Research Administration supports and promotes innovative research and encourages its implementation for safe, sustainable, and cost-effective transportation solutions that keep Michigan moving.

Recent Research Results

Innovation and Implementation

Michigan Department of Transportation
Research Administration
May 2023

Implementation of Research Findings

The Michigan Department of Transportation's (MDOT) research provides critical information and data on transportation issues that are essential for effective transportation planning, design, and operations decision-making. Transportation research generates knowledge and innovations that can enhance the safety, efficiency, and sustainability of transportation systems. This report provides a summary of research findings and results for the last two years' worth of research. The full value of this research is only realized when research findings are implemented in practice. Research implementation is essential because it ensures that research findings are used to address practical transportation problems, and it allows stakeholders to reap the benefits of the research investment. With implementation as a goal, Research Administration (RAd) guides MDOT subject matter experts, focus area managers, and executive staff through the following process:

MDOT Research Advisory Committees (RAC) meet every two years to review implementation opportunities resulting from MDOT research projects and Michigan supported Transportation Pooled Fund (TPF) studies. Prior to the RAC meetings, RAd provides direction and training to assist Project Managers (PM) overseeing these projects with implementation planning.

The PMs present their respective implementation plans to the RAC chairs and discuss the assignment of an Implementation Manager (IM) with the resources and authority to champion the implementation efforts. Approved implementation plans are then presented to the Research Executive Committee (REC) to make a final determination.

Following the REC meeting, approved implementation plans are given to the assigned IM. The IM is responsible for ensuring that the approved implementation plan is followed and updated as needed throughout the implementation phase. The RAC chair and RAd are updated by the IM, on an as-needed basis, as to the progress of implementation and when implementation completion is expected. RAd tracks the status of implementation and provides periodic reports to the RAC chair.

Research Administration engages in this process in a dynamic way planning new research projects and implementing the results of past projects, as transportation systems are subject to changing user needs, technological advancements, and environmental pressures, which require innovative solutions to address emerging issues. Reviewing this collection of project summaries will inform you of the research engaged in and provide a sense of the value of the research conducted.

Research Implementation Plans

Highways Delivery & Operations Research Advisory Committee (RAC)

OR No.	Research Project Title	Project Manager
OR19-052	Development of a Network-level Evaluation Tool for Managing ITS Infrastructure for Managing ITS Infrastructure	Joe Gorman
OR19-129	Recruit and Maintain/Upgrade a High-Tech Workforce for Emerging Technologies	Elise Feldpausch
OR19-056	Quantifying Effectiveness and Impacts of Digital Message Signs on Traffic Flow	Eliseo Gutierrez
OR19-064	Integration of Unmanned Aerial Systems Data Collection into Day-to-Day Usage for Transportation Infrastructure Program Asset Management and Systems Operations	Linn Smith
OR21-008	Quantifying the Impact of Super Single (Wide Base) Tires on Pavement Damage in Michigan	Justin Schenkel
OR19-122	Effectiveness of Crash Fact/Safety Message Signs on Dynamic Message Signs	Mark Bott
OR19-114	Performance and Safety of the US-23 Flex Route	Jason Firman
OR17-204	Research on the Operational Costs and Benefits of Speed Feedback Signs	Alonso Uzcategui

Multi-Modal Transportation & Finance RAC

OR No.	Research Project Title	Project Manager
OR19-032	Safety Enhancements at Short-Storage-Space Railroad Crossings	Nikkie Johnson

Planning & Organizational Development RAC

OR No.	Research Project Title	Project Manager
OR19-072	Synthesis of National Best Practices on Pedestrian and Bicycle Design, Guidance and Technology Innovations	Mark Bott
OR20-005	Assessing System Performance of the Michigan Trunkline: Measures and Analytical Procedures for Planning and Operations	Robert Maffeo

Highways Bridges & Structures RAC

OR No.	Research Project Title	Project Manager
OR19-002	Evaluation of Camber and Deflections for Bridge Girders	Kyle Kopper
OR19-017	Concrete Deterioration of Prestressed Bridge Beams	Rick Liptak

Research Implementation Plans (con't)

Highways Development RAC

OR No.	Research Project Title	Project Manager
OR20-003	Michigan Transportation Construction Price Index	Kirsti Kirkpatrick
OR20-002	Innovative Contracting Best Practices	Ryan Mitchell
OR20-004	Innovative Contracting Risk Management Best Practices	Ryan Mitchell
OR21-013	Infrastructure Protection and Rehabilitation Response to High Lake Levels	Hal Zweng
OR19-100	Developing a Consistent Data Driven Methodology to Multimodal, Performance Based, and Context Sensitive Design	John Martin

Highways Delivery & Operations RAC

Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Development of a Network Level Evaluation Tool for Managing ITS Infrastructure

START DATE: May 2019

REPORT DATE: March 2021

RESEARCH REPORT NUMBER: SPR-1700

TOTAL COST: $465,450

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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ITS evaluation tool calculates value and impact of highway technology

For decades, the Michigan Department of Transportation (MDOT) has been using intelligent transportation system (ITS) technology along the nearly 10,000 miles of highway it oversees. This system includes devices such as closed-circuit television cameras, environmental sensor stations, and dynamic message signs. To manage these assets, understand the advantages each provides and evaluate the potential of proposed ITS projects, MDOT sought a method to assess which devices most effectively improve safety and decrease delays on state highways. This project developed a methodology and tool to help MDOT compare the different technologies for improved planning and decision-making capabilities.

PROBLEM

Dynamic message signs are one element of MDOT's ITS statewide network. They rapidly convey important information about unexpected or changing conditions.

For 30 years the Federal Highway Administration's Intelligent Transportation Systems Joint Program Office has been working to accelerate the development and use of ITS technologies to enhance mobility, safety and efficiency in the nation's transportation system. Managing more than 10,000 miles of highway, MDOT has been an early and active participant, adopting, installing and promoting ITS devices and programs across the state. Some of the most heavily travelled corridors in Michigan are well-equipped with ITS devices, including closed-circuit TV cameras, vehicle detection stations, environmental sensor stations, dynamic message signs, and other data collection and transmission devices. These technologies are designed to enhance safety and decrease travel delays on highways.

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"The methodology developed through this research is an important step in the ability to compare intelligent transportation system projects and deployments in a common framework."

Joe Gorman, P.E.
Project Manager

There is a wide range of additional ITS devices and applications that could be installed on state highways, and MDOT is faced with the challenge of integrating new and existing technologies while ensuring statewide compatibility. As the systems become more complex, MDOT must manage its existing assets while making sound ITS investment decisions.

To objectively compare projects and identify any opportunity to better leverage existing assets, MDOT wanted a data-backed performance evaluation tool it could apply to ITS systems already in place, as well as proposed new projects.

RESEARCH

This research sought to define the parameters and capabilities of MDOT's current ITS network, to evaluate existing system performance and to develop an evaluation methodology and tool to make the task of assessing and comparing different types of devices and projects more consistent across the state.

Researchers began by identifying the data needed to make accurate calculations and how the information could be obtained. To accomplish this, the team first had to document and inventory the devices that are part of MDOT's current ITS network and quantify the safety and delay performance of each device.

Paring MDOT's database of 29,000 ITS devices down to those relevant to this project, the team eliminated equipment such as switches and utility poles to reduce the list to 2,832 devices in 11 categories. The researchers then devised a methodology to compare the costs of traffic delays and crashes, and the time-savings and safety improvements the devices supply. The team included a variety of data such as road classification, speed limit, traffic volume, delay, congestion, and crash history information, allowing MDOT to uniformly assess a device's performance across various regions and project types.

RESULTS

Combining the methodology with input from MDOT staff, national research and case studies, the researchers developed a software tool to make calculating the costs and benefits of ITS projects simple.

Designed as an extension of MDOT's existing geospatial tools, this new product allows staff already familiar with those resources to easily incorporate it into their work. The research team also created an accompanying installation and user's guide to facilitate quick adoption, as well as guidance for continuous updates and maintenance.

Applying the new methodology to MDOT's ITS network already in place, the research team was able to show that traffic delays cost Michigan about $1.3 billion per year, and an average of $3.9 billion per year in property damage, injuries and fatalities resulting from crashes. The ITS devices MDOT currently uses mitigate those annual costs by about 18.6 percent and 4.5 percent, respectively.

To start, the ITS evaluation tool will be part of a pilot implementation effort while MDOT examines and weighs a number of potential statewide ITS projects.

VALUE

The new methodology compares the benefits and costs of existing and proposed ITS devices on Michigan's extensive highway network, empowers MDOT to choose new ITS projects that promise the greatest value and identifies opportunities to maximize devices already installed.

As it is used throughout the state, the methodology and tool will be used to help regional planners continue to improve roadway safety and reduce traffic delays, and allow MDOT to make better-informed ITS project decisions within a complex system based on robust data.

Research Administration

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Research Spotlight produced by
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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: High-Tech Workforce Preparation for Emerging Transportation Technologies

START DATE: October 2019

REPORT DATE: June 2021

RESEARCH REPORT NUMBER: SPR-1699

TOTAL COST: $230,161

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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MDOT prepares its workforce for emerging transportation technologies

New technologies have emerged quickly throughout the transportation sector in the last decade. Intelligent transportation systems, big data analytics and connected and automated vehicles are a few of the advancements that have the capacity to revolutionize how the Michigan Department of Transportation (MDOT) manages the state's transportation system. This research study investigated the technologies on the horizon, recommended methods to identify expertise gaps in MDOT's current staff and provided recruitment and training strategies to help MDOT build a highly skilled and specialized workforce to meet future needs.

PROBLEM

The emergence and implementation of many new technologies over the last 10 years have brought positive changes for MDOT and present the potential for further progress. Innovations in areas such as wireless communications, data technologies, advanced traffic management systems, and civil integrated management have profoundly impacted the agency's work. With these technological advances comes the need for an agency staff that can understand, navigate and implement the necessary tools to maximize transportation opportunities and manage challenges across the state.

To ensure it will have a technologically sophisticated workforce in place to meet demands in the coming years, MDOT sought to identify which emerging technologies will have the greatest impact on the agency's work as well as the skills staff will need to use it. With that knowledge, MDOT could then begin to recruit new specialists and help current workers update and expand their skills.

Drones, mobile robots and traffic operations centers allow agencies to be more effective, but their use depends on trained and experienced operators.

RESEARCH

Researchers began by identifying the key technologies that will likely affect transportation operations and management

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> *"A strategic and nimble workforce, able to manage the changes inherent in transformational technologies, will ensure MDOT meets the public's needs in the most effective and conscientious ways."*
>
> **Elise Feldpausch**
> Project Manager

into the future. Working closely with MDOT, the team narrowed its focus to five areas of technology: mobile robotics, advanced traffic management systems, data analytics, mechanistic-empirical design and engineering, and complete streets design with context-sensitive solutions.

