



KTC Research Briefs Compilation 2018-2022

December 2022



KENTUCKY TRANSPORTATION CENTER

OUR MISSION:

Advancing Transportation Through
Innovative Research and Education

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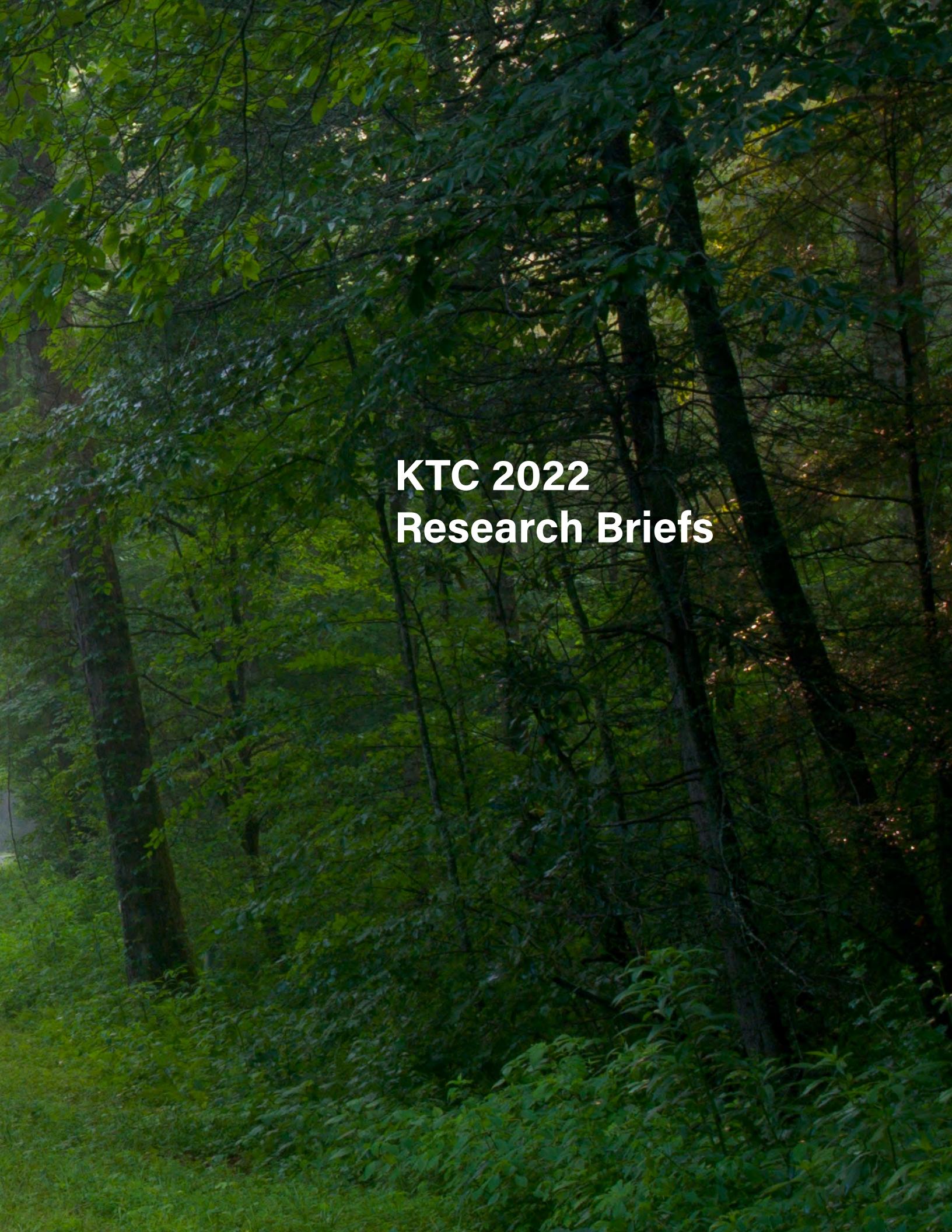
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Each year Kentucky Transportation Center (KTC) researchers complete between 15 and 20 studies on behalf of the Kentucky Transportation Cabinet as part of the agency's State Planning and Research (SPR) program. Most projects last between one and three years and culminate in a final report that summarizes work that was done, findings, and recommendations. Because of their thoroughness and length, final reports are critical for helping practitioners understand what problems were investigated and deciding how to implement study results. However, delving into reports demands a significant time commitment. Most agency personnel are already stretched to their limits and have an ever-growing list of responsibilities, which often precludes in-depth reviews of multiple reports. To help Cabinet staffers quickly identify studies relevant to their areas of expertise, KTC in 2018 began producing one-page summaries which contain essential information from reports. Informally dubbed the Big Book of Research, this document is a living compilation that includes all one-pagers prepared to date. Each one-pager introduces the project and the questions it addressed and briefly describes research methods, findings, and recommendations generated by researchers. Moving forward, new one-pagers will be prepared for all projects funded by Kentucky's SPR program — and incorporated into this document.

One-pagers are not intended as a substitute for full research reports. But they are valuable tools for helping readers jump start their understanding of the problems addressed by individual studies. As an entry point into each study, one-pagers help practitioners make informed decisions about whether they will benefit from taking a closer look at the full study and how they might use research findings to improve their everyday practices.

A photograph of a dense forest. Sunlight filters through the canopy of green leaves, creating bright highlights on the trunks and branches. The forest floor is covered in green undergrowth and fallen leaves. The overall atmosphere is natural and serene.

KTC 2022 Research Briefs



Assessment of Deteriorated Structural Concrete to Provide Durable Repairs



Research Project

Assessment of Deteriorated Structural Concrete to Provide Durable Repairs
Report #
KTC-21-32/SPR15-505-1F

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Study Timeline

Completed November 2021

The Challenge

Approximately 27,000 structural elements on Kentucky bridges are made of reinforced/prestressed concrete. Many of these elements deteriorate from the corrosion of reinforcing steel caused by carbonation and application of chlorides. Evaluating and repairing these elements poses one of the greatest maintenance challenges the Kentucky Transportation Cabinet (KYTC) faces. There are a wide range of nondestructive evaluation (NDE) techniques available to assess reinforced concrete bridge elements. According to a 2016 survey, many state transportation agencies (STAs) are not using all available NDE methods, KYTC included. This study explored a variety of NDE methods and minimally invasive tests that could be incorporated into KYTC's biennial bridge inspection process and maintenance practices.

Building Solutions

- Researchers reviewed procedures other STAs and KYTC officials use to assess structural concrete, focusing on NDE methods and laboratory and field tests that evaluate structural concrete for chloride contamination, rebar corrosion, concrete chemical assessment, and deterioration.
- Because considerable research has been done on NDE and bridge deck repair, the report addresses issues with other bridge elements (beams, piers, abutments, barrier and retaining walls).
- Two vendors performed field demonstrations of concrete and NDE test equipment so that KYTC could become familiar with the equipment and procedures required to assess reinforced concrete.

Finding Solutions

Both routine and preventive maintenance are the most proactive ways to help preserve reinforced concrete and minimize future deterioration/repairs. Routine maintenance can include tasks such as removing debris, washing bridge elements, opening drains, cleaning gutter lines, cutting brush abutting the bridge, or stream upkeep. Preventive maintenance tasks can be directed by routine inspections and NDE assessments. Those tasks may include application of surface sealers and coatings, sealing cracks, and electrochemical treatments. A product of this research is guidance for the use of advanced structural concrete evaluation methods, analysis of test results, scoping of work, and proper reporting of findings to facilitate preventative maintenance or repairs.

Recommendations

- Provide a structured plan for protecting reinforced concrete elements on bridge members.
- Review NDE and test methods discussed in this report and provide district personnel with the equipment and training needed to evaluate reinforced concrete bridge elements other than decks.
- Develop training for district personnel on the selection of NDE methods and tests.
- Initiate a pilot program in one district to address routine and preventive maintenance focused on reinforced concrete bridge elements.
- Pursue future research on concrete with structural issues, subsidence, or constraint issues. While repairs that involve electrochemical methods are discussed briefly, KYTC has not employed this technology.

KTC: A History of Excellence in Transportation

Since 1981, The Kentucky Transportation Center (KTC) has been a nationally recognized leader in applied transportation research. Multidisciplinary teams provide innovative research, exemplary technology transfer, and real-world education to the transportation community. KTC maintains its strong collaborative relationship with KYTC by delivering projects in the state highway plan and aiding the implementation of research findings. The Center also partners with federal, state, and local agencies, private stakeholders, and other university transportation centers to develop transformative solutions to the most pressing issues facing all modes of transportation.



Electric Vehicles: Analysis of Revenue Issues and Charging Station Implementation Plans

The Challenge



Electric Vehicles (EVs) have many benefits, including the reduction of environmental pollutants and lower costs associated with maintenance and fuel. Automakers are ramping up production of EVs and promising to phase out vehicles that have internal combustion engines (ICEs). Three types of EVs are available:

- Hybrid electric vehicles (HEVs), which have both an ICE and battery,
- Plug-in hybrid electric vehicles (PHEVs), which have both an ICE and a larger battery that can run the vehicle for short distances, and
- Battery electric vehicles (BEVs) which run entirely on battery power.

Research Project

Electric Vehicles: Analysis of Revenue Issues and Charging Station Implementation Plans
Report #
KTC-22-02/KHIT147-1F

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Study Timeline

Completed March 2022

Finding Solutions

Widespread adoption of EVs poses challenges to state government policies and to the planning of infrastructure needed for charging facilities. To help inform the decision making of KYTC leadership, researchers at the Kentucky Transportation Center (KYTC) projected fuel tax revenue losses, examined Kentucky's current charging station infrastructure, and summarized the approaches other agencies have adopted to increase the number of EV corridors.

Key Takeaways

EV Infrastructure:

- In 2016, 391 BEVs were registered in Kentucky. This number jumped to 3,621 by the end of 2021 - a 59.3% increase.
- To keep pace with the expected uptick in EV ownership in Kentucky, the number of charging stations must continue to grow and should be distributed more evenly throughout the state.
- In many states, grants and federal funds have been directed toward installing electric vehicle service equipment and infrastructure. Several state governments are working with multiple stakeholders to identify charging station locations and coordinate corridor planning.

Fuel Tax Revenue Loss:

- Federal tax credits for EVs are being depleted rapidly. While the future of federal incentives is unclear, states, power companies, and other entities continue to offer incentives like tax credits and rebates.
- Researchers estimated a projected fuel tax revenue loss of about \$14.2 million per 100,000 vehicles. Since 2016 the state has likely lost over \$1.3 million in revenue.
- Many states have embraced annual fees on BEVs and hybrids to make up for lost fuel tax revenues. Kentucky will benefit from charging an annual registration fee of \$150 for non-commercial BEVs.
- Another potential option for recovering fuel tax revenue loss is a road usage charge (RUC), which levies a fee for each mile driven.
- The combined accessibility of L2 charging stations and DC fast chargers appears reasonable for most current EV owners in Kentucky, with 86 percent of non-Tesla owners and 89 percent of Tesla owners being able to travel 10 miles or less to the nearest station.

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Non-Nuclear Methods for Compaction Control of Unbound Soil and Granular Layers



The Challenge

In highway construction, the correct soil compaction must be attained before construction activities begin. The nuclear density gauge (NDG) is widely used at state transportation agencies (STAs) for measuring soil density and moisture, but because they emit radiation NDGs are expensive to maintain and have unique storage requirements. Operators must earn specialized certifications and adhere to rigorous safety protocols. Equipment manufacturers have introduced several non-nuclear density gauges that eliminate the certification and training requirements and have fewer costs and logistical hassles – although their accuracy has sometimes not equaled NDGs. Kentucky Transportation Center (KTC) researchers performed a comparative field study of NDGs and the eGauge and explored other stiffness/strength devices that can be used as alternatives to NDGs.

Research Project

Non-Nuclear Methods for Compaction Control of Unbound Soil and Granular Layers

Report #

KKTC-21-06/SPR19-573-1F

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Study Timeline

Completed March 2021

Building Solutions

The team collected over 100 soil density and soil moisture measurements at nine field sites across Kentucky. The test sites were classified into four groups based on soil characteristics: 1) silt/clay and shale, 2) stabilized clay, 3) clay, and 4) full depth reclamation (FDR). Soil moisture readings from NDGs and the eGauge were compared to samples dried in an oven laboratory.

Finding Solutions

- Across all sites, 82.5% of the NDG and eGauge density readings were within +/- 5% of one another.
- In silt/clay soils, shales, and stabilized clays, the eGauge produced sufficiently similar soil density readings to those of the NDG.
- At sites with clay or FDR, the eGauge density readings differed significantly from NDG measurements. Before employing eGauge on these types of sites, further study is needed.
- While no significant differences were noted in moisture readings for stabilized clays, for the other soil types, the eGauge returned lower measures of soil moisture than NDGs and the lab samples.
- The eGauge, unlike the NDG, does not have a back scatter mode. It can only obtain a density reading in the direct reading mode by driving the probe into the soil. Therefore, soil densities obtained on projects mixed with rock and/or FDR projects can vary greatly. The eGauge may not be suitable for projects such as these.

Future Considerations

- A promising non-nuclear alternative for evaluating in-place soil properties is measuring soil stiffness/modulus instead of soil density.
- Portable soil stiffness gauges and light weight deflectometers produce accurate measurements while being faster, cheaper, and safer to use than NDGs.
- 84% of STAs use NDGs for in-place density-moisture measurements, while 70% do not use any stiffness/strength methods.
- Some STAs have tried using stiffness/strength methods: it appears the GeoGauge and LWD were tried by roughly 50% of STAs, while the Clegg Hammer (15%) and DCP (32%) have been less widely used.

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Evaluating the Safety Cultures of Kentucky Transportation Cabinet Maintenance Crews



The Challenge

Between 2003 and 2017, over 1,800 workers died on road construction sites. To eliminate injuries and deaths, state transportation agencies must cultivate a strong and positive safety culture. Although there is a clear relationship between a positive safety culture and worker behaviors, workplace culture is not easily defined and can be difficult to measure. To understand the safety cultures of Kentucky Transportation Cabinet (KYTC) maintenance crews, researchers at the Kentucky Transportation Center (KTC) conducted a survey based on the Safety Climate Assessment Tool (S-CAT) developed by the Center for Construction Research and Training (CPWR).

Research Project

Evaluating the Safety Cultures of Kentucky Transportation Cabinet Maintenance Crews
Report #
KTC-21-25/SPR20-582-1F

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Study Timeline

Completed August 2021

Building Solutions

- The safety assessment tool used in this study is the first tool developed exclusively for the construction industry.
- The survey was distributed via Qualtrics to all KYTC maintenance Superintendents I and II, who were told that responses would remain anonymous.
- Questions addressed eight safety climate categories: employee risk perception, management commitment, aligning and integrating safety as a value, ensuring accountability at all levels, improving supervisory leadership, empowering and involving employees, improving communication, and safety training.
- Respondents assigned ratings on a five-point Likert scale – Inattentive (1), Reactive (2), Compliant (3), Proactive (4), Exemplary (5).

