



USDOT SMART FY2022 Grant: Smart Counties in Kansas

Recipient: North Central Regional Planning Commission

Final Implementation Report

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**North Central Regional
Planning Commission**

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EXECUTIVE SUMMARY INTRODUCTION AND PROJECT OVERVIEW

Executive Summary

The SMART Stage 1 project aimed to enhance transportation efficiency and safety by planning and prototyping smart technologies in rural communities in Kansas. This project focuses on introducing and uses select technologies in a rural setting. Specifically, infrastructure inspection utilizing drone technology and developing a GIS-based platform to integrate local infrastructure information. The two together offer innovative data solutions and decision-making tools. A key feature is the use of drone technology for bridge inspections, addressing the challenge of over 5% of structurally deficient bridges in Kansas. Drones provide an efficient, safe, and effective method for bridge inspections, particularly in hazardous conditions. The drone-collected data was processed using AI and integrated into a GIS platform, combining various data types to support large-scale inspections. This platform promises to enhance infrastructure safety and resilience in rural communities while engaging the public to raise awareness and encourage investment. The drone technology allows for quicker, safer inspections, helping prioritize bridge maintenance and repairs and promoting transparency and public communication.

Project Overview

The project had two main goals: developing a proof-of-concept for asset monitoring using drones and evaluating the feasibility of expanding the project across Kansas. Success in Stage 1 could lead to participation in SMART Stage 2. The project also fostered partnerships with government, industry, and academia, including Kansas State University, and the University of Maryland's Build America Center. Collaboration with American drone manufactures, highlights the project's commitment to using cutting-edge technology. Feedback from county engineers and bridge inspectors underscores the benefits of drones, such as accessing hard-to-reach areas, providing detailed imagery, and improving safety. Drones can identify structural deficiencies early, offering cost savings and reducing the need for emergency repairs. By removing inspectors from hazardous situations, drones increase safety and efficiency, supporting the project's broader goals of improving transportation infrastructure in Kansas.

Project Location

The Stage 1 SMART prototype was implemented in four Kansas counties: Sedgwick, Saline, Cowley, and Cloud. Table 1 presents each county's population, community proportional size, number of census tracts within Areas of Persistent Poverty (APP), proportion of the population living in APP, number of federally certified Opportunity Zones (OZs), and population within OZs. The project represents a regional collaboration among NCRPC, two rural counties, one large county, and one mid-sized county, with a combined population of 621,708. As shown in Table 1, the project area includes 60 APP tracts with a total population of 200,017—meaning nearly one-third of residents within the project's geographic scope live in persistent poverty.

On the other hand, the average proportion of structurally deficient bridges in the four counties that comprise the project area is nearly 4% (Table 2). Further, on average, approximately 56% of bridges in those four counties do not meet the currently acceptable standards for at least one traffic safety feature (i.e., bridge railings, transitions, approach guardrail, approach guardrail ends) or are

missing such safety-related information. The above statistics highlight the need for thorough bridge inspections to understand the conditions of bridges in the project’s study area and assess the safety risks they present

Table 1. Stage 1 Project Service Area

County	Population	Community Size	No. of Census Tracts	APP	Population in APP	% Population in APP	# of OA	Population in OA	% Population in OA
Sedgwick	523,824	Large	124	53	176,418	33.7%	9	25,301	4.8%
Saline	54,303	Midsized	12	3	12,993	23.9%	2	7,954	14.6%
Cowley	34,549	Rural	11	4	10,606	30.7%	2	7,904	22.9%
Cloud	9,032	Rural	4	0	0	0%	0	2,215	24.5%
Total	621,708	—	151	60	200,017	32.2%	13	43,374	7.0%

Notes: APP = Area of Persistent Poverty; No. = Number, OA = Opportunity Zone

USDOT defines rural areas as areas outside of metropolitan areas with populations of 50,000 or more.

Source of Data: U.S. Census Bureau, 2020 Census Population Data

[USDOT Grant Location Verification map](#)

[Community's Opportunity Zones map](#)

Table 2. Bridge Deficiency and Safety Information within the Project Service Area

County	No. of Bridges	No. of Structurally Deficient Bridges	% of Structurally Deficient Bridges	Bridges Not Meeting Traffic Safety Standards
Sedgwick	1,327	46	3.47%	30.17%
Saline	371	4	1.08%	51.15%
Cowley	339	21	6.19%	76.62%
Cloud	317	15	4.73%	65.06%
	Total = 2,354	Total = 86	Average = 3.87%	Average = 55.88%

Notes: No. = Number; % = Percentage

Source of Data: [FHWA's 2022 National Bridge Inventory \(NBI\)](#)

