



Accelerated Innovation Deployment (AID) Demonstration Project: Asset Management Tool for Iowa County Engineers - Unpaved Granular Road Modulus

Iowa Department of Transportation / Buena Vista County

Final Report

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AID Demo
Accelerated Innovation Deployment

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16. Abstract The objective of this project is to use validated intelligent compaction (VIC) technology to map 1/4 to 1/3 of the unpaved gravel road network across the state of Iowa. This work will be done over 2 summer seasons to be completed in the 3 year time frame set forth in the AID Grant NOFO. The mapping will gather Modulus Values; Road Geometry (x,y,z); Surface material type, gradation, moisture control; and Digital photos. Collected data will be analyzed. Modulus values will be calculated. Independent DCP tests will be taken at locations when k-values are less than an identified amount to determine if low k-values are surface or subgrade issues.					
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Executive Summary

The Iowa Department of Transportation (Iowa DOT), in partnership with Buena Vista County and the Iowa County Engineers Service Bureau (ICEASB), was awarded a \$1,000,000 Accelerated Innovation Deployment (AID) Demonstration Grant in 2021 to accelerate the implementation of Validated Intelligent Compaction (VIC)–based modulus mapping as an asset management tool for unpaved granular roadways. Iowa maintains more than 66,000 miles of unpaved roads that are critical to agricultural production, manufacturing logistics, emergency services, and rural mobility. Effective management of this extensive network has historically been constrained by the lack of objective, spatially continuous data describing roadway structural capacity and performance.

This project demonstrated the use of real-time modulus mapping technology to collect continuous, geo-referenced measurements of roadway stiffness and associated material properties across approximately 12,000 miles of unpaved roads in 24 Iowa counties. Data collection was performed using COMP-Score® RT (RT) equipped rollers integrated into routine maintenance operations, enabling efficient, network-scale mapping with minimal disruption to traffic. The mapping generated high-resolution datasets including modulus values, roadway geometry, surface material type, permanent deformation, and digital imagery.

To validate the modulus measurements and establish performance-based relationships, targeted field testing was conducted using Automated Plate Load Testing (APLT) and Dynamic Cone Penetrometer (DCP) methods. Testing was performed across a wide range of materials, traffic levels, and seasonal conditions, including spring thaw. These data were used to develop models that link measured modulus values to rutting susceptibility and to estimate remaining service life, providing a direct connection between structural capacity and roadway performance.

All collected data were transmitted to ICEASB and integrated into a centralized database within the Operations Management System (OMS), a web-based, map-driven platform used by county engineers statewide. Through the OMS, users can visualize, query, and analyze modulus and performance data at the segment, project, and network levels. Integration with existing granular road management tools further enhanced the utility of the data and supported consistent decision-making across jurisdictions.

The project demonstrated that continuous modulus mapping significantly reduces the time, labor, and uncertainty associated with traditional point-based testing and visual inspections. By enabling early identification of structurally weak locations, the technology supports targeted, preventative maintenance, optimized material use, extended service life, and reduced lifecycle costs. Counties benefit from improved

maintenance prioritization, increased confidence in engineering decisions, and enhanced user satisfaction among staff.

Beyond technical outcomes, the project successfully advanced implementation and adoption of a proven innovation, transitioning modulus mapping from pilot use to operational deployment at scale. Standardized data workflows, operator training, and system integration established a sustainable framework for continued use and future expansion. Interest in broader adoption has grown among counties not included in the initial demonstration, and the centralized OMS platform provides a scalable foundation for statewide implementation.

Overall, this AID demonstration achieved its objective of accelerating deployment of validated intelligent compaction and geospatial data collaboration technologies for unpaved granular roads. The project established a performance-based, data-driven approach to managing one of Iowa's most critical transportation assets and created a transferable model that can benefit other states with extensive unpaved road networks.

Introduction

The Iowa Department of Transportation and Buena Vista County were awarded an Accelerated Implementation and Deployment (AID) Demonstration Grant of \$1,000,000 in 2021 to support their goal of using Validated Intelligent Compaction to map approximately 12,000 miles of the unpaved granular road network across 24 counties in the State of Iowa. The mapping gathered a geospatial record of support capacities (e.g. modulus), surface material type, gradation, and digital photos.

This project aligns with the Technology and Innovation Deployment Program (TIDP) goals, significantly accelerating the adoption of innovations in Validated Intelligent Compaction and Geospatial Data Collaboration by the counties of Iowa. The project demonstrates and promotes new asset management practices for unpaved granular roads in Iowa that will result in improved safety, faster construction, reduced construction-related congestion, and improved quality and user satisfaction. It will also improve the efficiency, safety, mobility, reliability, service life, environmental protection, and sustainability of unpaved granular roads. The results of this project will be shared across transportation agencies that manage unpaved roads in other states.

ACCELERATED INNOVATION DEPLOYMENT (AID) DEMONSTRATION GRANTS

The Federal Highway Administration (FHWA) AID Demonstration Grants Program, administered through the FHWA Center for Accelerating Innovation (CAI), provides incentive funding and other resources to eligible entities to offset the risk of trying an innovation and accelerate its implementation and adoption in highway transportation. Entities eligible to apply include State departments of transportation (DOTs), Federal

land management agencies, and tribal governments, as well as metropolitan planning organizations and local governments that apply through the State DOT as subrecipients.

The AID Demonstration program is one aspect of the multi-faceted Technology and Innovation Deployment Program (TIDP). AID Demonstration funds are available for any project eligible for assistance under title 23, United States Code. Projects eligible for funding shall include proven innovative practices or technologies such as those included in the Every Day Counts (EDC) initiative. Innovations may include infrastructure and non-infrastructure strategies or activities that the award recipient intends to implement and adopt as a significant improvement over their conventional practice.

REPORT SCOPE AND ORGANIZATION

This report documents the Iowa DOT's and Buena Vista County's demonstration grant award results, developing an *Asset Management Tool for Iowa County Engineers - Unpaved Granular Road Modulus*. The report presents details relevant to the employed project innovation(s), the overarching TIDP goals, performance metric measurement and analysis, lessons learned, and the status of activities related to the adoption of modulus measurement technologies as an asset management tool for transportation agencies that maintain unpaved granular-surfaced roadways.

Project Overview

Iowa's transportation system includes more than 66,000 miles of granular unpaved roads that are critical to agricultural production, manufacturing logistics, and rural mobility. These facilities support the movement of commodities, equipment, and materials that underpin Iowa's position as a national leader in corn, soybean, and pork production. County road agencies invest substantial annual resources to maintain this network; however, decision-making regarding maintenance strategies and structural design is constrained by the lack of reliable, spatially continuous information on the in situ structural capacity of unpaved road layers.

Current assessment practices rely primarily on indirect, point-based surrogate tests to estimate layer modulus. While these methods can provide localized structural indicators, they have limited correlation to actual roadway performance measures, such as rutting, and do not adequately represent the high spatial variability inherent in granular road systems. Moreover, the cost and time required to conduct these tests at sufficient density make them impractical for segment-level characterization and infeasible for network-level analysis. As a result, County Engineers must often make asset management and design decisions under significant uncertainty.

The objective of this project is to implement a system that collects continuous, georeferenced measurements of structural support (resilient modulus) and associated properties for granular unpaved roads, enabling both segment-level and network-level

evaluation of roadway performance. The project will utilize the COMP-Score® RT real-time modulus mapping technology, which the Iowa Department of Transportation is currently implementing on pilot construction projects for real-time design verification and construction quality control. Using this technology, approximately 25 to 33 percent of Iowa's unpaved gravel road network will be mapped over two spring/summer/fall field seasons within the three-year AID Grant period.