Finding Solutions

The survey generated 143 responses from staff across the Cabinet's 12 districts. Analysis of survey responses at the statewide and district levels found that KYTC's safety climate score is 3.71, which is characterized as between compliant and proactive. The highest scores were in the categories Aligning and Integrating Safety and Improving Supervisory Leadership. KTC researchers followed up by meeting with focus groups of maintenance superintendents in two districts. To evaluate the Cabinet's current safety culture, groups discussed eight elements of organizational life: Safety Controls, Routines, Rituals, Stories, Symbols, Power, Safety Structures, and Underlying Assumptions.

Recommendations

KYTC can adopt several practices across the organization to achieve excellence in safety:

- Use formal incentives to recognize crews for positive safety performances.
- Continue using routines that are already integrated into Cabinet practices – weekly safety meetings, job hazard analyses, and toolbox talks.
- Continue to ensure that KYTC staff feel empowered to speak up when conditions are deemed unsafe, and to discontinue work until the hazard passes or can be mitigated.
- Add multiple layers of defense to prevent accidents – safety controls, consistently practiced routines, symbols, and structures.
- Use stories as a powerful way to communicate potential jobsite hazards and preventive actions that can be taken to reduce the likelihood of injuries.

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Analysis of Truck Weight Limit Regulations

The Challenge



On interstates the maximum allowable gross vehicle weight (GVW) is 80,000 pounds. Each state determines its own rules for permitting overdimensional and overweight (OD/OW) vehicles. Many vehicles that carry specific commodities are exempt from standard weight limits. To help mitigate the infrastructure damage caused by heavy loads, researchers at KTC investigated strategies that Kentucky can adopt to modernize and standardize enforcement of OD/OW vehicles.

Research Project

Analysis of Truck Weight Limit Regulations
Report #
KTC-21-15/SPR19-570-1F

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Study Timeline

Completed June 2021

Building Solutions

- Studied national laws pertaining to OD/OW vehicles.
- Reviewed Kentucky Revised Statutes and Kentucky Administrative Regulations that govern the permitting of OD/OW vehicles.
- Surveyed state DOTs and law enforcement agencies about truck weight limit policies and regulations.

Finding Solutions

- KYTC district staff share the concerns of other states – that bridge and highway networks cannot support overweight vehicles and believe many roadways are not designed to withstand GVWs of 80,000 pounds.
- States surveyed feel that permitting fees and fuel taxes are insufficient to ameliorate roadway damage caused by OD/OW vehicles.
- Heavier vehicles with commodity exemptions are especially damaging to collector and local roads.
- Reduced funding and staff shortages make enforcement a challenging proposition.
- Several Kentucky statutes and regulations pertaining to OD/OW vehicles are obsolete, contain ambiguous language, or contradict one another.

Recommendations

- Consider changes in legislation and judicial practices such as reducing the number of commodity exemptions or using axle-based weight limits.
- To improve pavement design for heavier vehicles, increase data collection on the weights of trucks involved in crashes and the impacts of truck traffic on bridge deck deterioration.
- Implement advanced technologies to improve tracking of OW vehicles (e.g., scale houses, advanced WIM, mobile unit automated systems, GPS).
- Increase the issuance of citations through targeted efforts and track the commodity the vehicle is carrying when cited.
- Increase fines for violations and better prosecute citations.
- Increase law enforcement staffing and resources by creating enforcement units that focus on OW vehicles.
- Integrate GIS data into KYTC's interactive route maps and revise the Metal Commodities Hauling Network map.

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Best Practices for Highway Project Scoping



The Challenge

One of the Kentucky Transportation Cabinet's (KYTC) foremost priorities in fulfilling its mission is to deliver successful projects. A successful project meets the defined scope with quality solutions and is delivered on time and within the budget specified in the highway plan. A 2002 AASHTO study found that a focus on pre-construction activities is one of four indicators that can be used to measure agency effectiveness. Good project scoping includes a detailed project description that addresses the purpose and need and clearly communicates what the project will and will not deliver. Ideally a project scope is defined in the early phases of the highway project development process. KYTC initiated a study to help program and project managers strengthen scoping processes in order to clearly and accurately identify project needs, better control project development activities, optimize resource use, keep activities on schedule, and improve project outcomes.

Research Project

Best Practices for Highway Project Scoping
Report #
KTC-23-08/ SPR22-632-1F

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Study Timeline

Completed August 2022

Building Solutions

This research defines principles to (1) help KYTC programmatically improve its project scoping, (2) identify tools and processes to facilitate programming, and (3) help program and project managers narrow and hone a project's scope before it is established in the Highway Plan. KTC researchers performed a literature review, analyzed peer state scoping processes, and held several KYTC brainstorming workshops which unveiled valuable insights into current scoping practices.

Finding Solutions

The research team investigated scoping processes for several different project scenarios:

- Different project scales: minor, intermediate, major
- Several project types: (1) Capital Improvement Projects (i.e., Mobility and Economic Development), (2) Safety, (3) Asset Management (i.e., Bridges/ Pavement), and (4) Maintenance and Operations
- The first 0-3% of project development and up to 30% of project development (when the environmental phase is complete)

Recommendations

- Throughout the study researchers documented project scoping practices by project type.
- Each recommended best practice was described by its title, background information, goal, implementation strategies, and a ranked score for implementation effort and value to KYTC.
- Best practices were grouped into the following categories: (1) Human Resource-Focused Practices, (2) Programmatic Changes, (3) Project-Level Improvements, and (4) Secondary Best Practices.
- The best practices for Capital Improvement projects had universal application across project types, so a General Best Practices category was created. Eight general best practices were selected as top practices:
 - Strengthen Commitment to Robust Scoping and Lengthen Early Project Stages
 - Ramp Up Project Development Activities During Scoping
 - Increase the Number of Project Managers
 - Multidisciplinary Coordination and Risk-Based Scoping
 - Cross Program Coordination and Collaboration
 - Scoping and Project Delivery Performance Measures
 - Scoring of Project Alternatives
 - Increase Human Resources for Project Scoping

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Evaluation of Manual Infrared Brake Screening Technologies

Background



Due to limited staff and resources, only a small percentage of the commercial vehicles passing through Kentucky each day can be screened or inspected by enforcement personnel. Inspection facilities need the best available tools and technologies to assist them in selecting trucks for inspection so they can focus on those carriers and vehicles most likely to be in violation of laws and regulations. Kentucky has used infrared (IR) technology for approximately 20 years, providing enforcement personnel with visual indicators to identify trucks with brake or tire deficiencies. With the goal of enhancing the quality and efficiency of Level 1 safety inspections, KTC worked with enforcement personnel at two inspection facilities to test the value of IR technology in identifying trucks with safety-related brake and tire violations.

Research Project

Evaluation of Manual Infrared Brake Screening Technologies
Report #
KTC-22-06/RSF19-71-1F

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Study Timeline

Completed April 2022

Building Solutions

The two sites selected to install and operate manual IR brake screening systems were eastbound Lyon County (on I-24 in western Kentucky) and Rowan County (on westbound I-64 in eastern Kentucky). The addition of an IR radio button feature allowed a direct comparison of number of violations identified per inspection and out-of-service rates for IR-generated inspections versus all other inspections. The Rowan County facility lacked sufficient data over the project timeline, so the evaluation focused on inspections at the Lyon County site for a 60-day period during September and October 2021.

Finding Solutions

- When IR technology was used to select trucks for inspection, nearly 100% found violations, with more than three violations found per inspection. Brake and tire violations were found more frequently.
- The Out-of-Service (OOS) rate for IR inspections was 74%, compared to 41% for all inspections.
- Inspectors favored implementing the technology at all inspection facilities in Kentucky so that everyone could be trained to use the system and gain experience.
- Inspection personnel felt the technology helped them do their jobs more efficiently, and they preferred selecting trucks for inspection based on visual indications instead of a credentials flag.

Recommendations

The conclusions of this study were based on limited data from one facility. Additional data should be collected and analyzed to determine if the system continues to benefit inspection facilities. Strong consideration should be given to installing this technology at additional sites, with the eventual goal of making it available at all fixed enforcement locations.

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Combined Behavioral and Engineering Approach to Preventing Highway Fatalities



The Challenge

Traditional approaches to highway safety can be augmented through multidisciplinary approaches that consider both engineering and behavioral interventions. The primary focus of this study was on behaviors targeted in Kentucky's Strategic Highway Safety Plan such as aggressive driving, distracted driving, impaired driving, and driving without proper restraint. The research team sought to understand factors that affect driving behaviors and crash probabilities in order to improve safety across the state. Factors included latent conditions (e.g., demographics, socioeconomic status) and proximate influences (e.g., vehicular and roadway factors) on crashes.

Research Project

Combined Behavioral and Engineering Approach to Preventing Highway Fatalities
Report #
KTC-23-01/SPR21-601-1F

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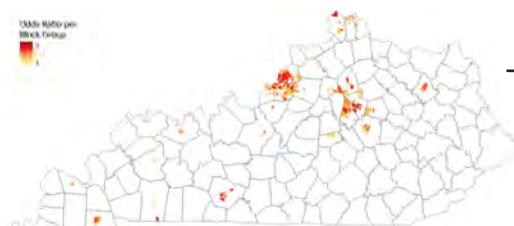
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Study Timeline

Completed August 2022

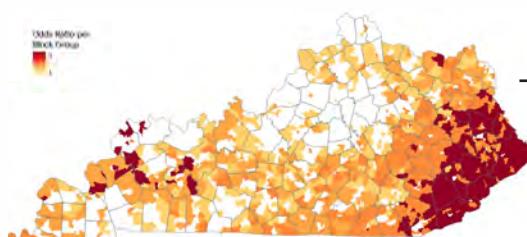
Building Solutions

- Reviewed literature from public health and systems-based approaches to safety.
- Utilized a systems-based framework of roadway safety data, statistical and geospatial analysis, and SPF modeling and network screening.
- Examined a data set of over 500,000 crashes in Kentucky between 2014 and 2018 to generate statistical models that predict crashes involving risk-taking behaviors.
- Developed an analytical framework to help understand the variables that influence crash occurrences and outcomes.



All aggressive driving crashes

This map shows the results for all aggressive driving crashes and demonstrates a clear connection between urbanized areas, and in some cases wealthy suburbanized areas, and aggressive driving crashes. College towns are also implicated.



Severe aggressive driving crashes

This map shows the results for all severe (fatal or incapacitating injury) aggressive driving crashes. In this map, rural areas, including southeastern and parts of western Kentucky, demonstrate increased likelihoods.

Key Takeaways

Researchers proposed a process that identifies when and where behavioral modification strategies could complement or substitute for engineering strategies. In some cases, a behavioral-related modification may be more effective than an engineering solution. The result is a tool practitioners can use to identify communities and corridors where a high number of behavioral-related crashes occur. This in turn can inform the selection of countermeasures.

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A Review of Kentucky's Extended-Weight Hauling Programs

The Challenge



Kentucky established its Extended Weight Coal or Coal Byproducts Hall Road System (EWCHRS) to increase the state's competitiveness within the coal industry and reduce financial burdens on coal haulers. A new extended-weight haul system for unrefined petroleum products will be implemented in 2022, and further expansion of extended-weight hauling is possible. The Kentucky Transportation Cabinet asked KTC to examine current laws and strategies related to vehicle weight limits and identify methods for improving the state's extended weight limit policies.

Research Project

A Review of Kentucky's Extended-Weight Hauling Programs
Report #
KTC-21-22/SPR20-589-1F

Building Solutions

- Surveyed literature on how overweight vehicles affect the integrity of roads and bridges.
- Described Kentucky statutes and regulations pertaining to the EWCHRS and vehicle weight limits.
- Reviewed policies and strategies used in other states to handle extended-weight hauling.
- Surveyed personnel at other state transportation agencies about challenges related to weight limit policies and regulations.

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Doug Kreis, PhD, P.E.
Director

Study Timeline

Completed November 2021

Finding Solutions

Overweight loads are getting heavier, presenting safety hazards and increasing damage to roads. Roads and bridges that are continuously exposed to overweight vehicles have shorter service lives, and there are few methods for quantifying rates of deterioration. Combined with these factors, there are several reasons the current level of revenue collected from permitting fees is not sufficient to offset damage caused by overweight trucks:

- Some vehicle owners run overweight because the resulting fines and fees can be less expensive than obtaining the correct permit.
- Enforcing overweight trucks is complicated by exemptions that apply to specific industries and commodities.
- Inadequate staffing and inconsistent weigh station operating schedules further hamper enforcement.

Recommendations

- Investigate the feasibility of a statewide long-haul network with weight limits based on axle weight and wheelbases that accommodates all commodities.
- Modify the EWCHRS fee structure by either raising decal fees, including a higher flat rate based on truck configuration, or enacting a fee structure similar to Kentucky's Weight Distance tax.
- Strengthen enforcement of weight limits on the EWCHRS by imposing more stringent penalties.
- Mandate installation of GPS systems on vehicles that travel the EWCHRS to streamline mileage reporting and improve driver awareness of routes that cannot accommodate their vehicles.
- Eliminate inconsistencies, ambiguities, and redundancies in regulatory and statutory language and establish regulations that address specific commodities.
- Establish a centralized, easy-to-search database that provides more information on routes, networks, and construction lettings.
- Review how EWCHRS routes are displayed/characterized on parkways that end at interstates.

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Fill Materials at Integral End Bents



The Challenge

Jointless bridge designs have become increasingly popular at state transportation agencies (STAs) due to their low construction and maintenance costs. However, there are risks associated with the design. Soil movement in embankments and loads carried by the superstructure can displace integral end bents. The Kentucky Transportation Cabinet (KYTC) addressed this challenge by placing elasticized geofoam between the soil and the integral end bent. There are issues with this treatment – the geofoam is expensive and the design needs to be modified in the location where the geofoam and overlying pavement meet. KYTC asked researchers at the Kentucky Transportation Center (KTC) to identify less costly materials that would reduce the settlement of integral end bents.

Research Project

Fill Materials at Integral End Bents
Report #
KTC-22-03/SPR19-572-1F

Principal Investigators

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Tony Beckham, P.G.
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KYTC Contributors:
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Michael Carpenter

Study Timeline

Completed March 2022

Building Solutions

- Established a lab procedure to evaluate the recoverable deformation and maximum resistant stress on different integral end bent samples.
- Evaluated seven materials derived from recycled tires to determine which have similar elastic properties to elasticized geofoam.