SMART PROJECT: Smart Counties in Kansas

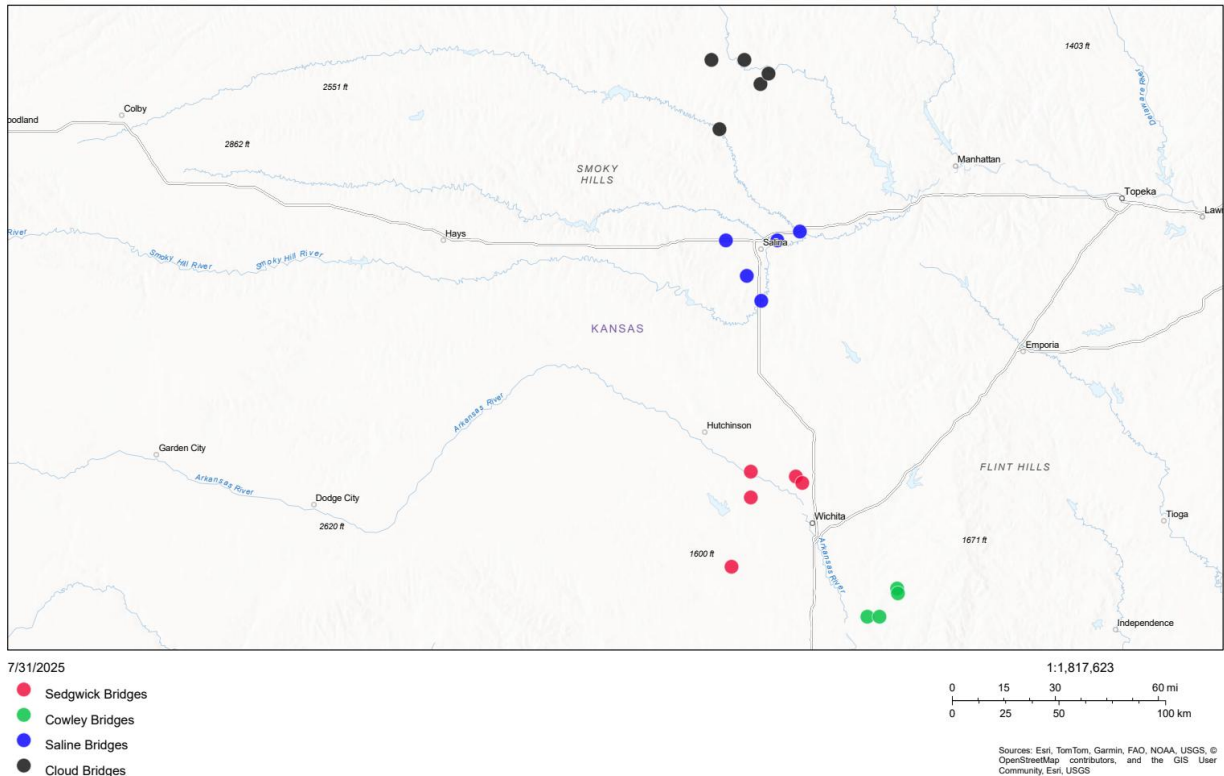


Figure 1. Map of Inspected Bridges

The initial step in project implementation was to conduct pilot testing to begin to understand the use of the technology and build a foundation for the algorithm. The selection of the three bridges in Saline County for pilot testing was based on specific criteria designed to maximize the effectiveness and applicability of drone technology. The selected bridges are county-owned and in fair condition, ensuring that they are representative of typical infrastructure challenges while still being safe for initial testing. All bridges are constructed from concrete, a common material in the area, which allows for consistent assessment across similar structures. Additionally, the bridges were ranked based on their span, which helps prioritize those that present unique structural challenges and opportunities for data collection. The algorithm used in this project was developed using a large dataset of bridge damage images sourced from public repositories. This dataset was customized with project-specific damage labeling, allowing for precise detection of structural issues and enabling the effective identification of damage patterns from drone collected imagery. This careful selection process ensures that the pilot testing will provide valuable insights into the benefits and limitations of drone-based bridge inspections.

Deployment Status and Project Activities

By the conclusion of this Stage 1 project, drone technology has been successfully deployed to inspect a total of twenty-two bridges across four counties including Saline County, Cowley County, Cloud County and Sedgwick County in Kansas. These bridges, mostly in fair or poor condition, served a demonstration and verification purpose to gather critical data and assess drone

operational efficiency and reliability. This phase allowed the project team to test different drone sizes and evaluate their effectiveness in detailed bridge inspections. We have also trained and deployed a machine learning model, YOLOv11, (You Only Look Once [YOLO] is a state-of-the-art, real-time object detection algorithm introduced in 2015 in the research paper [You Only Look Once: Unified, Real-Time Object Detection](#)) to automate the detection of bridge element damage, enhancing our data analysis capabilities by accurately identifying structural deficiencies and correlate with the bridge condition rating. This AI workflow would be critical in streamlining the inspection process and improving data accuracy. Specifically, starting this past spring, a large-scale implementation of drone-based bridge inspections across all four counties was successfully carried out as part of the project. This broader application included the integration of a GIS system platform that seamlessly incorporates bridge condition data and other data create a comprehensive view of the physical and social conditions surrounding the bridge. This integration is expected to facilitate efficient monitoring, analysis, and public communication of infrastructure assets, offering a comprehensive view of transportation safety and resilience. The ultimate goal is improving the reliability of existing transportation facilities and systems. In addition to bridge inspections, the NCRPC is exploring other potential applications of drone and GIS platforms, such as wildfire detection, search and rescue operations, improved emergency response and bulk material (e.g. construction material stockpile) surveys. These applications demonstrate the versatility of drones and GIS technology in addressing various community needs. Through these initiatives, we aim to improve the safety and resilience of critical infrastructure while expanding the capabilities of drone technology in Kansas.

As detailed in the quarterly reports, the following project activities have been completed during the SMART Stage 1 grant period of performance:

- **Use Case Identification:** As an initial activity, identifying use cases was crucial for understanding the specific needs and ensuring the selection of appropriate drones for the project. To gain a comprehensive understanding, we conducted internal interviews with staff engineers from the four participating counties. Major use case scenarios for drones were identified, including bridge inspection, emergency response, real estate appraisal, wildfire monitoring and flooding evaluation. These findings were meticulously documented and served as key inputs for the subsequent drone procurement process. The documentation process ensured that every possible application of drones was considered, aligning the technological capabilities with practical field requirements.
- **Drone Procurement:** In collaboration with the four pilot counties, NCRPC project staff began with an in-depth study of drone specifications and capabilities, followed by issuing a Request for Proposal (RFP) to identify potential suppliers. In June 2024, we received a total of five qualified bid packages. The Build America Center (BAC) assisted in evaluating the capacity of various drones. The decision-making process involved comprehensive internal surveys, detailed questionnaires, and interviews with county engineers and staff to ensure the selection of the best drones suited for the project needs. The evaluation focused on aspects such as drone durability, imaging quality, and operational range to ensure alignment with the project's specific use cases.
- **Drone Testing in Four Counties:** Pilot testing was conducted on three bridges in Saline County using two different sizes of drones to evaluate their performance and suitability for bridge inspections in late July 2024. In Spring 2025, formal field tests on twenty bridges were carried out. These bridges represent different bridge types, age, span length, deck and

superstructure conditions, overall bridge condition rating. Before the field tests, a drone-based bridge inspection data collection procedure was developed for this project. This procedure and a best practices document outline the process for conducting efficient, safe, and thorough bridge inspections using Unmanned Aerial Systems (UAS), ensuring structural integrity, identifying potential defects, and adhering to regulatory standards. A guide for bridge inspection was also developed and provided to county engineers participating in the field test with an aim to leverage drones to gather a comprehensive dataset of bridge information for developing an AI algorithm to detect structural issues. This guideline establishes a pilot testing workflow for standardized operations, focusing on data collection within four counties in the pilot project: Saline, Sedgwick, Cowley, and Cloud. These tests provided essential data on the operational efficiency and reliability of the drones, allowing us to assess their capability to perform detailed inspections. During this process, we collected valuable field data and identified both the strengths and weaknesses of the drone models, which informed decisions for future deployments and adjustments in drone technology utilization.

- **Algorithm Testing:** NCRPC contracted with BAC to train the YOLOv11 AI model on an expanded benchmark dataset to enhance its accuracy in detecting structural deficiencies with a focus on eight types of defects/damages common in concrete and steel bridges. These eight types of damages include cracks, rust, washout (wet concrete), concrete spalling, efflorescence, etc. The dataset was modified to fit the YOLO v11 format and additional images from Kansas were annotated and included into the training dataset. Reliably identifying reinforced concrete defects plays a crucial role in assessing the structural integrity, traffic safety, and long-term durability of bridges. Building on the established architecture of YOLO, YOLOv11 has enhanced performance compared with YOLOv8, achieved through introducing architectural innovations and parameter optimization. This testing phase was crucial for refining our data analysis capabilities, allowing for precise identification of potential issues in infrastructure elements. The advanced algorithm serves as a critical component of the drone inspection process, enabling automated analysis and interaction. The insights gained from AI-driven knowledge extraction will be pivotal in enabling informed decision-making, such as streamlining maintenance prioritization processes.
- **Training Preparation:** Collaboration with Kansas State University (KSU) was integral to our training efforts. KSU utilized well-established training modules for licensed pilots, project team members, and stakeholders, focusing on drone operation, data collection, and safety protocols. This one-week training program from August 19 to 22, 2024 at the KSU Salina campus, aims to equip participants with the necessary skills to operate drones efficiently and safely, ensuring high-quality data collection and analysis.
- **Drone-based Bridge Inspection Across Four Counties:** Building on the success of the pilot tests, we have conducted a large-scale implementation of drone-based bridge inspections across all four counties. Table 3 (page 7) lists the bridges selected for this field test of drone-based bridge inspection technology. In the field tests, drones were operated and flown over selected bridges in accordance with an established guideline for bridge inspections using drones to collect images and videos of bridge elements. The NBI condition rating data for several bridges was compared with the AI-detected defect counts from video clips collected by drones in the field test. The insights gained from AI-driven knowledge

extraction will be pivotal in enabling informed decision-making, such as streamlining maintenance prioritization processes.