Next, to learn what skills MDOT will need to incorporate into its current workforce, the researchers examined MDOT's existing strategic plans, organizational structure and current practices, as well as national transportation employment statistics and the best practices of several other state DOTs. The team also reviewed the relevant academic and training programs that have already been established in Michigan to support the evolving needs of the transportation industry. These efforts led researchers to understand how other transportation organizations are managing the rapidly changing technological landscape, the resources available and the context within which MDOT's workforce strategies need to be implemented.

Finally, the team set out to develop recommendations that would guide MDOT in its workforce preparation strategies.

RESULTS

The researchers produced a comprehensive analysis of the future workforce needs at MDOT. While the team found that MDOT is among the leading state DOTs for developing a workforce geared toward emerging technologies, they offered several recommendations to strengthen the agency's workforce in the following five areas:

- **Ideal core competencies.** Seek workers with both technical skills, such as data analytics, artificial intelligence, neural networks, and cybersecurity needs, and soft skills like a growth mindset, communication and emotional intelligence.
- **Organizational structure.** Model MDOT's program after the U.S. Chamber of Commerce's Talent Pipeline Management, which uses a supply chain management methodology, to ensure a steady pool of qualified candidates. Conduct skills mapping for positions across MDOT to help workers identify career pathways.
- **Recruitment.** Increase workforce diversity, engage with academia, embrace social media to reach younger workers, and quantify benefits to be competitive with the private sector.
- **Training and development.** Invest in diversified training programs and education assistance, establish a succession planning committee and understand workforce generational differences.
- **Retention.** Create employee support programs, implement a transparent system for promotions and incentives and provide leadership training.

Researchers also analyzed postsecondary education and training programs to support emerging technology and occupational trends in the transportation industry. Compiling insights and forecasts, educational resources and desired skills and wage analyses, the team developed recommendations for recruiting professionals to five high-demand occupations critical to MDOT's future success: civil engineers, civil engineering technicians and technologists, electricians, surveyors, and highway maintenance workers. Through customized pathways, such as internships, apprenticeships and other special programs, MDOT can develop a pipeline over time to replenish these hard-to-fill roles.

IMPLEMENTATION

With a better understanding of the technologies to come and its future staffing needs, MDOT can use the training and recruitment strategies outlined in this project to cut a path toward strengthening MDOT's workforce over time. The results will serve as a roadmap going forward, ensuring Michigan has the high-tech workforce it needs to support its evolving transportation management practices across the state.

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Quantifying Effectiveness and Impacts of Digital Message Signs on Traffic Flow

START DATE: November 2019

REPORT DATE: March 2022

RESEARCH REPORT NUMBER: SPR-1709

PROJECT COST: $155,900

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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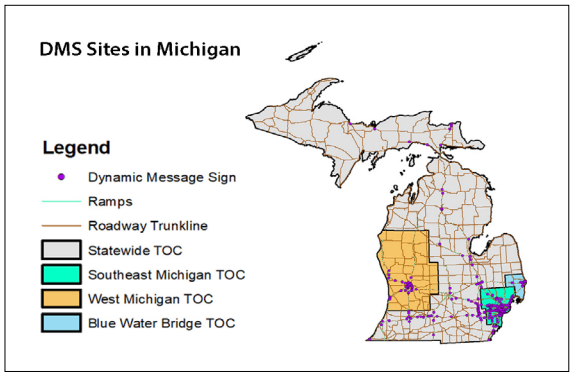
Benefits of dynamic message signs on driver behavior and traffic flow

A dynamic message sign (DMS) can be an effective tool to keep drivers informed of road conditions and traffic flowing smoothly. With finite resources, the Michigan Department of Transportation (MDOT) needs to invest in message sign uses that result in the greatest benefits. A multi-faceted research study identified effective DMS practices and messaging refinements for the agency to consider, providing a clear strategy for maximizing the benefit of DMS deployments.

PROBLEM

For more than four decades, MDOT has used digital signs with changeable messages to alert drivers to inclement weather, crashes and other incidents. Today, more than 200 DMSs are managed by the agency's traffic operations centers. In addition to safety campaigns, keeping drivers informed with real-time messages related to congestion, road condition and travel times can be an effective way to manage traffic and enhance safety.

Given the myriad possible DMS applications but with limited resources available, MDOT has to be strategic in when, where, why, and how DMSs are deployed and messages are displayed. The agency needed to understand the usefulness and cost-effectiveness of DMS technologies and practices to guide investment and maximize traffic flow improvements.



The majority of MDOT's DMSs are deployed in urban areas where there is more congestion and variable travel times. Other DMS applications, such as weather warnings, are useful across the state.

RESEARCH

With the goal of assessing the effectiveness of different DMS types, purposes and deployments in Michigan, researchers undertook a multifaceted approach to explore driver perceptions, traffic data and observations, simulations, and economic analyses.

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"This research gave us quantified benefits of having portable or fixed dynamic messaging capability in specific places for certain purposes, allowing MDOT to take a more holistic approach to managing these tools."

Eliseo Gutierrez
Project Manager

After reviewing past DMS studies in Michigan and literature pertinent to other states' practices and guidelines, researchers surveyed road users in the state for feedback on their preferences and perspectives on DMS applications. They also examined drivers' understanding of and compliance with the signs' messages.

Collecting data from sources including MDOT traffic counters, road weather monitoring, traffic sensors, and video cameras, a series of field case studies evaluated the signs' impacts on driver behavior, including:

- Whether drivers' speeds vary in response to weather-related messages.
- Whether drivers divert from their original routes based on DMS displaying alternative route travel times.
- Whether portable DMSs at construction sites improved traffic flow.

Researchers then performed cost-benefit analyses on these three practices.

Additionally, case studies helped assess the feasibility of automating weather-related messages and addressed the accuracy of displayed travel times. Researchers also conducted a virtual-reality laboratory experiment in which participants used driving simulators to demonstrate comprehension and the effectiveness of MDOT's practice of presenting alternating messages on the same screen (known as "message phasing").

RESULTS

Researchers found that many of MDOT's existing DMS practices are cost-effective, encourage safer driving and improve traffic flow. Weather-related messages effectively slow drivers traveling over the speed limit while portable signs with messages placed in work zones can help drivers merge earlier and keep traffic flowing more evenly. When traffic was slowed due to congestion or an incident, displaying alternative routes on DMSs improved traffic flow. Also, as displaying accurate travel times is essential for maintaining drivers' trust, researchers compared posted times with the time actually required to travel the specified distance. The effort showed DMS-displayed travel times are generally accurate, though higher traffic volumes and other factors can affect actual travel times in urban areas.

In analyzing the economics of these applications, the research showed certain benefits, such as travel time savings and potential reductions in speed-related crashes, outweighed the costs of deploying and operating the equipment.

Researchers also identified ways MDOT could increase DMS effectiveness.

Message clarity: Surveyed Michigan road users indicated they are more likely to comply with messages that are brief, easy to understand and specific. In addition to text color (yellow text on a black background was found to be most visible) and having enough signs that drivers notice them, the wording of the message matters as well. When a message includes a location, such as for an incident or a congested stretch of road, street name suffixes (such as St. or Rd.) should be used. Also, the distance to the incident and travel times for a suggested alternative route should be included.

Message phasing: The virtual-reality laboratory experiment illustrated a connection between message phase time and drivers' comprehension of the message. The ability to read the alternating messages on a DMS when phasing was used was the most significant issue identified by drivers. Driving speed, message display time and message length were factors affecting understanding.

IMPLEMENTATION

The research project results will be useful in considering any updates to MDOT's DMS guidelines and will inform the agency's Transportation Operations Centers in altering current practices. The cost-benefit analyses will help prioritize deployment of message signs for work zones, inclement weather and alternative routing.

In addition, a case study examining the pairing of environmental sensor stations with DMSs will inform MDOT's research in progress on automated DMS warnings on icy bridges, as well as related future studies. DMS technology advances, including full-color displays, may prompt further study as well.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Integration of Unmanned Aerial Systems Data Collection into Day-to-Day Usage for Transportation Infrastructure—A Phase III Project

START DATE: June 2019

REPORT DATE: June 2022

RESEARCH REPORT NUMBER: SPR-1713

PROJECT COST: $871,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Integrating drones into MDOT's day-to-day traffic and asset management

Previous research by the Michigan Department of Transportation (MDOT) illustrated the capabilities of unmanned aerial systems (UAS, sometimes called drones) for a variety of asset and traffic management purposes. Case studies of four applications common to MDOT's day-to-day operations will help expand the uses of drones and illustrate new potential, such as the integration of high-resolution geospatial data integrated into MDOT's workflows and databases. Overall, the efficient and effective data collection afforded by UAS will improve MDOT worker safety, increase mobility and offer a significant return on agency investment.

PROBLEM

MDOT's day-to-day management of the transportation system requires significant and ongoing data collection. As technology changes, capabilities to collect timely, detailed and accurate data evolve. Integrating data into systems and platforms that the agency uses to carry out its mission is challenging (and is often a moving target).

In 2013, MDOT initiated a three-phase investigation into the viability and potential of using UAS for data collection for a variety of day-to-day operations. Phases one and two demonstrated that several types of drones are able to perform comparably to traditional data collection methods in a variety of applications. As highlighted in an MDOT video Research Spotlight, the research showed the capabilities, efficiencies and cost-effectiveness UAS can offer.

Traffic can be viewed, and traffic density analyzed, in real time with data from unmanned aerial systems processed through automated machine learning algorithms.

Phase three expanded on the previous work, enabling MDOT to incorporate UAS as an established data collection tool into the agency's daily operations. With a better understanding of the platforms, sensing technologies and data collection potential,

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"Collecting data with UAS results in safer and more efficient management of our transportation system, which translates into increased mobility for road users. Now, we can more effectively integrate this tool into our day-to-day operations."

Steven J. Cook, P.E.
Project Manager

MDOT sought to apply the technology to four real-world data collection activities: monitoring traffic, surveying, and inspecting bridges and construction sites.

RESEARCH

Investigators explored how and where to fly UAS to effectively monitor traffic and how to analyze live-stream data. For bridge and construction inspections, data collected from a variety of bridge sites represented the range of conditions MDOT inspectors encounter and demonstrated the capacities of artificial intelligence (AI) to enhance collected data. To monitor construction, drones flown over pavement removal, concrete and asphalt paving projects collected thermal imagery and orthoimagery, which geometrically corrects an image to make the scale uniform.

Tests of UAS-based light detection and ranging (LiDAR) data identified topographic characteristics for design surveys. The data was compared to existing mobile LiDAR and traditional survey data to determine its utility and accuracy.

Lastly, the team explored how UAS-collected data and methods could be integrated into MDOT's existing workflows and databases.