Finding Solutions

Two lower cost materials were selected: shredded tire chips and recycled tire granules. The shredded tire chips performed the best in terms of recoverable deformation, but the resistant stress was less than that the geofoam tested at the same strain. Recycled tire granules exhibited the best performance for both resistant stress and recoverable deformation.



Installing chips or particles on construction sites is the biggest challenge in using these alternative materials. Researchers developed two step-by-step installation procedures: 1) recycled tire derivatives are delivered in bags and stacked against the back of the end bent/abutment, and 2) bulk-packaged recycled tire derivatives are placed into baskets located against the back end of the bent/abutment.

Recommendations

KYTC has not yet identified a demonstration project to test the use of tire derivatives and the proposed installation methods. An implementation study will follow when the Cabinet selects a site.

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A photograph of a paved road curving through a dense forest. The sun is low on the horizon, casting a warm, golden glow through the trees and reflecting off the wet asphalt. Power lines and poles are visible on the left side of the road.

KTC 2021 Research Briefs



Investigation of Driver License Issuance Alternatives



The Challenge

Prior to 2020, Kentucky's licenses were distributed by circuit court clerks at 142 offices across the state. The Kentucky Transportation Cabinet (KYTC) provided central and regional support for specific license types. Due to the administrative challenges of implementing REAL ID, KYTC and circuit court clerks identified the need for an alternative distribution model. Researchers at KTC proposed ways for Kentucky to more efficiently distribute licenses, meet federal requirements, and make necessary changes to workflow processes. Of particular interest was a system that transferred all license and ID issuance to the Cabinet.

Research Project

Investigation of Driver License Issuance Alternatives
Report #
KTC-20-17/SPR20-583-1F

Principal Investigators

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Jennifer Walton, P.E.
Program Manager

Study Timeline

Completed 2020

Methods

- Estimated license distribution costs for FY 2020
- Projected the cost of opening and operating 18-24 regional field offices to implement REAL ID and distribute standard licenses
- Forecasted revenues & the number of IDs & licenses to be issued between 2020 & 2027

Findings

In FY 2020, Kentucky spent \$18.5 million to distribute licenses at county clerk offices. This included labor, operating costs, and the vendor contract to supply and service ID production equipment. Projections showed the regional model would initially cost between \$10.4 and \$16.4 million. Shifting from a 4-year license cycle to an 8-year cycle increased revenues from \$31.8 million in CY 2020 to \$35.8 million in CY 2023.

Recommendations

- Transition from 4-year to 8-year license renewal cycle
- Transfer responsibility for issuing licenses to KYTC
- Implement a web-based system for driver license renewals
- Adopt a newer, more dynamic driver licensing database to replace the outdated mainframe system
- Raise the License Fund share to \$29 for standard IDs and \$33 for travel IDs to avoid additional Road Fund supplements
- Keep allocations to the General Fund and Motorcycle Safety Education Program Fund at current levels

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Optimizing Commercial Vehicle Enforcement Investments and Activities to Improve Safety and Increase Revenue Collections



The Challenge

The Kentucky Transportation Cabinet (KYTC) owns and maintains 14 commercial vehicle enforcement (CVE) facilities. The Kentucky State Police (KSP) is responsible for enforcement of commercial motor vehicles (CMVs) at these facilities, while KYTC collects taxes and fees. Like many states, Kentucky has experienced a decline of personnel trained to operate weigh stations which adversely impacts safety enforcement and revenue collection. Two CVE facilities in Fulton and Henderson counties will eventually be bypassed due to the new construction of I-69. A third facility in Hardin County on I-65 will eventually be demolished due to a proposed I-65 interchange reconstruction project. To determine if these weigh stations should be replaced or closed, KYTC asked researchers at the Kentucky Transportation Center (KTC) to evaluate the facilities, taking into account the level of compliance with both tax-related and safety regulations.

Research Project

Optimizing Commercial Vehicle Enforcement Investments and Activities to Improve Safety and Increase Revenue Collections
Report #
KTC-21-611

Principal Investigators

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Andrew Martin, PhD
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Study Timeline

Completed 2021

Methods

- Measured revenue collection of Kentucky's weight-distance tax (KYU) and fuel taxes (KIT and IFTA) against operating costs.
- Collected and analyzed violation and citation data from KSP-operated weigh stations for 2017 - 2019.
- Determined each facility's potential impact on safety by looking at its proximity to crash hot spots, identification of out-of-service drivers/vehicles and violations, and enforcement intensity.
- Assessed hours of operation and staffing levels for weigh stations and their impact on performance.
- Developed and applied a decision matrix to determine if a facility should be closed, replaced, or transitioned to remote monitoring.

Findings and Recommendations

- The Hardin weigh station has insufficient parking capacity and entrance ramp length to accommodate its location on the second highest-volume CMV corridor in Kentucky. This facility should be replaced and simultaneously upgraded to continue its safety mission while improving upon its revenue collection.
- The Henderson weigh station should be replaced to continue its notable safety and self-sustaining revenue collection performance.
- The Fulton weigh station resides on the least traveled CMV corridor among all Kentucky weigh stations resulting in minimal safety benefits and revenues. This facility should be converted to a remote monitoring station to enable limited CMV screening without imposing excessive costs.
- High inspector turnover at weigh stations imposes additional costs from recruitment and training, prevents full facility staffing, and degrades safety and revenue performance. KSP should investigate inspector compensation packages and identify best practices to improve KSP's ability to attract and retain high-quality candidates.
- Due to Kentucky's weigh stations only staying open 33 percent of the time, KSP should evaluate options for increasing hours of operation to improve safety benefits and revenue collection.
- KSP should evaluate its policies and procedures for weigh station inspectors and sworn officers to improve the consistency in enforcement (citations-to-violations rate) across locations.
- The guidance developed in this study can be applied beyond these three facilities to help make future decisions about weigh stations in Kentucky.

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Potential Effect of Cable Median Barriers on CMV Crossover Crashes



The Challenge

In 2016, commercial motor vehicles (CMVs) were involved in 4,079 fatal crashes in the U.S., representing 11.8 percent of all fatal crashes. Kentucky's per capita crash rates exceed the national average, and from 2009 to 2016 CMV crashes increased 27 percent in the state. Of all crash types, crossover crashes are among the most serious. They occur when a vehicle leaves its intended path and veers into opposing traffic, typically resulting in head-on or sideswipe opposite-direction crashes. Cable median barriers are a safety countermeasure used to mitigate crossover crashes. This project investigated the potential effectiveness of cable median barriers on interstate CMV crashes.

Research Project

Potential Effect of Cable Median Barriers on CMV Crossover Crashes

Report #
KTC-20-24/KIPC20-2-1F

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Research Engineer

Study Timeline

Completed 2020

Methods

- A literature review examined how vehicle, roadway, and driver factors influence the number and severity of CMV crashes.
- Analysis combined expert panel input and statistical analysis of a Kentucky State Police (KSP) dataset to estimate the potential impacts on a crash if a cable median barrier were present.
- Safety performance functions (SPFs) were developed, resulting in crash prediction models.

Findings

In the KSP data set, 32,291 crashes involved a CMV and 24,023 were two-vehicle crashes where a CMV collided with another vehicle, 6,350 were single-vehicle crashes, and the remaining crashes involved more than two vehicles. Expert panel analysis concluded that installing cable median barriers can improve safety and that they are most effective at reducing fatalities. SPFs generated by researchers also supported the overall expert panel assessment.

Recommendations

- Statistical analysis and expert panelists found that CMV crash outcomes benefit from installing cable median barriers.
- Benefits may be greater on divided roadways because space limitations on two-lane roads make it more challenging to install barriers.
- Additional research should evaluate how the effects of cable median barriers vary based on what type of vehicle crosses the median.

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Evaluation of Orange Pavement Striping for Use in Work Zones

The Challenge

Two critical safety issues that arise in long work zones on interstate widening projects are driver confusion over unclear pavement markings and the absence of continuous work zone signage. Both concerns are more pronounced in transition and taper areas. The use of pavement markings which employ a non-standard color (e.g., orange) may help motorists better identify the correct travel path and prevent them from resuming normal driving behaviors and speeds after passing the initial transition area. To explore whether pavement markings painted an alternative color can improve work zone safety, KTC applied orange edge and lane lines in a work zone test area to assess their effect on speed, crashes, and driver behavior.

Methods



- Researchers compared retroreflectometer data on orange markings to data from standard markings to ensure visibility standards were met.
- KTC surveyed the public to understand their reaction to orange pavement markings.
- Researchers interviewed agency and contractor personnel who worked on the installation to assess their experiences with orange pavement markings.
- Using probe and crowd-sourced data, researchers evaluated work zone speeds.
- KTC gauged safety benefits by performing crash analysis of periods before and during installation of orange work zone striping.

Research Project

Evaluation of Orange Pavement Striping for Use in Work Zones
KTC-21-03/FRT-227-1F

Principal Investigators

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Study Timeline

Completed 2021

Findings

During implementation in Kentucky, the number of crashes increased by 20 percent where orange paint was used; very few drivers lowered their speed as they traveled through the work zone. The increase could be attributed to the fact that few drivers exercised greater caution. However, crash frequencies for wet and nighttime conditions fell significantly – likely because the markings were used. Surveys found the public receptive to the use of orange pavement markings in work zones.

Recommendations

- To help motorists understand the meaning of orange pavement markings, install more roadside signs or develop public awareness campaigns.
- Avoid using shades of orange that incorporate too much red. Motorists with red-green color blindness may have issues with perception. Red can also be interpreted as indicating the motorist is going in the wrong direction.
- Post additional law enforcement in work zones when orange pavement markings are introduced.
- Long-term work zones may increase complacency among drivers, which cannot be solved with novel pavement markings alone. Increased law enforcement presence may be necessary.

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Training Curricula for the Kentucky Transportation Cabinet Department of Highways



The Challenge

State departments of transportation (DOTs) confront several pressing challenges, including reduced staffing levels, declines in funding, and the loss of in-house technical knowledge. Agencies strive to offer employees training and professional development opportunities to build up institutional knowledge, but may not have the resources to supply sufficient training or to continuously update training materials. The Kentucky Transportation Cabinet (KYTC) offers several trainings to its staff, but the agency lacks exhaustive training curricula to help professionals and paraprofessionals systematically grow their expertise and expand technical competencies. Training opportunities are unevenly distributed across the Cabinet's 12 districts. To address these issues, KTC researchers developed training curricula for different subject-matter areas.

Research Project

Training Curricula for the Kentucky Transportation Cabinet Department of Highways
Report #
KTC-19-12/SPR17-543-1F

Principal Investigators

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Jeff Jasper, PE
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Study Timeline

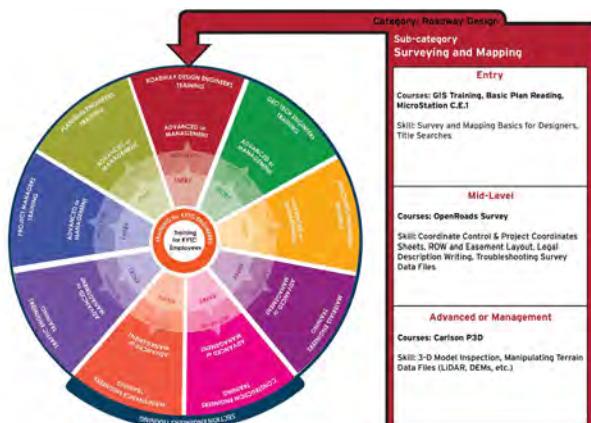
Completed 2020

Methods

- Researchers examined training programs at other state DOTs that target professional development.
- Curricula of KYTC's available trainings were analyzed, including: the Highway Technician Series, Advanced Leadership Academy, Construction Management Academy, Project Manager's Boot Camp, and the Supervisor Training and Resources Program.
- To clarify which courses have been most valuable, KYTC supplied information about previous course offerings and attendance figures.

Findings

Researchers developed training curricula for five subject-matter areas – construction, maintenance, roadway design, project management, and section engineers. Courses and skills in each curriculum are broken into categories and sub-categories and classified as entry, mid-level, or advanced. Figure 1 presents an example curriculum for a Roadway Design Engineer under the category of Surveying and Mapping.



Recommendations

KYTC can utilize KTC's training curricula to select needed courses and help employees identify areas where training could be useful. This will help the agency expand training and define requirements/needs as various skills evolve. Working continuously to ensure that KYTC employees have the requisite skills and expertise to meet job requirements is critical for the agency to fulfill its responsibilities amidst declining staff levels.

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Project Management Research Support



The Challenge

If state departments of transportation (DOTs) are to deliver projects on time and within scope and budget, their project managers (PMs) need access to project management concepts, tools, and resources. PMs also benefit from cultivating an understanding of the engineering, environmental, legal, and funding issues that can impact project delivery. With most DOTs losing institutional knowledge through staff retirements and attrition, it is more difficult than ever to deliver complex transportation projects. To address the most pressing project management issues at the Kentucky Transportation Cabinet (KYTC), KTC researchers worked with agency leaders to craft an implementable vision for project development and identify the necessary tools and resources that help PMs succeed.

Methods

- Researchers reviewed other state DOTs project management practices, guidance documents provided to PMs, and how project management fits into their organizational structures.
- Stakeholders from KYTC and KTC participated in a peer exchange with the Utah DOT to understand its approach to project development.
- The research team evaluated KYTC's current project management resources, including Project Manager's Boot Camp training and yearly project development webinars, compiled a database of transportation-related policy, and developed articles on project time management.

Research Project

Project Management Research Support

Report #
KTC-21-12/SPR18-562-1F

Principal Investigators

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Study Timeline

Completed 2021

Findings

The peer exchange with Utah DOT helped KTC and KYTC formulate a list of action items to improve the Cabinet's project management. Researchers catalogued strategies, project management tools, and other documentation that can assist PMs. During the study, KTC researchers led 30 facilitated sessions with KYTC leadership to brainstorm a vision for Project Development. These sessions helped KTC envision new approaches to planning, scoping, and programming projects in the Highway Plan. Researchers worked with KYTC staff to devise performance measures and establish a project selection process that gives all proposed projects equal consideration.