- **Drone Flight Path Planning Strategy:** The flight path strategy was developed to ensure complete visual coverage of all structural components of the bridge while maintaining optimal imaging conditions for defect detection. The planning considered critical parameters such as flight height, lateral offset, camera angle, image overlap, and drone speed based on the desired ground sampling distance (GSD). Distinct paths were defined for the top, sides, and underside of the bridge, ensuring safe drone navigation and consistent data quality. The planning also factored in obstructions like piers and abutments, with flexible path adjustments to capture hard-to-reach areas. See Figure 2 below for a schematic view of the drone flight path proposed for the field test.

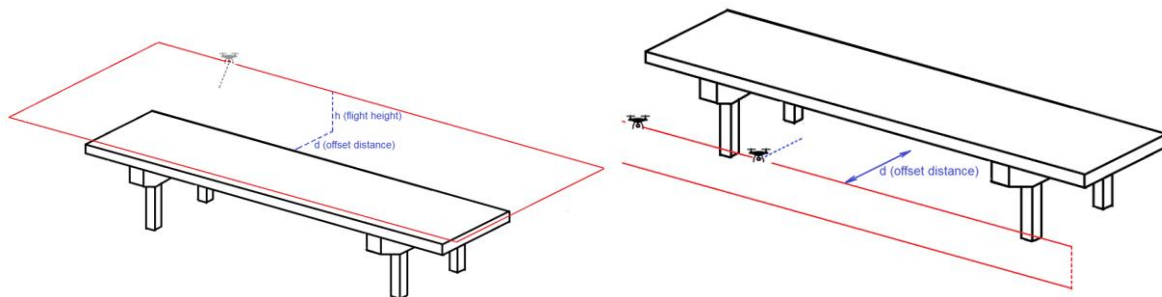


Figure 2: Simplified flight path strategy for inspecting the top and sides of the bridge, intended for use by county engineers in defect detection.

- **GIS Platform Integration:** The SMART phase 1 project allowed the NCRPC to make significant progress in planning the integration of drone-collected data into a Geographic Information System (GIS) platform. This integration will facilitate public communication of the project, enabling efficient monitoring and analysis of infrastructure assets. The GIS platform will serve as a central repository for data visualization, allowing stakeholders to access real-time information about infrastructure conditions and maintenance needs.

Stage 1 has been marked by significant achievements, setting a solid foundation for the project's subsequent phase. There have been no significant deviations from the original proposal. The engagement of key partners, and the successful completion of all planned tasks have positioned us well for future expansion and implementation.

For a Stage 2 SMART Grant, including at-scale implementation across the state of Kansas, over 20 counties and regional organizations have expressed interest in joining this broader implementation. This expansion will include a wide range of drone applications, such as agricultural surveys, health device and medical delivery, wildfire detection, disaster assessment, and rescue operations for people and animals. Additionally, a new technical platform and GIS system will be developed, deployed, and implemented to deliver integrated benefits across various sectors. The scaled-up deployment aims to ensure regular, systematic inspections of infrastructure assets in rural Kansas, enhancing the safety, reliability, and resiliency of the state's transportation infrastructure. By leveraging advanced drone technology, the project seeks to create a sustainable, efficient, and cost-effective solution for continuous infrastructure monitoring and maintenance. This initiative will not only improve infrastructure management but also position Kansas as a

leader in innovative drone applications, benefiting various sectors and communities across the state.

Table 3. List of drone inspected bridges in Stage 1 project field tests

Bridge	LAT 016 (deg)	LONG 017 (deg)	Age (Yr)	STRUCTURE TYPE 043B	DECK COND 058	SUPER-STRUCTURE COND 059	SUB-STRUCTURE COND 060	BRIDGE COND. RATING
Cowley Co. Bridge#1	38.523438	-97.475464	62	3	6	7	7	F
Cowley Co. Bridge#2	38.433614	-97.411324	27	1	7	7	7	G
Cowley Co. Bridge#3	38.372852	-97.363754	65	4	6	6	6	F
Cowley Co. Bridge#4	38.523742	-97.312357	41	2	6	8	7	F
Cowley Co. Bridge#5	38.544885	-97.240350	40	2	7	7	7	G
Sedgwick Co. Bridge#1	37.525936	-97.253046	72	2	4	6	6	P
Sedgwick Co. Bridge#2	37.301069	-97.461568	19	1	6	7	5	F
Sedgwick Co. Bridge#3	37.542235	-93.95552	26	1	4	6	6	P
Sedgwick Co. Bridge#4	37.474810	-97.394800	26	1	4	5	7	P
Sedgwick Co. Bridge#5	37.512145	-97.232186	68	2	6	8	7	F
Saline Co. Bridge#1	38.523438	-97.475464	62	3	6	7	7	F
Saline Co. Bridge#2	38.433614	-97.411324	27	1	7	7	7	G
Saline Co. Bridge#3	38.372852	-97.363754	65	4	6	6	6	F
Saline Co. Bridge#4	38.523742	-97.312357	41	2	6	8	7	F
Saline Co. Bridge#5	38.544885	-97.240350	40	2	7	7	7	G
Saline Co. Bridge#6	38.523438	-97.475464	62	3	6	7	7	F
Saline Co. Bridge#7	38.523742	-97.312357	41	2	6	8	7	F
Saline Co. Bridge#8	38.572178	-97.454075	73	2	7	7	6	F
Cloud Co. Bridge#1	39.312875	-97.364872	56	1	7	7	7	G
Cloud Co. Bridge#2	39.595249	-97.535747	5	1	8	8	8	G
Cloud Co. Bridge#3	40.000756	-97.545652	42	2	7	7	6	F
Cloud Co. Bridge#4	39.340070	-97.542383	70	2	7	7	7	G
Cloud Co. Bridge#5	39.593521	-97.555539	51	2	7	7	7	G

Public Attention

The project has garnered significant interest and attention within county staff, underscoring its importance and potential impact on local infrastructure. Although we are still in the preliminary phase and have not yet presented at conferences or published academic articles, these opportunities may be considered in the future. [A video](#) detailing the project's objectives was posted on YouTube by Build America Center, further increasing the visibility and engagement of the project. The NCRPC project manager also presented about the project to a regional Kansas Department of Transportation Meeting shortly after award.



