Smart Counties in Kansas: System Integration for Safe and Resilient Transportation Assets

Project Narrative for Stage 1 SMART Grants Application

a. Overview/Project Description

In alignment with the goal of the SMART Stage 1 grant, this project aims to improve transportation efficiency and safety by planning and prototyping smart technologies and systems in various disadvantaged communities. The project will use system integration as well as technology interventions such as drone technologies and Geographic Information Systems (GIS) applications to build data and technology capacity and experience, thereby leading to safer and more resilient transportation assets within Kansas communities.

Particularly, the project will focus on the development of a prototype GIS-based platform that integrates local infrastructure assets information to provide innovative data, monitor asset condition, and inform technological solutions and comprehensive decision-making processes. An innovative feature of the project is the application of drone technology for bridge inspection and condition evaluation activities. Currently, over 5% of bridges in Kansas are structurally deficient. This presents a safety risk to the public and emphasizes the need for comprehensive bridge inspection and related data collection activities to monitor and assess the condition of bridges in Kansas. By leveraging drones for performing bridge inspections and collecting bridge inspection data, the proposed project will help to increase the safety, reliability, and resiliency of the transportation system within many communities in the state of Kansas.

Drone technology has the capability to conduct and collect data for bridge inspections in an efficient and effective way, particularly in conditions that are unsafe for human operations. In this project, the drone-collected bridge inspection data will be processed using Artificial Intelligence (AI) techniques. This will provide input for a GIS platform that integrates transportation asset data such as traffic volume data, pavement condition data, bridge condition data, and bridge inspection data for each county within the project area. It is anticipated that combined with the application of the GIS system, large-scale bridge inspections will be achieved with well-documented data and processes.

The platform is also expected to provide safety- and resilience-related benefits to the traveling public, including the disadvantaged populations, through improvements to the system integration and promotion of infrastructure safety. We anticipate that by leveraging smart technologies, bridge inspections can be completed within shorter timeframes and in a safer manner. The bridge inspection data collected in Stage 1 of this project will enable prioritization of bridge repair and maintenance activities in each county. Allowing, County officials to effortlessly prioritize and plan bridge repair and infrastructure investments. The integrated process can also promote data transparency, accessibility, and public communication. Once an integrated platform for county infrastructure assets is developed through Stage 1 of the project, layers for various community public services can be added to it, including but not limited to, emergency response times and resilience to climate change effects.

The goal of the proposed Stage 1 project is twofold: a) to use the system integration and innovative aviation technology to develop a proof-of-concept for asset condition monitoring and assessment, particularly with respect to bridges; and b) to evaluate the feasibility of expanding the project by engaging more agencies/counties in Kansas. If at the conclusion of Stage 1 project, the prototype is successfully developed and expansion of the project is deemed feasible, participation in the SMART Stage 2 implementation grants will be considered.

The proposed Stage 1 project will seek to build sustainable partnerships across sectors and levels of government as well as collaborate with industry and academic partners. In particular, the collaboration of public research universities such as Kansas State University (KSU) and the University of Kansas (KU) is sought to build GIS-related technology capacity and workforce development for unmanned aircraft systems (UAS). The Build America Center at the University of Maryland has committed to support the development and implementation of this project. With regards to the drone technology, the project will utilize a partnership with Skydio—a US-based drone manufacturer with extensive experience in the application of drone technologies in transportation, who currently works with the Kansas Department of Transportation.

Several benefits of using drones for bridge inspections are expected. Based on feedback received from a few county engineers and bridge inspectors, the advantages of the application of drone technology to bridge inspections as proposed in the Stage 1 of this project include:

- Drones can supplement traditional bridge inspection methods by accessing hard-to-reach bridge components and providing high-quality images and videos;
- Bridge inspectors who use drones can complete bridge inspections in a timely manner, particularly where high-water is present since a drone-performed inspection, is less of a health and safety risk;
- The bridge inspection information obtained from a drone on hard-to-reach bridges will be more thorough by providing high-quality imagery of critical areas of the bridge, which may expose deficiencies in the structure sooner. This may allow a repair instead of a bridge replacement. Earlier detection will result in overall cost savings if the repair can occur quickly, avoid emergency bridge closures and provide relevant cost savings;
- Drone-performed inspections remove the bridge inspector and their vehicle from the roadway and may eliminate the need for repeated on-site visits to the bridge. This increases safety for the inspector and the traveling public, and also provides cost savings by elimination of multiple visits to the bridge to obtain additional information.