RESULTS

The research revealed a number of findings in the four test applications:

Traffic monitoring: In addition to identifying optimal flying heights and when to use single or multiple drones for specific purposes, researchers developed algorithms for analyzing live-stream video to provide quantitative data on traffic counts, flow and density. These analyses are applicable to both daily traffic operations and analytical traffic studies.

Bridge inspection: UAS imagery processed through an algorithm detected the location, depth and surface area of bridge deck concrete surface defects such as spalling. A different process used thermal imagery to detect delamination in bridge decks to a greater and safer extent than traditional methods. UAS was also able to access dangerous or difficult-to-reach bridge locations and process data with AI into 3-D models to better illustrate bridge lifecycles and maintenance needs.

Construction inspection: Drones can support MDOT project managers in the field by monitoring the progress and quality of a project during construction. UAS-collected thermal images may help identify problem areas such as temperature segregation in recently laid asphalt, and can also estimate work progress, or paving rates, without having additional workers in dangerous situations or potentially disrupting construction.

LiDAR for design survey: While field conditions like dense vegetation may influence the accuracy of UAS-based LiDAR, the data collected was generally comparable to other survey data gathered by traditional methods. The right kind of reflective ground control targets can help with collecting high-quality LiDAR data.

Finally, the research team developed workflow diagrams that integrate and map UAS data into MDOT's workflows, databases and decision processes for the four investigated uses. They also conducted demonstration and training sessions for MDOT staff.

IMPLEMENTATION

Across the state, MDOT's certified pilots are already using UAS for design surveys, monitoring material stockpiles and mapping invasive species. Drawing from this research, the agency will continue to expand use of UAS while exploring solutions to regulatory challenges for using the tool in certain situations (such as over traffic). Finally, MDOT will continue to acquire equipment and train staff in ways to integrate UAS into their daily operations.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Quantifying the Impact of Wide Base Tires on Pavement Performance in Michigan

START DATE: March 2021

REPORT DATE: December 2022

RESEARCH REPORT NUMBER: SPR-1720

PROJECT COST: $170,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Understanding the impacts of wide base tires on Michigan's pavements

The trucking industry has recently started using wide base single tires (WBTs) in place of conventional dual tires on commercial trucks to achieve better fuel economy and improved truck stability. While WBTs offer benefits for freight hauling, their larger size can cause more pavement damage than conventional dual tires. To design and maintain pavements that can withstand these potentially increased stressors, the Michigan Department of Transportation (MDOT) initiated a research project that collected data on wide base tire use within the state and developed methods to predict pavement performance under the corresponding tire loads.

PROBLEM

The smaller surface area of wide base tires (left) can cause more pavement distress than typical dual tires (right). This research will help MDOT design pavements that can better withstand these challenges.

Dual tires have been the standard on commercial trucks for decades – it's why the vehicles are often known as "18-wheelers." Some fleets, however, have begun to use WBTs because they can reduce fuel consumption, resulting in cost savings and fewer gas emissions. Compared with dual tires, WBTs have a smaller area of contact with the road.

MDOT designs its concrete and asphalt pavements using design software that estimates pavement damage based on anticipated truck traffic and other traffic inputs and assumptions, including tire load distribution and tire contact area or pressure.

For decades, MDOT has built the state's pavements and measured their performance based on the presumption that trucks will ride on dual tires. To accommodate a new tire configuration, the agency needed to

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"This work validated our suspicion that we have a measurable quantity of wide base tires on Michigan roads. Having an idea of the tires' impacts will help us predict pavement performance as they are likely to become more common."

Justin Schenkel, P.E.
Project Manager

identify the impact of WBTs on both asphalt and concrete pavements of different thicknesses and potentially modify its pavement designs for the future.

RESEARCH

To estimate the number of WBTs on Michigan roads, the investigators observed truck tires at various weigh stations and truck parking lots around the state. Additionally, the investigators gathered video recordings and used a computational learning tool to distinguish axle and tire types. As a result, they estimated the percentage of truck tires on Michigan's roads that are WBTs.

Next, investigators explored how WBTs affect pavement performance by reviewing the differences between dual- and wide-tire stresses on road surfaces. Multiple pavement analysis tools helped to predict pavement stresses from WBTs. The analyses measured the potential for fatigue cracking and rutting in hot mix asphalt pavements of varying thicknesses, as well as cracking and faulting distresses in rigid concrete pavements. The results allowed investigators to develop predictive models to show how WBTs are likely to damage pavements.

The study also explored how weigh-in-motion (WIM) devices, which detect and record axle and gross vehicle weight as a truck passes over sensors on a roadway, can be used to distinguish the types of tires on a truck. Reviews of the WIM devices used in Michigan and other related technologies revealed newer and more advanced tools that promise to differentiate between tire types and detect other vehicle characteristics, such as wheel spacing and even tire pressure.

RESULTS

The research showed that of all the commercial trucks driving on Michigan's roads today, approximately 10 percent of the tires currently are WBTs. This information will help MDOT engineers design pavements that are appropriate for the type and volume of traffic they will need to support, to design more effective pavements. Investigators calculated the increased distress due to WBTs and accordingly made recommendations for potential pavement design revisions.

As expected, the impacts of WBTs on asphalt and concrete pavements are greater compared to a dual tire configuration:

- **Asphalt:** Added pavement distress is relatively minor, though fatigue cracking is a possible concern. Increasing the thickness of pavement layers will help to reduce cracking but will not alleviate rutting.
- **Concrete:** Rigid pavements are susceptible to faulting from wide tire loads, and constructing thicker slabs can reduce this effect.

For both pavement types, pavement smoothness is not significantly affected by WBT loads.

Finally, this study summarized the capabilities of WIM technologies in detecting wide tires. Newer systems may accurately distinguish between tire types, which the current versions used in Michigan do not.

IMPLEMENTATION

MDOT will use the estimates of wide base tires on state roads, as well as the prediction functions for pavement impacts, as it continually works to improve the accuracy of its pavement design models. With a better understanding of how the wider tires will likely affect Michigan's roads, the agency will be better able to anticipate pavement performance over time and evaluate alternative pavement designs. The agency will also consider updating its statewide design standards to account for WBTs on the state's roads.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Insights into the Effective Use of Dynamic Message Signs for Traffic Safety

Dynamic message signs (DMSs) have been used successfully by many transportation agencies to display travel and weather information. Increasingly, the Michigan Department of Transportation (MDOT) and other agencies use DMSs to communicate safety messages as well. There has been little study, however, on how effective these messages are in improving traffic safety. An MDOT research project provided guidance on the best ways to use DMSs for safety messaging, and the results are consistent with federal recommendations.

Project Information

REPORT NAME: Effectiveness of Crash Fact/Safety Message Signs on Dynamic Message Signs

START DATE: March 2019

REPORT DATE: June 2021

RESEARCH REPORT NUMBER: SPR-1686

TOTAL COST: $127,022

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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PROBLEM

Dynamic message signs can display up-to-date fatality statistics throughout the state.

Many states, including Michigan, have used programmable electronic DMSs for years to display current travel and weather information. More recently, DMSs have been used to convey a variety of safety messages. While vehicles have become safer and more investments have been made in crash countermeasures, traffic fatalities have increased over the past decade in Michigan and across the United States due to driver behavior and other factors.

To encourage safer driving, MDOT has used DMSs to display both factual and more creative messages as part of a safety campaign since 2013. However, there has been little study about the effectiveness of safety messaging on driver behavior and traffic safety. MDOT engaged researchers to understand how the public perceives these messages and if the messaging is decreasing crashes and other incidents.

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"This research provides MDOT clear direction in setting future guidance for using these invaluable devices for communicating to the motoring public. The messages we display must benefit their daily travels."

Mark Bott, P.E.
Project Manager

RESEARCH

Researchers employed a variety of methods to understand whether DMSs are effective in improving traffic safety. A literature review found that while the impact of DMSs on traffic operations has been broadly researched, there has been limited exploration into the use of DMSs for safety messaging.

Researchers examined public opinions on DMSs by analyzing commentary on safety messaging over a six-year period. The team collected data from e-mails to MDOT and comments on social media, relevant newspaper articles and MLive, Michigan's largest news and information website. Additionally, a statewide survey yielded 937 responses to questions eliciting feedback on various safety messages on DMSs and self-reported changes in driving behavior in response to the messages.

To further assess the relationship between safety messaging on DMSs and traffic safety, researchers combined five years of historical DMS messaging with crash, roadway and traffic volume data into a geospatial dataset and analyzed possible correlations. Finally, the researchers conducted field studies at three sites to evaluate drivers' responses to DMS messages, including those related to Michigan's Move Over law, which requires drivers to slow down and change lanes when passing stopped emergency and service vehicles.

RESULTS

The research showed that almost half of the public commenters thought the DMSs' safety messages were valuable for raising traffic safety awareness. A concern raised by the commenters included the DMSs' potential for causing distracted driving (by drawing drivers' attention away from the road to read the sign) and the preference for the signs to be used for travel times. Others appreciated the DMSs and safety messaging.

Of the survey respondents, more than 90 percent supported the use of DMSs for communicating travel and weather-related information, while about half supported using DMSs for safety messages and crash facts. The survey also found that messages eliciting positive emotions, such as "Don't drive wild. Think of your child," were more likely to improve driving behavior – both immediately and over the long-term – than were messages eliciting negative emotions, such as "Don't drive wicked, avoid a ticket."

The researchers' analysis of historical messages and crash data showed that speed-related crashes decreased as the frequency of speed- and tailgating-related messages increased. In the field studies, drivers were more likely to comply with targeted messages relating to Michigan's Move Over law when a police car was also parked along the roadside than when an MDOT service vehicle was present. Drivers' responses to speeding-related messages were less definitive, leaving researchers to recommend these types of targeted safety messages be combined with enforcement campaigns.

VALUE

With research results in hand, MDOT now has a better understanding of best practices for effective messaging. This study supports the notion that safety messages displayed for short durations are supported by the public, as travel and weather advisory information are the more popular subjects for DMS messages. Also, these results are consistent with current Federal Highway Administration guidance and upcoming changes to the Manual on Uniform Traffic Control Devices on the use of DMSs for safety messaging, suggesting that safety messaging should be simple and straightforward and is most effective when part of a larger safety campaign with a clear law enforcement component. This study reinforces MDOT's alignment with federal guidance and suggests the best uses of DMSs.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Evaluation of an Active Traffic Management System with Part-Time Use of the Inside Shoulder

START DATE: March 2019

REPORT DATE: July 2021

RESEARCH REPORT NUMBER: SPR-1706

PROJECT COST: $184,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Evaluating safety and traffic improvements along Michigan's first flex route

The Michigan Department of Transportation (MDOT) opened the state's first flex route in 2017 along an 8.5-mile stretch of US-23 near Ann Arbor. By monitoring traffic flow and allowing drivers to use the inside shoulder lane during peak travel times, traffic control operators can alleviate traffic congestion and improve safety for all road users. Researchers surveyed drivers and compared operational and crash data before and after the addition of the flex route to evaluate its success and inform recommendations for similar routes in the future.