Recommendations

- Continue to prioritize work on project management guidance, particularly Highway Knowledge Portal (H KP) articles on core competencies and job responsibilities
- Continue to monitor and update the KRS/KAR Excel database as legislative changes are made
- Explore strategies for integrating software (e.g., Microsoft Project, PDP PreCon, AASHTOWare Estimation) into current project management systems
- Create (1) a project definition document and (2) a document that captures the planning and scoping process
- Use H KP project time management articles and work performed for PDP-PreCon to develop Gantt charts and milestones for all projects that go through the letting process
- Focus on strategies to accelerate environmental clearance and the right-of-way process
- Prioritize performance measures within each division to increase efficiency
- Fine tune a project development process able to program long-term projects and forecast beyond what is covered in the Highway Plan

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The Challenge

Verifying whether state driver licensing agencies (SDLAs), law enforcement, and court systems comply with federal regulations related to motor carriers and drivers is challenging. Traffic conviction data for commercial driver license (CDL) holders has a complex chain of custody, leading to reporting delays, making it difficult to trace CDL convictions through pre-screening, inspections, and entry of conviction records into CDLIS. KTC developed strategies the Kentucky Transportation Cabinet (KYTC) and other agencies can adopt to improve data quality, evaluate performance, and supply data on CDL issuance, enforcement, adjudication impacts, and safety outcomes.

Methods



- Reviewed how other states handle CDL integration between law enforcement, courts, and SDLAs
- Surveyed stakeholders to discuss issues with software applications and database technologies
- Developed guidance on upgrading information technology (IT) infrastructure and improving tools to track CDL issuance, enforcement, adjudication, and status changes

Research Project

CDL Data Quality Assessment
Report #
KTC-20-33/RSF81-1F

Principal Investigators

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Study Timeline

Completed
2020

Findings

Substandard data quality results from (1) state courts lacking CDL-specific case disposition data, (2) SDLAs relying on aging technologies for recordkeeping, and (3) law enforcement having inadequate software and hardware tools to capture detailed and accurate data. Kentucky's Division of Driver Licensing added two reports to its daily workflow to preserve CDL data quality and comply with regulations, identifying over 200 cases of CDL conviction masking in the process. The state's county attorney diversionary program has suffered due to instances of CDL holders completing the program, despite statutory prohibitions. However, this issue can be remedied by educating county attorneys and judges on the correct adjudication of CDL-related cases.

Key Recommendations

- Establish stronger requirements for states making changes that impact AAMVA Code Dictionary equivalencies
- Automate and standardize data collection/entry to reduce data entry errors by SDLAs, court systems, and law enforcement agencies
- Fund programs and initiatives to strengthen CDL data quality and processing, hire and retain staff, and build out necessary IT infrastructure
- Implement new metrics for CDL data quality (e.g., validity, accuracy, and the completeness of traffic citations, accuracy and timeliness of court actions)
- Include a CDL indicator in citation and adjudication software to enable better tracking of CDL-related traffic and to distinguish CDL holders from other operator licenses

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2020 Kentucky Transportation Cabinet Maintenance Customer Survey



The Challenge

Understanding levels of driver satisfaction with highway maintenance is critical for the Kentucky Transportation Cabinet (KYTC) to determine areas in which it can improve maintenance operations. In 2020, KTC researchers surveyed 2,400 licensed drivers throughout KYTC's 12 districts to gauge their perceptions of highway maintenance. Survey participants answered questions about the maintenance of roadside features, pavement surfaces, shoulders, drainage, and signs/markings. Another focus of the survey was identifying future investment priorities and sources of traffic and weather information which drivers most frequently rely on.

Research Project

2020 Kentucky Transportation Cabinet Maintenance Customer Survey
Report #
KTC-21-02/SPR20-592-2F

Principal Investigators

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Study Timeline

Completed 2020

Methods

- For questions related to maintenance, respondents answered using a five-point Likert scale, where a rating of 1 denoted unacceptable performance and a rating of 5 indicated excellent performance.
- For questions related to investment priorities, a five-point Likert scale was also used, with each item being scored from 1 (low priority) to 5 (high priority).
- Researchers compared results of the 2020 survey those from previous surveys administered in 2010 and 2016.

Table 1
Statewide Trends in Perceptions of KYTC Highway Maintenance (2010 – 2020)

Category	2010	2016	2020
Overall Appearance	3.39	3.42	3.51
Visual Obstructions	3.49	3.56	3.57
Fencing	3.62	3.60	3.64
Guardrail	3.91	3.83	3.83
Surfaces and Potholes	3.90	2.93	3.14
Shoulders	4.36	3.41	3.53
Drainage	4.04	3.60	3.70
Signage	4.25	4.07	4.07
Roadway Markings	3.99	3.87	3.94

Findings

Customer satisfaction levels remained consistent between 2010 and 2020. Table 1 summarizes mean scores for each category. Boxes shaded green indicate an increase in score; red boxes a decline in score; and gold boxes an unchanged score. Mean scores fell for seven categories between 2010 and 2016, but modest rebounds were recorded between 2016 and 2020. Maintenance of signs, striping, and guardrails elicited the highest ratings, while pavement surfaces, potholes, and overall appearance received the lowest ratings. The most important investment priorities were pavement surfaces and signs/markings.

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Development, Implementation, and Tracking of Preventative Safety Metrics

The Challenge

The primary metric used to assess employee health and safety at the Kentucky Transportation Cabinet (KYTC) is the OSHA recordable incident rate. It measures how often a Cabinet employee sustains an injury that demands more than basic first aid. Although this is a useful metric to understand how often injuries occur, it cannot help with management of the safety, health, and well-being of KYTC staff. To assist the Cabinet with improving safety, KTC identified a comprehensive list of safety leading indicators that could be applied by the agency and implemented measurement protocols to evaluate their performance.

Methods

- Identified the main dimensions of a safety program based on a review of previous research
- Surveyed safety researchers and KYTC safety personnel to gauge the relative importance of each safety dimension
- Analyzed survey data using the Analytic Hierarchy Process (AHP) method and determined the leading indicators of safety performance for each area of the safety program
- Conducted a safety metric scorecard pilot study that included participants from 8 KYTC districts and the agency's Central Office

Research Project

Development
Implementation, and
Tracking of Preventative
Safety Metrics
Report #
KTC-21-04/SPR19-568-1F

Principal Investigators

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Program Manager and
Associate Professor

Study Timeline

Completed 2021



Findings

The five major dimensions of an effective safety program are management leadership and commitment, employee engagement, training and competence, hazard identification and control, and evaluation and improvement. Researchers used Microsoft Excel to develop a macro-enabled workbook for the safety scorecard. The pilot study found that the safety metrics performed well and that maintenance crews can use the safety scorecard to predict areas in their safety programs needing improvement.

Recommendations

- Because of the low scores for employee engagement, KYTC will benefit from identifying more opportunities to involve staff in the safety program. Engagement can take many forms, including the establishment of empowered safety committees, involving staff in developing safety policies and procedures, and increasing participation in hazard control practices (e.g., toolbox talks, job hazard analyses).
- Consistent adoption of the safety scorecard will help the Cabinet identify safety issues needing attention before system failures emerge.
- Achieving a strong commitment from management to support robust safety practices is critical for reducing incidents and injuries.

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Investigation of Workflow Processes and Best Practices in Kentucky's CDL Program

The Challenge

Kentucky's Division of Driver Licensing (DDL) maintains driver history records for all drivers licensed in the state. The agency relies on temporary labor funded by federal grants to verify and process documents and to field phone calls from customers. Without access to this funding, DDL will not be able to retain staff and comply with Federal Motor Carrier Safety Administration (FMCSA) regulations. Working on behalf of DDL, KTC researchers investigated the strategies used by transportation agencies in other states to administer federal and state commercial driver license (CDL) requirements.

Methods



- Reviewed practices and strategies adopted by state driver licensing agencies (SLDAs) to manage manual data entry processes related to CDL citation and adjudication databases
- Surveyed other states about automation of manual CDL data entry processes, funding opportunities in their state for automation, and overall levels of automation
- Shadowed DDL staff while they completed manual processes such as document reviews and keying data into driver history records

Research Project

Investigation of Workflow Processes and Best Practices in Kentucky's CDL Program
Report #
KTC-21-16/RSF-55-1F

Principal Investigators

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Study Timeline

Completed 2020

Findings

Many states struggle with aging agency driver license databases, which are on old computer mainframes and written in outdated programming language. While some agencies are beginning to invest in automation and e-government to address these problems, they are hampered by limited funding and staffing. Agencies are upping their reliance on email for communication; relatively few leverage it for workflow processes. Shadowing DDL employees revealed good reasons for manual entry of some data, including limited funding for information technology (IT) system upgrades, the difficulty of automating some of the more complex legal processes, and lack of constituencies demanding more resources to address technology shortfalls. Development and implementation of the myCDL portal has let DDL cope with staffing losses by helping employees process and verify medical certificates, self-certifications, and commercial driver license and permit applications. In spite of the new efficiencies created by myCDL, meeting the 10-day reporting window and other FMCSA requirements is still a challenge for DDL.

Recommendations

- Manual data entry and human judgment are required for some activities (e.g., correcting errors in court records, tracking failure to comply with out-of-state citations), however; other processes can benefit from automation (e.g., documenting pretrial suspensions).
- Agencies elsewhere can benefit from adopting systems like Kentucky's myCDL portal to automate portions of workflows and bolster efficiency in the face of declining staff numbers.
- Making email a routine tool for communication with agencies in other states will increase efficiency.

KTC: A History of Excellence in Transportation

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Evaluation of Liquid Deicing Materials for Winter Maintenance Applications

The Challenge

Every year the Kentucky Transportation Cabinet (KYTC) spends between \$40 and \$80 million to remove snow and ice from the state's roads. Historically, the Cabinet has kept roads free of snow and ice using a mixture of brine and calcium chloride as this has proven an effective practice. However, manufacturers of new anti-icers claim that their products outperform calcium chloride. KYTC asked KTC researchers to devise laboratory procedures to evaluate how well anti-icers disrupt bonds between pavement and ice and to apply these methods to test the performances of five new anti-icers.

Methods

- Reviewed industry practices to identify anti-icing candidate products and gain insights into road treatment practices
- Designed a novel laboratory testing protocol by modifying guidance from the Strategic Highway Research Program that mitigates challenges encountered in past studies
- Performed cost analyses for each anti-icer and calculated the price per lane mile for each anti-icer diluted with brine solution
- Examined the environmental impacts of new anti-icers, including effects on infrastructure and biosystems

Research Project

Evaluation of Liquid Deicing Materials for Winter Maintenance Applications
Report #
KTC-21-20/SPR18-566-1F

Principal Investigators

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Research Engineer

Study Timeline

Completed 2021



Findings

Among anti-icers, FreezGard CI Plus performed the best, undercutting the largest average area. Calcium chloride was 60% less effective than FreezGard CI Plus. Other anti-icers performed modestly better than calcium chloride. In terms of cost, calcium chloride is the least expensive treatment option on a cost per lane mile basis, followed by Ice Ban 305 and FreezGard CI Plus. These novel anti-icers pose less acute threats to the environment than calcium chloride, which corrodes reinforcing steel, defoliates vegetation, and harms aquatic life by reducing dissolved oxygen levels in streams, wetlands, and lakes. None of the anti-icers are hazardous to wildlife or the environment when applied as directed.

Recommendations

- Mixing calcium chloride with brine is functional and the most cost-effective option. Calcium chloride works quickly and at temperatures as low as -25°F.
- FreezGard CI Plus and Ice Ban 305 are potential substitutes for calcium chloride. FreezGard CI Plus is 1.6 times more effective than calcium chloride at 1.5 times the cost, while Ice Ban 305 is 1.1 times as effective at 1.25 times the cost. Both products are compatible with KYTC's current application equipment and storage facilities.
- Although undercutting tests performed in the laboratory are adequate to evaluate how anti-icers will perform on roads, field testing is strongly encouraged before large-scale implementation.

KTC: A History of Excellence in Transportation

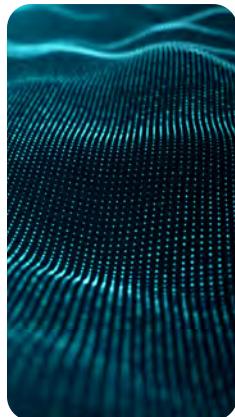
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KTC 2020
Research Briefs



Construction-Ready Digital Terrain Models



The Challenge

The Kentucky Transportation Cabinet (KYTC) routinely provides contractors with Electronic Engineering Data (EED), including a digital terrain model (DTM) representing the as-designed terrain. Responding to contractor demands, in 2006 KYTC began furnishing supplemental design files to bidders. Yet 14 years later, these files have inconsistent contents and structures, making it challenging to extract usable data. Wanting to remedy this situation, the Cabinet asked KTC researchers to explore how DTMs might better support modern construction management methods for both in-house staff and contractors.

Building Solutions

Researchers looked at how other state transportation agencies handle DTMs, surveyed KYTC construction and design staff, interviewed Cabinet and private industry stakeholders to understand current practices, and reviewed 12 EED project folders to determine their levels of completeness.

Research Project

Construction-Ready Digital Terrain Models

Report #
KTC-20-06/SPR19-576-1F

Principal Investigators

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Study Timeline

Completed May 2020

Finding Solutions

KYTC design and construction stakeholders observed that EED are used for critical work tasks and that design consultants are skillful at evaluating DTM details and using models for quality control, while contractors leverage EED to plan work, measure progress, and identify conflicts. Most interviewees agreed that generating accurate surface data yields a positive return on investment and that projects that are poorly modeled lead to negative outcomes. KTC's review of EED file folders found a wide range of quality.

Recommendations

Researchers laid out 15 recommendations for ensuring that EED support modern construction methods. Quick wins can be implemented quickly with few resource requirements.

Quick Wins

- Reinforce existing CAD standards
- Mandate a Consistent Rate of Template Drop
- Deliver Breaklines in a Point File Format
- Deliver KMZ Formatted Files of Proposed Manuscript Data
- Train Construction Staff and EED Reviewers
- Consistent Information Exchange with Industry Representatives
- Track and Measure Case Studies for Links between EED Quality and Costs
- Evaluate Alternative to Average End Area Method

Longer-Term Initiatives

- Review the EED Quality at Construction Contract 25% Completion
- Implement CAD Standards Specific to Project Types
- EED Submittals Increased within Existing Plan Review Processes
- Update Shelved and Aging Projects' EED to Most Current Software
- Revise Production Hours and Descriptions to Modern Workflow
- Establish Support for Construction Surveying

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Evaluation of Alternative Rumble Strip Designs



The Challenge

Transportation agencies install rumble strips along roadways to alert errant drivers that their vehicle is departing the roadway. But noise from vehicle-rumble strip interactions can be loud, disturbing nearby residents. Eager to update its rumble strip designs, the Kentucky Transportation Cabinet (KYTC) asked KTC to identify alternative design and installation procedures that improve performance, reduce damage to new pavement, dampen noise pollution, and allow for reinstallations on thin overlays.

Building Solutions

KTC researchers synthesized guidance from NCHRP and FHWA publications on alternative rumble strip designs, reviewed many state DOT websites for alternative rumble strip practices, and in consultation with KYTC staff examined Kentucky's current rumble strip installation techniques.