The mapping process will generate a continuous spatial dataset comprising x, y, and z coordinates; modulus values; surface material type; gradation characteristics; moisture content; and digital imagery. This data will be used to compute performance-related indicators, including rutting potential and estimated remaining service life. To validate the COMP-Score® RT measurements and to support the development of performance prediction models, selected locations will be tested using Automated Plate Load Testing (APLT) and Dynamic Cone Penetrometer (DCP) methods.

All collected data will be transmitted electronically to the Iowa County Engineers Service Bureau (ICEASB) and stored within a centralized database. The dataset will be integrated into the Operations Management System (OMS), a web-based platform currently under development by ICEASB to support management of roadway and operational assets. Through the OMS interface, County Engineers will be able to visualize, query, and analyze modulus and performance data at the roadway segment, project, and network scales using an interactive map environment. The data will also be compatible with existing granular road design and management tools developed under previous Iowa Highway Research Board projects, including GRAMS and the Granular Road Structural Design Tool.

This project will provide a data-driven framework for evaluating the structural condition and performance of Iowa's granular road network, improving County Engineers' ability to identify structurally deficient segments, prioritize maintenance activities, and optimize design decisions. In addition, the centralized database developed under this effort will establish the technical foundation for a potential Phase 2 implementation to complete statewide mapping of all granular unpaved roads in Iowa, enabling comprehensive network-level asset management.

Project Details

BACKGROUND

Iowa maintains one of the largest unpaved road networks in the United States, consisting of approximately 66,000 miles of county-owned granular roads, which account for nearly 57 percent of the state's total roadway mileage. This extensive network is critical to Iowa's agricultural, manufacturing, and freight-based economy, as well as to the daily mobility of rural residents. Unpaved granular roads provide essential access to farms, industrial facilities, residences, and emergency services, and they

frequently serve as alternate routes during incidents or extreme weather events that disrupt the paved highway system.

Despite the scale and importance of this network, county engineers face significant challenges in effectively managing unpaved granular roads due to the lack of objective, spatially continuous data describing roadway structural capacity and performance. Local agencies collectively invest millions of dollars annually in maintenance activities; however, these investments are often guided by experience-based judgment rather than quantitative performance metrics. Traditional evaluation methods rely on indirect, point-based geotechnical tests that provide limited information on layer support capacity (e.g., modulus) and have weak correlation with observed performance indicators such as rutting under traffic. Moreover, the inherent variability of granular materials and subgrade conditions results in localized performance deficiencies that are difficult to identify without continuous data.

The absence of comprehensive structural information limits the ability of county engineers to make informed decisions at both the segment and network levels. This constraint affects maintenance prioritization, rehabilitation strategies, and long-term planning, including the estimation of funding needs for statewide programs. In addition, the inability to accurately identify structurally weak locations can result in inefficient allocation of resources, increased user costs, and accelerated deterioration of the unpaved road network.

These challenges disproportionately affect rural communities, where dependence on unpaved roads is highest. Poor roadway conditions can restrict access to healthcare, emergency response services, and employment opportunities, particularly during periods of adverse weather. When granular roads become unusable or impassable, travel distances increase, leading to higher fuel consumption and increased greenhouse gas emissions. Rural populations, which often include lower-income households and minority workers employed in agricultural, manufacturing, and meat processing industries, are therefore more vulnerable to the impacts of inadequate unpaved road performance.

Recent climate trends have further underscored the importance of maintaining a resilient unpaved road network. Iowa has experienced multiple widespread flood events over the past decade, including several events characterized as having a 500-year recurrence interval. During these events, interstate and state highway facilities have been inundated or damaged, increasing reliance on the unpaved granular road system to maintain mobility for emergency response, freight movement, and local travel. These conditions highlight the need for improved data and tools to support resilient design and maintenance practices for granular roads.



Figure 1. COMP-Score® RT enabled roller performing modulus mapping on an unpaved roadway

To address these challenges, advances in construction monitoring and geospatial technologies offer new opportunities for unpaved road asset management. COMP-Score® RT shown in Figure 1 technology enables continuous, real-time measurement of stiffness or modulus during construction or maintenance operations, while Geospatial Data Collaboration frameworks allow these data to be stored, analyzed, and visualized within centralized databases. These technologies have reached Technology Readiness Level 9, indicating successful deployment under full operational conditions. In Iowa, Intelligent Compaction has been validated and implemented by the Iowa Department of Transportation through previous Advanced Innovation Deployment efforts and has demonstrated the ability to identify structural variability not visible at the surface.

Preliminary applications of these technologies on unpaved granular roads in Iowa have shown promising results. In 2020, approximately 20 miles of granular roads in Tama County were mapped (Figure 2 and Figure 3) using RT mapping, revealing significant spatial variation in modulus values, including soft subgrade locations and areas of high structural capacity associated with bridges and railroad crossings. These results validated the underlying concepts and demonstrated the potential value of continuous modulus mapping for identifying performance-critical locations. Building on these initial efforts, the proposed project seeks to rapidly accelerate the adoption of these validated technologies at a broader scale.

Modulus Mapping in Tama County

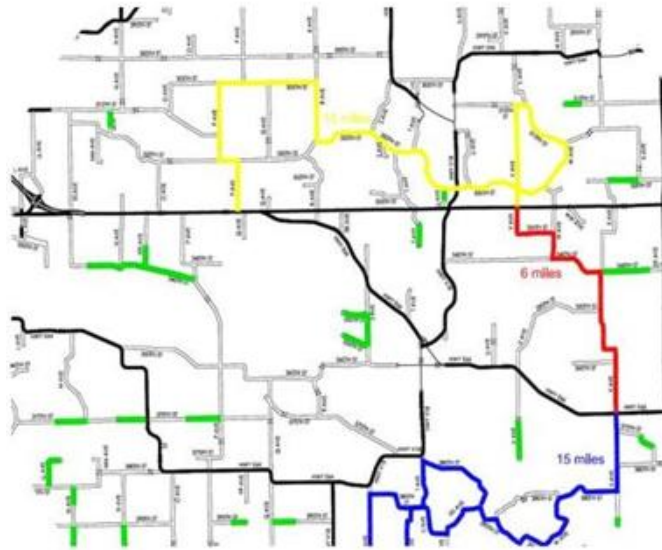


Figure 2. Tama County mapping locations

COMP-Score analysis allows determination of % of Area below a Target Value.
For this Example, about **24% of the area** is below a threshold target of 9,000 psi

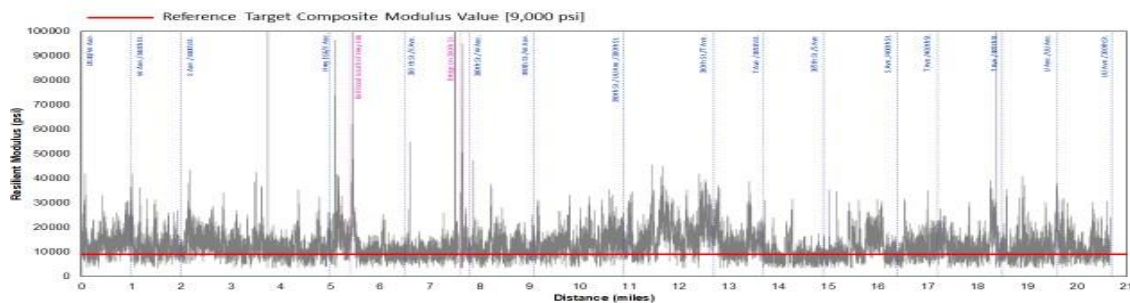


Figure 3. Output data of Tama County mapping

The Iowa County Engineers Association Service Bureau (ICEASB) is developing a web-based Operations Management System (OMS) to support integrated management of roadway and operational assets across all Iowa counties. The OMS provides an interactive map-based interface and serves as a centralized platform for data visualization, analysis, and decision support. Integration of continuous modulus and performance data into the OMS will enable county engineers to conduct segment- and network-level analyses, evaluate historical trends, and incorporate structural information into daily maintenance and construction practices. Once OMS development is complete, data collected under this project will be immediately available to county engineers, and future data collection efforts can be seamlessly incorporated to support long-term asset management.