NCRPC SMART GRANT



PROOF-OF-CONCEPT OR PROTOTYPE EVALUATION FINDINGS

In collaboration with the BAC team, an instance segmentation-based machine learning model and corresponding training dataset to automate the bridge condition assessment with drone collected imagery and video data was developed. The instance segmentation algorithm can be viewed as a combination of semantic segmentation and object detection commonly used for computer vision. Whereas an object detection system coarsely localizes multiple objects with bounding boxes, instance segmentation produces a segment map of each category as well as each instance of a particular class, therefore, providing a more meaningful inference on an image. The YOLO-v11 instance segmentation model was adopted to perform bridge condition assessment by detecting damages in drone collected videos and images in this project. This model was trained using approximately 6,000 labeled images of concrete bridges, covering eight types of concrete damage: cracking, alligator cracking, efflorescence, concrete corrosion, spalling, wetspots, rust staining, and exposed reinforcement. A corresponding flight path planning strategy was developed to support accurate data collection for these defect classes.

Based on findings from the Kansas bridge inventory data analysis, the bridge condition assessment using machine learning model training is focused on concrete bridges. Figure 3 below shows the Kansas distribution of national bridge inventory data (NBI) on bridge element condition rating in Year 2023. Element numbers 110 and 105 refers to reinforced concrete girder/beam and closed web/box girder respectively. Element numbers 16 and 38 refers to reinforced concrete top flange (of beams) and slab respectively. Element number 12 is a reinforced concrete deck. It is seen from Figure 3 that the major population of Kansas bridges are concrete bridges and those bridge members with low condition rating (e.g., CS4) requiring attention and likely repair action are made of concrete with steel reinforcements. Therefore, the current training dataset is primarily comprised of concrete damage patterns (cracking, efflorescence, washouts/concrete corrosion, spalling, wet spot, exposed rebar, alligator cracking, rust) adapted from a public shared database - dacl10k with significant effort made in correction and modification to fit with the YOLO format. This adapting work includes manual conversion of each image to a YOLO compatible format and re-annotation by removing unused object polygons in the original image datasets. It was also noted during model training that the original dacl10 dataset has errors in annotation that have to be first

corrected before a YOLOv11 machine learning model can be trained with acceptable accuracy. Additional bridge damage images from Kansas bridges were also annotated and added to the training dataset, with more data collected by drones during the field tests conducted in spring 2025.

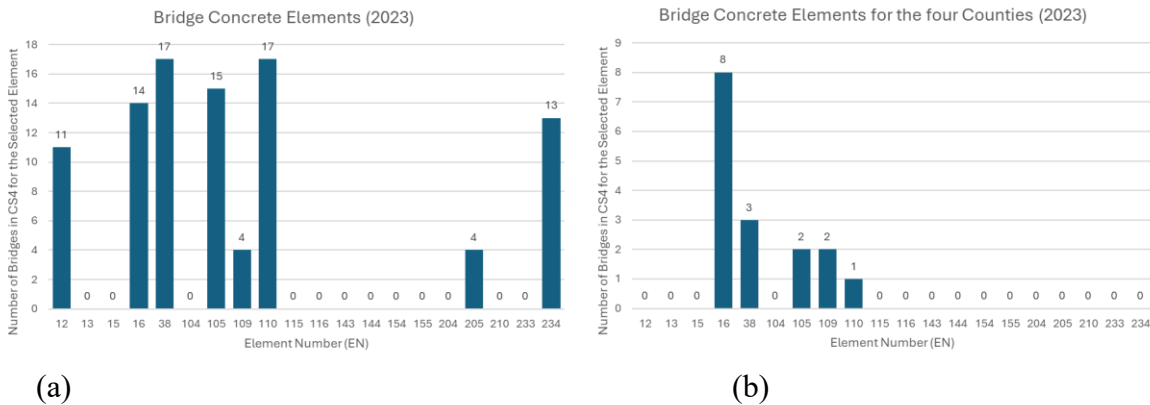


Figure 3. Histogram of Kansas State Concrete Bridge Elements in Condition Rating 4 (CS4) from Year 2023 NBI Data: (a) Kansas statewide; (b) Four counties (Cowley, Cloud, Sedgwick, Saline Counties)

To leverage the trained machine learning models using data gathered through drones to evaluate bridge conditions, a large-scale field implementation of drones was carried out on twenty bridges across four counties (Cowley, Cloud, Sedgwick, Saline Counties, Kansas). Information on these bridges are shown in Table 3. Figure 4 below shows sample images collected by drones of these bridges during the field tests. Most bridges are concrete bridges while some bridges have steel girders. Drones were used to collect overall and local bridge condition data through cameras and LiDAR sensors mounted on the drones. The bridge inspection data collected by drones has been processed by the BAC team to prepare data for machine learning based automated condition assessment (concrete damage pattern recognition at this stage).



Figure 4. Sample bridges selected for full-scale implementation field test in Spring 2025

Major Findings

The prototype AI-powered bridge condition assessment workflow using drone-collected data offers a useful tool in bridge management. At its core, this system integrates two key components: advanced drone-based inspection and sophisticated machine learning models. The primary objective is to equip engineers with powerful tools that dramatically enhance the efficiency and effectiveness of bridge inspections. By automating a critical part of the assessment process, the workflow is intended to help engineers more quickly and accurately identify potential problem spots that require immediate attention and maintenance action.

The true value of the machine learning component lies in its ability to automatically detect damage. This capability is particularly useful and transformative because the overwhelming majority of images captured during a typical drone-based field inspection are of locations where manual inspection may be difficult to access such as in the middle span over a river. Traditionally, engineers would have to manually sift through thousands of high-resolution images, a time-consuming and often tedious task. The machine learning models effectively act as a powerful filter, intelligently analyzing the visual data to pinpoint and highlight only the anomalies, such as cracks, spalling, or corrosion. This automation allows engineers to focus their valuable expertise on analyzing these specific flagged locations, performing more detailed assessments, and formulating precise maintenance plans, thereby optimizing their workflow and redirecting resources to where they are most needed. In essence, the framework transforms a resource-intensive, manual review process into a data-driven, exception-based workflow. Machine learning models are thus highly desirable and instrumental in assessing the quality of bridge inspections conducted via drones. It is worth noting that the Stage 1 project results suggest strong evidence of a distinguishable correlation existing between NBI bridge element condition ratings and the number of defects detected by AI from drone-collected inspection video images. This correlation shows promise for enabling automated AI-powered bridge condition assessment and rating. Further research is needed in the next phase to develop methods for deriving NBI condition ratings for selected bridge elements (e.g., superstructure, deck) based on normalized AI-detected defect counts from drone video footage and more bridge inspection cases.

The YOLOv11 machine learning models trained by the BAC team were applied to images collected during the bridge field test in all four counties in Kansas (Cloud, Cowley, Saline, and Sedgwick counties). Figures 4 to 7 present proof-of-concept results showing how the model can support bridge condition assessment by detecting and annotating eight categories of concrete damage.

