Improving Striping Operations through System Optimization

tech transfer summary

Increasing efficiency in striping operations represents a substantial opportunity for state transportation agencies to reduce their annual expenses.

November 2015

MTC RESEARCH PROJECT TITLE
Designing and Applying a Decision-Support System for DOT Fleet Assignment and Operation

SPONSORS
Missouri Department of Transportation (MoDOT)
Midwest Transportation Center
U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology (USDOT/OST-R)

PRINCIPAL INVESTIGATOR
Ronald G. McGarvey, Assistant Professor
Center for Excellence in Logistics and Distribution (CELDi)
University of Missouri - Columbia
573-882-9564 / mcgarveyr@missouri.edu

MORE INFORMATION
www.intrans.iastate.edu/

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

The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.

IOWA STATE UNIVERSITY
Institute for Transportation

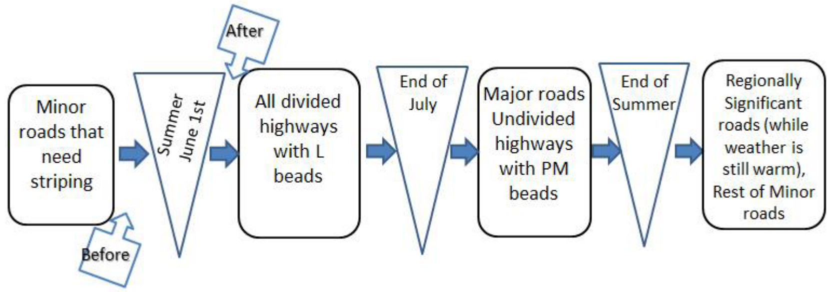
Background

Striping operations generate a significant workload for state department of transportation (DOT) maintenance operations, including Missouri's (MoDOT), which co-sponsored this project. The requirement for each striping crew to replenish its stock of paint and other consumable items from a bulk storage facility, along with the necessity to make several passes on most of the routes to stripe all of the lines on each road, can lead to deadhead miles that striping crew vehicles must travel while not actively applying pavement markings. These deadhead miles generate extra travel, wasted time, and vehicle wear.

For this project, striping operation considerations included the following activities:

- Obliteration of pavement markings (removing existing or temporary pavement markings that are conflicting or might mislead traffic)
- Application of permanent pavement markings after construction or maintenance of roads
- Removal of permanent markings
- Line-striping for all major and minor roads that require it
- Symbol markings, turn markings, etc.
- Maintenance of striped lines (keeping track of line conditions and making a decision which roads should be striped immediately and this year)

MoDOT maintenance activities accounted for roughly 21 percent of expenditures in 2014.



MoDOT striping plan starting in 2015 (with the introduction of a new type of beads for divided highways that require higher drying temperatures)

Problem Statements

For MoDOT, coordinating a plan to accommodate the striping of both major and minor highways annually represents a significant logistical challenge. Inefficient scheduling can create an excess of deadhead miles.

Striping operations for the state are generally limited to the period between March and October, and operations procedures include many constraints that must be addressed in scheduling and in the optimization model representation of the network.

Objectives and Scope

The goal of this project was to develop a decision-support tool that utilizes optimization models to increase the efficiency of striping operations. This project addressed the scheduling of striping operations for a subset of MoDOT roads, those located in the Central District of Missouri, with a focus on minimizing deadhead miles.