PROBLEM

The nearly 9-mile corridor of US-23 north of Ann Arbor is prone to fluctuating traffic volumes depending on the time and day of the week. On weekdays, an influx of commuters routinely clog the four-lane divided highway during the morning and afternoon rush hours, while traffic on weekends is often minimal. To increase the road's capacity during peak times without the expense, delay and environmental impact of constructing an additional permanent lane, MDOT created the state's first flex route along the stretch in 2017. This intelligent and dynamic traffic management system uses cameras and other technology to help dispatchers in MDOT's Statewide Transportation Operations Center determine when the median shoulder in either direction should become a temporary third lane and alert drivers to its availability through digital signs along the roadway.

In a flex route, MDOT authorizes the use of the interior shoulder lane during peak traffic times to alleviate congestion, reduce crashes and improve safety.

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"The data show the flex route has successfully reduced traffic delays and crashes, and costs significantly less than adding a permanent third lane."

Jason Firman, P.E.
Project Manager

To learn the effectiveness and success of the flex route, MDOT looked to assess the system's operational and safety performance since its implementation, gauge public perception and identify potential improvements for future routes.

RESEARCH

To evaluate the performance of Michigan's flex route, researchers began by reviewing the best practices and lessons learned reported by other transportation agencies that have used part-time shoulders in the United States and around the world.

Researchers next gathered historical and recent traffic data, comparing average speed, travel times and crash data collected from the US-23 corridor before MDOT installed the flex route and compared it with measurements taken after installation. Notably, the COVID-19 pandemic reduced the amount of usable data for this study as fewer drivers and faster average speeds contributed to anomalies that made the 2020 data unusable for comparison purposes.

Finally, the research team surveyed hundreds of drivers and residents living near the roadway to gauge users' experience and level of satisfaction with the flex route's performance. The researchers also conducted focus groups with drivers and catalogued comments users made on social media to better understand public perception.

RESULTS

The researchers hailed the flex route as a success story and a model for future congestion-prone roadways in Michigan. The data showed that travel on US-23 has generally improved since the flex route became operational in November of 2017. Average travel speeds increased substantially during peak weekday hours, resulting in fewer delays and shorter travel times in both directions.

The route's safety-related data was similarly positive, with crashes reduced overall by nearly 17 percent. While the southbound lanes saw a greater improvement in the number of crashes, travel on the northbound lanes did get better with the addition of the flex route and MDOT anticipates even more safety and performance improvements for travelers heading north once a planned extension of the flex route is complete. The research showed the flexible third lane also improves safety by guiding traffic around crashes or roadside debris, allowing emergency personnel to respond to crashes and clear roadside incidents more quickly.

Users were overwhelmingly happy with the changes, with almost 70 percent of US-23 drivers saying they were satisfied or very satisfied with the flex route and would support expanding the current route and adding additional routes throughout the state. While most of the feedback received was positive, some drivers reported being confused by some of the overhead messages and offered solutions to improve the clarity of communications.

The researchers compiled a list of recommendations for MDOT to consider when designing future flex routes, including:

- Adding additional sensors, cameras and other technology to capture traffic volume, speed data, road capacity, and shoulder availability for better traffic management and enforcement.
- Configuring the termination of flex routes to avoid bottlenecks.
- Notifying drivers at least 3 miles in advance of a lane change or merge to support a smooth transition and reduce crashes.

IMPLEMENTATION

With data showing the flex route's success by just about every metric, MDOT has a proven and cost-effective strategy for mitigating congestion on other roadways in the future.

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Evaluation of Dynamic Speed Feedback Signs on Freeway Interchange Ramps

START DATE: July 2018

REPORT DATE: December 2021

RESEARCH REPORT NUMBER: SPR-1704

PROJECT COST: $200,700

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Dynamic signs along Michigan's freeway ramps improve driver behavior

Like other transportation agencies in the United States, the Michigan Department of Transportation (MDOT) devotes significant resources toward reducing lane departure crashes, which account for nearly half of all traffic fatalities nationwide. Freeway exit and entrance ramps, which often require drivers to slow down significantly to navigate a horizontal curve, are common crash sites. To lower the risk, MDOT installed and tested dynamic speed feedback signs at six critical sites and evaluated their effectiveness on driver behavior. With promising results in hand, MDOT developed guidance for implementing these life-saving devices statewide.

PROBLEM

Dynamic signs can be an effective speed-reduction strategy for vehicles leaving the freeway.

Crashes that occur when a vehicle crosses over the center or edge line of the roadway are frequently severe and often fatal. These crashes, which can result in head-on collisions or leaving the road altogether, comprise slightly less than half of all traffic-related deaths in Michigan – and national studies report similar statistics. The risk of these lane departure crashes is even higher where horizontal curves are present, such as freeway interchange ramps, which also demand drivers reduce their travel speeds significantly to navigate the road.

Dynamic speed feedback signs, which use radar to measure passing vehicles' real-time speeds and issue targeted warning messages to drivers, offer a promising solution to help alter their behavior and reduce crashes. While the devices are often used successfully in Michigan to remind

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"In keeping with MDOT's commitment to safety and the Toward Zero Deaths initiative, this project provides a promising strategy for reducing traffic crashes and fatalities across the state."

Alonso Uzcategui, P.E.
Project Manager

drivers to slow down in school zones and near roadway work zones, MDOT hasn't used them frequently at freeway entrances and exits. To learn whether the signs could work effectively to reduce speeds at these locations as well, MDOT engaged a team of researchers to conduct a series of tests and provide recommendations.

RESEARCH

The researchers began by reviewing published policies and technical guidance regarding the use of dynamic speed feedback signs and surveying other state DOTs about their experiences with the devices. These resources provided support in favor of using the signs as a speed countermeasure and offered valuable suggestions for maximizing the signs' effectiveness. Only a few DOTs indicated they had used the devices at freeway exit ramps, signifying the innovation in this line of research.

The team applied lessons learned from around the country to field evaluations in Michigan, selecting several commercially available signs and installing them at six freeway interchange ramps in the state. Testing a variety of variables and configurations, the researchers assessed the different signs' physical characteristics, detection capabilities, placement along the ramp, and effectiveness at influencing driver speeds and behavior.

RESULTS

The field evaluations consistently showed the dynamic speed feedback signs successfully lowered speeds as vehicles approached and entered the curves at freeway exit ramps. With data collected from the test sites, researchers identified a variety of optimization strategies that resulted in average speeds that were up to 4 mph lower than when the signs were not present.

To help MDOT's traffic engineers replicate the signs' success statewide, the researchers developed a series of best practices for designing, operating and installing effective dynamic speed feedback signs at freeway interchanges.

Site selection – Prime locations include exit ramps that have experienced frequent lane departure crashes in the past, where the average vehicle enters the ramp at least 10 mph faster than the posted speed limit and at sites that have sufficient space and visibility to accommodate a sign safely.

Messaging strategies – Signs should display a vehicle's actual speed when a driver is traveling no more than 10 mph over the posted limit. For vehicles exceeding the limit by 10 mph or more, the speed number should alternate with a "SLOW DOWN" message.

Design characteristics – To increase visibility, signs should include reflective elements and be large enough to display amber letters and numbers that are at least 15 inches high.

Installation guidance – Signs should be placed on the right-hand side and within 250 feet of the start of the ramp's curve. The radar that detects approaching vehicles should be placed at least 250 feet ahead of the curve to give drivers ample time to slow down.

IMPLEMENTATION

With substantial data confirming that speed feedback signs work to improve driver behavior, as well as guidance for expanded use across the state, MDOT is better positioned to reduce the number of traffic deaths in Michigan. As the agency continues to collect additional data in the coming years, the signs' impact on the frequency and severity of crashes will become clearer. Future data will also help MDOT determine whether the signs' behavior-improving effects change over time as drivers become more accustomed to seeing them and provide additional guidance on how best to deploy this technology.

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Multi-Modal Transportation & Finance RAC

Michigan Department of Transportation RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Safety Enhancements at Short-Storage-Space Railroad Crossings

START DATE: January 2020

REPORT DATE: December 2022

RESEARCH REPORT NUMBER: SPR-1721

PROJECT COST: $100,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Enhancing safety at short-storage railroad crossings

Rail lines that cross traffic near street intersections, which offer little space to "store" stopped vehicles, often present challenges to drivers. New research investigated historical crash data, driver behavior at these types of crossings and the effectiveness of various signs and pavement markings for reducing crashes. Suggested revisions to Michigan Department of Transportation (MDOT) guidance documents and facilitated collaborations among staff will support the agency's efforts to enhance safety at short-storage railroad crossings.

PROBLEM

MDOT strives to ensure Michigan's rail system meets the state's economic needs in ways that are safe for all road users, railroad employees and train passengers. Certain highway-rail grade crossings, however, can present a safety challenge when there are high traffic volumes, frequent trains or adjacent intersections.

Train crossings with short storage can be challenging for drivers. Additional road markings and signage can reduce crashes.

Short-storage crossings are roadway segments that have insufficient space for vehicles to queue while waiting for a train to pass. Without enough distance, vehicles at these intersections may stop too close to the tracks or even enter into the railroad crossing. MDOT uses a variety of treatments to increase safety at railroad crossings. Active measures like gates and traffic signals are typically more effective than passive signs, flashing lights or pavement markings, but they are also more costly.

With little information available on the efficacy of passive safety treatments at rail crossings and the challenges associated with

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"What we learned from the project, including in the workshop discussions, will be extremely helpful in guiding future efforts to enhance safety at short-storage crossings. Our toolbox for making site-specific modifications has grown."

Nikkie Johnson
Project Manager

short-storage train crossings, MDOT initiated this research project to better understand which passive safety improvements are most effective and what other variables may impact safety at short-storage railroad crossings.

RESEARCH

To better understand the current state of knowledge and practice at highway-rail grade crossings, researchers reviewed past studies on crossing characteristics and operational factors, the effectiveness of passive and active safety treatments and driver behaviors at train crossings. Crash data at train crossings from 2015 to 2019 informed an analysis of crossing types, safety treatments, crash specifics – including the cause and severity of any injuries – and the spatial distribution of crashes across Michigan.

The crash data analysis provided the basis for a safety evaluation of long- and short-storage crossings. Two safety indexes developed with existing methods enabled an assessment of the relative risks and collision predictions for each crossing type.