Figure 5 shows the detection results from the Sedgwick Bridge (structure number 00000000870040), with polygons drawn around identified defects such as cracks, alligator cracks, and concrete rust. Figure 6a illustrates the detection of washed concrete (WConccor) and concrete spalling on two piers of a bridge in Sedgwick County, while Figure 6b highlights multiple defects—spalling, cracks, and rust—on another bridge in the same county. Figures 6a and 7b display results from Saline County, where 7a captures a large spalling defect, and 6b shows the model successfully identifying multiple defects that coexist at the same location such as rust, spalling, and exposed rebars on the same bridge pier. Figures 8a and 8b show test results from a bridge in Cowley County, demonstrating that the model performs well even when defects are small or difficult to see. For instance, Figure 8a shows detection of a small spalling that is on underside

of the bridge deck and difficult to see, and Figure 8b shows small and dispersed defects of rust on the bridge girders. While the results are promising, the YOLOv11 model can still be improved in next stage research. Expanding the training dataset with additional images and more damage patterns with different severity will help make the model more robust and better suitable for detecting a wider variety of concrete defects. Moreover, close-up view images tend to be more effective than overall views for local damage detection due to the higher resolution details they provide for instance segmentation.



(a) (b)

Figure 5. Various concrete defects on the Sedgwick County bridge (structure number 000000000870040) detected using the trained AI model: (a) original image; (b) image with polygonal annotations generated by the YOLOv11-trained model.



(a) (b)

Figure 6. Detection of WConcocr and multiple surface defects on Sedgwick County bridges using YOLOv11 trained model: (a) Washed concrete and spalling on bridge piers (Structure No. 000000000870670); (b) Spalling, cracking, and rust detected on a second Sedgwick County bridge (Structure No. 000000000870090).



Figure 7. Concrete defect detection on Saline County bridges using YOLOv11: (a) Large spalling area identified (Structure No. 000000000850950); (b) Simultaneous detection of rust, spalling, and exposed rebar at the same location (Structure No. 000000000850770).



Figure 8. Detection of small defects that are difficult to see on Cowley and Sedgwick County bridges using YOLOv11: (a) Spalling identified on the underside of the bridge deck (Structure No. 000000000180890); (b) Small rust fragments detected on bridge girders (Structure No. 000000000870040).

To support counties in quickly identifying and classifying bridge damage, the project team developed and deployed an AI-powered detection API, available at <http://yolo-ecs-alb-1-2142871012.us-east-1.elb.amazonaws.com/docs>. County engineers can upload inspection images or video frames via the API interface, which processes the input in real time and returns both the predicted damage category and the location of the damage within the image as bounding boxes. Results are provided in a standardized JSON format, enabling seamless integration into existing GIS platforms or asset management systems. By automating the detection step, the API streamlines

inspections, reduces the need for manual image review, and accelerates decision-making for maintenance prioritization.

In this project, the project team also evaluated the effectiveness of field data collection using drones and algorithms to optimize drone flight paths for generating point cloud data through photogrammetry and LiDAR sensors. A guideline for planning drone flight path and operation was also developed to enable accurate data collection for AI-powered bridge damage detection and classification. Figure 9 shows the rendering of the point cloud data of a concrete haunch bridge located in Saline County. The point cloud data was collected using the LiDAR sensor mounted on a Skydio drone purchased for this project.



Figure 9. Point cloud data collected by Skydio drone in Saline County, Kansas

Objective Alignment

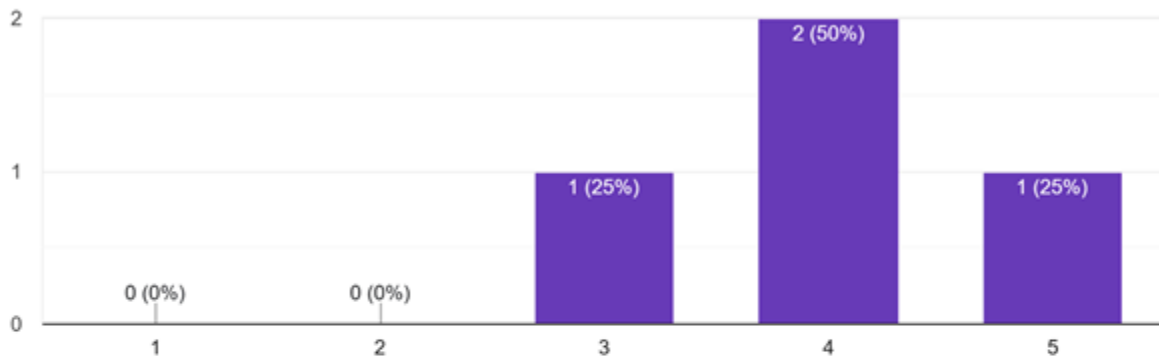
The objective alignment of this project focuses on several key areas: transportation safety and efficiency, community benefit, cost savings and economic impact, and workforce development. Specific touch points are addressed later. For transportation safety and efficiency, pilot testing was conducted on three bridges to evaluate inspection time and quality. Results showed that the use of drones reduced inspection time, confirming scalability and alignment with our proposal targets. This commitment to minimizing disruptions in underserved areas is a priority, and will continue to be monitored in a SMART Phase 2 project. In terms of cost savings and economic impact, a survey was conducted comparing manual inspection costs with those associated with using drones. Preliminary findings suggest that at-scale implementation of drone technology could lead to significant cost reductions, offering a more economical solution for infrastructure inspections. Finally, for workforce development, we trained 11 local officials in drone-based inspection techniques, with all of them becoming certified drone pilots. This initiative is ensuring that local personnel are equipped with the skills needed for modern infrastructure management. These aligned objectives demonstrate a comprehensive approach to improving transportation systems while supporting community and economic development.

County Engineers' Evaluation of the GIS and Drone Implementation

Overall, county engineers expressed positive feedback regarding the use of both GIS and drone technologies, with GIS in particular standing out as a valuable tool. On a five-point scale, the average rating for GIS outputs being understandable, relevant, and actionable was 4.0, indicating that engineers found the platform very clear and very easy to use. Confidence in identifying assets posing immediate safety risks also scored very high. Engineers also reported that the visual and interactive nature of GIS mapping improved their ability to verify information and communicate findings to stakeholders. Drone usage received an average satisfaction score of 4 out of 5, reflecting a generally satisfactory experience. Respondents appreciated the opportunity to gain exposure to drone technology and valued the additional perspectives that aerial imagery could provide.

1. To what extent did you find the GIS outputs understandable, relevant, and actionable?

4 responses



3. To what extent did the StoryMap improve your confidence in identifying assets that pose an immediate safety risk ?

4 responses

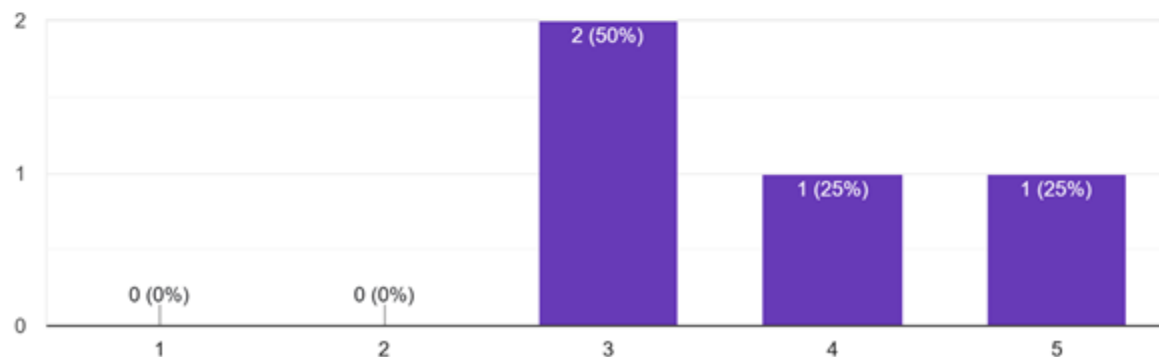


Figure 10. County Engineers' Feedback on GIS Use

In terms of efficiency, GIS demonstrated clear advantages. Engineers reported an average of 20 minutes saved per asset when using the StoryMap compared with prior methods of locating inspection data (Table 4). This efficiency came from the ability to consolidate spatial data in a single platform, reducing the need for manual cross-referencing. In contrast, the drone-based

bridge inspection component showed little measurable time savings. The average estimated reduction in worker-hours within three years was only 2%, with one engineer stating that drones, while useful for supplementary imagery, did not replace the need for conventional on-site inspections. For many, the additional preparation, compliance requirements, and data processing offset any potential time efficiencies.