b. Project Location

The project location for the proposed Stage 1 prototype includes the following counties in the state of Kansas: Sedgwick County, Saline County, Cowley County, and Cloud County. Table 1 shows the population, community size, number of Historically Disadvantaged Communities, and the proportion of the county population that lives in Historically Disadvantaged Communities. The project is considered a regional collaboration between two rural counties, one midsized county, and one large county, with a total population of 611,692 individuals. Table 1 also indicates that the project's area covers 57 Historically Disadvantaged Communities with a total population of 200,287 individuals. This means that nearly one third of the population within the geographic scope of the planned project lives in Historically Disadvantaged Communities.

On the other hand, the average proportion of structurally deficient bridges in the four counties that comprise the project area is nearly 4% (Table 1). Further, on average, approximately 56% of bridges in those four counties do not meet the currently acceptable standards with respect to 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 risk they present to the public.

Additional counties under consideration for a potential inclusion in the Stage 1 project are Cherokee, Finney, Douglas, Lyon, and Washington Counties. Two key analysis criteria will be considered in determination of final counties that will comprise the service area for the Stage 1 project: a) the proportion of Historically Disadvantaged Communities located within the county; b) the extent of structurally deficient bridges within the county.

Table 1. Stage 1 Project Service Area and Bridge Deficiency

County	Community Size	No. of HDCs (Census Tracts)	Population in HDCs	% Population in HDCs	No. (and %) of Structurally Deficient Bridges	% Bridges Not Meeting Traffic Safety Standards
Sedgwick	Large	43	139,324	27.2%	46 (3.47%)	30.17%
Saline	Midsized	5	21,479	39.1%	4 (1.08%)	51.15%
Cowley	Rural	6	31,770	89.3%	21 (6.18%)	76.62%
Cloud	Rural	3	7,714	85.1%	15 (4.73%)	65.06%
Total (or Average%)		57	200,287	32.7%	86 (3.87%)	55.88%

Notes: HDC = Historically Disadvantaged Community; No. = Number
Source of Data: Climate and Economic Justice Screening Tool: https://screeningtool.geoplatform.gov/en/downloads; FHWA's 2022 National Bridge Inventory (NBI): https://www.fhwa.dot.gov/bridge/nbi/ascii.cfm