Leveraging a study of driver behavior and driving simulations, researchers examined how drivers tend to approach and traverse crossings and selected 10 sites for field testing. These short-storage crossing locations featured five types of passive safety methods: crossbuck signs by themselves; crossbuck signs with either stop signs or yield signs; near-side stop lines; and dynamic envelope markings, which are a series of "X"s on the pavement designed to make the crossing more pronounced.

Analyzing speed and acceleration, drivers' head rotation and whether drivers followed signs or pavement markings illustrated how motorists' actions varied with different safety treatments.

RESULTS

The research found there is little uniformity in the selection of safety treatments for highway-rail grade crossings. Additionally, crossings with passive treatments can be difficult for drivers, who must simultaneously navigate various signs and make decisions regarding an approaching intersection.

The results of the crash data analysis and safety evaluation of train crossings revealed most highway-rail grade crashes happened on local undivided roadways, and more crashes occurred at short-storage crossings than others. Failure to yield or stop, and disregarding traffic controls, were the most common driver violations.

The driver behavior study and simulator data yielded measures of effectiveness for passive safety treatments. Dynamic envelope markings and crossbucks with stop signs were found to be more effective than the other passive safety treatments reviewed. The data confirmed, however, that following signs and pavement markings near short-storage crossings is generally challenging for drivers.

Finally, researchers facilitated discussion among staff from MDOT's Office of Rail and Traffic Safety Office about crossing improvements, which led to potential modifications to several of MDOT's guidance documents. The variety of manuals, plans and guidance affected by this research illustrate the broad reach of the short-storage crossing issue into other MDOT areas.

IMPLEMENTATION

Improved understanding of driver-related distraction and driver ability to follow signs provides a new perspective on short-storage train crossing safety. Knowing how to use the modifications and countermeasures studied in this research project will be an important part of revising key MDOT guidance documents on this topic. Continuing the collaborative discussions between MDOT's offices will set the stage to implement effective crossing safety tools.

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Planning & Organizational Development RAC

Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Synthesis of National Best Practices on Pedestrian and Bicycle Design, Guidance, and Technology Innovations

START DATE: April 2019

REPORT DATE: December 2021

RESEARCH REPORT NUMBER: SPR-1708

PROJECT COST: $206,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Updating best practices to keep pedestrians and bicyclists safe

With increasing numbers of pedestrians and bicyclists on the state's roadways, the Michigan Department of Transportation (MDOT) strives to provide the safest experience possible through infrastructure design and other transportation management practices. To inform potential enhancements statewide, MDOT gathered input from experts and advocacy groups and a thorough evaluation of the cutting-edge strategies and design innovations that have been implemented across the country. The efforts will help MDOT and Michigan's local transportation agencies ensure that nonmotorized road users are considered and safeguarded at every opportunity.

PROBLEM

MDOT strives to integrate the needs of pedestrians and bicyclists into all facets of transportation design.

Pedestrians and bicyclists are among the most vulnerable road users. Working to meet goals of the Toward Zero Death safety campaigns in Michigan and at the national level, MDOT has promoted innovative pedestrian and bicycle design in the state's transportation infrastructure. However, as more of the population travels by foot, wheelchair or bicycle for a variety of reasons, fatalities and serious injuries continue to be a grave concern.

Advances in nonmotorized safety measures across the United States, broad strategies identified in Michigan's Strategic Highway Safety Plan and recent federal initiatives provide an opportunity for potential improvements. To ensure MDOT and Michigan's local transportation agencies are doing everything possible to keep these vulnerable road users safe, MDOT sought a comprehensive review of the leading design innovations for pedestrians and bicyclists and recommendations for incorporating nonmotorists' needs wherever possible into Michigan's transportation system.

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"This comprehensive and timely research gives MDOT updated tools to assist us and local agencies in putting vulnerable road users at the forefront of all of our transportation management efforts."

Mark Bott, P.E.
Project Manager

RESEARCH

Researchers began with a thorough literature review of existing practices in nonmotorized planning and design. The team consulted national, state and local agency guidance, plans and academic research on topics such as facility planning, traffic control devices and intersection design. To explore what procedures MDOT may need to update, the researchers also reviewed 50 different MDOT policies that impact the planning and design of roadway facilities and features for nonmotorized users.

Researchers then surveyed various transportation agency professionals, including pedestrian and bicycle coordinators from state DOTs, staff from 39 local agencies beyond Michigan and experts representing the cities and counties within Michigan that have implemented the policies locally. The survey solicited information regarding each agency's strategies, guidance, plans, and other resources related to nonmotorized user safety.

Additionally, a survey of Michigan residents investigated pedestrian and bicyclist behavior and perceptions regarding existing infrastructure. Researchers also conducted online focus groups with key stakeholder groups in Michigan representing retirees, people with disabilities and advocates for trails and bicycling. Discussion topics included infrastructure and design treatments, concerns, challenges, and desired improvements.

RESULTS

This comprehensive effort resulted in a variety of guidance and other resources that MDOT and local transportation agencies can use to select and implement strategies that make Michigan's roadways safer for nonmotorized users. These include:

- **Recommendations regarding several MDOT guidance documents.** To integrate or enhance the protection of pedestrians and bicyclists across agency functions and programs, researchers recommended changes to 12 agency documents addressing road and bridge design, guidance for crosswalks, traffic control near schools, and other themes.
- **Revisions to MDOT's *Best Design Practices for Walking and Bicycling in Michigan*.** Originally published over a decade ago, researchers updated this toolbox of engineering ideas to improve safety and mobility for nonmotorized users. The revisions reflect changes in practices across the country, feedback from stakeholder groups and recently adopted practices and treatments for use at intersections and other crossings and corridors.
- **Development of *Tools for the Planning and Design of Pedestrian Crossing Enhancements*:** Researchers developed a Michigan-specific version of a federal pedestrian safety guidebook. Intended to be a pocket reference guide for designing pedestrian-friendly crossings, the draft focuses on state issues and incorporates MDOT's current design standards and guidance.

IMPLEMENTATION

MDOT staff can immediately start implementing the recommended updates to agency policies, procedures and documents. Once the draft state-specific reference guide is finalized it will also be available for local transportation agencies to use.

Future research efforts on nonmotorized user safety could include exploring the best lighting for pedestrian crossings at night and design tools for pedestrian and bicyclist infrastructure near high-speed roadways.

With a better understanding of nonmotorists' needs and the strategies and designs that have worked well elsewhere, MDOT will be better able to protect pedestrians and bicyclists across the state. Putting these best practices to work will provide safer roads, sidewalks and paths for all who use Michigan's transportation system.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Assessing System Performance of the Michigan Trunkline: Measures and Analytical Procedures for Planning and Operations

START DATE: August 2020

REPORT DATE: December 2022

RESEARCH REPORT NUMBER: OR20-005

PROJECT COST: $180,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Measuring Michigan's highway network performance is critical for planning

Measuring, tracking and forecasting the operational performance of the state's highway system all help the Michigan Department of Transportation (MDOT) make strategic and cost-effective transportation decisions. New performance measures, developed from emerging and evolving data sources, focus on reducing delays and improving the reliability of travel times. These measures will help planners prioritize the agency's improvement projects to better meet the current and future needs of the traveling public.

PROBLEM

To manage Michigan's network of roads and highways, MDOT's planners forecast travel demand, identify trends, and prioritize improvement projects. Ensuring the state's transportation needs will continue to be met into the future requires an understanding of how well the system is operating.

Previously, MDOT relied on an annual volume-to-capacity ratio and level-of-service report, both of which measured traffic volumes relative to the designed capacity of a roadway segment. But these metrics are no longer being reported, and emerging crowdsourced data and other high-tech tools offer opportunities to gauge traffic and roadway conditions like never before. To ensure MDOT's planners have meaningful options for defining and measuring success, this project sought to identify performance measures that will support the efficient investment of resources and enhance MDOT's ability to communicate the state of the road system to the public.

To improve the efficiency and cost-effectiveness of its transportation investments, MDOT needs performance measures that are sensitive to planning and operational functions.

RESEARCH

A comprehensive review of state and federal transportation system performance management resources was followed by a nationwide survey of state DOTs and metropolitan planning organizations. Researchers asked about common performance measures and how they are used, data sources, analysis methods, and reporting strategies.

A review of MDOT's current and historical performance management practices

(continued)

"By reviewing MDOT's needs and performance measurement practices from across the country, we now have system-level planning tools to understand congestion and travel time reliability on our roads and highways.

Robert Maffeo
Transportation Planner

provided a backdrop for interviews with agency staff and others within Michigan. With input from MDOT, researchers spoke with staff from regional offices and transportation service centers, as well as a few larger metropolitan planning organizations across the state about their experiences measuring performance. These discussions led to the identification of possible road and highway system performance measures for MDOT.

Researchers ranked potential measures by importance and relevance to three categories of uses: operational evaluation, project prioritization and short- and long-range transportation planning. A follow-up survey distributed to transportation agencies across the country provided information to determine parameters of the chosen performance measures, including definitions, thresholds, calculation methods, and targets.

RESULTS

Performance measures traditionally used by the MDOT Planning Division, such as volume-to-capacity ratio and level of service, are quickly becoming outdated and no longer meet the requirements of current planning-level analysis. MDOT and other transportation agencies around the country indicated that more informative aspects of congestion and travel time reliability tend to be more applicable to current needs. Also, data sources have changed over time to support such measures.

The national review and survey identified the most used mobility and travel time reliability measures. Reviewing MDOT's performance management practices and in-state interviews led researchers to recommend these new system-wide performance measures:

Total Delay: A representation of traffic density and its consequences for travelers, total delay measures the extra time spent driving in congested conditions as compared to free-flow travel conditions on a roadway segment.

Travel Time Index: Defined as the ratio of average peak-period travel time to free-flow travel time on a roadway segment, travel time index compares the actual time it takes to travel between two points against the ideal time.

Planning Time Index: Based on a distribution of the most common travel times, planning time index determines the extent of unexpected delay.

Researchers also modified historical measures of volume-to-capacity and level-of-service to better assess system performance and provide consistency with past data and reporting.

Finally, researchers recommended thresholds and targets to gauge success within each of the three performance measures, as well as reporting methods to improve MDOT's transparency and communications with other agencies and members of the public. As existing information sources have become more sophisticated and can facilitate the calculation and reporting of performance measures, MDOT could supplement future printed reports with an online performance dashboard that serves a variety of user needs and potential applications.

IMPLEMENTATION

Updated performance measures will help MDOT planners assess system performance, identify needed improvements and ensure the state's highway operations align with the agency's short- and long-term goals, including the Michigan Mobility 2045 Plan that outlines the state's transportation objectives for the next 20 years. The revised indicators will also help MDOT more accurately predict and estimate the impacts of its investments, resulting in a more efficient allocation of resources.

Moreover, the data and visualization products potentially developed from this project, if properly adapted, could meet the needs of other units and programs across the agency.