Research Project

Evaluation of Alternative Rumble Strip Designs
SPR 20-595

Principal Investigators

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Study Timeline

Completed 2020

Finding Solutions

Transportation agencies have made several design adjustments to improve rumble strip performance, including placing rumble strips farther from the traveled way in residential areas and adopting sinusoidal patterning, which maintains required noise levels in vehicle cabs, mitigates exterior noise, and facilitates bicycle traffic. Discussions with KYTC personnel revealed that durability is a key issue for center pavement joints; they also helped guide recommendations on the installation of edge line and centerline rumble strips.

Recommendations

- Rumble stripes (rumble strips with the edge line placed atop them) should be universally adopted on two-lane roads.
- Moving rumble strips from the shoulder to the edge line warns drivers earlier of a lane departure, improving safety.
- FHWA's guidance on rumble strips for thin overlays merits consideration as it supports chip sealing without remilling.
- Using shallow rumble strips reduces exterior noise pollution near residential areas and is less disruptive to bicycle traffic.
- KYTC should experiment with the use of sinusoidal rumble strips as they reduce noise pollution and provide protected centerline and edge line markings suited to the use of wet-reflective beads without risking damage from snowplows.
- Due to the nature of the sinusoidal milling equipment, local contractors suggest prioritizing the installation of sinusoidal rumble strips on straight roads (e.g., interstates) before transitioning efforts to roads with greater horizontal curvature.

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Developing a Baseline for Customer Satisfaction in the Department of Vehicle Regulation



The Challenge

Of the Kentucky Transportation Cabinet's (KYTC) business units, customers are mostly likely to interact with the Department of Vehicle Regulation (DVR) as its divisions administer the state's driver licensing, motor vehicle licensing, motor carrier programs, and customer service for all divisions. Knowing the importance of providing high-quality customer service and having an exceptional work environment, the Cabinet asked KTC researchers to measure employee morale and customer satisfaction and develop methods for tracking changes in both over time.

Building Solutions

Researchers began by synthesizing work on customer satisfaction, surveying to and conducting follow-up interviews with DVR staff, and developing a baseline customer satisfaction survey consisting of multiple-choice and open-ended questions. After analyzing the survey and interview data, KTC developed recommendations to improve employee performance and morale as well as customer service. Approximately 1.5 years after the baseline customer survey, KTC administered a follow-up survey to gauge the effectiveness of new policies.

Research Project

Developing a Baseline for Customer Satisfaction in the Department of Vehicle Regulation
Report #
KTC-20-05/SPR17-535-1F

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Study Timeline

Completed 2020

Finding Solutions

DVR employees responded positively to questions about workplace dynamics, but nonetheless felt it critical to foster open, supportive, equitable, and collaborative workspaces free of hostility, favoritism, and prejudice. They also encouraged KYTC to improve the technological resources available to perform key job functions.

Roughly 81% of customers were satisfied with DVR's level of service in the baseline survey, and 77% were satisfied in the followup survey. This drop was not statistically significant and likely due to the differences in survey participants. The followup survey showed that more DVR customers prefer to interact with the department online, and that average queue time and call duration increased significantly. A separate survey of online vehicle registration renewal found that 9% of customers were satisfied with the department's online vehicle registration renewal application.

Recommendations

- DVR must reduce call escalations, lower average call times, expand website services, and improve the functionality of its Motor Carrier Portal. It should also explore adding an online chat feature to its website.
- DVR should routinely survey customers and employees to identify problems that need to be resolved.
- Encourage more collaboration and cooperation across DVR's divisions to improve operations.
- Replace aging computer systems, such as the Automated Vehicle Information System and Kentucky Driver License Information System.
- Prioritize sending customers information via email and text messages to reduce mailing costs.

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Crash Modification Factor Recommendation List

The Challenge



Practitioners use crash modification factors (CMFs) to estimate the number of crashes that will occur if a given safety countermeasure is implemented. The Federal Highway Administration maintains the CMF Clearinghouse, which includes CMFs developed by researchers in the U.S. and around the world. While a valuable resource, using the Clearinghouse demands a lot of time and significant expertise. To help Kentucky Transportation Cabinet (KYTC) staff and design consultants pick out CMFs most suited to the state's highways, KTC researchers were asked to develop a spreadsheet-based tool.

Building Solutions

To identify key CMF needs, researchers conducted a workshop with experienced Cabinet engineers in the Divisions of Planning, Design, and Traffic Operations from the agency's Central Office as well as district offices. After identifying prospective countermeasures, workshop participants rated the importance of each. These results were used to devise a Kentucky-specific CMF needs list. The highest priority countermeasures were striping, guardrail, signing, and intersection improvements.

Research Project

Crash Modification Factor Recommendation List
Report #
KTC-20-22/SPR19-578-1F

Principal Investigators

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Study Timeline

Completed 2020

Finding Solutions

Practitioners can use KTC's Microsoft Excel-based tool to filter and search for the countermeasures used to evaluate Kentucky's highways. KYTC's newly established CMF Committee approves or rejects the use of new CMFs on internal and consultant-led projects. When a project requires a CMF, the practitioner downloads and fills out a web-based form, records which filters were applied in the spreadsheet tool, and submits the form for approval.

Recommendations

The tool can be easily expanded to accommodate the Cabinet's future needs. KTC researchers are now working to build a fully online system that lets users fill out the form and apply the spreadsheet tool. The project report contains detailed instructions for using the tool.

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Social Justice Mitigation in Transportation Projects: Supporting the Lexington Community Land Trust's Path to Self-Sustainability

The Challenge

Lexington, Kentucky, has a critical shortage of affordable housing, making it difficult for families earning 50% to 80% of the area's median income to purchase a home. To mitigate the impacts of the Newtown Pike Extension (NPE) project and increase the availability of affordable housing, land in the Davis Bottom neighborhood was placed into the Lexington Community Land Trust (LCLT). Most of the homes in the LCLT are well below LFUCG's definition of permanent affordability. Recently, the NPE Team asked the Lexington Fayette Urban County Government (LFUCG) to help the Lexington Community Land Trust (LCLT) grow its portfolio of permanently affordable, owner-occupied housing, and to help the organization achieve self-sustainability. KTC developed recommendations to reach this goal.

Building Solutions

KTC researchers examined the benefits and drawbacks of traditional homebuyer assistance programs, reviewed the national performance of CLTs and the policies required to ensure their effectiveness, and catalogued the potential benefits of LFUCG embracing a CLT model. With the goal of developing a cost-effective housing strategy and growing the portfolio of affordable housing without additional subsidies, KTC investigated the benefits of LCLT collaborating with the Lexington-Fayette Urban County Landbank Authority (LFUCLA) and Lexington's Affordable Housing Trust Fund. Along with recommending new development incentives, researchers identified the type of partnership LFUCG and LCLT should forge.

Research Project

Social Justice Mitigation in Transportation Projects: Supporting the Lexington Community Land Trust's Path to Self-Sustainability

Report #
KTC-20-09/FRT222-1F

Principal Investigators

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Study Timeline

Completed 2020

Recommendations

Researchers recommended that Lexington adopt the community land trust model (CLT) for its ability to reach six standard achievement measures; most notably, preventing foreclosure and protecting public investment, which in turn stabilizes neighborhoods and safeguards family wealth.

Actions for LFUCG to pursue are:

- Funding LCLT's operations, staffing, and marketing and establishing a 10-year goal of adding 600 homeownership units to the LCLT portfolio.
- Committing at least 50 percent of LFUCG affordable housing resources into permanently affordable homeownership and placing at least \$4 million per year into the Affordable Housing Trust Fund.
- Reestablishing a land bank that is adequately staffed and funded as well as reconsidering the use of inclusionary zoning.
- Codifying the current taxation strategy adopted by the Fayette County PVA for LCLT homeowners.
- Evaluating the Grounded Solutions Network's HomeKeeper software for its effectiveness in tracking data.

Actions for LCLT to pursue are:

- Updating its business plan to include a path to sustainability and the adoption of detailed stewardship policies.
- Partnering with non-profit and for-profit developers that are willing to create quality, permanently affordable housing.
- Protecting lower income families from gentrification and building CLT homes in locations that provide easy access to economic opportunities.
- Exploring the development of condominiums and limited equity cooperatives.

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Vehicle on Shoulder and Crash – Correlation or Causation?



The Challenge

Crashes that occur on roadway shoulders reduce highway capacity by up to 19% and increase the likelihood of secondary crashes. Historically, personnel in traffic management centers have learned about incidents and hazards through traffic cameras and emergency services dispatch. Crowdsourced data collected via apps such as Waze have begun to transform how transportation agencies get information about traffic jams, crashes, and hazards. But these data make it challenging to understand the sequence of events leading up to and following an incident. Accordingly, the Kentucky Transportation Cabinet (KYTC) asked KTC researchers to explore correlational and causational linkages between vehicles on shoulders, traffic slowdowns, and crashes on interstates.

Research Project

Vehicle on Shoulder and Crash – Correlation or Causation?
Report #
KTC-20-25/SPR20-598-1F

Principal Investigators

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Study Timeline

Completed 2020

Building Solutions

Researchers gathered and analyzed information from official crash reports, archived speed data, and Waze user-generated traffic alerts. Association rule mining was used to explore the relationships between vehicles on shoulders and congestion and crashes. They prepared heatmaps to illustrate speed data and chains of events related to incidents, and reviewed crash narratives to further clarify where vehicles on shoulders led to crashes.

Finding Solutions

In 36% of crashes studied, a vehicle was present on the roadway shoulder within 0.25 mile upstream or downstream of the crash site no more than 30 minutes before the crash occurred. Increasing the spatial window to 0.5 mile increased this figure to 54% of crashes. Congestion was a factor in roughly 25% of crashes, while congestion and a vehicle on the shoulder were implicated in 12% of crashes. The crash narrative review found that about 2% of crashes directly involved a vehicle on the shoulder; congestion was cited in 23% of the narratives. Crash narratives, however, did not illuminate the ways in which vehicles on shoulders contributed to crashes.

Recommendations

Vehicles on shoulders constitute an operational hazard and may worsen crash outcomes when involved in an incident. Therefore, it is critical for emergency responders to adopt practices for removing vehicles disabled on shoulders as quickly as possible. Utilizing technology such as hotspot maps and improving coordination between the Kentucky State Police and local law enforcement can help accomplish this goal. Future research should examine other incident alerts generated by Waze (e.g., road objects, road ice) to document their effects on crashes.

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KYTC Maintenance Field Operations Guide Supplement

The Challenge

The Kentucky Transportation Cabinet's (KYTC) Division of Maintenance spearheads efforts to maintain over 27,500 miles of roadways and 9,000 bridges across the state. Robust maintenance practices help to preserve the transportation network, facilitate safe and efficient travel for all residents, and support current and prospective businesses by providing access to a reliable transportation system. KYTC's 12 highway districts carry out routine maintenance activities such as mowing, litter pickup, cleaning out culverts, and performing emergency roadway work. However, no systematic method has been established to prioritize general maintenance functions and special projects, or to capture the ways in which maintenance practices evolve. To address this situation, the Cabinet asked KTC researchers to assist with developing a supplement to the agency's Field Operations Guide (FOG).

Building Solutions

Researchers began with a survey of maintenance programs at other state transportation agencies to understand current best practices for prioritizing and evaluating maintenance functions. Next, KTC held 24 workshops across KYTC's 12 highway districts with Maintenance Supervisors and Section Engineers to get a handle on pressing maintenance challenges. During these workshops, participants inventoried all maintenance activities assigned to district personnel and ranked the importance of each. A calendaring exercise was also done to gauge the frequency of each activity.

Research Project

KYTC Maintenance Field Operations Guide Supplement
Report #
KTC-20-17/SPR18-563-1F

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Doug Kreis, Ph.D., P.E.
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KYTC Contributors:
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Study Timeline

Completed 2020

Finding Solutions

KTC formulated a statewide maintenance calendar and district-specific maintenance calendars to supplement the FOG. With these calendars, district staff can improve the scheduling and coordination of critical maintenance activities. Data on the importance and recommended frequency of each maintenance activity can help staff develop workplans for county crews and facilitate maintenance request prioritization – even when special projects arise.



Recommendations

Despite the introduction of new maintenance calendars, decreased funding and staffing shortages are unavoidable. Nonetheless, it is possible to mitigate these issues by leveraging maintenance calendars and differentiating urgent issues from more routine problems. KTC researchers also encouraged improved communication and if an app is developed for maintenance requests, that the ranking results from this project could guide staff in slotting requests as they are received.

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Full-Depth Reclamation of Asphaltic Concrete Pavements

The Challenge

With in-place recycling and reclamation, deteriorated asphalt pavement is renewed using in-situ materials instead of virgin paving mixtures and materials. Recycling and reclaiming asphalt pavements optimizes the value of in-place materials, and reduces construction time, traffic flow disruptions, and construction-related traffic. The Kentucky Transportation Cabinet (KYTC) has recently experimented with full-depth reclamation (FDR) to rehabilitate asphalt pavements exhibiting widespread base failures. This process transforms existing hot-mix asphalt (HMA) pavement and underlying granular materials into a stabilized base layer that is then paved over with a new surface layer. Hoping to expand the use of FDR, the Cabinet requested that KTC researchers develop updated implementation methods and guidelines.

Building Solutions

Before this effort, KYTC relied on contract language to provide guidance for FDR projects, and depended on the contractor for acceptable materials design. KTC researchers previously examined different binding compounds, including cement, asphalt emulsion, and foamed asphalt. This guidance described a method for identifying projects suitable for FDR and outlined recommendations for evaluating material samples, testing, mixture design, and structural design parameters. Building on this work, KTC researchers crafted a new special note which can direct the Cabinet and its consultants and contractors in the use of FDR to transform degraded pavements.

Research Project

Full-Depth Reclamation of Asphaltic Concrete Pavements
Report #
KTC-20-20/SPR18-558-1F

Principal Investigators

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Highway Design, Pavement
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Study Timeline

Completed 2020

Findings and Recommendations



FDR can rehabilitate worn asphalt pavements while maintaining pavement geometrics and layer thicknesses. Furthermore, FDR conserves energy and natural resources and is an ideal solution for rehabilitating routes with low traffic volumes on which multiple base failures have occurred. Researchers also suggested creating a program focused on quality control/quality assurance testing and monitoring to verify design performance.