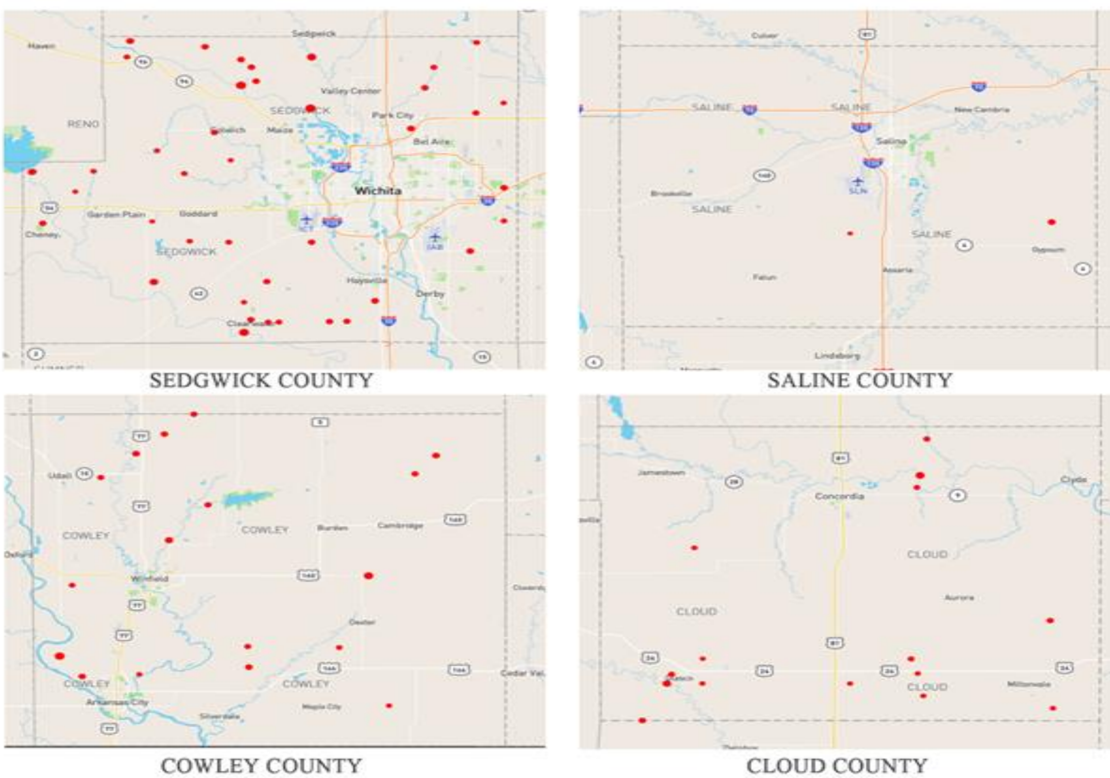

Figure 1. Map of County-Owned Bridges in Poor Condition
Notes: Maps are Not To Scale; Red dots indicate bridges that are in poor condition
Source of Data: Kansas Local Infrastructure Planning (KLIP) Tool: https://klip.ksdot.gov/

c. Community Impact

Data indicates that nearly 40% of the census tracts included in the four counties within the project location are designated as Historically Disadvantaged Communities (HDCs). A considerable proportion of bridges in the project location are structurally deficient (nearly 4%), while approximately 56% of bridges do not meet the traffic safety standards (Table 1). This indicates that the bridge condition issues and any related public safety implications directly impact HDCs within the project target area. Detailed and high-quality bridge inspections enabled by usage of drone technology can assist inspectors in evaluating the conditions of bridges located in these HDCs in a timely and safe manner, and help identify any risk that such bridges can present to public safety sooner. The benefits of employing drone technology for bridge inspections to HDCs can be quantified using various metrics including but not limited to 1.) the potential reduction in the number of bridge closures due to safety reasons within census tracts designated as HDCs, 2.) potential reduction in the traffic volume impacted by such bridge closures in HDCs, and 3.) potential improvements in emergency response times in HDCs. Additional benefits from the project will accrue to other HDCs through sharing of project results, which will help in future utilization of drone technology in additional counties. This will create opportunities for quicker and safer bridge inspection, cost savings for citizens, and also enhanced information collection—all of which are likely to benefit other aspects of community infrastructure. We do not expect any negative externalities caused by the proposed project.

d. Technical Merit Overview

- *Understanding of the Problem*

Bridge safety is one of the major public concerns in Kansas and beyond. According to FHWA's 2022 National Bridge Inventory Data (Table 1), 86 bridges (representing 3.7% of total bridges) in the counties of Sedgwick, Saline, Cowley, and Cloud, are classified as structurally deficient. In terms of safety standards, 56% of bridges within the considered four counties fail to meet at least one safety feature in the categories of bridge railings, transitions, approach guardrails, approach guardrail ends or do not provide any safety information. Without a full understanding of up-to-date conditions, bridges remain a risk factor to public safety.

Because many bridges call for repairs or replacement, detailed inspections are in wide demand to understand the health conditions of bridges. However, the traditional inspection process is time consuming and labor intensive. In response to high inspection demands, drones can be employed. Drone technology has the ability to collect data and complete inspection tasks in an efficient and effective way, especially in conditions that are unsafe or unreachable for workers. In addition, the collected data can be processed with other advanced IT techniques rapidly, which further facilitates the inspection process. For county-level bridge inspections, organization of geospatial data is a big concern. A GIS platform can provide functionalities for storing, retrieving, managing, displaying, and analyzing geospatial data. Therefore, the combined adoption of GIS systems and drone technology can innovatively contribute to the integrated geography-based, large-scale bridge inspection tasks. By replacing traditional manual inspection methods with a GIS platform and drones, data pipelines can get streamlined and promoted. Therefore, the critical problem in terms of bridge inspections can be addressed in a quality way with data transparency, accessibility, and integrity.