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Highways Bridges & Structures RAC

Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Evaluation of Camber and Deflections for Bridge Girders

START DATE: March 2019

REPORT DATE: March 2021

RESEARCH REPORT NUMBER: SPR-1697

TOTAL COST: $271,598

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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New MDOT design tool predicts how bridge beams will flex and settle over time

The bump drivers often feel as they approach or leave a bridge reflects a common and complex engineering challenge. Unevenness at these transition points can occur over time as the beams supporting the bridge deck adjust to their surrounding environment differently than designers had estimated. To improve ride quality and minimize the need for costly on-site realignment, the Michigan Department of Transportation (MDOT) reevaluated its existing design procedures, developing a new methodology that allows bridge designers to more accurately predict how beams will behave at any stage of their service life.

PROBLEM

Prestressed concrete beams stored in a fabricator's yard display a slightly arched shape, or camber.

Beams used in modern bridge designs are typically made of either steel or prestressed concrete. Both beam types are naturally prone to changes in curvature over time as they age and bear loads: Beams that take on an upward curve are referred to as cambered, while beams that curve downward are deflected. Engineers consider the current and anticipated curvature of each beam when designing or repairing a bridge; however, a range of issues can arise when a beam behaves differently than predicted.

Drivers traveling over the bridge may feel a bump where the road and bridge sections meet, which can cause minor discomfort. For vehicles passing under the bridge, beam deflections greater than estimated can affect the vertical clearance between the bridge and the roadway beneath it, potentially resulting in traffic restrictions.

(continued)

"The methodology developed through this project will help us accurately predict camber and deflections in bridge beams over time, allowing us to make any needed adjustments during the design phase and avoid delays and added expense during construction."

Kyle Kopper, P.E.
Project Manager

The challenge of unplanned deformations can be addressed during the construction phase or with repairs during the bridge's service life, but fixes in the field increase project costs and require additional time. Recognizing that improved prediction accuracy would provide the most cost-efficient solution and improve ride quality for all travelers, MDOT sought to reevaluate the calculation methods its bridge designers use to estimate camber and deflection and minimize the need for design-related corrections on-site.

RESEARCH

Predicting camber and deflection accurately presented a complex endeavor for project investigators, largely because of the quantity and variety of factors that must be understood and considered. In addition to specific data such as the size, age and precise composition of each beam, the entire bridge's geometry, additional components and surrounding environment also affect how the beams will behave independently and collectively over the bridge's service life.

An additional complicating factor is that beams can rebound when weight is removed, such as when a bridge deck is replaced. How much each beam rebounds varies, depending on factors like material composition and the amount of weight it had been supporting, and this affects how the replacement deck is designed and constructed.

Investigators began by reviewing literature on cambered and deflected beams. They found that while studies have been done to improve the accuracy of camber predictions involving individual beams, the long-term changes to the beams and how they affect the bridge structure as a whole – including the impact of beam rebound – are not as well understood.

Next, the research team made note of seven methods commonly used in the concrete industry for calculating camber, as well as the drawbacks of each method. The team then conducted a national survey to learn more about the practices used by other state departments of transportation (DOTs).

Drawing from existing methods, the researchers developed and fine-tuned a mathematical framework for calculating long-term camber and deflections. The researchers' methodology was validated by comparing the predicted measurements against actual data for 17 MDOT projects and a bridge under construction in Canada. To further improve the proposed methodology, the team identified additional data that should be collected and worked with fabricators to refine their specifications for creating, storing and measuring camber in concrete beams.

RESULTS

The new methodology performed very well, accurately predicting camber and deflection about 94 percent of the time – a significant improvement over the 70 percent accuracy rate MDOT experienced with previous methods.

As a final step, the team created a computer program that allows engineers to enter data and receive an accurate prediction of the curvature changes of any prestressed concrete or steel bridge beam, individually or as part of a larger structure with a concrete deck, at any time in its service life.

IMPLEMENTATION

For MDOT, the benefits of this research are immediate; the prediction tool has already been adopted into everyday practice as engineers have been trained to use it in their bridge designs.

As new bridges are built in the state and older bridges are repaired, MDOT will realize significant savings in both time and costs. More accurate bridge designs will minimize the need for on-site alterations, and travelers will experience a smoother ride when they cross over bridges in Michigan.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Concrete Deterioration of Prestressed Bridge Beams

START DATE: March 2019

REPORT DATE: July 2022

RESEARCH REPORT NUMBER: SPR-1703

PROJECT COST: $309,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Remedies for concrete bridge beam deterioration

Prestressed concrete beams in Michigan's bridges can experience cracking and other deterioration from a variety of causes, including the state's harsh weather. Understanding the causes, both common and uncommon, and identifying where deterioration is occurring allows MDOT to effectively plan and prioritize bridge maintenance. New research addressed this need from several perspectives, including new bridge inspection guidelines, load rating calculations for damaged beams, and use of concrete coatings and sealants to protect and repair deteriorating concrete.

PROBLEM

Prestressed concrete beam bridges built in the 1970s and 1980s are experiencing varying amounts of deterioration. Some materials in concrete – aggregates containing silica and cement alkali – can produce a chemical reaction, creating a gel that causes expansion and cracking of the concrete. The reactivity between these materials is exacerbated by moisture and the concrete deterioration is promoted by Michigan's freeze-thaw cycles.

This particular type of deterioration generally results in longitudinal or alligator cracking along a fascia beam's bottom flange. As current bridge inspection procedures do not include documenting the condition of fascia beams, MDOT did not have a standardized process for recording and tracking the deterioration.

Before it could explore strategies for rehabilitating the distressed concrete, MDOT first needed to know the extent of the reactive damage among the bridges in its inventory. The agency could then improve its inspection methods for assessing the deterioration and better understand how the damage affects the state's bridges.

Longitudinal and alligator cracking may be caused by alkali-aggregate reactivity and generally occurs on beams exposed to direct sunlight.

RESEARCH

To identify bridges with concrete deterioration damage, researchers began by surveying MDOT's regional bridge engineers and reviewing inspection reports for all 1,136 prestressed concrete beam bridges in the state for indications of alkali-aggregate

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"MDOT was aware of this unique form of deterioration but didn't have good solutions. Now we have methods to identify it, understand the extent and implications of the damage and remedy not only this issue but other concrete deterioration as well."

Rick Liptak
Project Manager

reactivity and similar distress. Of this inventory, 136 bridges were found to have material-related deterioration on the beams.

A subsequent field inspection on a sampling of the bridges confirmed the damage and revealed similarities in where the deterioration generally occurred on the structures. With evidence of a relationship between crack characteristics and sun exposure, the research team conducted tests on the concrete to detect any gel produced by the materials' reaction.

Back in the laboratory, the gel was reproduced using reactive aggregates and different concrete mix designs, and experiments of two staining techniques were conducted to help MDOT choose a reliable method for identifying the substance on bridges in the field. Additionally, load rating procedures for bridges with deteriorated beams were developed, and the guidelines for the most accurate calculation of beam capacity by incorporating deteriorated concrete and prestressing strands were presented.

Next, researchers tested the performance of various protective coatings and penetrating sealants under extreme conditions. As heat from sunlight brings moisture to the concrete's surface, the breathable protective coatings and sealants must allow for evaporation to control the internal relative humidity of the concrete.

Finally, a review of MDOT's bridge inspection procedures, data recording formats and definitions of condition states revealed opportunities for improvement.

RESULTS

This project resulted in numerous findings and recommendations concerning several aspects of concrete deterioration:

Modified inspection guidelines: The updated condition descriptions and reference photographs digitally linked to inspection templates will help inspectors describe and document deteriorations consistently to identify bridges with material-related distress in fascia beams. A nondestructive procedure is presented for inspectors to calculate crack depth to evaluate the condition of prestressing strands for load ratings.

Alkali-aggregate reactivity screening: Using uranyl acetate to stain and identify areas of reactivity is the most reliable method for use in the field, though there are challenges. The fluorescence of the stains changes as the solution dries, potentially complicating interpretation. As a result, various improvements to these procedures could be further explored to enhance the reliability of the results.

Load ratings: While existing guidance excludes the strands adjacent to cracks in capacity calculations, a more accurate method incorporates the depth of the crack and the specific strand layout. The research results include guidelines and a calculation tool.

Concrete protective systems: This research resulted in specific product recommendations as well as cost estimates for applying concrete surface coatings and penetrating sealants on prestressed concrete beams to seal cracks and improve long-term performance. MDOT's product qualification process should be revised to ensure these coatings and sealers are applied to the appropriate concrete mixes.

Finally, an ArcGIS file was developed to help MDOT catalog and monitor the 136 bridges with fascia beam deterioration.

IMPLEMENTATION

MDOT plans to implement as many of the recommendations as feasible. Using the ArcGIS tool to prioritize bridges – and adding to the database as more are identified – the agency will test the updated inspection guidelines, assessing beams for the reaction-based damage and calculating load ratings using the new methods. Finally, MDOT will evaluate the protective coatings and sealants on many types of concrete deterioration.

Research Administration

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Highways Development RAC

Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Michigan Transportation Construction Price Index

START DATE: January 2020

REPORT DATE: October 2020

RESEARCH REPORT NUMBER: SPR-1693

TOTAL COST: $95,111

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Michigan-specific construction cost index improves highway project planning

A highway construction cost index (HCCI) provides information about cost fluctuations in highway construction markets. The Federal Highway Administration (FHWA) maintains a national cost index, and many state agencies have created their own versions to focus on state-specific costs. Researchers created a custom HCCI for the Michigan Department of Transportation (MDOT) as well as strategies for using the index beyond typical budgeting and estimating. These new tools will help MDOT develop more transparent and accurate construction cost estimates, as well as predict future budget needs based on market trends.

PROBLEM

A price index is a tool used by experts in a variety of sectors to measure inflation and estimate long-term expenses. In the transportation industry, an HCCI can be used to predict how much future highway projects will cost in consideration of market fluctuations, empowering agencies to budget effectively and procure competitive bids.

The costs of highway renovation, including earthwork, concrete pavement replacement and temporary traffic control, will be more easily and accurately determined using MDOT's new highway construction cost index.

FHWA produces a quarterly price index based on the national average of expenses. However, the real costs of highway construction may vary significantly depending on local market conditions. As a result, many state departments of transportation, including Iowa, Ohio and Wisconsin, have opted to develop their own indexes while others rely on those produced by neighboring states. In early 2020, the Michigan Senate passed a bill requiring MDOT to establish a state-level cost index and provide regular updates to lawmakers. Though COVID-19 ultimately prevented the bill from becoming law,

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> *"This project developed a powerful and versatile HCCI tool that will allow MDOT to calculate rising construction costs accurately over time, improving our budgeting and estimating practices."*
>
> **Kristi Kirkpatrick**
> Project Manager

MDOT decided to pursue the effort without an official mandate.

