IOWA STATE UNIVERSITY
Institute for Transportation

Development of Granular Roads Asset Management System

tech transfer summary

This study developed a user-friendly, data-driven granular roadway asset management system tool that local agencies can use to estimate annual gravel loss on a system-wide basis.

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RESEARCH PROJECT TITLE
Development of Granular Roads Asset Management System

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Goal

The goal of this project was to develop a user-friendly granular roads asset management system (GRAMS) tool as a decision-support and communication-of-strategy tool for county engineers.

To accomplish the goal, the research team investigated the factors influencing granular roadway deterioration—annual traffic, precipitation, subgrade soil, and aggregate material quality—in order to develop a tool that simulates the performance of a given granular roadway system under varying conditions, and recommends the most effective roadway treatment for a given desired level of service/reliability and budget.

Problem Statement

County engineers need to know how their systems actually perform and the different types of feasible maintenance, preservation, and rehabilitation options to ultimately maximize the value of their roadway system investments. To date, there are no readily available tools to evaluate granular roadway material costs versus field performance, nor to evaluate and optimize operational strategies.

Background

Granular roads serve as an economically sustainable option when the traffic volume is insufficient to warrant paved roads. Approximately 67,000 of the 90,000 miles of Iowa's secondary roadways consist of granular roads, but in 2018, only about 4 of the 291 miles of newly constructed secondary roads were granular roads. The sustainability of granular roadways is also very important to Iowa's rural economy, since these roads provide access to local farms and enable the transportation of agricultural products.

Ad hoc maintenance strategies are common in management policies for granular roads, given they are not very expensive to construct and experience lower usage compared to their paved counterparts. However, proactive and effective maintenance policies are essential. Adequate maintenance of Iowa's granular roads will increase overall roadway system safety, ride quality, and environmental sustainability.

Project Description

After an initial literature review of existing granular road asset management systems, the research team conducted an online survey of Iowa's county engineers, began to collect data on key factors influencing granular roadway deterioration, and conducted a second survey of county engineers and motor grader operators to gain further inputs. The researchers then analyzed the collected data to develop the GRAMS tool. Details of the steps follow.

- **First survey, February 2018:** The survey collected information on operation and maintenance practices for granular roads. Survey questions ranged from understanding the granular roadway maintenance practices from a practical point of view (i.e., annual gravel replacement requirements and rock and aggregate sources, factors influencing maintenance decisions, and budget and cost information) to current documentation and management practices (i.e., types and extents of current roadway inventory databases and software and technologies used). The survey was sent to county engineers in Iowa's 99 counties and yielded a 39% response rate.

- **Data collection, key factors:** The team determined that the most influential factors toward roadway deterioration were annual average daily traffic (AADT), annual precipitation, and subgrade soil quality. They divided the state into regions based on those factors and determined a zone standard normal for each county. To test the methodology, the team also tracked gravel loss deterioration and roadway maintenance activities on a roadway test section for 21 months to compare the observed performance to the model predictions.

- **Second survey, October 2018:** Upon meeting the challenges associated with developing a robust mathematical model of roadway deterioration, the team distributed a second web-based survey to collect experience-based, subjective opinions to better understand the deterioration processes. The purpose of this survey was two-fold: (1) construct an empirical database on granular roadway conditions and deterioration rates for each county, and (2) understand the relationships between maintenance activities performed by local agencies and the resulting granular roadway conditions. Twenty counties participated in the second survey.

Key Findings

Survey Results

- Most local agencies keep historical roadway operation and maintenance records, focused primarily on tracking amounts and locations of aggregate application and purchase prices. Local agencies place a higher emphasis on cost rather than quality of aggregate in their decision-making process.

- Local agencies tend to follow experience-based approaches to assess roadway condition and aggregate quality.

- A total of 43% of the respondents to the second survey reported that the thickness of a granular road section should be a minimum of 4 in. to classify as excellent condition, and the majority (71%) reported 2 in. as the minimum gravel thickness before resurfacing must be performed.

- In addition to the six influential factors—truck traffic, aggregate quality, frost boils, freeze-thaw action, subgrade quality, and rainfall—affecting roadway deterioration identified by the research team, many respondents to the second survey reported that traffic generated by agriculture activities (both farming and livestock related) as key factors causing deterioration of granular roads.

- Among those influential factors, frost boils were rated as having the least influence on the deterioration of granular roadways. The combined factors of truck traffic and agricultural activities, which may have some overlap, were considered the most influential.

GRAMS Tool Findings

Although the previously developed Highway Development and Management (HDM-4) model from the World Bank yielded better performance than the beta regression (BR) model developed in this study, local agencies may be unable to adopt the HDM-4 model since it requires collection of large volumes of high-quality data, which they may find impractical.

For the BR model, such information is analyzed beforehand during the model development phase, and the finalized model can therefore yield satisfactory results with limited user inputs. Further, survival analysis was used to predict the roadway deterioration timeline and estimate the minimum aggregate requirements to keep the roadway system operational at the desired level of service.

With these analyses, an Excel-based GRAMS tool was developed. The tool provides local agencies with a range of options for varying budget conditions to estimate aggregate requirements under different roadway levels of service.

Strengths

- This tool can estimate annual gravel loss on a system-wide basis. Gravel loss predicted by this model was compared to a field test section, and the model yielded similar results with a small percent error.

- User input requirements to utilize the GRAMS tool are readily available to local agencies, making it practical, feasible, and easily adoptable.

- This model can provide estimations of minimum annual aggregate requirements based on survival analysis, and users can simulate aggregate requirements for various budget and risk scenarios.

- Users can conduct trade-off analyses using different aggregate materials for road work and identify the most effective and economical options.

Limitations

- This model was primarily developed from secondary data sets such as survey responses, empirical opinions, and historical data sets, and should therefore be further validated.
- Two key factors influencing roadway deterioration, annual precipitation and subgrade soil properties, were identified as less significant and employed as indirect variables in the model. Further research on these factors is needed to better capture their influence.

Implementation Readiness and Benefits

This study developed a data-driven granular roadway asset management system (GRAMS) tool that local agencies can use to estimate annual gravel loss on a system-wide basis. The tool provides a range of options for varying budget conditions to estimate aggregate requirements under different roadway levels of service.

Implementation Recommendations for Local Agencies

The following recommendations are offered for local agencies to implement more comprehensive roadway management policies for their granular roadway networks:

- Develop roadway management policies at the agency level to address unique county-specific factors
- Consider the adoption of subjective, opinion-based policies using simple index values to assess material quality and roadway condition, which will provide a foundation to further develop a data-driven granular roadway management system
- Use the following data management approach: (1) prepare an aggregate ticket/load sheet that includes the aggregate amount, location, and date of application for each section, (2) enter the load sheet data into a spreadsheet, and (3) enter the data into geomapping software, such as ArcGIS
- Require that grader operators from each district complete the roadway condition rating report developed in this study twice a year to provide information on roadway performance and condition, as well as provide historical data for the agency

Future Research and Implementation Recommendations

The research team recommends a three-year pilot project focusing on field monitoring in selected Iowa counties to further calibrate and validate the GRAMS tool. The following steps will serve as implementation guidelines:

1. Select local agencies for participation
2. Develop a comprehensive roadway inventory
3. Select test road sections and monitor their performance under application of a variety of aggregate materials
4. Form a data matrix that includes historical data from previous steps to provide a summary of granular roadway deterioration across Iowa
5. Calibrate and validate the current GRAMS tool and develop a GRAMS 2.0 model for a dynamic geomap-based online platform
6. Add features to simulate the impacts of roadway stabilization in the GRAMS tool