This project is intended to serve as a demonstration and deployment effort under the Advanced Innovation Deployment program, accelerating the use of COMP-Score® RT and Geospatial Data Collaboration technologies for unpaved granular roads. Successful implementation is expected to lead to subsequent phases that expand coverage to all 99 counties in Iowa and establish a comprehensive statewide database of granular road structural capacity. In addition, the methodologies and outcomes developed through this effort may be transferable to other states with extensive unpaved road networks, thereby further extending the project's impact.

PROJECT DESCRIPTION

Iowa was the nation's leading producer of corn, soybeans, and pork. The state's network of more than 66,000 miles of unpaved granular roads formed the backbone of Iowa's agricultural and manufacturing economy and was essential to feeding the world. These roads were required to remain serviceable year-round. When they became unusable, particularly during the spring thaw, road users experienced hazardous driving conditions, increased travel distances, higher user costs, delays in essential services, and longer emergency response times.

Road conditions such as those shown in Figure 4 occurred annually across Iowa during the spring months. These conditions resulted from Iowa's naturally expansive soils undergoing repeated freeze-thaw cycles. Until granular roads thawed, dried, and regained strength, users faced unsafe and unreliable driving conditions. Vehicles such as garbage trucks, fire trucks, ambulances, school buses, semi-trucks hauling grain, and even road maintenance equipment routinely became stuck during this period. In some cases, the only way to move vehicles through these roads was by pulling them with earth-moving equipment such as dozers.



Figure 4. Iowa annual road conditions.

The primary objective of this project was to use modulus mapping—which had been implemented on pilot projects by the Iowa Department of Transportation (DOT) for new roadway construction—to map approximately 25 percent of Iowa’s unpaved granular road network during the initial phase of work. This effort was completed over the three-year timeframe established in the AID grant Notice of Funding Opportunity (NOFO).

The mapping process collected a geospatial record (x, y, and z coordinates) of modulus values, surface material type, gradation, moisture content, and digital imagery. These data were used to calculate performance indicators such as rutting potential and remaining service life. Selected locations along the mapped routes were tested using Automated Plate Load Testing (APLT) and Dynamic Cone Penetrometer (DCP) testing to validate the modulus mapping results and to develop models for predicting performance indicators. All results were archived in a centralized electronic database implementing geospatial data collaboration and were integrated into the Operations Management System (OMS) web application under development by the Iowa County Engineers Association Service Bureau (ICEASB). This AID project enabled all 99 Iowa counties, ICEASB, and numerous public-agency transportation partners statewide to use high-resolution digital information.

[Task 1 – Project Selection Criteria and Route Planning](#)

This task consisted of a desk study conducted by the mapping project team, in collaboration with ICEASB, to identify project selection criteria using data available from the Iowa DOT Research and Analytics Bureau. Selection criteria included Annual Daily Traffic (ADT), surface material type, subgrade soil type, roadway ownership, and the presence of existing research test sections.

Based on discussions during preparation of the AID grant application, the initial roadways selected for mapping extended from west to east across central Iowa, covering 24 counties and multiple Iowa geomorphological landforms, as shown in Figure 5. As part of this task, the project team developed detailed route and personnel plans to enable continuous mapping operations across selected roadway segments in each county. The project budget included the use of three rollers to conduct mapping during the spring-to-fall field seasons.

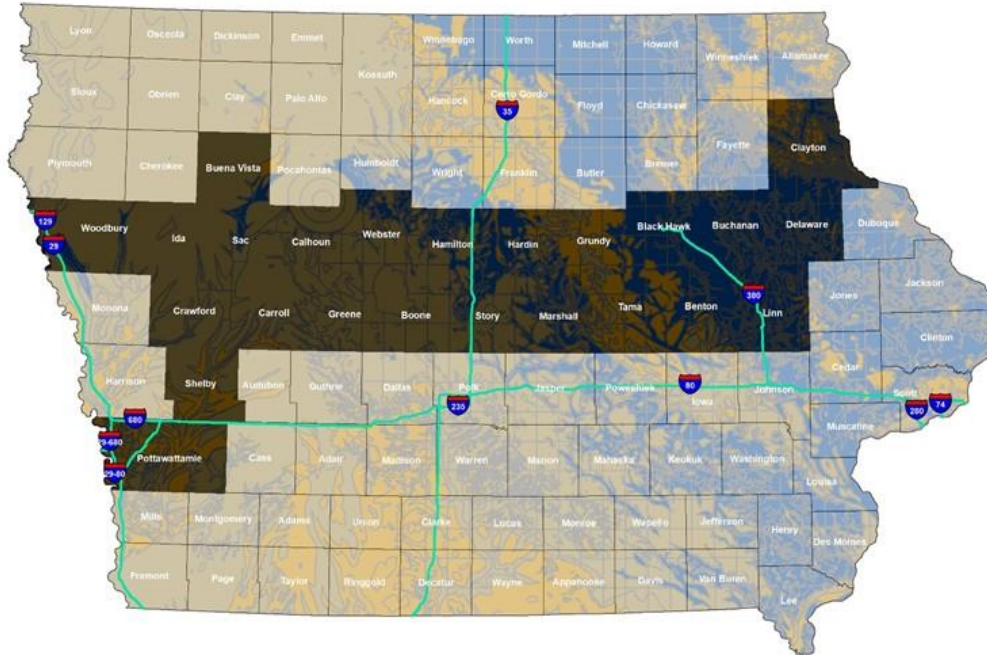


Figure 5. Proposed data collection locations.

Task 2 – Data Mapping Definition, Processing, and Database Requirements

This task defined the data to be collected, collection and processing requirements, and the database structure needed to ensure seamless data transfer from field collection to ICEASB. The process was illustrated in Figure 8. Data were collected in real time using instrumented rollers during mapping and were transmitted to centralized cloud storage for each mapped segment. Data from multiple counties were then processed into structured datasets and transferred securely to ICEASB via an API for local storage and access by county engineers through the OMS web application.

Data segments are automatically captured on 15-minute consecutive intervals during collection. Raw and processed data are stored in secure cloud storage for backup. A subset of processed data is stored in a database accessible to ICEASB via a secure API. Each record of the processed data represents one square foot of mapped unpaved granular roadway. Each record includes values for permanent deformation, modulus, a date and time stamp, latitude, longitude, easting, northing, elevation, county identifier, a geolocated bounding box around the one-foot square, and an identifier for the data segment.