To improve its planning capabilities, MDOT sought to develop a methodology and tool for calculating the Michigan-specific HCCI and its historical trends. With these tools, MDOT would be prepared to determine future budget needs while potentially identifying and accounting for the reasons behind price changes in the past.

RESEARCH

Drawing from other agencies' methodologies to identify best practices and opportunities for improvement, researchers devised a custom plan for Michigan. The team conditioned MDOT's historical data, removing anomalies and outliers to achieve a reliable set of information. Combining this with sampled bid items to ensure reliability and an industry-standard formula for calculating HCCI, the team developed an index that incorporates a representative list of construction bid-items and historical prices pulled from Michigan's available bid data since 2010.

Researchers tested and compared the new index against those used by other state transportation agencies and FHWA, as well as labor reports and industry publications tracking the prices of specific goods and services. Initial findings led the team to develop further calculations for Michigan that consider specific items and geographic regions, giving MDOT an even greater ability to understand and manage the projected costs of construction for different bid items and local markets within the state.

RESULTS

Michigan's new HCCI tool is an automated calculation system in three parts: a database to store all historical bid item information, an HCCI algorithm and a user interface that allows MDOT staff to easily access the system and generate HCCI results.

To provide MDOT with guidance for maximizing the HCCI, the researchers conducted a literature search and nationwide survey to examine how indexes have been used by other state transportation agencies and FHWA. A second survey was directed to a group of MDOT staff to learn their goals and aspirational uses for the index.

Though participants reported a wide range of possible applications for the index, including forecasting construction costs, monitoring the construction market, comparing prices in other states, measuring purchase power and checking historical trends, the researchers identified three priority uses to help MDOT realize the greatest impact:

- *Budgeting*. The index can be leveraged to convert current dollar amounts into future dollars.
- *Cost estimating*. If data is unavailable, historical bid prices can be adjusted and substituted.
- *Project scoping*. The index can provide a five-year estimate of costs for any region in Michigan.

Additionally, the team encouraged close inter-departmental collaboration and data sharing but advised the index should be managed and maintained by only one dedicated MDOT official.

Finally, researchers noted that the COVID-19 pandemic may have significant economic effects that should be considered carefully when using the index.

VALUE

MDOT's new HCCI will provide the agency with guidance in projecting future funding needs. Developing and using more accurate highway construction cost estimates will help Michigan get the best use of its budget to serve the state's travelers and the entire transportation system. Improved monitoring, benchmarking and reporting on construction markets, made possible by the new index, will aid with budgeting, planning and setting priorities for years to come.

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Innovative Contracting Best Practices

START DATE: February 2020

REPORT DATE: August 2021

RESEARCH REPORT NUMBER: SPR-1694

PROJECT COST: $317,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Innovative contracting provides flexibility to customize project results

Most of the projects funded by the Michigan Department of Transportation (MDOT) and other public transportation agencies are completed by a contractor who executes the plans developed by a separate design team. However, when circumstances call for a different approach, MDOT can choose to apply one or more alternative strategies to expedite project timelines, maximize efficiency and encourage creative problem-solving. To ensure its program aligns with national best practices, as well as to identify any potential enhancements, MDOT sought to compare its innovative contracting practices with those of other agencies.

PROBLEM

The majority of MDOT's transportation projects are planned and constructed by separate entities according to a linear timeline, through a process known as design-bid-build. First, a designer develops the project's concept, and then MDOT issues a request for proposals and awards the construction work to the lowest bidder. Finally, the selected builder completes the project following the designer's plan. While this process successfully achieves MDOT's goals much of the time, a project occasionally presents a unique set of challenges or opportunities that can be accomplished through alternative delivery methods.

Innovative contracting can help streamline complicated construction projects, such as the Jackson Street bridge replacement effort in Jackson, which requires close coordination with rail authorities.

Innovative contracting describes the broad spectrum of options MDOT can apply at its discretion to meet a variety of objectives: completing a project more quickly, increasing collaboration between designer and builder, or encouraging creative solu-

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> *"By periodically evaluating MDOT's innovative contracting program, we can see what we're doing well and where improvements could lead to even better outcomes."*
>
> **Ryan Mitchell**
> Project Manager

tions to specific challenges. Since it began piloting alternative delivery methods in the 1990s, MDOT has developed, refined and documented its strategies, routinely employing innovative contracting methods since 2008. However, as the transportation construction industry rapidly changes, there is a demand for a similarly cutting-edge and nimble innovative contracting program. To ensure its innovative contracting program is aligned with current best practices, MDOT sought an objective evaluation of its procedures, recommendations for potential enhancements and an update of its guidance documents.

RESEARCH

To better understand MDOT's program, researchers began by reviewing recently published literature on the innovative contracting strategies used across the industry and examining MDOT's existing contracting guidance documents and manuals to learn the agency's current state of practice. The team then distributed surveys and conducted interviews with local contractors and engineering professionals who have experienced MDOT's innovative contracting process first-hand, gathering feedback and insight about what worked and where improvements could be made.

Next, researchers organized a virtual peer exchange event with MDOT and representatives from 10 other state departments of transportation (DOTs) to facilitate discussion on a range of topics, including the delivery methods the agencies prefer and what criteria each agency uses to match appropriate methods and projects, the benefits of choosing a best-value approach versus low-bid, how to measure programmatic accomplishments, and how each DOT manages project risk. The meeting also allowed attendees to describe their agency's innovative contracting successes and compare their strategies with those of other peer agencies.

RESULTS

By learning more about MDOT's innovative contracting program and practices, those of other transportation agencies and national best practices, the researchers were able to identify what MDOT already does well and where enhancements could be made. Among MDOT's attributes, the team found that the agency's organizational structure, formalized documentation practices and internal support from upper management give MDOT's Innovative Contracting Unit a strong foundation for success.

The researchers also provided recommendations to help MDOT align with recognized best practices across the country, such as improved tracking of project costs and timelines, establishing discussion groups between MDOT and industry partners to increase communication and standardizing contract forms for greater consistency across projects. The team devised a phased implementation plan to help MDOT understand the costs and benefits of each recommendation, identify long-term priorities and establish realistic timelines for putting the proposed recommendations into practice.

IMPLEMENTATION

The results of the research will be used to update MDOT's 2015 Innovative Construction Contracting Guide, the go-to resource referenced by MDOT staff and MDOT's industry and agency partners. The document outlines MDOT's program and processes and provides the critical details industry partners need to participate. Greater transparency and clarity about MDOT's innovative contracting program will improve consistency and make it easier for contractors to understand and engage, leading to more involvement and opportunities for creative problem-solving.

For MDOT, the recommendations developed through this research will help the agency maximize efficiencies, increase consistency and continuity between projects, and encourage innovation from industry partners. With a stronger and more competitive program in place, MDOT will have the tools it needs to encourage innovation and reward the contractors who bring creative solutions to transportation challenges across the state.

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Innovative Contracting Risk Management Best Practices

START DATE: August 2020

REPORT DATE: December 2021

RESEARCH REPORT NUMBER: SPR-1711

PROJECT COST: $350,400

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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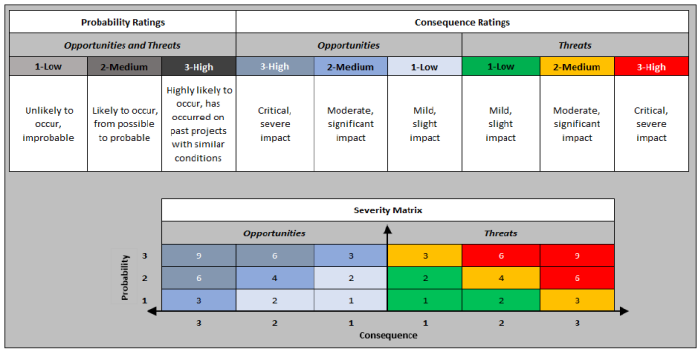
Risk management tools help MDOT deliver projects on time and on budget

The innovative contracting program within the Michigan Department of Transportation (MDOT) can complete certain projects more quickly and cost-effectively than through traditional contracting. To determine whether a project is suitable, a team of professionals relies on specialized techniques and tools to evaluate potential projects to analyze risks and other factors that could affect the project's intended goals. Documenting and incorporating best practices from transportation agencies across the country, researchers developed a new set of customized tools, documents and other resources to streamline MDOT's innovative contracting program and help it identify and manage risks more effectively.

PROBLEM

Through its innovative contracting program, MDOT develops and delivers transportation projects using alternative contracting methods in less time and at lower cost than traditional methods. As unforeseen issues can increase a project's budget or extend its timeline, ensuring every aspect of the project is considered and accounted for is crucial. This process, known as risk management, requires the project team to work together throughout the duration of the project to develop and execute an action plan for any uncertainties that could impact the intended results.



Probability Ratings			Consequence Ratings					
Opportunities and Threats			*Opportunities*			*Threats*		
1-Low	2-Medium	3-High	3-High	2-Medium	1-Low	1-Low	2-Medium	3-High
Unlikely to occur, improbable	Likely to occur, from possible to probable	Highly likely to occur, has occurred on past projects with similar conditions	Critical, severe impact	Moderate, significant impact	Mild, slight impact	Mild, slight impact	Moderate, significant impact	Critical, severe impact

MDOT's updated severity index helps stakeholders identify the likelihood that a risk will affect a transportation project's goals.

While every project has risks, such as local laws that must be navigated or utilities that require coordination, identifying these at the outset and continually monitoring mitigation efforts helps to avoid delays and unnecessary expenses later on.

MDOT's risk management procedures have been refined over the years; however,

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> *"With standardized documentation and user-friendly tools, MDOT's risk management processes will be even more practical, efficient and effective."*
>
> **Ryan Mitchell**
> Project Manager

time and resource constraints have hindered efforts to catalog the lessons that have been learned from each project. Formally documenting these insights and all of the program's processes would increase effectiveness and provide more standardized training for the various stakeholders who participate in each project.

To make its entire risk management process more streamlined and productive for everyone involved, MDOT sought to evaluate the best risk management practices nationwide and use the information to develop new tools, templates, training documents, and customized guidance.

RESEARCH

Investigators began by reviewing recently published studies and reports documenting successful risk management practices and the tools and resources other state DOTs use to identify and mitigate project risks. Next, a series of interviews with MDOT staff, state and federal transportation agencies and industry representatives revealed valuable local and national perspectives, suggestions and feedback from those familiar with state-of-the-art risk management.

Finally, MDOT hosted a virtual peer exchange with representatives from eight state DOTs and the Federal Highway Administration. The forum offered an opportunity for leaders from transportation agencies across the country to discuss their own agency's approaches to managing risk and to share details about the resources and methods they rely on to achieve their risk-management objectives.