Table 4 Time Savings from the Use of GIS and Drone for Bridge Inspection

Respondent	Time Savings from StoryMap	Time Savings from Drone Use for Bridge Inspection	New Job Required for Using GIS/Drone	Safety Impact
Engineer #1	60 min	30% worker-hours	1-2	Low Risk
Engineer #2	4 min	No time savings	1	Low Risk
Engineer #3	0	Longer than regular Inspection	0	Low Risk
Engineer #4	20 min	N.A.	N.A.	N.A.

Regarding workforce impacts, responses suggested limited but notable potential for job creation. The average estimated number of new full-time roles (e.g., technicians, data analysts) needed for at-scale county-level operations was 1 per county, reflecting that most respondents did not foresee large-scale hiring in the immediate term. However, engineers recognized that GIS maintenance and expansion, as well as specialized drone operation and image analysis, could create new technical roles in the future. Several also highlighted the importance of ongoing training, such as FAA Part 107 certification for drone pilots and GIS/AI model tuning skills, to sustain the use of these technologies.

Despite these benefits, survey responses indicated no significant improvements in coordination with other agencies, with average ratings in this category falling into the neutral range. Communication workflows appeared largely unchanged, suggesting that the tools alone did not drive stronger inter-agency collaboration. Similarly, there was no observed improvement in safety, which engineers attributed to already low incident rates—most counties reported zero or near-zero inspector injuries or near-misses over the last five years. As a result, while GIS and drones enhanced data visualization and offered potential for new technical roles, they did not significantly alter coordination practices or safety outcomes in this initial implementation.

ANTICIPATED COSTS AND BENEFITS OF AT-SCALE IMPLEMENTATION

The at-scale implementation of our drone technology project across the state of Kansas involves collaboration with over 20 counties and regional organizations eager to join Stage 2. This expansion will cover a variety of drone applications, including agricultural surveys, wildfire detection, and disaster assessment, as well as rescue operations. A Drone Application Center will be established in the north central region of Kansas to coordinate with the emphasis on UAS technology in the region. One facet of the Center work will include training and technical support to local governments. Additionally, the existing GIS platform will be expanded state-wide to

ensure regular, systematic inspections of infrastructure assets across all regions in Kansas. This initiative aims to enhance the safety, reliability, and resiliency of Kansas's transportation infrastructure while providing cost-effective solutions for continuous monitoring and maintenance. Through this large-scale deployment, Kansas will set a precedent for innovative drone applications, benefiting diverse sectors and communities across the state.

Impact of at-scale implementation

Based on the findings in stage 1 implementation, the anticipated impacts of at-scale implementation for each key goal area are as follows:

Safety and Reliability: Survey results from Stage 1 show that counties already maintain a strong safety record in bridge inspections, with most reporting zero inspector injuries or near-miss incidents in the last five years. This means that immediate safety gains from scaling up may be modest in routine operations. However, at a statewide scale, the integration of drones and GIS has the potential to further reduce risk exposure by minimizing the need for inspectors to enter difficult or hazardous areas. Even with the Stage 1 finding of a modest 2% estimated reduction in worker-hours from drone use, broader adoption could accumulate into substantial statewide labor savings and reduced exposure hours over time. Being able to reliably visualize, via drone technology, portions of a bridge that are not always physically accessible is a positive use case.

Resiliency: Drones equipped for rapid aerial assessment could improve situational awareness during natural disasters, such as floods or wildfires, enabling quicker protective actions and potentially saving lives and property. GIS integration would further support and improve emergency response by providing real-time mapping of impacted areas and helping coordinate resources more effectively. For specialized tasks such as quantity takeoff, drones could replace the need for personnel to conduct physical measurements in hazardous environments, reducing the risk of falls and other injuries while maintaining accuracy and efficiency.

Access and Sustainability: Comprehensive drone data allows for the identification of underserved areas. This information enables targeted improvements, such as enhancing bridge safety and infrastructure in low-access regions, ensuring equitable distribution of transportation resources and providing all community members with improved mobility options. Drones enable more efficient and frequent inspections, preventing infrastructure failures and reducing the need for extensive repairs. At-scale implementation can also reduce the travel requirements for inspectors.

Partnerships: The at-scale implementation of drones in bridge inspection will foster strong partnerships among government agencies, private companies, and community organizations. Collaborative efforts will be essential for deploying and operating advanced transportation technologies. For example, the BAC center can develop machine learning algorithms, KSU can provide pilot training, and various counties can integrate and share data. These partnerships will drive innovation, share expertise, and pool resources, ensuring efficient project implementation and shortening the learning curve.

Integration: The at-scale implementation of drones in bridge inspection aims to create a fully integrated process. Data from multiple sources can be stored and incorporated into a GIS system, making it accessible to the public. Additionally, drones can be shared among various county

departments, including the police and engineering departments, promoting technology integration and skill sharing. Figure 11 shows the county engineers practicing drone flying in the KSU Salina drone training workshop from August 19 to 22, 2024.



Figure 11. Photos of county engineers practicing drone-flying in the KSU Salina drone training workshop from August 19 to 22, 2024

Workforce Development: Survey results from Stage 1 indicate that at-scale implementation would generate a modest but measurable increase in technical staffing, with county engineers estimating an average of 1 new full-time positions per county for roles such as drone pilots, GIS analysts, or AI model managers. While most counties expect to rely primarily on existing staff, large-scale deployment would require significant upskilling of inspectors and related personnel, including FAA Part 107 certification for drone operation and advanced GIS or AI-model training. This expansion in technical capability aligns with Buy America compliance, supporting domestic drone manufacturing and fostering sustainable business practices through the development of a skilled local workforce. Through the project, NCRPC was able to support the local community college by enhancing the drone fleet that they use for student training. A series of training videos were also developed and are housed on the NCRPC website. These videos are a reference tool for new drone pilots and are specific to the bridge inspection use case.

Cost Estimation

The cost estimate for scaling up drone technology includes several major components. Drone equipment and technology costs account for the purchase of 50 Skydio X10 drones (or equivalent) at \$18,000 per unit, totaling \$900,000. Each unit will require onboard batteries and chargers (\$500 each) and an RTK/PPK package (\$1,500 each). Software licensing is projected at \$20,000 for a three-year period per county. To support advanced applications such as 3D modeling, surveying, and rescue operations, the plan includes acquiring 10 Carlson CRD-1 UAVs (or equivalent) (NDAA-compliant, equipped with LIDAR and thermal sensors) at \$150,000 per unit, for a total of \$1,500,000.