- *Appropriateness of Proposed Solution*

In this project, Skydio S2+ and Skydio X2E will serve as the drone hardware models, together with the software support of Skydio Autonomy Enterprise and Skydio 3D Scan. Skydio drone suites are sufficiently developed for bridge inspections with efficiency. For example, Skydio 3D Scan™ is first-of-its-kind adaptive scanning software built on top of Skydio Autonomy Enterprise, which is the autonomous flight engine behind every Skydio drone. 3D Scan builds a model of the scene, allowing the drone to automate the data capture process needed to generate 3D models with comprehensive coverage in ultra-high resolution. That means crews can perform high-quality inspections in less time and with minimal pilot training. Compared to traditional methods, Skydio 3D Scan is expected to be up to 75% faster in data capture, to reduce reinspection by up to 30%, and up to 50% lower cost. Besides, with less labor hours needed, adoption of autonomous drone products can help in solving the complication of limited workforce and the high-volume of bridge inspections. Further, Skydio is a US-based company and their products are manufactured within the territory of the United States. Using the Skydio suite for bridge inspection can deliver value to public innovations.

The workflow of drone inspection and GIS platform development in bridge inspection offers the benefit of a scalable approach. On the one hand, the FAA regulation governing commercial Small Uncrewed Aircraft Systems (sUAS), also known as the Small UAS rule Part 107, outlines the requirements for small UAS pilots operating UAS for work or business purposes, including obtaining a Remote Pilot Certificate from the FAA. Once the pilots get certified, they are able to repeatedly implement inspection tasks. On the other hand, a GIS platform supports repetitive and scalable data storage and analysis for each county.

Skydio's Unmanned Aerial Vehicles (UAVs) also demonstrate significant improvements compared to current practice in bridge inspection. Presently, counties perform their own bridge inspections, either human inspections or manual drone inspections. Human-based inspection methods are expensive, time-consuming, and dangerous. Manual drones are expensive and have untrustworthy obstacle avoidance, requiring many hours of pilot training to avoid crashes. By providing high-quality imagery, Skydio will be able to inspect those hard-to-reach bridge components and keep inspectors out of harm's way. Besides advanced data collection ability, Skydio 3D Scan will provide the Counties with the data to create accurate 3D surface models with less rework. Other potential scalable applications include topographic survey of roadways, aggregate stockpile volumetric calculations, and structure integrity analysis.

In this project, eight Skydio drones (four Model S2+ and four X2E) will be used to satisfy various sizes and field conditions of bridges. Skydio drone models are light (S2+ model 800g, X2E model 1325g). The deployed resource can be easily circulated around the practice areas.

- *Expected Benefits*

Significant benefits by using advanced data, technology, and application could include:

- ❖ Increased inspection details: high-quality imagery of bridge components can be analyzed in the office, which will provide a higher level of inspection and details for any needed structural analysis;
- ❖ Elimination of revisits: the need for the structural engineer to revisit the bridge to obtain additional information may be eliminated, which saves money on unnecessary expenses;
- ❖ Earlier detection: deficiencies in difficult-to-access bridges can be detected sooner, which may allow a repair of the deficiency instead of a bridge replacement. Repairs are almost always cheaper than replacing a bridge;
- ❖ Increased inspection safety: the nature of bridge inspections can be very dangerous. The terrain under most bridges is steep, rocky, slippery, and has a water feature flowing through it. Worker safety is a top priority. A UAV can be used on higher risk inspections and thus lower the chances of having an injury on the job, which can save time and money for both

the employee and the county;
- ❖ Community justice: the project brings significant equity, safety, and resilience benefits by focusing on disadvantaged communities.

e. Project Readiness Overview

- *Feasibility of Workplan*

It is expected that the full scope of work in Stage 1 Grant will be completed within 18 months of the date on which the grant is received. The workforce developed through the proposed Stage 1 project is expected to acquire deep knowledge on the topic and develop the necessary skills required for high-quality job placements through the apprenticeship/internships programs and has the free and fair choice of joining a union. Major tasks in this project include:

- ❖ Kickoff, planning and partnership building;
- ❖ Drone-based data collection, conditional evaluation, and prototype development;
- ❖ Pilot GIS system platform development for counties' asset management;
- ❖ Workforce development, project evaluation, and recommendations.

The four counties included in the project's study area currently perform bridge inspections using traditional methods, which can be time-consuming, labor-intensive, and more importantly, can present a safety risk to the inspectors—particularly, with respect to difficult-to-access bridge components. The high-quality images and videos produced by drones can provide faster and more accurate data as well critical inspection details needed for structural bridge analysis. This may eliminate the need for the inspectors to revisit the bridge site to obtain additional data, which in turn, can eliminate unnecessary expenses. Drone inspections may also expose deficiencies in the bridge sooner, which may allow a repair, thereby extending the life of the bridge before replacement is needed. Earlier detection will result in overall cost savings if the repair can occur in a timely manner.