Research Description

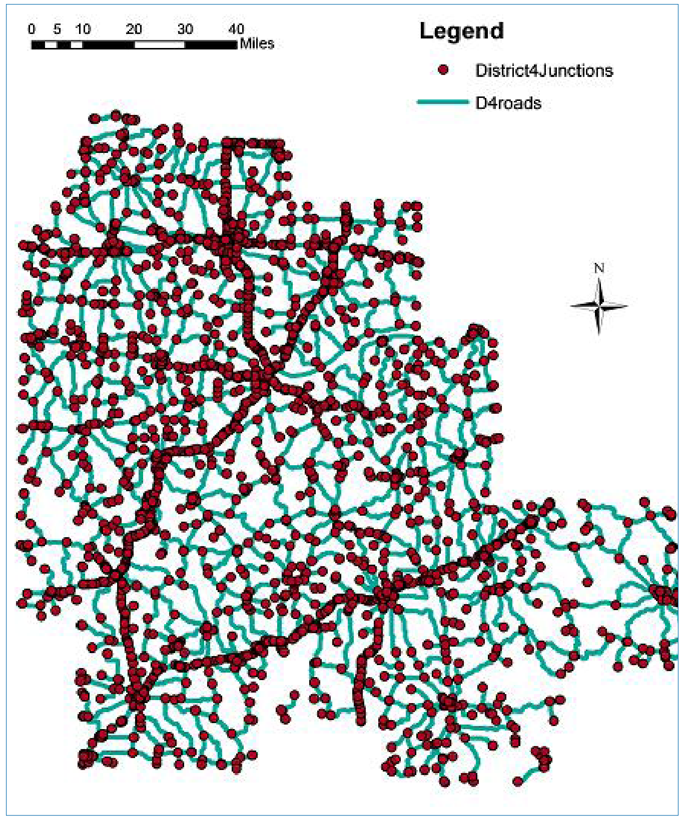
The following datasets, with their associated data elements, were deemed critical to effectively model the preliminary representation of MoDOT striping operations across the Central District of Missouri.

The first dataset determined the set of roads maintained by MoDOT to both establish the set of potential roads to be striped and establish the network in which striping crews may travel given striping operations procedures.

The second critical dataset included the number and direction of passes required for striping operations as determined by the number of lanes and the presence or absence of white edge lines.

The last dataset located the maintenance buildings/locations for parking striping equipment overnight throughout the Central District.

In general, most of the information was recorded and available for extraction; however, the information was scattered across various forms. Each form provided portions of the information necessary for the creation of our model, but no individual form provided sufficient information independent of the others. As such, an important element of analysis involved creating a combined dataset in which the data relevant to our analysis could be more easily referenced.



Missouri Central District network with arcs and nodes

The data were available in three different program files: an Access database file, an Excel spreadsheet file, and a geodatabase feature class file. While some road segment details were present in all three files, many differences were found in their presentation due to different file purposes.

To consolidate the data files, the first step involved creating a geodatabase feature class from the current MoDOT geodatabase feature class to reduce the contained set of cataloged road segments to only the segments maintained by MoDOT.

In general, MoDOT is responsible for most national and state highways across the state. Some of the arcs eliminated from the new dataset included city and county roads, which are either maintained by local government groups or contracted to outside agencies.