Data Storage and System Maintenance expenses will include \$500,000 for hardware, system, and GIS maintenance, alongside another \$500,000 for machine learning implementation, which is essential for automating data analysis and enhancing the precision of inspections.

Training and Workforce Development is a significant investment, with \$1,500,000 allocated for the establishment of a training center and program to develop the necessary skills in drone operation and data management. Operational and Maintenance Costs are estimated at \$1,000,000 for initial setup and deployment, ensuring that all systems are operational and efficient. Project Management and Miscellaneous Costs include \$600,000 for management and administrative tasks, ensuring smooth project execution.

To complete the inspection of all regions within scope over a three-year timeline, the total labor cost is \$1.1 million. For at-scale implementation, which could encompass 20 counties in the future, the total estimated cost is approximately **\$8.6 million**. This budget will cover the expansion of infrastructure, workforce training, and technological enhancements necessary for broad deployment.

Benefit-Cost Analysis

The benefits and savings that this project would provide are substantial and likely to exceed the costs. Key aspects are identified below.

- **Risk Reduction of Poor Infrastructure Condition:** While Stage 1 data did not directly measure reductions in infrastructure failures, county engineers noted that GIS provided clear, actionable outputs and improved confidence in identifying high-risk assets (4 out of 5). At scale, these capabilities could enable earlier detection of deteriorating structures, allowing for preventive maintenance that avoids costly emergency repairs. For example, preventing a single bridge failure can save hundreds of thousands in emergency response, detour construction, and rehabilitation.
- **Employee Safety:** All counties reported zero inspector injuries or near-misses in the last five years, indicating an already strong safety baseline. While drones did not significantly change safety outcomes in Stage 1, statewide adoption could further reduce inspector exposure in hazardous environments—particularly for high or obstructed bridge components—lowering the likelihood of rare but costly incidents. This would also reduce potential expenses related to worker injury claims and healthcare costs.
- **Reduced Labor Hours:** The most tangible Stage 1 efficiency gain came from GIS integration, with an average of 20 minutes saved per asset when locating and reviewing inspection data. Applied statewide, this could save thousands of staff hours annually. Drone inspections, while rated positively, produced only a 2% average estimated reduction in worker-hours during Stage 1. Even at that modest rate, scaling across hundreds of inspections could free up significant labor time for other critical tasks, indirectly reducing labor costs and improving productivity.
- **Public Communication Benefits:** County engineers highlighted that GIS outputs were both understandable and actionable, which supports effective communication with the public and stakeholders. Integrating inspection data into publicly accessible GIS systems would improve transparency and trust, helping secure public and political support for maintenance projects. This can reduce project delays caused by community pushback, saving both time and administrative costs in project delivery.

Beyond economic benefits and cost savings, the project offers unquantifiable social and environmental advantages. By reducing the need for extensive travel by inspectors and lowering

the frequency of emergency repairs, it improves efficiency of transportation infrastructure maintenance. Improved safety and reliability of infrastructure boosts public confidence and satisfaction, while enhanced community engagement and transparency foster a better relationship between authorities and the public. In the preliminary phase, potential benefits and cost savings were identified.

Baseline Data

In Stage 1 of the evaluation for at-scale implementation, procurement contract data was collected and analyzed to understand the financial, logistical foundations, and drone specifications of the project. This data includes detailed records of all contracts awarded for goods, services, and technologies necessary for the implementation phase. Each contract contains information such as the vendor's name, contract value, duration, and specific deliverables, which could be used as a comparative basis for at-scale procurement.

In Stage 1 of the evaluation for at-scale implementation, preliminary baseline data was meticulously gathered using drone pictures and videos and tested in a pre-trained YOLOv11 model by the BAC center. These videos provide valuable insights into the frequency and nature of bridge data, highlighting specific locations where accidents occur most often. The footage allows for a detailed analysis of peak times and common causes of collisions, enabling targeted interventions to enhance safety.

CHALLENGES & LESSONS LEARNED

During the project implementation, several challenges emerged, each offering valuable lessons for future deployments of GIS and drone technologies in Kansas. The survey results from county engineers helped clarify where technical, organizational, and operational barriers were most significant.

- **Legal, Policy, and Regulatory Requirements:** Navigating legal, policy, and regulatory requirements remained a persistent challenge. While FAA Part 107 licensing for drone pilots was achieved, counties noted that compliance was time-consuming and required specialized training. Data governance regulations, particularly around data storage and long-term archival of drone imagery, were identified as unresolved issues by multiple respondents. Procurement processes also had to comply with the Buy America Law, which extended timelines. For drone bridge inspections, federal and state rules—such as hands-on inspection requirements for certain bridge components—limited the extent to which drones could replace manual inspections.
- **Procurement:** The procurement process for drones and related software was lengthier than anticipated. Vendor selection created bottlenecks. In some cases, technology acquisition was delayed by several months due to delivery delays. The lesson learned was the importance of pre-vetting suppliers to accelerate timelines.
- **Technology Suitability:** While GIS software performance was consistently strong, the suitability of drone technology varied. Environmental conditions such as wind and weather were recognized as potential risks, and counties stressed the need for contingency plans. Survey feedback revealed that drones could not access certain bridge components due to structural obstructions, meaning drone imagery often supplemented, but did not replace, physical inspections. Some staff also expressed a learning curve or intimidation factor with the

new technology, reinforcing the need for structured training and gradual adoption. Ongoing staff support is critical to long-term success.

- **Data Governance:** Counties identified data storage as one of the top unresolved barriers to scaling drone use. With limited dedicated IT staff, storing and organizing high-resolution imagery and integrating it with the GIS platforms posed a challenge. The absence of centralized storage protocols made it difficult to ensure consistent and secure data handling across jurisdictions. The cost of storage is also a concern.
- **Workforce Capacity:** Local governments lack surplus staff capacity for managing GIS or drone operations. Instead, counties relied on reallocating duties among existing staff, which created workload pressures. Without strategic staffing plans, scaling up the project could be constrained by human resource limitations.

Based on the challenges identified, NCRPC has developed the following recommendations to guide future project phases:

- **Early Engagement with Regulatory Authorities:** Initiate early and continuous communication with regulatory bodies to streamline compliance processes and address legal and policy requirements proactively.
- **Expedited Procurement Process:** Implement strategies to expedite the procurement process, such as standardized procurement documentation, pre-qualifying suppliers, and establishing clear procurement timelines.
- **Environmental Monitoring and Change Management:** Establish robust protocols for monitoring environmental conditions, such as wind speeds, to ensure optimal drone performance during testing.
- **Comprehensive Training Programs:** Expand training programs to include extensive support for staff to overcome the intimidation factor of new technology, ensuring all team members are comfortable and proficient with drone operations. Ongoing training and support is critical.
- **Centralized IT/Data Management:** Develop a regional or statewide IT support and data management system to assist counties without dedicated IT staff, ensuring consistent storage, retrieval, and integration of data with GIS platforms.
- **Strategic Staffing Plan:** Develop a strategic staffing plan to address workforce limitations, including hiring additional personnel and leveraging external expertise where necessary.
- **Enhanced Project Management:** Implement advanced project management tools and techniques to optimize resource allocation and ensure efficient project execution.