Another aspect of how the project can impact the community concerns the level of traffic on the bridges. Based on data from the FHWA's 2022 National Bridge Inventory (NBI), the Average Daily Traffic (ADT) volume on structurally deficient bridges within the project's area equals 1,709 vehicles. This provides an estimate of the number of people within the project's location (including those living in Historically Disadvantaged Communities) who endure the safety risk of traveling on structurally deficient bridges every day. Conducting bridge inspections using drones can expedite the process of preventive maintenance or repair activities on bridges, which provides safety- and resilience-related benefits to the traveling public. Further, the inspection can be conducted and the data can be obtained with less disruption to normal traffic flow, which is an added benefit. Moreover, the higher accuracy of inspections performed using drones can delay or avoid emergency bridge closures. To measure broader expected benefits and community impacts of the project, performance improvements in emergency response time and reliability of the transportation system can also be considered.

Based on the above arguments, a few methods to measure and validate the expected benefits and community impacts of conducting bridge inspections, collecting bridge inspection data using drones within the project location, and developing a GIS-based platform for monitoring and assessing bridge conditions as proposed in this project include (but are not limited to):

- ❖ Number of bridges inspected and monitored annually;
- ❖ Annual inspection costs;
- ❖ Annual labor hours required for asset condition inspection and monitor;

- ❖ Positive community impact in terms of minimizing closures for inspection, especially to disadvantaged communities;
- ❖ Emergency response time and impact.

- *Community Engagement and Partnerships*

The North Central Regional Planning Commission (NCRPC) has a 50-year history of building coalitions in rural areas, thereby generating cost effective solutions to problems where staff and equipment can be shared across multiple jurisdictions and also utilized to serve a wide variety of city/county departments. The organization provides comprehensive planning and development services with a focus on community-led and innovative solutions. NCRPC has been a strong advocate for community-based planning and engaged local communities into the regional planning process. In this project, NCRPC will extend its best practices to engage local communities.

The proposed project requires close and continuous collaborations among several public as well as private stakeholders including the four counties identified in the Project Location section. The University of Kansas (KU), Kansas State University (KSU) Aerospace and Technology Campus, The Kansas Department of Transportation, Kansas WorkforceONE, Skydio Robotics Company, ESRI ArcGIS, Build America Center (BAC) and the NCRPC. Skydio, a pioneer in uncrewed aircraft system (UAS) autonomous flight, workflow, and operations will support workforce development, perform asset-related data collection, and implement the prototype at county level. The Applied Aviation Research Center at the KSU Aerospace and Technology Campus will leverage its Uncrewed Aircraft Systems (UAS) program to develop UAS training materials, conduct UAS training, and support apprenticeship programs required for the proposed project. Those training courses are available to help prepare the workforce for the FAA Uncrewed Aircraft general knowledge exam, develop and enhance flight skills, collect and process high-quality data and imagery, and gain knowledge on public safety aspects of operating drones. KU will support this project through the state of Kansas GIS Clearinghouse, the Data Access and Support Center located at the Kansas Geological Survey, for providing access to any public domain geospatial data produced from this project. BAC will provide technical support for all activities including the bridge condition evaluation using machine learning techniques.

- *Leadership and Qualifications*

The project lead will Be Debra Carlson Ohlde with NCPRC, who has over 30 years of experience in community and economic development and grants management. She has strong group facilitation skills and an extensive network with the key partners in this application. Examples of NCRPC project implementation with partnership entities include the following:

- ❖ Introduction of an internet service provider model to serve rural communities with funding from CDBG, USDA and local private sector providers. This service has been ongoing for approximately 15 years and was recognized by a Smithsonian Medal of Distinction;
- ❖ Managing the Weatherization program for 41 counties in Kansas funded by DOE and HHS;
- ❖ Serving as the fiscal agent for Homeland Security funds received by 100 of the 105 counties in Kansas. This project involves coordination of 7 regional homeland security councils and partnership with the Kansas Highway Patrol;
- ❖ Implementing funding from sources including USDA, CDBG, and KDHE to secure and manage over $150 million in community infrastructure project;
- ❖ Serving as an Economic Development District through EDA to prepare and coordinate the region's Comprehensive Economic Development Strategy. The current CEDS contains a section on Economic Prosperity through Innovation.