Data reports were also generated, including analyses of rut depth forecasting and remaining service life, based on field testing conducted under Task 3 and the analysis requirements established in Task 4. This work led to early concepts for future implementation to assist County Engineers in developing guidelines for load embargos during the spring thaw, based on the modulus mapping data.

Task 3 & 4 – OMS Coding and Data Visualization

Tasks 3 and 4 encompassed the design, development, and deployment of the data infrastructure and web-based visualization tools needed to make modulus-mapping data actionable for county engineers statewide. Under these tasks, ICEASB designed and implemented an Application Programming Interface (API) to enable secure, automated transfer of field-collected data from cloud storage to the ICEASB centralized e-database. The database structure was engineered to accommodate the high-resolution spatial dataset generated by RT mapping, with each record representing approximately one square foot of mapped roadway surface and containing values for modulus, roadway geometry, surface material classification, and time-stamped metadata. Data quality checks were applied during ingestion to verify spatial alignment, timestamp continuity, and record completeness for each mapped segment.

Concurrently with database development, ICEASB completed server-side and client-side coding of the Operations Management System (OMS), the web-based, map-driven platform used by county engineers across Iowa. The OMS was enhanced to incorporate granular road modulus data, enabling users to visualize structural performance information at the roadway segment, project, and network scales through an interactive geospatial interface. Data visualization features allowed county engineers to identify structurally weak segments, compare performance across counties, and integrate modulus data with existing granular road management tools. By project completion, the OMS has successfully ingested and made accessible data from 24 Iowa counties covering approximately 12,000 miles of unpaved granular roads, representing more than 400+ million individual data records collected across three seasons.

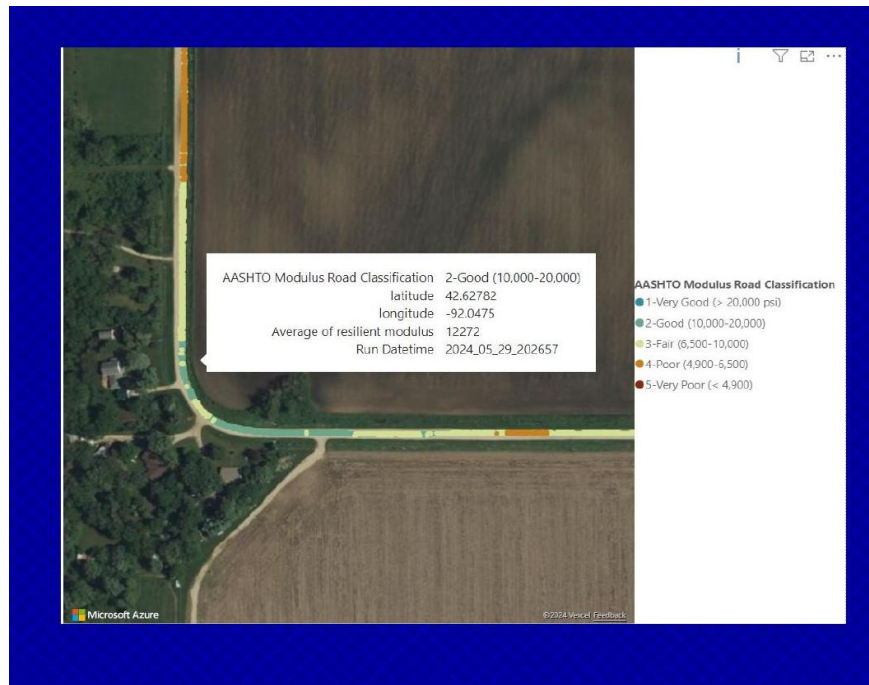


Figure 6. OMS data visualization showing AASHTO modulus road classification and average resilient modulus values on an unpaved granular roadway.

Task 5 – Field Data Collection and Analysis

This task involved mapping approximately 12,000 miles of selected unpaved roadway segments using three instrumented rollers operated by trained personnel. Mapping was conducted between late spring and late fall over the three-year project period.

In addition, Automated Plate Load Tests (APLT), shown in Figure 7, were performed at locations selected based on mapping results to represent a wide range of modulus values (e.g., less than 5 ksi to greater than 100 ksi). These tests determined in-situ resilient modulus (M_r) and permanent deformation (rutting) under cyclic loading, using up to 1,000 load cycles. Measuring both M_r and permanent deformation under repeated loading was critical to developing regression models that linked modulus values to traffic loading (expressed as equivalent single axle loads, ESALs) and rutting performance.

The number of loading cycles was extended to 10,000 cycles at selected locations to further validate rutting prediction models for heavily trafficked segments. Testing accounted for seasonal variations, including spring thaw, summer, and wet conditions. An example relationship between resilient modulus and the number of 18-kip load cycles (W18) required to reach a target rut depth was shown in Figure 7.

Aggregate material characterization was also performed during the mapping process using a new material-identification sensor. Mapping surface material type alongside modulus values improved understanding of aggregate performance across roadway segments. Examples of aggregate surface types are shown in Figure 11.



Figure 7. Cyclic APLTs to determine in situ composite resilient modulus (M_r) and permanent deformation (p) or rutting

Task 6 – Data Analysis

This task used data generated under Task 3 to develop performance-based analyses for unpaved granular roads. Seasonal variations in modulus values derived from APLT testing were combined with monthly ADT data for each roadway segment to estimate remaining service life and to generate engineering forecasts for maintenance and rehabilitation needs.

These analyses provided county engineers with critical decision-support information at both the segment and network levels. This approach represented a significant advancement beyond the largely empirical and ad hoc methods previously used for granular road design and maintenance. By directly linking measured modulus values to roadway performance, this project established a data-driven framework for predicting rutting and managing unpaved road assets.

DATA COLLECTION AND ANALYSIS

Data Mapping and Information Management

The project team defined the data elements, collection protocols, processing requirements, and database structure required to support the transfer of field-collected data to the Iowa County Engineers' Service Bureau (ICESB). Data handling followed the workflow illustrated in Figure 8.