The researchers compiled the results and insights from the literature review, interviews and virtual event into an extensive list of available tips, resources and best practices. MDOT then identified the items that would help meet the agency's objectives and add the most value to its program.

RESULTS

The researchers developed a new risk management toolbox, consisting of a variety of new and easy-to-use applications, templates and procedural guidance to supplement and build upon MDOT's existing practices and materials. Among the new resources are:

- Clear and concise procedural guidance that MDOT engineers can use on statewide projects.
- A user-friendly, spreadsheet-based risk management workbook that contains step-by-step instructions to guide new and experienced users as they enter project-specific information. Once entered, the workbook can integrate the data into a variety of reports and automatically prioritizes risks to make tracking, monitoring and updating the risks easier throughout the project's lifespan.
- Standardized practices to improve the risk workshop process. As key stakeholders meet regularly throughout the project, the new practices will make these collaborations more effective.
- A training presentation that MDOT will offer to project teams and new users can consult to better understand MDOT's risk management program and the roles and expectations of each participant.

To test the products' effectiveness under real-world conditions, MDOT selected the US-131 design-build project in Kent County and facilitated a risk workshop to pilot the new resources. With minor modifications, the resources are now available for use on any of Michigan's innovative contracting projects.

IMPLEMENTATION

With new, customized tools and formal documentation to enhance its risk management processes, MDOT will be better able to identify and manage project risks. By promoting clarity, consistency and user-friendliness at every opportunity, MDOT can be sure that each project's team of stakeholders has the resources needed to work collaboratively and efficiently to keep the project on track and make its goals a reality.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Infrastructure Protection and Rehabilitation Response to High Lake Levels

START DATE: February 2021

REPORT DATE: March 2022

RESEARCH REPORT NUMBER: SPR-1712

PROJECT COST: $350,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

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Tools to protect coastal roadways from high water

Understanding how Great Lakes water level trends are changing will help the Michigan Department of Transportation (MDOT) protect coastal roadways from flooding and erosion damage. Research and analysis of several sites around the state at risk for high water damage have produced a tool to inform agency decision-making on preventive mitigation measures. Identifying hazards, predicting potential damage and estimating costs and benefits of taking action will allow MDOT to prioritize future infrastructure investments.

PROBLEM

Great Lakes water levels are naturally variable. High water near roads may cause flooding, backed-up drainage systems or erosion that requires mitigation measures. As seasonal variations have been relatively predictable over the years, MDOT has successfully managed impacts on roadways near lakes and tributaries.

Dyke Road through St. John's Marsh is a key thoroughfare that becomes nearly impassable during high water and wind conditions. Potential mitigation measures include raising the road and building a raised causeway.

In 2019 and 2020, however, water levels in the Great Lakes rose higher than in the past three decades. While MDOT was able to address impacts to coastal roadways with minimal loss of service, the agency recognized the increasing need for preparedness. Representatives from each region formed a High Water Team to discuss historical high water periods and regional responses. The team noted that institutional knowledge of how these threats have been addressed in the past is limited.

MDOT needed a greater understanding of lake water level cycles and changing trends. Wanting proactive, long-term solutions to roadway infrastructure threats, the agency sought to identify at-risk areas and potential mitigation options in order to develop well-informed plans and prioritize infrastructure protection strategies.

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"This project was very successful in giving MDOT a planning and forecasting tool to be proactive in our management of roadways at risk of high water damage."

Hal Zweng, P.E.
Project Manager

RESEARCH

Leveraging the work of the High Water Team, researchers undertook a multifaceted research and planning project to assess risk and propose mitigation alternatives for MDOT's coastal roadways. The team first reviewed research and other literature on water level trends and predictions, adaptation options for transportation infrastructure, benefit-cost analysis approaches, and other topics. Team members then conducted interviews of regional staff across the state to understand past impacts of high water on roadways, and the different measures each region implemented in response.

After reviewing details of approximately 50 sites impacted during the 2019-2020 season, including localized risks, previous mitigation attempts and estimated costs, researchers prioritized five sites for in-depth analyses. The locations represent a range of water hazards and characteristics that are seen across the state. Two of these sites, located in the Bay and North regions, are at increased risk of flooding. The three sites in the Grand, Southwest and North regions have high erosion potential, as the coastal bluffs or dunes that stabilize each road are at risk of deteriorating.

An extensive analysis of each site included additional interviews with regional MDOT staff familiar with the locations, reviews of drawings and studies, site visits, and documentation through aerial imagery. The team also undertook engineering assessments of the risks and mitigation potentials.

Next, a benefit-cost analysis for each site highlighted possible solutions. Assuming a 10-year planning period, researchers estimated the costs of various temporary and permanent measures and compared these with the future costs of damages and travel-time lost if no action were taken. The team also compared the costs of capital investments for permanent solutions against the costs of temporary mitigation measures.

Finally, the team developed a scoring system and decision spreadsheet tool to help MDOT prioritize its mitigation efforts. Considering a location's particular characteristics, factors include the type and degree of hazard threat, traffic volume supported, detour options available, and other metrics. The decision tool can be enhanced as needed to account for changing costs and other variables and will support communicating trade-offs in prioritizing future capital improvements.

RESULTS

The researchers' comprehensive analyses produced a number of findings.

Both flood-prone sites saw multiple periods of flooding over the past 50 years. While the number of flooding events was higher at one site, losses would be greater at the other due to more use. Researchers suggested raising the roadways as a permanent solution, which would be more cost-effective than just one temporary installation of sandbags or taking no action.

The three locations at risk of erosion pose an additional challenge due to the many variables that may impact the potential for erosion. Recommendations for some sites include regularly replenishing sand at beaches, building structures to protect the shoreline or relocating the roadway, though researchers also identified the need for further hydraulic, hydrologic and geotechnical study.

Lastly, the research team applied the new scoring system to 53 sites across the state, giving MDOT greater insight into where its mitigation investments would be most impactful.

IMPLEMENTATION

With new tools and a better understanding of the potential threats to the state's infrastructure, MDOT will have greater decision-making power when it comes to reducing the impacts of high water along Michigan's coastal roadways.

Research Administration

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Michigan Department of Transportation
RESEARCH Administration

RESEARCH SPOTLIGHT

Project Information

REPORT NAME: Developing a Consistent Data Driven Methodology to Multimodal, Performance Based and Context Sensitive Design

START DATE: October 2019

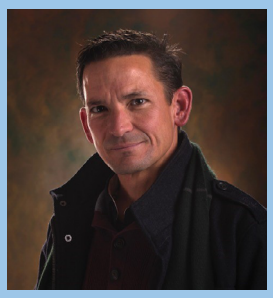
REPORT DATE: September 2022

RESEARCH REPORT NUMBER: SPR-1719

PROJECT COST: $300,000

COST SHARING: 20% MDOT, 80% FHWA through the SPR, Part II, Program

MDOT Project Manager



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New tool helps MDOT customize roadway designs for all users

In Michigan and across the United States, road design has historically focused on the needs of motor vehicles, with intersections, lane characteristics and other features designed to accommodate anticipated traffic volumes. In recent years, design practices have expanded to also consider the needs of other road users, such as pedestrians and bicyclists, as well as the traits of the surrounding community. To support its planners and road designers in creating context-sensitive and inclusive infrastructure, the Michigan Department of Transportation (MDOT) developed a tool that leverages data to identify site-specific solutions that meet the needs of all road users.

PROBLEM

Through context-sensitive design practices, MDOT can create roadway features that increase mobility and safety for all users.

Historically, transportation agencies have designed streets, sidewalks and other roadway features with a one-size-fits-all approach, using standards and specifications that tend not to consider the broader context of where these facilities are located or who uses them. Modern transportation design practices are more flexible, however, recognizing the individuality of each community and the range of complex social, economic and environmental factors that play a role in whether a person walks, bikes or uses another form of transportation to get around.

To help MDOT's planners and engineers create transportation infrastructure that is more context-sensitive, or better suited to its setting and purpose, the agency wanted data-backed tools that could be used in project scoping and early planning stages to engage community members and help all stakeholders visualize and understand how different treatments would realistically affect safety, mobility and other considerations.

(continued)

"These new tools help MDOT consider design options earlier, which can increase public engagement and ensure that the final plans will suit the needs and goals of the community."

John Martin
Project Manager

RESEARCH

In an effort to better understand the principles and benefits of context-sensitive design and identify national best practices, researchers examined previously published research and other publications. These resources showed that the tailored solutions that come from applying context-sensitive design principles to transportation projects are often more cost-effective and result in greater customer satisfaction than traditionally designed treatments, since those that are designed specifically for the characteristics of the location are better sized and equipped to accommodate the needs of the community. A review of the documents used by MDOT and other state transportation agencies to guide their highway design decisions also revealed a number of successful pedestrian- and bicycle-friendly strategies installed across the country, such as pedestrian traffic signals with push buttons and bike boxes at intersections.

Finally, to develop a methodology that would help MDOT's planners and engineers identify appropriate transportation solutions for the scale and features of their surroundings, researchers combed through a variety of online databases to find reliable sources of information for traffic volumes, speed limits, population demographics, and land use data throughout Michigan. With data that can be scaled to four sizes of Michigan communities and applied to four different types of sites – including pedestrian segments, bicycle segments, midblock crossings, and intersections – planners gain a more holistic view of how the area is used as well as objective support for selecting traffic control devices, crosswalks and other treatments that increase safety and add value to the larger community.

RESULTS

The research culminated in a decision matrix for each of the four site types that can be used to identify potential treatments based on specific parameters and population levels. By offering solution options that consider a combination of factors, these matrices provide greater flexibility in the early stages of a project when it's easier and more economical to explore alternatives that will best meet the needs of pedestrians, bicyclists and other non-motorists.

To make using the matrices even simpler, a spreadsheet-based tool allows MDOT's planners to enter information related to traffic volume, speed limit, road features, and other conditions and receive up to three solutions that can be prioritized based on budget and other constraints. MDOT's new tool was designed to complement other Michigan planning resources, such as the multimodal tool developed by the Southeast Michigan Council of Governments. With a variety of resources available, MDOT's planners and engineers will have greater interdisciplinary insight and decision-making power in their holistic planning efforts. Future versions of MDOT's tool will be able to consider additional information, such as transit routes and bus stops.

IMPLEMENTATION

The new tools give MDOT's designers and planners a consistent and data-driven approach to identifying possible highway design treatment options. Traditional transportation engineering standards will still need to be applied during the design phase to confirm that the options can be installed at specific sites. With better decision-making power that can be applied earlier in the design process, MDOT will be well equipped to collaborate with local communities and find thoughtful solutions that work for the location and the people who will use them. As a result, the state's investments will be more cost-effective and valuable for everyone involved. After some finishing touches, MDOT hopes to make this tool available this year.

Research Administration

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