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Effect of Socioeconomic Factors on Crash Occurrence

The Challenge

Despite significant improvements in highway safety over the past 60 years, vehicle crashes remain a leading cause of death in the U.S. According to the National Highway Traffic Safety Administration, nationwide there were 22.5 crashes per 1,000 persons. In Kentucky, crashes per 1,000 people were significantly higher — 37.3. The state also witnessed a slight bump in traffic-related fatalities between 2018 and 2019, increasing from 722 to 728. Hoping to arrest these trends and further bolster roadway safety through the use of countermeasures, the Kentucky Transportation Cabinet (KYTC) asked KTC for help understanding factors which contribute to crashes.

Building Solutions

Using U.S. Census Bureau data, KTC researchers investigated the relationship between crashes and the socioeconomic and demographic characteristics of the zip codes where drivers live. Researchers began with spatial analysis to examine relationships between age, gender, and location to at-fault status, and generated county-level heat maps to visualize findings. Logistic regression models were developed to clarify how socioeconomic and demographic characteristics relate to crashes.

Research Project

Effect of Socioeconomic Factors on Crash Occurrence
Report #
KTC-20-03/SPR19-56-2-1F

Principal Investigators

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Samantha Wright, M.S.C.E
Research Engineer

Study Timeline

Completed 2020



Finding Solutions

- Younger and older drivers are more likely to be at fault in two-vehicle crashes
- Younger and middle-aged drivers exhibit the greatest risk for single-vehicle crashes
- Women drivers are less likely to be at fault than male drivers
- At-fault status is significantly influenced by driver age group, driver gender, rurality of accident location, local poverty rate, driver's average number of traffic-related convictions, and population density of a driver's residence zip code
- No strong regional disparities across Kentucky were apparent

Recommendations

Knowledge of the factors most likely to influence whether a driver will be at fault in a crash should be used to inform future educational efforts and decisions about where to install countermeasures. The Kentucky Safety Circuit Rider Program, for instance, can use information on crash rates to identify the most at-risk counties and target them for low-cost safety improvements. Educational outreach focused on demographics most likely to be at fault in a crash will also be beneficial. Future studies should look beyond one- and two-vehicle crashes and take a closer look at the geometric and environmental conditions at crash locations.

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Sloped and Mitered Concrete Headwalls

The Challenge

The Kentucky Transportation Cabinet (KYTC) uses several pipe culvert end treatments, including standard headwalls, sloped and flared headwalls, sloped and parallel headwalls, and safety metal ends. Portions of headwalls which project above the ground and locations where the embankment wraps around the headwall present a safety hazard to motorists and mowing crews. From 2012 through 2016 in Kentucky 49 fatalities and 148 incapacitating injuries occurred in incidents involving culverts or headwalls. Although sloped and mitered concrete headwalls can mitigate safety hazards, KYTC lacked a standard drawing for this end treatment. KTC researchers were asked to evaluate the viability of sloped and mitered concrete headwalls for widespread use.



Building Solutions

KTC reviewed industry guidance and previous research on sloped and mitered concrete headwalls, and surveyed state DOTs for information and details on construction specifications. They examined several projects on which sloped and mitered concrete headwalls were installed, and selected two other Highway Safety Improvement Plan (HSIP) projects to compare the unit bid costs of conventional headwalls to sloped and mitered concrete headwalls.

Research Project

Sloped and Mitered Concrete Headwalls
Report #
KTC-18-12/SPR17-537-1F

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Study Timeline

Completed 2020

Finding Solutions

Of the six agencies that responded to the survey, only the Oregon DOT uses sloped and mitered concrete headwalls. KTC's analysis of projects using sloped and mitered concrete headwalls confirmed the importance of establishing solid design and construction criteria, particularly in standard details. Sloped and mitered concrete headwalls are cast in place to match the embankment slope, eliminating the need to warp the embankment around the drainage end treatment. Installation can be done without special equipment, and a traversable grate can be installed when required.

Recommendations

Given their robust performance and low cost compared to standard pipe culvert headwalls, ample justification exists for expanded use of sloped and mitered concrete headwalls in Kentucky. To improve the durability of installations, it is important to establish the grade before installation, add grate bars, secure pipe ends to the headwall, and identify select headwalls for long-term monitoring.

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Identification of Bridges with Fracture-Prone Details

The Challenge

Of the 1,100 steel bridges the Kentucky Transportation Cabinet (KYTC) maintains, several make use of steel girders with weld details that, once exposed to service stresses, are prone to constraint-induced fractures (CIFs). Once a crack initiates, a brittle fracture can develop and severely damage or sever parts of the girders, undermining structural integrity. Recognizing this issue, the FHWA advises transportation agencies to evaluate steel bridges for problematic weld details. As major girder fractures have occurred on bridges in Kentucky, the Cabinet asked KTC researchers to evaluate welded girder bridges across the state.



Building Solutions

KTC reviewed KYTC's bridge inventory, identifying a list of 345 candidate bridges for inspection. Researchers evaluated these structures by searching for pictures and plans in BrM files and conducting site evaluations for bridges lacking BrM data. Based on this work, KTC found 45 bridges that have potentially problematic CIF details and another 55 steel span bridges labeled in BrM as being of a different material type, warranting up-close inspection. KTC also reviewed industry best practices to establish retrofit and mitigation methods for fracture-prone weld details.

Research Project

Identification of Bridges with Fracture-Prone Details

Report #
KTC-19-35/SPR18-553-1F

Research Team

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Research Engineer

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Sudhir Palle, P.E.
Research Engineer

KYTC Contributors:
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Joshua Rogers,
Ryan Cram, &
Erin Van Zee

Study Timeline

Completed 2020

Finding Solutions

Researchers developed arm's length inspection criteria which KYTC inspectors can use to determine whether the 55 steel span bridges have CIF details and if they are problematic enough to require repairs. Inspection criteria call for measuring the spacing between attachment welds and, if the measurement is below a critical value, the bridge is categorized as being a potential source of CIFs. Additionally, KTC devised a prioritization method for bridges, including specifics about fatigue and fracturing along with the recommended retrofit or mitigation action.

Recommendations

While girder fractures have not triggered a bridge collapse in the US, repairing CIFs is expensive and usually requires taking major travel routes out of service for extended periods. KTC recommended that the Cabinet continue with its inspection program targeting all bridges identified with CIF details. Doing so will help KYTC select correct mitigation actions and properly maintain their bridge inventory.

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Issues Pertaining to Rebuilt Vehicle Titles

The Challenge

Kentucky issues salvage titles when a vehicle has been wrecked, destroyed, or damaged and repair costs exceed 75 percent of the vehicle's fair market value. Before a salvage title is issued, repaired vehicles must be inspected to verify roadworthiness and confirm they have not been stolen. The Kentucky Transportation Cabinet's (KYTC) Division of Motor Vehicle Licensing (DMVL) has expressed uncertainty over whether inspections are rigorous enough to detect stolen vehicles and ensure rebuilt vehicles are safe. To address these concerns, the Cabinet asked KTC to evaluate its rebuilt titling process, update current practices, and review the salvage titling practices of other transportation agencies.

Building Solutions

Researchers administered a survey to transportation agencies in all U.S. states, as well as Canadian provinces and territories, requesting information on practices and regulations related to salvage title processes. KTC also carried out a detailed review of salvage title processes in Ohio and performed an in-depth economic analysis of rebuilt titles in Kentucky to document the cost of salvage and rebuilt vehicles.

Research Project

Issues Pertaining to Rebuilt Vehicle Titles
Report #
KTC-19-19/SPR17-535-1F

Research Team

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Research Associate

Andrew Martin, Ph.D.
Research Scientist

Jennifer Walton, P.E.
Program Manager

Study Timeline

Completed 2020

Findings



Ohio has an extremely robust inspection program and offers lessons Kentucky may follow. Several other states also have concerns about Kentucky's red titles and do not accept them. Ohio inspectors have identified multiple stolen vehicles that were titled in Kentucky. Economic analysis found that in 2018 the median cost of rebuilt vehicles in Kentucky was \$1,785 and the median price of salvage vehicles was \$3,136. Most salvage and rebuilt title vehicles are issued in south-central Kentucky. Statewide, the number of these red titles increased by 31 percent from 2014 to 2018.

Recommendations

In 2018, rebuilt and salvage titles had an economic impact of \$331 million in Kentucky. To improve its rebuilt and salvage title process and ensure that only safe vehicles from legitimate suppliers are issued titles, KYTC could benefit from implementing a program that mirrors Ohio's with respect to technology, workflows, and inspection costs. Updating the process will require amending statutes and administrative regulations, adopting inspection software, and integrating a law enforcement component.

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A night photograph of a multi-lane road intersection. The scene is filled with long, colorful light streaks from moving vehicles, creating a sense of motion. Several traffic lights are visible, some showing red and others showing green or yellow arrows. The overall atmosphere is dark and dynamic.

KTC 2019 Research Briefs



Using In-Place Lateral Pull Off Tests to Determine the Compressive Strength of Structural Concrete

The Challenge

Historically, the Kentucky Transportation Cabinet (KYTC) used two methods to assess the compressive strength of structural concrete. Both methods required that samples be delivered to an off-site facility for testing and analysis, delaying project work. While areas from which sample cores are extracted are repaired, patching can impact the area's structural integrity. To solve these problems, the Cabinet asked KTC researchers to identify an onsite testing method that inflicts minimal damage on structural concrete.



Building Solutions

KTC researchers selected the lateral pull off test to evaluate the compressive strength of structural concrete, as it can be carried out in the field and requires minimal patch work. To evaluate the lateral pull off test, KTC carried out laboratory testing on newly poured concrete slabs and performed in-situ testing at bridges being readied for demolition.

Research Project

Using In-Place Lateral Pull Off Tests to Determine the Compressive Strength of Structural Concrete

Report #
KTC-19-01/SPR17-541-1F

Principal Investigators

Charlie Sun

Study Timeline

Completed 2019

Findings

The lateral pull off test proved to be an accurate, non-destructive, and reliable procedure. Measurements of average strength obtained from compressive strength of cylinder tests and lateral pull off tests were nominal (approximately 2.5 percent) and therefore not practically significant. It is a sensible option if concrete in the one-inch cover layer is representative of the interior concrete, the concrete grading is judged good, and maximum aggregate size does not exceed 1.25 inches. Concrete structures may be tested more often than would be possible using cores alone.

Recommendations

KYTC should consider widespread implementation of the lateral pull off test – it generates results quickly, increasing the efficiency of project delivery. The Center's researchers transferred testing equipment to the Cabinet and recommended pursuing additional test demonstrations and pilot projects to put the research into practice.

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Deterioration Modelling of Bridges on BrM 5.2.3

The Challenge

A prerequisite for sound decision making on issues related to bridge maintenance, rehabilitation, and replacement is the application of deterioration and cost models. The purpose of these models is to use data on bridge elements, a structure's age and condition, and traffic volumes to forecast future trends in condition and service. The Kentucky Transportation Cabinet (KYTC) relies on AASHTOWare Bridge Management software (BrM) to aid in understanding the future performance of structures. The agency asked KTC researchers to facilitate the transition to BrM v. 5.2.3 and adapt its deterioration and cost modelling features in accordance with the Cabinet's specifications.



Building Solutions

As part of an earlier study, KTC researchers conducted an exhaustive literature search to identify the latest and most accurate techniques for analyzing element-level condition ratings and to pinpoint mathematical methods that could be applied to KYTC bridge and culvert element data. By exploring BrM 5.2.3, the research team studied available deterioration and cost modelling options and refined them to meet the Cabinet's maintenance requirements. Once the options had been adapted to KYTC's specifications, results were validated through statistical analysis.

Research Project

Deterioration Modelling of Bridges on BrM 5.2.3
Report #
KTC-19-02/SPR17-532-1F

Principal Investigators

Sudhir Palle
Ted Hopwood

Study Timeline

Completed 2019

Findings

Researchers honed modelling strategies to forecast bridge and culvert element condition and performance. When combined with guidance on condition-based preventive maintenance and rehabilitation, structures in need of corrective actions may be identified. Validation remains an ongoing effort due to a lack of available data required to undertake element-level modeling.



Recommendations

BrM 5.2.3 is a robust option for predicting the future performance and service capabilities of bridges and culverts. Model calibration and validation should be a priority for KYTC as additional element-level data (from both Kentucky and other states) becomes available. Doing so will enhance model performance and improve reliability.

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AID Project Summary for Intelligent Compaction

The Challenge

Intelligent Compaction (IC) is an eConstruction technology used to ensure road-building materials are compacted to an optimal, uniform density. In 2014, the Kentucky Transportation Cabinet (KYTC) received an AID Demonstration Project from the FHWA to implement IC on several Federal-aid construction projects. To facilitate application of IC technologies on these projects, the Cabinet developed a special construction note that contractors were required to follow. KYTC asked researchers at KTC to gather contractor feedback and evaluate IC data from these projects to verify that contractors had complied with specifications outlined in the special construction note.



Building Solutions

The Cabinet adopted IC on five projects - four mill-and-fill projects and one widening project. Researchers began with an evaluation of each dataset to determine which were suitable for assessment in Veta, which is software used to analyze geospatial data from IC-enabled machines. Analysis in Veta leveraged linear regression to understand relationships between asphalt density and Intelligent Compaction Measurement Values (ICMVs). Supplemental analysis was conducted in ArcGIS. To understand contractor perspectives, KTC researchers conducted structured interviews with staff from firms involved in the five projects.

Research Project

AID Project Summary for Intelligent Compaction
Report #
KTC-19-03/SPR16-523-1F

Principal Investigators

David Hunsucker
Kean Ashurst, Jr.
Brad Rister

Study Timeline

Completed 2019

Findings

Eight datasets across the five projects were analyzed. Researchers found that three datasets reflected acceptable target pass count coverage but did not attain minimum acceptable coverage for the ICMV. Three datasets achieved the minimum threshold coverage for ICMV but did not hit target pass counts. The other two datasets failed on both metrics. Regression analysis failed to uncover statistically meaningful relationships between density and ICMVs. And while contractors found real-time data on pass count, coverage, and mat temperature useful, they observed inconsistencies with ICMVs, commented on the slowness of uploading IC data, and remarked that due to the expense of IC rollers their adoption must be incentivized.

Recommendations

KTC issued nine recommendations designed to improve future evaluations of IC data. They addressed issues such as data collection and storage practices, established target pass counts and target thicknesses, software usage, the availability of contractor work plans, and contractor practices in the field.

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RESEARCH NOTE

April 2020

Rapid Retrofit and Strengthening of Bridge Components

The Challenge

As evidenced by the American Society of Civil Engineer's Infrastructure Report Card, key infrastructure assets in the United States are in a state of deterioration or disrepair. Of the country's more than 600,000 bridges, 9 percent are structurally deficient and 40 percent are at least 50 years old. With limited funding to invest in the repair or replacement of existing bridges, state transportation agencies need judicious, economical strategies to extend the service lives of bridges. Over the past decade, KTC researchers have pioneered new approaches to rapidly strengthen bridges through the development and implementation of carbon fiber reinforced polymers (CFRPs).