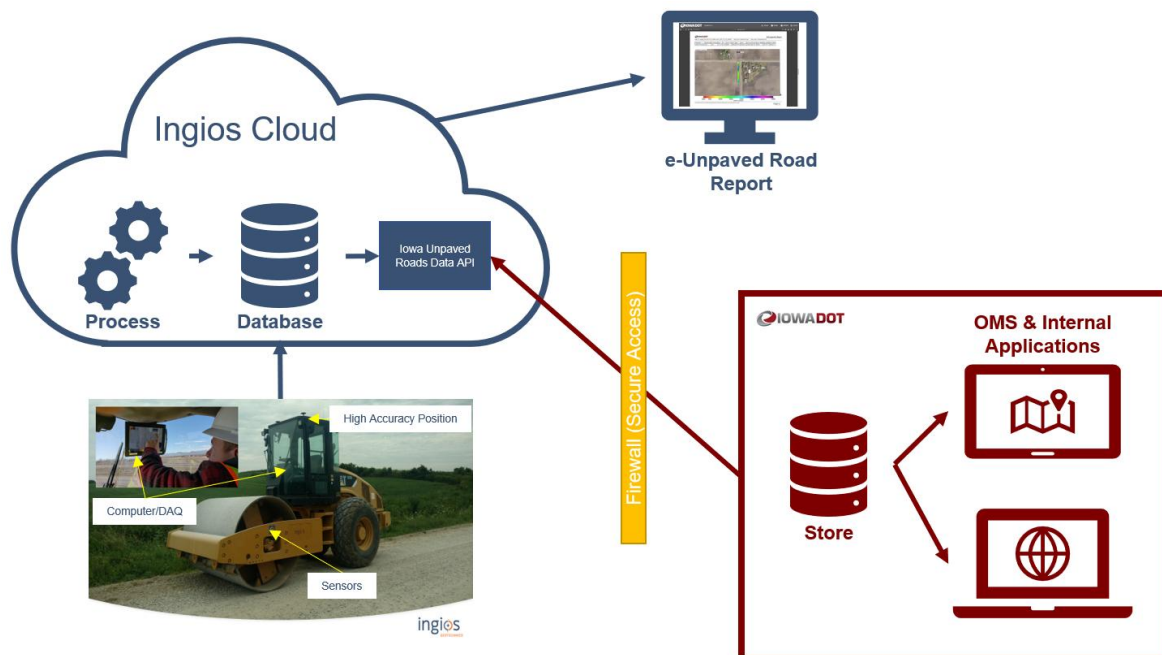


Figure 8. Illustration of data collection, cloud data processing, engineering report generation, and e-database structure for this project.

The team collected field data in real time during roadway mapping operations using RT-equipped compactors operating within designated test sections. Upon completion of mapping activities for each test section, the team transmitted the data to a centralized data storage system for processing. Data from multiple county roadway segments were processed into standardized datasets and made available through a secure data transfer mechanism. ICESB ingested and stored the datasets locally and made them accessible to County Engineers through the Office Management System (OMS).

The final dataset included RT-derived modulus values, roadway geometry (x, y, z coordinates), surface material classification, and time-stamped records at a spatial

resolution of approximately one square foot of roadway surface. The project team generated engineering output files to support subsequent performance analyses, including rut-depth prediction, ride-quality assessment, and remaining-service-life estimation.

Data quality checks were applied during ingestion and processing to verify spatial alignment, timestamp continuity, sensor functionality, and record completeness within each test section.

Field Data Collection

Field data collection consists of mapping nearly 12,000-miles of unpaved roadway at an average operating speed of approximately 3 mph. The team conducted mapping using multiple RT-equipped rollers operated by trained personnel. Data collection occurred during late spring through late fall across three field seasons within the evaluation period. Figure 9 shows mapping from within the cab of an equipped compactor.



Figure 9. COMP-Score RT enabled roller performing modulus mapping on an unpaved gravel road

The team conducted Accelerated Plate Load Tests (APLTs) at selected test sections identified based on RT mapping results. Test section selection captured a broad range of measured modulus values, from less than 5 ksi to greater than 100 ksi. The team performed APLTs to determine the in situ resilient modulus (M_r) and permanent deformation (δ_p) under repeated loading.

At most test sections, the team applied 1,000 loading cycles. At selected locations, the team extended testing to 10,000 cycles to support validation of rutting performance models. These tests produced datasets relating repeated vehicular loading, expressed as equivalent single axle loads (ESALs), to rutting behavior of unpaved gravel roadways. Figure 10 shows testing on a gravel road in Hamilton County, Iowa.



Figure 10. APLT in Hamilton County, Iowa in the spring of 2023

The team conducted testing across multiple seasons, including spring thaw, summer, and winter, to capture seasonal effects on modulus values and the permanent deformation response. As part of the RT mapping process, the team also completed aggregate material characterization by collecting approximately a dozen samples of the granular surfacing from each county. Figure 11 shows all gradations for Boone County plotted against the Iowa Department of Transportation specification for Class 'A' Roadstone.

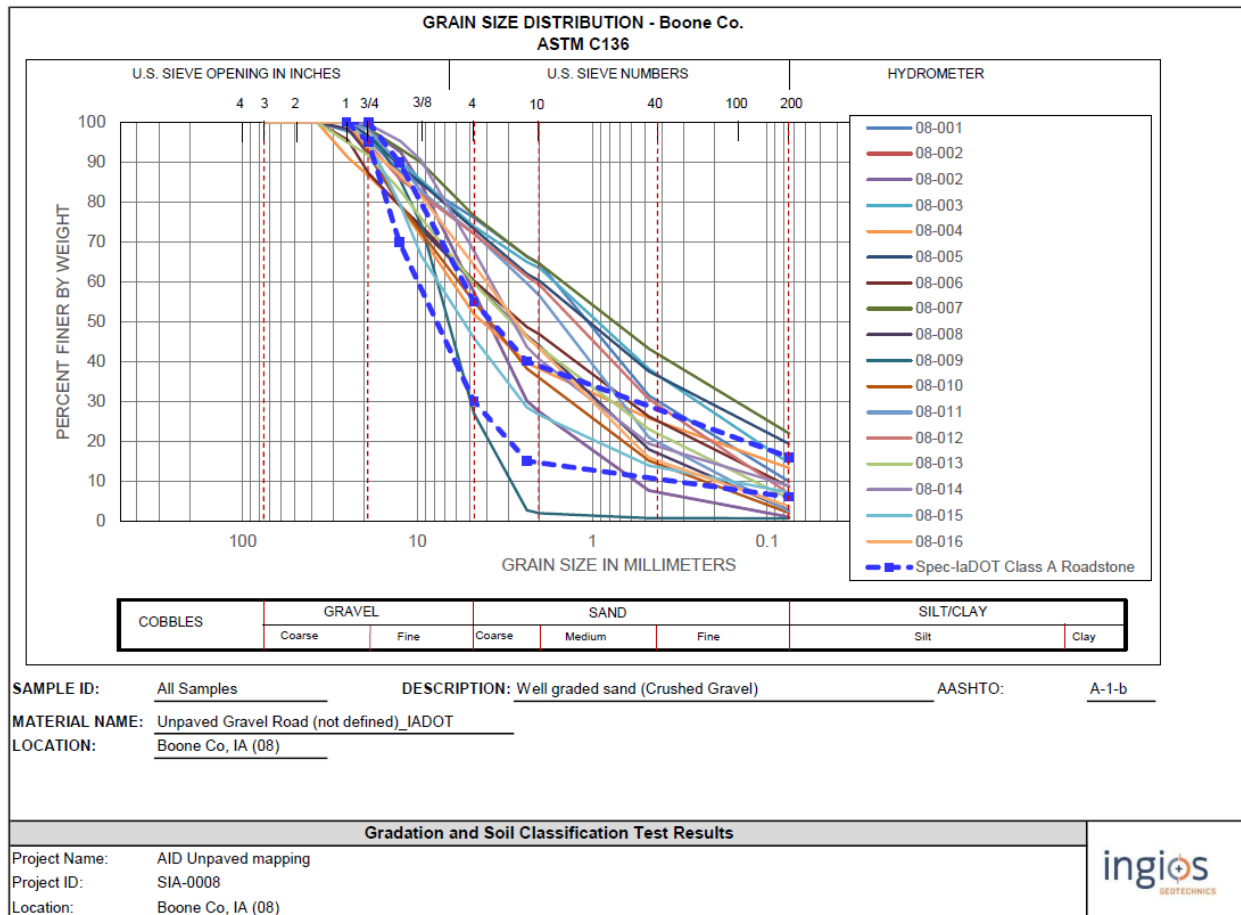


Figure 11. Granular surfacing gradations for Boone County.