DEPLOYMENT READINESS

The deployment readiness of drone technology for infrastructure evaluation presents a significant opportunity to revolutionize how we assess and manage transportation assets. Drones offer unparalleled technical advantages, including the ability to conduct detailed inspections and collect high-quality data efficiently and safely. Their use in infrastructure evaluation allows for more comprehensive assessments of bridges, roads, and other critical structures, reducing physical risks to inspectors and improving the accuracy of data collection. Beyond infrastructure, drones have wide-ranging applications with the potential to transform sectors such as agriculture, healthcare, and emergency response. For instance, they can be used for agricultural surveys, wildfire detection, and disaster assessment, showcasing their versatility and the value they add to various industries.

The potential to scale up drone applications across Kansas is immense, given the growing interest from local public officials eager to harness this technology for community benefits. This interest indicates a readiness to integrate drones into everyday operations, enhancing public service delivery and infrastructure management. The enthusiasm among local leaders highlights the technology's promise to improve safety, efficiency, and cost-effectiveness in both urban and rural settings. As the state moves towards broader deployment, the focus will be on ensuring the readiness of this technology to meet the diverse needs of Kansas communities, facilitating innovation and economic growth.

At-scale Implementation Strategies

For at-scale implementation, we consider the following requirements, obstacles, readiness factors, and risk mitigations:

- **Technology Suitability:** Environmental factors such as wind conditions can impact drone performance. Establishing robust monitoring protocols and expanding training programs will ensure optimal technology use. Addressing the intimidation factor of new technology through comprehensive training and support will increase staff proficiency and confidence.
- **Data Governance:** Data storage and management pose significant challenges due to the large size of files created by LiDAR, such as .las files. This can be mitigated by purchasing additional servers for local storage, which is a feasible solution for our needs. Ensuring robust data governance protocols will maintain data integrity and accessibility.
- **Workforce Capacity:** With a relatively small team, workforce capacity is a limiting factor. Developing a strategic staffing plan, including hiring additional personnel and leveraging external expertise, will enhance capacity. Implementing advanced project management tools will optimize resource allocation and efficiency. Sharing staff across local government through the regional development organizations is a realistic solution to the need for professional staff that may not be fully employed or affordable for each county individually.
- **Uncertainties and Risk Mitigations:** Uncertainties related to regulatory changes, budget constraints, and technology adoption can pose risks. Regularly updating risk assessments and developing contingency plans will mitigate these uncertainties. Continuous monitoring of project progress and adapting strategies as needed will ensure readiness for at-scale implementation.

Maintenance and operating requirements

To better understand the maintenance and operating requirements necessary for continuing this project after at-scale implementation, we identified the following key aspects:

Software Licensing: Local government needs to thoroughly understand the software licensing requirements, including the renewal cycles and associated costs. This involves identifying the types of licenses required for drone operation, data processing, and analysis tools, as well as ensuring compliance with all licensing agreements. Additionally, staying informed about updates or changes in licensing terms will help prevent unexpected costs and ensure uninterrupted access to essential software.

Data Storage: Given the substantial volume of data generated, particularly from LiDAR, understanding long-term data storage solutions is crucial. We need to evaluate the scalability of our current storage solutions, including server capacity and cloud storage options. Learning about data retention policies, backup procedures, and disaster recovery plans will help us manage data effectively and ensure its availability for ongoing and future analyses. Assessing the cost implications of expanding storage capacity will also be vital to budget planning. A github web data repository has been created to store and publicly sharing selected data and results from this project.

GIS Extended Functions: As of the time of compiling this report, the StoryMap has received close to 200 views, indicating its effectiveness as a tool for reaching a wider audience. We anticipate this number will continue to grow once it is fully launched. To maximize the utility of the NCRPC GIS platform, we need to explore its extended functions and capabilities. This includes learning how to integrate additional data sources, automate data processing workflows, and utilize advanced analytical tools. Understanding how to customize and extend GIS functionalities will enable us to adapt to evolving project requirements and technological advancements and better serve our region. Additionally, training staff to proficiently use these extended functions will ensure fully leveraging the GIS platform's capabilities for maintenance and operational efficiency.

Furthermore, a storytelling element has been incorporated by combining authoritative maps with text, images, and multimedia content. This is made possible through the use of StoryMap, which has proven effective for advocacy, outreach, and virtual tours—delivering accessible public information about bridges. To meet these requirements and ensure we have the capacity to update technology and prevent technical debt, we plan to set a budget and invest in continuous learning and development for our team. This includes staying current with technological advancements, participating in relevant training programs, and establishing dedicated personnel for system upgrades and maintenance. During our procurement process, we prioritized functionality and cost considerations for software licensing and data storage. We also accounted for future renewal costs in our contracts with service providers. Implementation at-scale will benefit from the knowledge acquired and can be quickly transferred to other areas. There is also potential for us to offer technical support to others at a reduced cost compared to the initial contract.

Job Creation

The large-scale implementation of drone and GIS technologies will positively impact well-paying jobs across three key areas. First, for inspectors trained in drone operation and data analysis, this initiative will create specialized roles that improve working conditions by reducing physical risks and enhancing the efficiency and accuracy of inspections. This transition to advanced technology will open new career opportunities for professionals in the field. Secondly, scaling this project will necessitate comprehensive training programs, generating jobs for trainers and coordinators who will equip the workforce with essential skills in drone operation, data analysis, and safety protocols. These roles ensure workforce readiness and support the development of expertise in cutting-edge technologies. Finally, increased demand for drones will stimulate job growth in the manufacturing sector, covering roles from assembly to quality control. This approach ensures that the deployment of drone technology not only advances technological capabilities but also fosters equitable job creation, ultimately benefiting the workforce and contributing to economic growth. This strategic integration of drone technology will help drive innovation and strengthen various sectors of the economy.

WRAP-UP

Reflecting on the course of the project, the proposed solution has largely met our expectations, with drone technologies and GIS delivering on core objectives of improving inspection efficiency, providing clear and actionable data outputs, and expanding technical skillsets among county staff. GIS integration produced significant efficiency gains—averaging 20 minutes saved per asset—while drones achieved satisfactory performance (4 out of 5 rating) and reduced inspector exposure in certain hazardous scenarios, despite Stage 1’s modest 2% worker-hour savings and limited measurable safety improvements due to an already strong baseline. At-scale implementation would benefit from stronger data governance and storage solutions, streamlined procurement to avoid delays, and expanded training to overcome the learning curve and “intimidation factor” reported by some staff, with a focus on deploying drones where greater efficiency gains are likely, such as for large-span or difficult-to-access structures and emergency assessments. For other communities considering similar efforts, NCRPC would recommend beginning with a focused pilot to refine workflows and training, engaging early with regulatory bodies to address FAA and data storage requirements, investing in comprehensive technical and change-management training, and ensuring from the outset that drone outputs integrate seamlessly into GIS platforms for accessible, actionable decision-making.