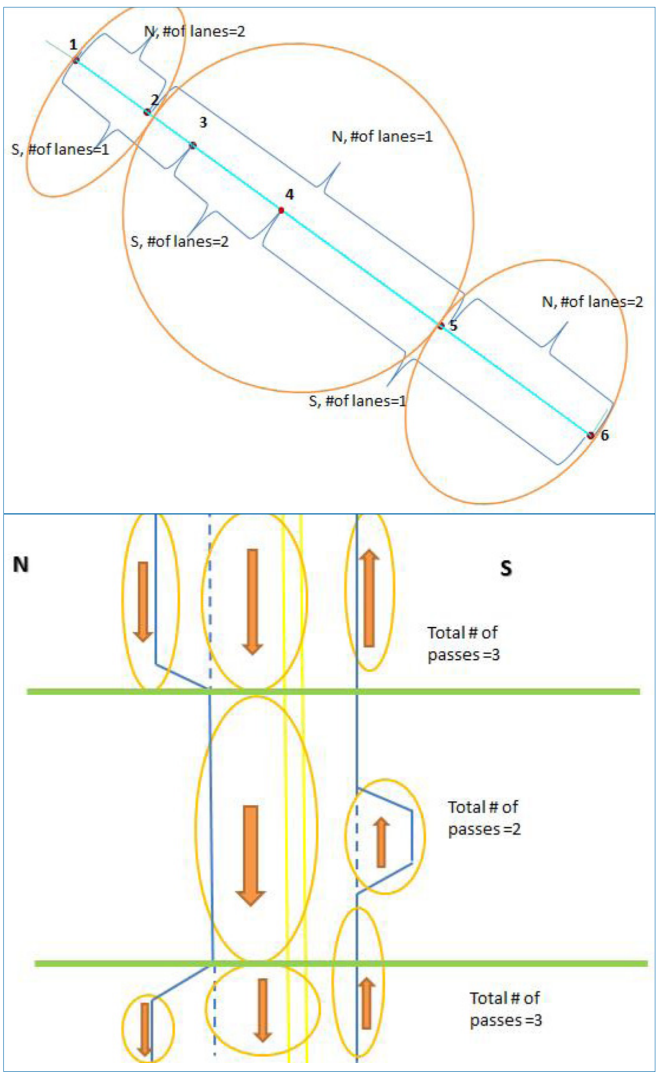
In addition, the striping crews examined in our analysis only operated within the Central District, which permitted the further reduction of the dataset to arcs contained within the 18 counties comprising the Central District.

After reduction of the dataset, we needed to make some modifications to prepare the data for use in our optimization model.

“Difficult” segments required additional analysis before being placed in the final input file (an Excel file) for the model. Next, the strong logic was developed for how many times each segment should be passed to finish the striping process for the optimization model.

Finally, a closest overnight location file was created, given that the striping crews park their striping vehicles in the nearest MoDOT maintenance facility overnight. The crew returns to the bulk storage facility in either a crew cab pickup or the nurse truck and return to their equipment at the start of the following day.

From here, we developed an optimization-based decision-support tool by implementing genetic algorithm (GA) techniques to identify a minimum-distance striping schedule that satisfies MoDOT operations requirements. The tool is a computer program that was developed for scheduling and routing road striping operations.



Example of “difficult” segment for which number of passes and end/start points are different (top) and how the segment looks with the different number of passes for striping operations (bottom)

The final report contains details on the theoretical foundations of the optimization model, along with a user’s guide that details the preparation of input data necessary to utilize the computer program and step-by-step instructions on use of the model.

Implementation Readiness and Benefits

Despite the fact that some factors remain unrepresented in the model (e.g., highway ramps that require striping), the current results of our model can be used to help MoDOT more quickly calculate a striping schedule and dynamically respond to unexpected conditions, such as schedule disruptions that occur (e.g., chip seal operations that were not completed on the scheduled date).

Even though MoDOT does not have records to compare and evaluate the current versus the proposed system, the advantage of the GA is apparent in alleviating the time and effort to develop a striping schedule.

This model provides an ability to significantly eliminate the effort necessary to produce the striping schedule as well as test what-if scenarios to examine the impact of changing resource levels, policies, etc.

Deadhead mile inefficiencies are manifested not only in additional, unnecessary miles traveled by striping crews, but also in crew and equipment capacity. Were a more-efficient utilization of road striping equipment possible, MoDOT could potentially reduce costs by decreasing its inventory of road striping assets without reducing the frequency with which it reapplies pavement markings to Missouri highways. In this regard, the what-if capabilities of our model could be useful beyond the creation of striping operations schedules.

In operations network optimization terms, the research involved our modification of what is called the “rural postman problem” to satisfy the conditions of the “slow-moving multi-pass postman problem with overnighting.” This constituted the formulation of a logistics model absent from the literature. As such, this formulation could be useful in the evaluation of other systems.

The focus with this project was on how increasing efficiency in striping operations represents a substantial opportunity for MoDOT and other state DOTs to reduce their annual expenses.