Data Analysis and Performance Evaluation

The project team conducted data analysis using RT mapping results and APLT test data collected during the evaluation period. The team evaluated seasonal variations in measured modulus values in conjunction with monthly Average Daily Traffic (ADT) data for each test section to assess roadway performance and estimate remaining service life and allowable loading cycles.

The analysis focused on performance measures relevant to unpaved gravel roads, including modulus variability, rutting susceptibility, and estimated remaining structural capacity. The team applied regression-based models to relate measured modulus values and traffic loading to permanent deformation.

The analysis outputs supported roadway- and network-level decision-making for maintenance planning, prioritization, and design. The results demonstrated a direct relationship between measured modulus values and observed performance, providing a performance-based analytical framework that supplements traditional empirical gravel road design methods.

Methodological Assumptions and Limitations

The project was conducted under the following assumptions and limitations:

- RT-derived modulus values represent near-surface structural response and may not fully capture deeper subgrade variability.
- APLT test results reflect localized test section conditions and may not represent full-length segment behavior.
- Traffic loading estimates were based on available monthly ADT data and assumed representative axle load distributions.
- Seasonal testing captured major climatic conditions; however, short-duration extreme weather events were not explicitly evaluated.
- Rutting performance models were calibrated using the observed range of materials and conditions present within the selected test sections; extrapolation beyond these ranges should be undertaken with caution.

Despite these limitations, the combined mapping and APLT testing approach provided consistent, repeatable measurements suitable for network-level evaluation and performance-based decision-making.

Summary

The data collection and analysis activities completed under this project produced a comprehensive, spatially resolved dataset describing the structural condition and performance of unpaved gravel roadways. The methods and analyses demonstrated the feasibility of integrating real-time modulus mapping with targeted field testing to support performance-based management of unpaved roadway networks.

SAFETY

A project-specific Safety, Security, Health, and Environmental (SSH&E) Plan was for personnel conducting Automated Plate Load Tests (APLTs) and COMP-Score RT mapping on unpaved Iowa county roads for the "Asset Management Tool" project.

Key Safety Components

Scope and Hazard: The work involves mapping 12,000 miles of roads between late spring and late fall (2024-2027) using RT-equipped rollers and APLTs. Primary hazards are associated with traffic, operating heavy equipment, and inclement weather.

Personnel Requirements: All Ingios employees must comply with this plan and Ingios' Safety Program and have completed OSHA 10-hr Construction Safety training, as well as APLT and RT-specific safety training. Temporary operators received safety training during orientation.

Mandatory PPE: All on-site personnel must wear eye protection (safety glasses), foot protection (safety toe boots), hand protection, and ANSI minimum Level 2 reflective vests. Hearing protection is also required near the generator during APLT or DCP testing.

Traffic Control (TTC): The plan uses temporary traffic control based on MUTCD guidance, with specific procedures for stationary APLT (flaggers/cones) and dynamic RT roller operations (flashing beacon, on-board signs, and potentially a rolling TTC system). All TTC must be coordinated with the County Engineer.

Safe Work Procedures: A Job Safety Analysis (JSA) table details hazards for tasks such as APLT setup, testing, and RT roller operations, outlining safe work procedures and required PPE to mitigate risks.

Working Alone (RT Mapping): A comprehensive plan is in place for lone workers, including:

- Daily Risk Assessment and Buddy Check-in at the start/end of the day.
- The buddy utilized a remote monitoring program to evaluate if the roller was moving as planned. The buddy checked in on the remote monitoring program every 15 to 30 minutes while the rollers were operating. If the rollers were not operating as expected, the buddy called the roller operator to check for any problems.
- Required use of a fully charged phone with a hands-free system for open communication.

Briefings & Emergency: Pre-Job Briefings (mandatory review of tasks and hazards) and Post-Job Briefings (lessons learned) are required daily, even when working alone. All personnel must know the location of the nearest hospital, and 911 will be the primary contact for serious emergencies.

Safety Summary

The project team is committed to maintaining a safe working environment for all personnel and the public during Automated Plate Load Testing (APLT) and COMP-Score RT mapping activities conducted on unpaved roads throughout Iowa. Field operations involve working in low-volume traffic areas, operating specialized heavy equipment, and exposure to variable weather and terrain. This safety summary outlines the key controls, procedures, and expectations that guide the safe execution of project tasks.

Project Safety Framework

All field staff are required to comply with Ingios' Safety Program and this project-specific SSH&E Plan. Personnel must complete OSHA 10-hour Construction Safety training and receive equipment-specific training for APLT, DCP, and RT roller operations. Daily PPE requirements include safety-toe boots, high-visibility garments, hard hats, gloves, and safety glasses, with hearing protection used as needed.

Hazard Awareness and Controls

Primary hazards include exposure to traffic, equipment operation, manual handling, weather-related risks, and working alone. A Job Safety Analysis (JSA) has been prepared to identify task-specific hazards, their severity and likelihood, and the residual

risk after controls are implemented. Safe operating procedures include proper equipment inspections, restricted access around machinery, use of spotters, adherence to railroad and bridge safety protocols, and minimizing time on the traffic-exposed side of vehicles.

Temporary Traffic Control

All APLT and RT mapping operations will use Temporary Traffic Control (TTC) measures aligned with MUTCD guidance and county requirements. APLT testing involves stationary work zones with warning signage and cones; RT roller mapping uses on-board beacons and, when warranted, rolling traffic control vehicles to alert approaching drivers.

Working Alone Protocol

RT mapping may require personnel to operate alone. A structured buddy-check system is used, including daily briefings, continuous communication via phone or hands-free devices, and web camera monitoring at 15-minute intervals. Personnel must conduct daily risk assessments, keep communication devices charged, and carry a first-aid kit and emergency contact information.

Environmental and Weather Considerations

Field staff must monitor weather conditions closely and suspend work during inclement weather. Procedures are in place to mitigate cold stress, heat stress, and ergonomic hazards. Equipment will be inspected daily for leaks, and spill kits are available on all units. Any generated waste will be properly managed and disposed of.

Pre-Job and Post-Job Briefings

Daily pre-job briefings are required to review tasks, hazards, and the JSA. Post-job briefings document lessons learned, incidents, changes in work conditions, and opportunities for improvement. All staff members present must sign both briefing logs.

Emergency Response

Ingios personnel will provide immediate first-aid response and contact emergency services as needed. Staff must always remain aware of the nearest medical facility. Incidents, near misses, medical events, and corrective actions must be reported to Ingios' safety leadership.

SCHEDULE

The use of modulus mapping will significantly reduce the time and labor required for data collection compared to traditional point-based testing methods. Traditionally, County Engineers have relied on dashboard surveys of unpaved roadway quality to identify areas requiring maintenance. These dashboard surveys are time-intensive and, due to the subjective nature of data gathering, can be somewhat unreliable for making maintenance decisions with limited budgets. Using observation in data gathering generally leads to maintaining the worst roads first, rather than maintaining roadways before they deteriorate. This worst-first mentality generally results in more time-

consuming maintenance activities on failing roadways. The alternative to dashboard surveys is conventional techniques such as DCPs and plate load tests provide information only at discrete locations, require lane closures, and demand substantial staff time to plan, execute, and interpret, making network-level assessments impractical. In contrast, modulus mapping collects high-resolution, geo-referenced modulus data continuously at normal construction speeds, allowing thousands of data points to be gathered in the time it would take to perform a handful of spot tests. By automating data collection, processing, and integration directly into the ICEASB Operations Management System, County Engineers gain immediate access to actionable information without manual data entry or post-processing. This enables faster identification of weak segments, quicker prioritization of maintenance, and more timely, data-driven decisions at both the project and network levels.

