Optimal Placement of Iowa DOT Maintenance Garages: Muscatine and Dubuque Case Studies

tech transfer summary

Two heuristic algorithms were developed to support the winter road maintenance planning decisions in terms of garage location, vehicle route design, and fleet schedule by leveraging existing data and models.

Objective

The objective of this project was to develop optimization-based approaches to sustainable replacement, improvement, and relocation of maintenance garages.

Background

Winter road maintenance operations involve complex operational strategies and long-term planning decisions. During the 2014 garage review, the Iowa Department of Transportation (DOT) District Maintenance Manager group evaluated the existing garages in each district in terms of operational efficiency, building considerations, and site characteristics.

Based on the repair/replacement urgency, the group recommended replacement of the Dubuque garage and the Muscatine garage as the highest replacement priorities.

Problem Statement

The Iowa DOT's maintenance trucks are mainly used in winter for plowing and material spreading. Satisfying the winter road maintenance level of service requirement is the main concern of the garage location and route design.

Image: M. J. "Charlie" Purcell, Iowa DOT Highway Division

Winter maintenance service level is a primary garage location concern

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RESEARCH PROJECT TITLE
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PRINCIPAL INVESTIGATOR
Jing Dong, Transportation Engineer
Center for Transportation Research and Education, Iowa State University
515-294-3957 / jingdong@iastate.edu
(orcid.org/0000-0002-7304-8430)

MORE INFORMATION
www.intrans.iastate.edu

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

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Research Description/Methodology

This research developed heuristic-based optimization approaches to support the winter road maintenance planning decisions in terms of depot location, vehicle route design, and fleet configuration. The first approach was applied to a case study focusing on maintenance operations and planning for the Muscatine area, and the second approach was applied to a case study focusing on maintenance operations and planning for the Dubuque area.

The Iowa DOT's geographic information management system (GIMS) database and snowplow automatic vehicle location (AVL) databases were the two major datasets used in this study.

In the first case study (new Muscatine garage), the depot location problem involved the comparison of the two candidate sites with an objective of minimizing the total deadhead travel time.

An arc routing problem (ARP) was formulated to design efficient routes for salting, pre-wetting, and plowing, considering the operational characteristics of winter road maintenance. The researchers incorporated a maintenance service-level requirement by imposing a maximum turnaround time constraint for each route.

In the second case study (new Dubuque garage), the technical advisory committee did not provide specific candidate locations. Instead, various practical considerations were discussed, which constrained the selection of candidate sites.

A second ARP approach was developed to account for maintenance service level requirements for the Dubuque area. Alternative garage locations were compared in terms of number of snow routes, deadhead times, and distances.

Key Findings

- Incorporating the route continuity constraint in the capacitated arc routing problem (CARP) significantly increases computational time. Solving the CARP on the Dubuque network takes 2–4 hours for each candidate site.

  Parallel computing cannot speed up the memetic algorithm (MA) process, since the algorithm builds up solutions from the previous generation to the next generation. A more efficient algorithm is desired to solve the CARP while guaranteeing route continuity.

- While this study dealt with the static routing problem for planning purposes, in the context of real-time operations, a dynamic route optimization model considering weather forecasts would be of great interest for practitioners.

Implementation Readiness and Benefits

To reduce operational costs, improve mobility, and reduce environmental and societal impacts, optimization-based approaches were proposed to locate winter maintenance garages by leveraging existing datasets and models.

In both case studies, the researchers developed heuristic solution algorithms to find the optimal snow routes that satisfy maintenance service level requirements. New garage locations were recommended to replace the existing Muscatine and Dubuque, Iowa garages.