



Optimizing Maintenance Equipment Life-Cycle for Local Agencies

tech transfer summary

October 2019

RESEARCH PROJECT TITLE

Optimizing Maintenance Equipment Life-Cycle for Local Agencies

SPONSORS

Iowa Highway Research Board
(IHRB Project TR-727)
Iowa Department of Transportation
(InTrans Project 17-613)

PRINCIPAL INVESTIGATORS

H. David Jeong, Professor
Department of Construction Science,
Texas A&M University
(orcid.org/0000-0003-4074-1869)

Jennifer Shane, Director
Construction Management and
Technology, Iowa State University
515-294-1703 / jsshane@iastate.edu
(orcid.org/0000-0002-2612-4269)

MORE INFORMATION

intrans.iastate.edu

CMAT
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

The Construction Management and Technology (CMAT) program is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the CMAT program is to improve the efficiency and cost-effectiveness of planning, designing, constructing, and operating transportation facilities through innovative construction processes and technologies.

The sponsors of this research are not responsible for the accuracy of the information presented herein. The conclusions expressed in this publication are not necessarily those of the sponsors.

Following input from Iowa county engineers, this project developed an equipment management template and a spreadsheet-based tool that can help local agencies improve their equipment purchasing decisions.

Objectives

- Investigate state-of-the-art life-cycle cost analysis (LCCA) methods to identify methodologies that can be adapted
- Identify and analyze current equipment management processes and data collection practices in Iowa counties
- Develop guidelines for counties to use data-driven equipment record-keeping practices to aid in decision making
- Develop a spreadsheet-based decision aid tool for assessing the values of repairing, replacing, or retaining equipment and generating options available to the equipment manager to help counties minimize total life-cycle costs of their equipment fleet

Problem Statement

Many Iowa county engineers use traditional record-keeping practices that do not take into account all the necessary life-cycle cost details for their equipment management, and thus rely on outdated methods of replacing their equipment, resulting in suboptimal decisions for managing their equipment fleet.

Background

Local road agencies are responsible for construction and maintenance of county roads and bridges. To accomplish that mission, local agencies heavily use road equipment for construction and maintenance activities. In Iowa counties, about half of the total budget is spent on road maintenance, and equipment expenditures constitute 27% of the total expenditures.

Determining the optimal time for equipment replacement is challenging, since the cost of maintaining road equipment increases with equipment operation, while the economic value of the equipment decreases.

The LCCA approach, used in advanced equipment management programs, takes the two conflicting trends into account and estimates the optimum replacement time of equipment. Accurately estimating the optimal replacement time and predicting future costs of road equipment contribute to the effective use of equipment, while avoiding expensive maintenance activities.

Project Description

- *Literature review:* Assessed current life-cycle cost analysis practices, found gaps, and reviewed equipment management studies
- *Conduct survey:* Reached out to Iowa county engineers to get input on their current equipment management practices
- *Follow-up interviews:* Sought additional information from counties that had the best practices and asked for historical data on their equipment fleets
- *Data analysis:* Prepared data, recognized patterns, and developed cost forecasting models
- *Deliverables:* Developed a spreadsheet tool that counties can use to better make equipment management decisions and developed a template for counties to employ data-driven record-keeping practices

Key Findings

Survey and Interview Findings

Local agencies in 54 of Iowa's 99 counties responded to the survey, 16 of which participated in follow-up interviews. Some of the findings include the following:

- Motor graders and trucks were the most common types of equipment in use and their associated costs constitute a large portion of an agency's total equipment maintenance budget.
- Just 30% of respondents collect equipment data and have a replacement process. The current replacement process included periodic equipment replacement based on a predetermined amount of equipment usage.
- The follow-up interviews showed that county engineers replace their motor graders after 10,000 to 15,000 working hours, or 7 to 25 years, and replace their trucks after 5 to 25 years, depending on the condition of the equipment.
- About one-third of current equipment is overdue for replacement.
- A budget analysis and a history of problematic maintenance activities play essential roles in determining whether to replace a piece of equipment.

Deliverables Findings

- To develop cost estimation models, the team collected, from 9 counties, the historical equipment data for 64 types of graders and 26 types of trucks, including 295 records for graders and 168 records for trucks, and transferred the data to a spreadsheet for careful review.

- The researchers detected missing and anomalous data and filled in the gaps using information from similar pieces of equipment from other counties in order to prepare a clean database for data analysis.
- The team performed regression analysis to identify the relationship between equipment usage and operating costs. Since the preliminary regression analysis yielded a linear model, the bootstrapping technique was used to recognize a polynomial pattern representing the correlation between equipment usage and operating cost.
- The team developed two modules for using the tool:
 - Deterministic analysis in which the tool captures single values as inputs and provides one-point estimation
 - Stochastic analysis in which a range of values are captured from the user to provide insights about the effect of uncertainties and better reflect actual practice

Recommendations

- Equipment data should be analyzed periodically to update the cost prediction models, as their predictive capability will decrease over time as prices and other estimations change.
- Counties should employ the proposed record-keeping template to enhance the quality and quantity of historical data over time, which can be used in future cost prediction models.
- Keeping track of trade-in values is essential in equipment management, as the LCCA approach determined equipment should be replaced when the annual maintenance costs are higher than the trade-in value of the equipment. The trade-in value can be recorded and tracked using the record-keeping template proposed as part of this research project.

Implementation Readiness and Benefits

The major benefit to Iowa counties is an enhanced ability to make defensible equipment management decisions. The tool's output can be used for planning, budgeting, and capital equipment purchasing decisions.

The tool is also designed to permit users to play "what-if" games—to not only better understand the sensitivity of assumptions, but also to be able to more completely explain decisions to upper management decision-makers.