COST

Continuous modulus mapping reduces overall maintenance costs for counties by enabling targeted, data-driven decisions rather than relying on reactive maintenance or uniform treatments across entire road segments. Traditional approaches depend on limited spot testing and visual inspections, which often fail to identify subsurface weaknesses, leading to premature failures, repeated blading, and unnecessary aggregate replacement. By providing a continuous, geo-referenced record of roadway support capacity, modulus mapping allows engineers to pinpoint and address only the weakest locations, optimize material quantities, and select the most cost-effective maintenance or stabilization strategies. This reduces over-design, minimizes wasted materials and labor, extends service life, and lowers lifecycle costs across the unpaved road network, resulting in more efficient use of limited county maintenance budgets.

QUALITY

This project demonstrates how widespread application of modulus mapping can improve the quality, reliability, and performance of Iowa's unpaved granular road network. Unpaved roads are essential for agriculture, manufacturing, emergency services, and daily travel, yet they are highly susceptible to seasonal deterioration from freeze-thaw cycles, moisture variations, and traffic loading. The project illustrates that systematic, statewide modulus mapping provides the data and insight needed to maintain higher-quality roads over time.

A key benefit shown by the project is the ability to measure roadway stiffness and structural capacity directly, rather than relying solely on visual inspections or experience-based judgment. Modulus mapping produced a detailed geospatial record of roadway condition, identifying weak areas prone to rutting, moisture damage, and early failure before surface problems became severe. Linking these measurements to performance indicators such as rutting potential and remaining service life enabled targeted, preventive maintenance that preserves roadway integrity.

Field validation using Automated Plate Load Testing (APLT) and Dynamic Cone Penetrometer (DCP) testing confirmed the reliability of the modulus mapping data, capturing seasonal and environmental variations. This ensured maintenance decisions could be based on real-world performance, extending service life and improving ride quality.

The project also demonstrated that mapping surface aggregate types alongside modulus values provides insight into material performance, supporting better material selection and placement practices. By integrating all data into a centralized geospatial database within the ICEASB Operations Management System (OMS), county engineers could compare segments, prioritize maintenance, and make network-level decisions to consistently improve road quality across jurisdictions.

In summary, the project demonstrates that widespread modulus mapping transforms unpaved road management from a reactive, experience-based approach to a proactive, performance-driven system. Applying this approach broadly enables smoother, safer, and more resilient roads, reduces rutting, optimizes material use, and extends service life, ultimately improving the quality of Iowa's unpaved road network for all users.

USER COSTS

The implementation of modulus mapping on Iowa's unpaved granular road network provides a cost-effective, data-driven approach to managing one of the state's most critical public assets. With more than 66,000 miles of granular roads serving agriculture, manufacturing, emergency services, and rural residents, even small improvements in maintenance efficiency and roadway performance translate into significant savings for taxpayers and road users.

Unpaved granular roads are especially vulnerable during seasonal freeze–thaw cycles, when reduced strength leads to rutting, vehicle damage, service delays, and increased maintenance needs. Traditionally, counties have relied on visual inspections and experience-based judgment to determine when and where maintenance is required. This reactive approach often results in over-maintenance on some roads and delayed intervention on others, increasing long-term costs and reducing roadway reliability.

Modulus mapping technology addresses this challenge by providing continuous, geospatial measurements of roadway stiffness (modulus) and surface material characteristics. By mapping these properties across entire road segments, county engineers gain objective, high-resolution data that identifies weak locations before severe damage occurs. This enables targeted, preventative maintenance rather than costly emergency repairs after roads have failed.

One of the primary ways this technology lowers public costs is by extending the service

life of granular roads. By linking measured modulus values to performance indicators such as rutting and remaining service life, maintenance activities can be timed and designed to preserve structural capacity. Preventing deep rutting reduces the need for frequent re-graveling, reshaping, or full reconstruction—each of which carries significant labor, material, and equipment costs borne by taxpayers.

The technology also reduces costs to road users. During spring thaw conditions, impassable or severely degraded roads force detours, increase travel times, and raise vehicle operating costs. Emergency vehicles, school buses, agricultural haulers, and waste collection trucks are particularly affected. Improved roadway reliability reduces delays, minimizes vehicle damage, and improves safety, resulting in direct economic benefits to the public and local businesses.

From an agency perspective, integrating VIC mapping data into the ICEASB Operations Management System (OMS) enables counties to coordinate maintenance activities more efficiently across their networks. Shared, standardized data reduces duplication of effort, improves budgeting accuracy, and supports data-driven prioritization of limited resources. Counties can plan maintenance schedules, material usage, and equipment deployment more effectively, lowering overall operational costs.

Additionally, the use of performance-based data supports better long-term investment decisions. By understanding how traffic loading, seasonal conditions, and material types affect road performance, counties can select more durable surface materials and optimize construction practices. This reduces the frequency of maintenance cycles and lowers lifecycle costs, delivering sustained savings over time.

In summary, modulus mapping lowers public costs by shifting granular road management from a reactive, experience-based approach to a proactive, performance-based system. The result is longer-lasting roads, fewer disruptions, improved safety, and more efficient use of public funds—benefits that accrue to taxpayers, road users, and local governments alike.

USER SATISFACTION

User satisfaction is expected to be high with the implementation of continuous modulus mapping due to its ease of use, efficiency, and direct relevance to day-to-day decision making. Unlike traditional data gathering techniques that are time-consuming, disruptive, and provide limited insight, modulus mapping integrates seamlessly into routine construction and maintenance operations and delivers immediate, intuitive results. County Engineers and staff gain access to clear, geo-referenced maps that visually identify weak roadway segments, increasing confidence in maintenance prioritization and design decisions. The reduction in field testing, paperwork, and manual data interpretation improves staff productivity and morale, while the ability to see measurable improvements in roadway performance following targeted interventions

reinforces trust in technology. Overall, the system transforms data collection from a burden into a practical management tool, leading to higher adoption rates and sustained use.

Project Outcomes and Lessons Learned

The Accelerated Innovation Deployment (AID) demonstration project successfully demonstrated the feasibility and value of using Validated Intelligent Compaction (VIC)–based modulus mapping as an asset management tool for unpaved granular roadways. Over the course of the project, approximately 12,000 miles of unpaved roads across 24 Iowa counties were mapped, generating a high-resolution, geo-referenced dataset describing roadway structural capacity, material characteristics, and performance-related indicators.

A primary outcome of the project was the establishment of a continuous, network-scale record of roadway modulus that revealed significant spatial variability not identifiable through traditional point-based testing or visual inspections. The mapping consistently identified weak subgrade locations, moisture-sensitive areas, and structurally robust features such as bridge approaches and railroad crossings. These insights enabled county engineers to move from reactive, condition-based maintenance toward proactive, performance-driven decision-making.

The project successfully validated RT-derived modulus measurements through Automated Plate Load Testing (APLT) and Dynamic Cone Penetrometer (DCP) testing across a wide range of materials, traffic levels, and seasonal conditions. The resulting datasets supported the development of performance-based relationships linking measured modulus values to rutting susceptibility and remaining service life. This represented a significant advancement beyond empirical gravel road design approaches and provided a defensible engineering basis for maintenance prioritization and design decisions.