Building Solutions

Researchers have developed, produced, and implemented the CatStrong family of products to address challenging bridge repairs throughout Kentucky. Included among these products are:

- CatStrong CRP (CFRP Rod Panel),
- CatStrong UCF (Unidirectional Carbon Fabric) and TCF (Triaxial Carbon Fabric), and
- CatStrong TCW (Triaxial Carbon Wrap).

Because these materials can be applied with limited work crews, their adoption reduces labor needs and expedites repair and strengthening operations. Six retrofit projects were carried out using CatStrong products. Three projects involved the use of CatStrong CRPs to strengthen reinforced concrete girder bridges, two projects deployed CatStrong UCF and TCF to strengthen cracked prestressed concrete girder ends and a cracked bridge pier cap, while the final project focused on the use of CatStrong TCW and TCF to repair and strengthen deteriorating timber piles.

Research Project

Rapid Retrofit and Strengthening of Bridge Components
Report #
KTC-19-07/SPR13-465-1F

Principal Investigators

Abheetha Peiris
Issam E. Harik

Study Timeline

Completed 2019

CatStrong In Action



During all repair and retrofit activities, KTC researchers were on hand to instruct Kentucky Transportation Cabinet bridge maintenance crews on the proper installation of CatStrong products and to provide any necessary guidance. Researchers have also prepared

a CatStrong Design Guide, which includes worked examples of design problems, as well as detailed construction specifications and write-ups on application techniques.

Moving Forward

CatStrong materials offer a reliable, proven method for repairing and strengthening bridge components. Used at an early enough stage, they can help prevent bridges from suffering irreversible damage and therefore greatly reduce maintenance costs while extending service lives. The CatStrong family of products can play an integral role in restoring and preserving valuable infrastructure assets.

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Developing Material Specification and Application Criteria for Sealing Concrete Bridge Decks

The Challenge

In an effort to extend bridge service lives, the Kentucky Transportation Cabinet (KYTC) has aggressively built a robust preventive maintenance program. Numerous activities fall under the heading of preventive maintenance: cleaning drainage systems and bridge decks, minor deck patches and repairs, lubricating bearings, painting steel, and sealing concrete, among others. KTC's researchers have been instrumental in shaping the Cabinet's preventive maintenance program for bridges by providing guidance and technical expertise. For this project, KYTC approached researchers to develop material specifications and application criteria for sealing concrete bridge decks.



Building Solutions

To craft material specifications and application criteria, researchers surveyed other state transportation agencies to document their guidelines, reviewed the most up-to-date literature, interviewed bridge deck sealer manufacturers for their input and recommendations, investigated factors which affect the sealing process, and established deck inspection criteria. Findings were synthesized to develop recommended best practices.

Research Project

Developing Material Specification and Application Criteria for Sealing Concrete Bridge Decks
Report #
KTC-19-09/SPR19-56-5-1F

Principal Investigators

Danny Wells
Sudhir Palle
Ted Hopwood

Study Timeline

Completed 2019

Findings

Ten agencies responded to KTC's survey with details on performance testing methods and application criteria. These, combined with the literature review, were used to characterize topical and penetrating sealers and specify the conditions under which the use of each sealer is appropriate. When selecting a sealer, transportation agencies need to take several factors into consideration: average daily traffic (ADT), exposure to deicing materials, the age of a bridge deck, whether overlays and/or cracks are present, concrete mix design, chloride content, type of reinforcing steel, and National Bridge Inventory (NBI) ratings.

Recommendations

The research team advanced several recommendations KYTC can adopt to improve concrete sealing:

- Apply penetrating sealers to all new concrete decks once they have cured for at least 28 days.
- Crack sealers are the best choice if large cracks are present, whereas monomer epoxies and other low viscosity healer/sealers offer the best performance for addressing shrinkage cracks.
- Apply sealers to decks with an NBI condition rating of 6 or higher at five-year intervals.
- Sealing decks with high chloride concentrations yields few benefits. Sealer application may proceed if chloride levels at bar depth have not reached the threshold for corrosion.
- When applying silane, maintain sufficiently high application rates to ensure 11 to 12 grams of silane per square foot.

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RESEARCH NOTE

April 2020

Redefining Construction As-Built Plans to Meet Current Kentucky Transportation Cabinet Needs

The Challenge

Despite their importance to planning maintenance work and designing new projects, the Kentucky Transportation Cabinet (KYTC) has relaxed its emphasis on developing timely and accurate as-built plans. As-built plans contain abundant information on transportation infrastructure and facilities such as above-ground and belowground utilities. How as-built plans are developed varies between KYTC Section Offices, and their preparation has also been hindered by a lack of resources. Recognizing the need for change, the Cabinet asked KTC researchers to submit recommendations for strengthening its process of creating as-built plans.



Building Solutions

Researchers conducted structured interviews with KYTC's as-built plan developers and end users to understand how as-built plans are currently produced and the most pressing challenges. To document best practices used at other state transportation agencies, researchers examined publicly available manuals and guidance. They also reviewed as-built practices common in private industry. Recommendations were finalized during a facilitated workshop that brought together researchers and Cabinet staff.

Research Project

Redefining Construction As-Built Plans to Meet Current Kentucky Transportation Cabinet Needs
Report #
KTC-19-10/SPR18-555-1F

Research Team

Victoria Lasley
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Tim Taylor
Roy Sturgill

Study Timeline

Completed 2019

Findings

The consensus among KYTC interviewees was that the process for developing as-built plans is not attuned to the needs of end users. Their development is often ad hoc, while the latest technologies and survey methods are not used in a way to maximize their benefits. The research team identified several hurdles which impede the creation of as-built plans, including lack of guidance on development, limited time for production, changing technologies, and formatting difficulties. Combined with literature review findings, KTC came up with ideas for improving the as-built plan process.

Recommendations

Along with outlining step-by-step guidance for streamlining as-built plan development using existing methods and resources, KTC researchers advanced a series of recommendations for simplifying the overall process. Specifically, these proposals addressed topics such as developing guidelines which reflect the needs of end users, improving storage and retention practices, formulating a process to update as-built plans following maintenance work, and leveraging novel technologies in the office and field to accelerate the creation of as-built plans.

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E-Tickets and Advanced Technologies for Efficient Construction Inspections

The Challenge

To reduce paper-based workflows and improve onsite project monitoring, the Kentucky Transportation Cabinet (KYTC) is beginning to experiment with eConstruction technologies. A number of studies have found that these technologies increase construction efficiency and safety. To assess the effectiveness of eConstruction, the Cabinet asked KTC to study their use on two pilot projects.



Building Solutions

Researchers evaluated the performance of three e-construction technologies: e-ticketing, paver mounted thermal profilers, and intelligent compaction (IC). Through a combination of literature reviews and field data collection, KTC measured the performance of each technique, focusing on how they can facilitate inspection activities, including the collection of ticket information, monitoring pavement temperatures, and quantifying asphalt compaction.

Research Project

E-Tickets and Advanced Technologies for Efficient Construction Inspections
Report #
KTC-19-14/SPR18-554-1F

Research Team

Roy Sturgill
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Dhaivat Patel
Joshua Withrow
Clyde Newcomer

Study Timeline

Completed 2019

Findings

- E-ticketing increased operational efficiency, reduced the amount of time needed to retrieve material tickets, and let inspectors compare theoretical tonnages to actual tonnages, which helps verify that crews are paving according to specifications. Inspectors also reduced their exposure to hazardous jobsite conditions.
- The accuracy of Pave-IR temperature profiles was not significantly different from temperature data gathered using conventional infrared guns. Pave-IR can help field staff visualize the impacts of paver speeds and use of material transfer vehicles. Due to the expense of purchasing this equipment, it may not be a cost-effective option on smaller projects.
- IC rollers produced inaccurate data on asphalt temperature and roller passes. However, other transportation agencies have successfully adopted them. Several factors may explain this result, such as poor communication between project stakeholders and faulty equipment setup. IC equipment must also be able to access geospatial data, which may not be possible if projects occur in remote locations.

Recommendations

Each technology has considerable promise and could potentially be adopted on a more widespread basis. To determine its scalability and potential for future use, 14 upcoming KYTC projects are slated to use e-ticketing. For e-ticketing to be a viable option on future projects, it will be critical to train stakeholders on the technology, confirm that all trucks assigned to a project have GPS transponders, and ensure geofences are set up. Internet accessibility at asphalt plants must be consistent so that all interested parties can access data when needed.

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Reducing Construction Costs Through Effective Field Communication and Administration

The Challenge

Like many state transportation agencies, the Kentucky Transportation Cabinet's (KYTC) highway program suffers from underfunding. Knowing that bolstering operational efficiencies can help lower costs, the Cabinet has aggressively sought out new project delivery methods to achieve this goal. A recent focus has been on improving the administration of construction projects – which is especially challenging given turnover in staff and the loss of institutional knowledge. To achieve this objective, KYTC commissioned researchers at KTC to identify strategies for enhancing the quality of project administration, staff management, and field communication.



Building Solutions

The research team began with a review of literature on field communication practices, focusing on those which other state transportation agencies have found effective. Best practices were identified and catalogued. To understand how KYTC can improve project administration in the field, researchers spoke with several Cabinet stakeholders, asking them to comment on the attributes of successful and unsuccessful projects. Data gathered during the literature review and from interviews were used to develop new strategies.

Research Project

Reducing Construction Costs Through Effective Field Communication and Administration
Report #
KTC-19-13/SPR18-555-1F

Research Team

Gabe Dadi
Roy Sturgill
Steve Waddle
Doug Kreis

Study Timeline

Completed 2019

Findings

Over time, KYTC has gradually deemphasized the importance of field communication skills, due in part to insufficient staffing. As a result, project stakeholders, both those internal to the Cabinet and those outside of it, often experience dissatisfaction and frustration. Project communication can be improved by developing solutions which draw from principles of risk management, organizational behavior and management, and partnering. Researchers envisioned a Putting the Project First initiative to make programmatic changes at KYTC.

Recommendations

In addition to describing the short- and long-term goals of Putting the Project First, researchers proposed five methods for increasing the soundness of KYTC's project field administration:

- Hold progress meetings with inspection crews and contractors at regular, agreed-upon intervals.
- Develop an escalation ladder for decision-making authority based on project complexity and cost.
- To build construction expertise and foster a culture of mentorship, hold a training class for Section Engineers.
- Work closely with contractors to formulate shared project goals and objectives.
- Update Construction Management Academy modules to address topics such as construction conflicts and partnering.

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Determination of Constructed Pavement Layer Thicknesses Using Nondestructive Testing (NDT)

The Challenge

Conventional methods for testing pavement layer thickness involve extracting a core sample from a pavement section. They are time consuming and labor intensive; patching core holes may require additional maintenance to correct weak spots as pavement ages. Although Kentucky Transportation Cabinet (KYTC) specifications instruct taking cores at random locations, often this method does not accurately estimate the thickness profile of an entire pavement section. KYTC requested that KTC identify and evaluate practical alternatives to coring.



Building Solutions

Researchers reviewed literature and other states' best practices to find alternatives to coring. They identified two commercially available, nondestructive testing (NDT) methods that can quickly measure pavement thickness: MIT-Scan-T2 (T2) and Ground Penetrating Radar (GPR). Researchers evaluated the benefits and shortcomings of each technology with an eye toward providing KYTC with guidance for measuring pavement layer thickness in a manner that extends pavement service life.

Research Project

Determination of Constructed Pavement Layer Thicknesses Using Nondestructive Testing (NDT)
Report #
KTKC-19-05/SPR17-539-1F

Research Team

Brad Rister
Jamie Creech
Kean Ashurst, Jr.

Study Timeline

Completed 2019

Findings

Test results from 19 state transportation agencies found the T2 consistently measures pavement layer thickness to an accuracy of +/- 2 mm. If base material properties are similar to concrete, other NDT technologies may provide thickness readings less accurate than the T2. The T2 also works in all weather conditions and can store hundreds of thickness measurements. Measurements can be taken as soon as pavement can be walked on. While the cost of a single core can range between \$90 and \$110, one T2 scan measurement costs around \$20.

GPR emits electromagnetic radiation that may be affected by moisture and/or other electromagnetic frequencies, and it also requires a sample core to calibrate the equipment. To obtain the most accurate reading with GPR, pavement must cure for at least 28 days. Although the T2 requires placing metal plates before paving, it is the preferred option because no core sample is required.

Recommendations

Several factors influenced KTC's recommendation of the T2: ease of use (it can be operated by one person), the immediate availability of thickness measurements, and few operator requirements. Pavement thickness can be measured at a location in less than 3 minutes. Although GPR is less destructive than core sampling, equipment costs, data collection and processing requirements, and the need for core validation make it the less appealing option.

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Review of Non-Standard Warm Asphalt Mix Projects

The Challenge

Until the introduction of warm mix asphalt (WMA), most highway projects employed hot mix asphalt. WMA has several benefits – it is more environmentally friendly and has lower fuel costs. When the Kentucky Transportation Cabinet's (KYTC) Division of Construction receives requests to use non-standard WMA technologies, it may be asked to waive temperature or other product specifications. But the implications of these waivers are not well understood and no follow-up studies have evaluated the performance of non-standard WMA projects. The Cabinet approached KTC to compare quality assurance/quality control (QA/QC) data on standard and non-standard asphalt mixtures, identify mixtures used in Kentucky, and evaluate the performance of non-standard mixtures.



Building Solutions

Researchers evaluated the performance of standard and non-standard mixes at sites where different types of WMA had been used. A key focus was on the overheating of asphalt mixtures. Non-standard mixes are slightly overheated to ensure they remain pliable if transported long distances in cold weather. Researchers visually inspected study sites and collected pavement data from the Division of Maintenance Pavement Management System (PMS). For standard and non-standard mixes, researchers compared wheel path rutting, transverse cracking, longitudinal cracking, and the International Roughness Index (IRI), which evaluates ride quality.

Research Project

Review of Non-Standard Warm Asphalt Mix Projects

Report #
KTC-19-15/SPR17-537-1F

Research Team

Tim Scully

Study Timeline

Completed 2019

Findings

Reviews of IRI data found that using WMA does not affect ride quality. However, non-standard mixes can suffer more pronounced wheel rutting than standard asphalt mixes. After pavement reaches an age of 650 days, the pace of longitudinal cracking in non-standard mixes accelerates more rapidly than in standard mixes. Non-standard WMA exhibits more significant transverse cracking than its standard counterparts once it passes the age threshold of 1,200 days.

Recommendations

All KYTC districts have realized benefits from using WMA. Employing non-standard mixes can lengthen the paving season and allow for longer haul times. However, paving contractors may see an increase in costs due to the higher heat requirements of the mix. Another potential downside is that non-standard mixes may become distressed more quickly than standard mixes.

