notes, classify defects, and denote elements. This data can then be integrated into the bridge inspection report database as condition codes and quantities.

Inspection-specific drone technology is maturing and several drone models now offer features such as sense and avoid, infrared imaging, autonomous flights, and collision avoidance to promote their use for bridge inspections.

With improvements in technology, the focus has shifted from collecting data to making effective use of the data. Artificial intelligence, mixed reality, holograms, and reality modeling are helping such efforts.

Cloud support was also crucial to this work. This project happened during Minnesota IT Services' broad-scale effort to shift executive branch agencies to cloud computing. Access to on-demand web-based resources—applications, servers (physical servers and virtual servers),

data storage, development tools, networking capabilities, and more—was tailor-made for this project. It accommodates huge amounts of data, images, videos, and 3D models.

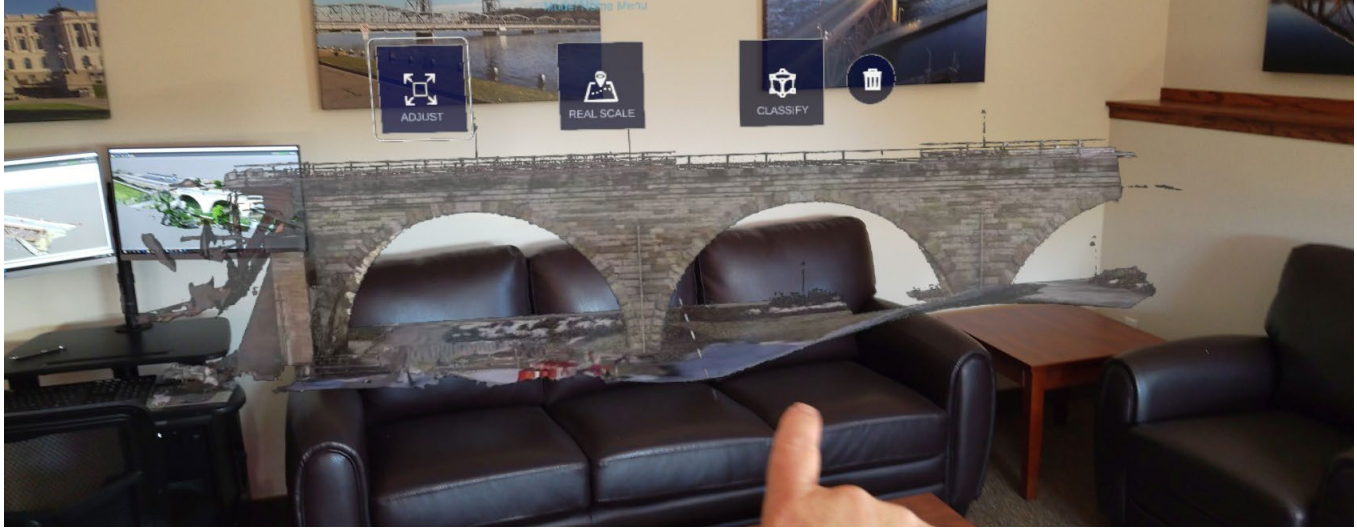
Mixed reality and cloud computing allow users to populate and review bridge inspection data from their offices and share it with experts in other locations to make decisions more quickly.

MnDOT aligned operations with the Office of Aeronautics before moving forward. Drone footage was turned into 3D models using Bentley Context Capture and Pix4D software to render models. The teams integrated the drone software DJI Pilot app. In conjunction with the Office of Aeronautics, MnDOT researchers began using Drone Logbook to help pilots plan and document missions and flights, and store maintenance records digitally. Hundreds of flights have been recorded now.

Solutions-Based Outcomes

Our efforts to find solutions helped address challenges along the way.

- The phased research-heavy approach helped MnDOT overcome various policy-related issues, allowing researchers to gather data while complying with rules and regulations.
- In 2015, Minnesota did not have a drone policy. This project helped initiate a state policy on drone use in Minnesota, and integrated operations with the Office of Aeronautics before moving forward.
- MnDOT researchers needed special permission from Minnesota's Governor before starting the project to address privacy concerns.
- The team worked with a lawyer to comply with FAA regulations. They relied on a commercial airline pilot to fly the drones until FAA Part 107 (rules for operating a drone commercially) removed that stipulation in 2016.
- The team relied on a drone logbook to capture records, help pilots plan and document missions and flights, and store maintenance records digitally. This ensured MnDOT complied with FAA record-keeping requirements, along with the team's work to adhere to other FAA drone rules and regulations.
- To document the work, before fieldwork began on any of the selected bridges, researchers had to prepare detailed investigation and safety plans for each structure, with site-specific plans addressing safety, potential hazards, and mitigation efforts. In Phase 4, this resulted in a drone inspection manual (Chapter U of the Minnesota Bridge and Structure Inspection Program Manual) which has been shared with other states, along with all of the research and statistics.



Extensive Research Paid Off

In the hands of experienced bridge inspectors, drones can help improve the safety and quality of inspections. The MnDOT project research showed drones can help reduce inspection costs over traditional inspection methods while producing sophisticated bridge inspection reports that include detailed still photos, videos, and 3D models.

Benefits:

- Require fewer crew members.
- Shorten or eliminate traffic closures.
- Improve safety for crews and drivers.

Shortening traffic closures is an important benefit because studies show the closure of traffic lanes is one of the biggest risks for bridge inspections. A work zone accident occurs every 5.4 minutes in the United States Between 2020 and 2021, work zone fatalities increased by 10.8 percent while overall roadway fatalities increased by 10.3 percent. There were increases in the percentages of fatal work zone crashes involving rear-end collisions, as well as those involving a commercial motor vehicle.

The Federal Highway Administration (FHWA) has identified this technology as a tool that can provide benefits for bridge inspections and the transportation industry. In 2022, FHWA updated the National Bridge Inspection Standards that approve the use of drones for routine bridge inspections.

Future Steps

MnDOT is moving to the next phase of this work, which will look at perfecting 3D modeling and other functionalities. Occasionally, the measurement of defects from the visual images gathered by drones may be less accurate, compared to the use of ground control points. As 3D modeling software based on drone data improves, so will measurement accuracy. MnDOT plans to refine its 3D modeling with the help of a consultant. The agency used an FHWA Statewide Transportation Innovation Council (STIC) Incentive Program grant to expand its drone fleet, buying drones with obstacle avoidance features and the ability to operate without GPS that are conducive to flying under structures with ease. MnDOT keeps track of drone inspections and plans to gather data over time to assess long-term savings. Drone inspections make identifying structural issues quick, efficient, and safe for immediate decisions for repairs, etc.

MnDOT will continue sharing information with other states along with all of the research and statistics.