Integration of mapping data into the Iowa County Engineers Service Bureau (ICEASB) Operations Management System (OMS) was another key outcome. The OMS enabled county engineers to visualize, query, and analyze modulus and performance data at the segment, project, and network levels using an interactive geospatial interface. This centralized data environment improved data accessibility, reduced duplication of effort, and facilitated consistent decision-making across jurisdictions.

From an operational perspective, the project demonstrated that continuous modulus mapping can be performed efficiently as part of routine maintenance, significantly reducing the time, labor, and traffic disruptions associated with traditional data collection methods. The availability of objective, repeatable data increased user confidence, improved staff productivity, and supported broader acceptance of the technology among

county engineers and field personnel.

Collectively, the project achieved the AID program objective of accelerating deployment of a proven innovation, established a scalable framework for statewide implementation, and created a transferable model for other states with extensive unpaved road networks.

Lessons Learned

Several important lessons were identified during the implementation of this project. First, continuous modulus mapping provides the greatest value when paired with targeted field validation and performance testing. While RT mapping effectively captures spatial variability, APLT and DCP testing were essential for calibrating results, understanding seasonal effects, and linking modulus values directly to performance measures such as rutting.

Second, data management and integration are critical to successful adoption. Early coordination between the mapping team and ICEASB to define data formats, processing workflows, and database requirements was essential to ensuring seamless data transfer and usability within the OMS. Establishing standardized data structures and quality-control procedures reduced post-processing effort and improved user confidence in the results.

Third, operator training and consistency played a key role in data quality. Ensuring that RT-equipped rollers were operated at appropriate speeds and under consistent conditions improved data repeatability and minimized noise in the datasets. Dedicated training and clear operational protocols were effective in maintaining data integrity across multiple counties and seasons.

Fourth, seasonal variability significantly influences unpaved road performance and must be considered in analysis and decision-making. Data collected during spring thaw conditions exhibited markedly different modulus and rutting behavior than during summer and fall, reinforcing the importance of multi-season data collection for accurate performance assessment.

Finally, user engagement and clear communication were essential to successful deployment. Providing county engineers with intuitive visualizations, practical performance metrics, and direct links between data and maintenance decisions increased acceptance and encouraged sustained use of the technology. Framing modulus mapping as a decision-support tool rather than a research exercise was critical to its integration into daily practice.

Overall, the lessons learned from this AID demonstration project provide a clear

roadmap for future expansion, including statewide implementation and transferability to other agencies. Incorporating these lessons will further enhance the effectiveness, efficiency, and long-term impact of performance-based asset management for unpaved granular road networks.

Recommendations and Implementation

Based on the outcomes of this Accelerated Innovation Deployment (AID) demonstration project, the following recommendations are offered to support continued implementation, expansion, and effective use of continuous modulus mapping for unpaved granular roadways.

RECOMMENDATIONS

Expand Modulus Mapping to Full Statewide Coverage

The project demonstrated that continuous modulus mapping provides valuable, actionable information at both segment and network levels. It is recommended that future phases expand mapping coverage to the remaining unpaved road network in Iowa to establish a comprehensive, statewide structural inventory. Completing statewide coverage would enable consistent asset management practices across all counties and support long-term planning and funding prioritization.

Integrate Modulus Mapping into Routine Maintenance and Construction Activities

To maximize value and minimize cost, modulus mapping should be incorporated into routine maintenance operations such as re-graveling, shaping, and stabilization projects. Performing mapping concurrently with these activities reduces the need for dedicated testing mobilizations and ensures that structural data remains current. Establishing standardized operating procedures for when and how mapping is performed will further support consistency across jurisdictions.

Continue Targeted Field Validation and Seasonal Data Collection

While RT-derived modulus mapping proved reliable, periodic validation using Automated Plate Load Testing (APLT) and Dynamic Cone Penetrometer (DCP) testing remains important for calibration and performance modeling. It is recommended that targeted validation testing continue, particularly to capture seasonal effects such as spring thaw and wet conditions, which significantly impact unpaved road performance.

Formalize Performance-Based Decision Frameworks

The ability to link measured modulus values to rutting susceptibility and remaining service life represents a significant advancement in unpaved road management. Counties are encouraged to formalize the use of these performance-based metrics in maintenance prioritization, design decisions, and budgeting processes. Doing so will help shift practices from reactive, experience-based approaches to proactive, data-driven asset management.

Enhance Training and Knowledge Transfer

Ongoing training for county engineers, technicians, and equipment operators is recommended to ensure consistent data quality and effective interpretation of results. Training should focus not only on data collection procedures but also on using modulus and performance data within the ICEASB Operations Management System (OMS) to support decision-making. Sharing best practices and case examples across counties will further encourage adoption.

Leverage the Centralized Database for Emergency Response and Resilience Planning

The centralized modulus database provides a unique opportunity to support resilience planning and emergency response, particularly during flooding and extreme weather events. It is recommended that counties explore using the data to identify vulnerable roadway segments, plan detour routes, and prioritize post-event inspections and repairs.

Promote Transferability and Knowledge Sharing Beyond Iowa

Given the success of this demonstration, it is recommended that project findings, methodologies, and tools be shared with other states and agencies that manage extensive unpaved road networks. Outreach through FHWA, peer exchanges, and technical workshops can help extend the benefits of this project and support broader adoption of validated intelligent compaction and geospatial asset management practices nationwide.

STATUS OF IMPLEMENTATION AND ADOPTION

Since the start of this project, the team has initiated steps to transition continuous modulus mapping from a demonstrated research innovation into a practical tool for unpaved road asset management. The project has established the technical basis for using RT-derived modulus data to assess structural support conditions, support maintenance decisions, and improve planning for Iowa's unpaved road network.

Implementation activities completed or initiated to date include the following:

- Demonstrated the feasibility of continuous modulus mapping for identifying structural variability along unpaved road segments.
- Developed procedures for collecting, processing, and interpreting modulus data at both project and network levels.
- Conducted targeted field validation using Automated Plate Load Testing to support calibration of RT-derived modulus values.
- Established a centralized modulus database to support future asset management, maintenance planning, and resilience applications.

- Identified opportunities to integrate modulus mapping with routine county maintenance and construction activities, including re-graveling, shaping, stabilization, and rehabilitation work.
- Began defining how modulus-based performance measures may be incorporated into the ICEASB Operations Management System and related county decision-making processes.

Full adoption will require continued coordination among state, county, and technical partners. The proposed adoption plan is as follows:

1. Near Term: Finalize standard operating procedures for data collection, validation, quality control, and database management. Provide initial training for county engineers, technicians, and equipment operators.
2. Mid Term: Expand mapping coverage to additional counties and incorporate modulus mapping into scheduled maintenance and construction activities where practical. Continue seasonal validation to improve calibration and performance modeling.
3. Long Term: Complete statewide mapping coverage of Iowa's unpaved road network and maintain the modulus database as a routine asset management resource.
4. Full Adoption: Integrate modulus mapping into standard operating procedures for maintenance prioritization, project selection, design support, budgeting, and emergency response planning. Ongoing training, periodic validation, and database updates will be used to sustain consistent implementation across jurisdictions.



U.S. Department of Transportation
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AID Demo

Accelerated Innovation Deployment

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The AID Demonstration program provides funding as an incentive for eligible entities to accelerate the implementation and adoption of innovation in highway transportation. The AID Demonstration program is one initiative under the multi-faceted Technology and Innovation Deployment Program (TIDP). For more information please visit:
<https://www.fhwa.dot.gov/innovation/grants/>