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Bridge Load Testing Versus Bridge Load Rating

The Challenge

AASHTO's method of load rating bridges can underestimate bridge behavior and often produces a result that resembles the capacity of non-composite bridges. The calculations used do not account for the rigidity of supports or the effects of friction between girders and the slab. Alternative methods of load testing require considerable time and labor to instrument a bridge and collect data. However, commercially available strain gauges can reduce the time required to instrument a bridge. At the Kentucky Transportation Cabinet's (KYTC) request, KTC compared the performance of two strain gauges – the magnetic Sensormate QE-1010 and the reusable BDI ST350 – and determined if their use reduced the time needed to load test a bridge.



Building Solutions

Researchers focused on the efficiency of gauge installation and gauge data collection. Both strain gauges were initially evaluated in the laboratory under flexural load and their readings compared to readings obtained from traditional foil-type strain gauges. Two bridges were selected for field load testing: the KY 1068 bridge in Lewis County and the KY 220 bridge in Hardin County. Both gauge types had wireless data transmission capabilities.

Research Project

Bridge Load Testing Versus Bridge Load Rating

Report #
KTC-19-16/SPR06-423-1F

Research Team

Abeetha Peiris
Issam Harik

Study Timeline

Completed 2019

Findings

Data acquisition was made easier by the wireless data transmission capability of both systems, which significantly reduced the amount of wiring typically associated with strain gauges. Although the magnetic Sensormate QE-1010 performed well in the field and reduced installation time, at higher strains the gauges slipped. The reusable BDI ST350 strain gauge balanced rugged performance with short installation times. Field load tests revealed the load rating factor for strength was adequate for the KY 220 bridge in Hardin County, while the load rating for the KY 1068 bridge in Lewis County could be increased by 68%.

Recommendations

With low-cost, wireless, non-contact sensing technology now available, evaluating bridge load ratings in the field can be done quickly and efficiently. BDI strain gauges coupled with wireless transmitters can describe bridge behavior, highlight unintended factors that may increase load ratings, and diagnose structural deficiencies. For bridges with characteristics such as unintended composite action or end fixity, implementing this method would increase the feasibility of load testing bridges, leading to a more favorable load rating. Due to the rugged conditions often encountered in the field, magnetic strain gauges should not be considered for future use.

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RESEARCH NOTE

Edge Drain Performance

April 2020

The Challenge

Edge drain systems remove water that infiltrates the pavement block. In doing so, they reduce moisture in the pavement block and subgrade. Maintaining dry conditions in and around these components increases subgrade strength and extends pavement surface life. But edge drains are only effective if the entire subsurface drainage system functions properly. Although the Kentucky Transportation Cabinet (KYTC) has revised specifications for run length, drain geometry, materials, and the use of drainage blankets, no comprehensive evaluation of edge drain system performance has been done in over 20 years. KYTC staff have recently voiced concerns about the long-term performance of edge drains and their construction and maintenance issues. After identifying problems with an edge drainage system on Interstate 275 in Kenton County, the Cabinet asked KTC to evaluate the performance of edge drains on road segments slated for resurfacing.

Building Solutions

Researchers first revisited its previous studies of edge drain systems to identify factors that compromise their effectiveness. KTC's initial inspections of edge drains in Kenton County revealed that 26 of the 32 headwalls were so blocked or overgrown with vegetation that the perforated edge drain could not be inspected. Furthermore, 65 of the 72 edge drains that outlet to a catch basin insert (CBI) or ditch bottom inlet (DBI) were blocked or crushed. After initial work, researchers selected 10 road segments to evaluate the following edge drain system features: headwall, outfall waterway, outlet waterway, outlet pipe, rodent screen, and perforated pipe – an estimated 60,000 linear feet of edge drain.



Research Project

Edge Drain Performance
Report #
KTC-19-21/SPR18-557-1F

Research Team

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Study Timeline

Completed 2019

Findings

All of the 126 edge drain systems KTC inspected were in good condition and free of structural issues. Researchers classified systems as good, compromised, or undetermined (if conditions prevented a full inspection) and identified a probable failure mode. Key findings include:

- 29% of outfall waterways prevented water flow from the headwall
- 65% of outlet waterways were at least partially obstructed by gravel, mud, silt, or other debris
- 61% of the outlet pipes were blocked
- Of the 110 edge drain systems draining to catch basin inserts or ditch bottom inlets, 97% had clear outfall waterways, but just 14% of the edge drains were unobstructed.

Recommendations

KTC studies in the 1990s found that 42% of the problems associated with edge drain performance were maintenance related. In this study, researchers attributed 75% of the problems to maintenance. The remainder were the product of construction activities. To preserve edge drains in a functional condition, KYTC should conduct post-installation inspections and consider alternative methods to outlet water, such as a dry well. Additionally, KYTC would benefit from annual inspections, cleaning headwalls and outlet pipes each year, and limiting the use of T-Junctions.

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Evaluation of Guardrail Needs and Update of Guardrail Rating Program

The Challenge

Roadway departure crashes can severely injure or kill motorists. The Kentucky Transportation Cabinet (KYTC) attempts to mitigate roadside departure crashes by installing roadside barriers such as guardrail. KYTC's Division of Maintenance is responsible for prioritizing guardrail installations based on available funding and safety concerns. The Cabinet established its guardrail rating program (GRP) in 1989 to identify and prioritize guardrail needs. Despite periodic updates, the existing program no longer conforms with the transportation industry's safety guidelines and policies. KTC, at the Cabinet's request, studied national and state guardrail best practices and developed a new methodology for prioritizing guardrail installations.

Building Solutions



KTC reviewed AASHTO's Roadside Design Guide, the Manual for Assessing Safety Hardware, and the Highway Safety Manual for guardrail-related material. Researchers also did high-level reviews of guardrail programs at 23 state transportation agencies, eventually identifying two states whose efforts are most salient to KYTC's program – California and Virginia. After KTC evaluated all 32 rating elements of the existing GRP, they worked with KYTC to decide if each rating elements would be modified, removed, or remain unchanged. After assigning scoring attributes to each rating element, four guardrail prioritization models were developed and tested.

Research Project

Evaluation of Guardrail Needs and Update of Guardrail Rating Program
Report #
KTC-19-28/SPR19-577-1F

Research Team

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Study Timeline

Completed 2019

Findings

The selected GRP model focuses on two main factors: crash frequency and crash severity, with the goal of maximizing safety outcomes for roadway departure crashes. The new model removes annual average daily traffic (AADT) and shoulder width and assigns more weight to clear zone and crash characteristics. Although the new model is not significantly different from the previous one, it produced different rankings. For example, 23 of the guardrail sites ranked under the old program as being high-need fell in the rankings.

Recommendations

KTC and the KYTC research advisory committee suggest:

- Adopt the new GRP model methodology to rank prospective guardrail projects
- Prove KYTC personnel and district offices with the revised guardrail survey form so they can collect necessary data
- Provide information and training sessions to KYTC personnel that describes the rationale for the new model and its implementation
- Update the GRP online application and back-end IT architecture to match the new model's data collection and processing requirements

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Critical Path for Project Development

The Challenge

Delivering a highway design project at the Kentucky Transportation Cabinet (KYTC) presents a set of unique and complex challenges as it requires the skillful coordination and management of resources. Although project managers typically estimate critical milestone dates and project hours when a project begins, a detailed schedule is not usually available until a design consultant is selected. KYTC is currently exploring whether it should require consultants to develop critical path method (CPM) schedules for all projects. To aid KYTC, the Center developed a methodology for producing CPMs and created high-level CPM templates that are representative of the Cabinet's project delivery process.



Building Solutions

Researchers looked at academic literature on CPM, finding that despite it gaining popularity in many arenas the transportation industry has not fully embraced it. The content and quality of CPM trainings remain inconsistent because standardized curricula have not been widely developed. To develop CPMs for the Cabinet, KTC met with KYTC subject-matter experts, who assisted with developing work-breakdown units, templates, and Gantt charts for three project contexts: 1) Rural Federal Bridge Replacement (Categorical Exclusion I), 2) Urban Federal Bridge Replacement (Categorical Exclusion I), and 3) 4-Mile Rural Road Widening into Urban Intersection (Environmental Assessment, Finding of No Significant Impact).

Research Project

Critical Path for Project Development
Report #
KTC-19-22/SPR17-547-1F

Research Team

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Candice Wallace
Rachel Catchings
Sarah McCormack

Study Timeline

Completed 2019

Findings

Researchers developed workflows and flow charts for each project context. Project descriptions discuss underlying assumptions related to environmental issues, right of way, utilities, and railroads. An in-depth glossary explains work-breakdown units and highlights issues that merit close attention during project development. For the CPM tool to be effective throughout a project, project managers and consultants must update schedules regularly and revise original timelines and Gantt charts when events occur that result in adjustments to the project schedule.

Recommendations

With the CPM tool, KYTC's project managers can more effectively oversee the limited resources needed to deliver projects quickly and efficiently. Having access to the project contexts and glossary will help project managers and consultants work in a more organized manner and respond to unexpected contingencies or risk events. Future efforts should focus on project time management training and creating CPM schedules for additional project contexts. A CPM training will equip KYTC project managers with the requisite knowledge and tools to apply CPM on actual projects.

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Waterproofing Options for Bridge Decks

The Challenge

The increased use of deicing chemicals on bridges and roadways introduces unacceptable levels of chlorides into the underlying concrete of bridge decks, resulting in shorter service lives and increased maintenance needs. The Kentucky Transportation Cabinet (KYTC) asked researchers at the Kentucky Transportation Center (KTC) to assist with identifying waterproofing materials and methods that could help bridge decks better resist the effects of traffic-induced moisture. The purpose of this study was to find waterproofing products and application techniques that KYTC can eventually implement in new construction and maintenance projects.



Building Solutions

To identify materials for further testing, the research team reviewed four groups of waterproofing products: 1) liquid membranes, 2) sheet membranes, 3) friction polymers (laminates), and 4) polymer asphalts. Manufacturer data and a literature review did not offer information on permeability testing or provide a common waterproofing test method. In response, KTC developed a single waterproofing test to compare the performance of the available products. The testing focused on the permeability and absorption characteristics of treated concrete specimens.

Research Project

Waterproofing Options for Bridge Decks
Report #
KTC-19-39/SPR17-531-1F

Research Team

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Danny Wells

Study Timeline

Completed 2019

Findings

Prior to this study, no common test had been established to compare the performance of waterproofing products. The new test method closely follows ASTM D5084, "Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter." The method is a good comparative test of waterproofing capabilities, however, it should be further refined for use in material qualification trials.

Recommendations

Each of the waterproofing products requires a different application technique – some can be maintained over the life of a bridge with periodic renewal, while others can be replaced easily with minimal impact to the travelling public. Some must be applied by state forces, while others must be applied by contractors using specialized equipment. To find the most appropriate waterproofing material for use on bridge decks, KTC recommends expanding the new test method to qualify materials for inclusion in the KYTC Approved Product List. Candidate materials should be subjected to field testing through the implementation and monitoring of pilot projects. KTC should support these projects and conduct training on how to perform the testing.

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KTC 2018 Research Briefs



Streamlined Project Closeout for Construction at KYTC

The Challenge

Project closeout is the period of time between the end of construction and when a contract is finalized. During closeout, resources that could often be used for other highway improvements are held in encumbered funds intended for the project and in the contractor's bonding capacity. The Kentucky Transportation Cabinet (KYTC) and its contractors have expressed concern about the prolonged duration of project closeouts. Although KYTC's goal is to close out projects within 240 days, in 2016 the average duration of project closeout was 366 days. KYTC's closeout goal is currently longer than several other DOTs, which suggests the process warrants improvement.

The Kentucky Transportation Center (KTC) identified strategies and put forth recommendations to help the Cabinet streamline its project closeout process. To find methods of improving KYTC's practices, researchers analyzed KYTC's project closeout process, conducted interviews with stakeholders, studied the best practices of other state transportation agencies (STAs), and examined principles derived from lean construction, Six Sigma, and Civil Integrated Management (CIM).

Personnel often do not realize that additional documentation is needed until the project closeout stage, which can significantly impact the project closeout process.



Research Project

KTC-17-08/SPR14-492-1F
Streamlined Project
Closeout for Construction
at KYTC

Principal Investigator

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Program Manager

Contributors

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Research Scientist
Sudhir Palle, P.E. Research
Engineer

Study Timeline

Completed 2018

The Outcome

As a first step of reforming project closeout, the Cabinet should investigate ways to improve the preparation of final documentation and reduce the amount of time allocated for development and completion of the materials check.

Researchers noted steps that caused the process to lag and recommended new practices to accelerate and streamline project closeout:

- Establish a KYTC task force to conduct high-level analysis of the project closeout process
- Develop an incentive program to encourage more timely project closeouts
- Revise project closeout checklists from the Section Engineer's Manual to standardize the process and to retain only the necessary steps
- Create more specific, detailed checklists for Central Offices, the districts, and key project personnel
- Review and modify the KYTC's current duration goal(s) for closing out projects
- Optimize project closeout processes at the district level to help personnel adopt best practices

Researchers attempted to align other state's best practices—Virginia (VDOT) in particular—with KYTC's current process. This task was vetted through a presentation with the study advisory panel.

As KYTC standardizes methods for streamlining project closeout, they should be implemented by KYTC personnel, as this increases the likelihood of staff buy-in across the agency.

Why It Matters

The greatest time savings can be derived from improving work in the Resident Engineer's Office, which includes tasks from the completion of corrective work to the resident final check.

KYTC currently uses SiteManger LIMS to conduct materials management, which can be difficult to access at the job site. Investigating this system's effectiveness and its role in the preparation and completion of the materials check could result in significant time savings.

Releasing funds encumbered by projects that have been completed but not yet finalized should be a common goal of KYTC leadership, field personnel, and contractors given that those funds could potentially be used to resurface approximately 2,000 to 7,000 total lane miles.

E-construction, a best practice used across DOTs, could automate steps of the project closeout process. KYTC is in the process of adopting aspects of e-Construction and is investigating electronic ticketing.

Photo Caption: E-construction offers the following benefits: reduces delays in checking documents, stores weigh tickets in a single database, and centralizes record-keeping within tightly controlled and monitored databases.



E-construction offers the following benefits: reduces delays in checking documents, stores weigh tickets in a single database, and centralizes record-keeping within tightly controlled and monitored databases.

The Impacts

Comparable initiatives undertaken at other STAs to improve project closeout have resulted in savings of up to 25 staff workdays per year.

VDOT's closeout process takes 90 days from acceptance to contract completion, thus KTC researchers felt it prudent to compare their practices to KYTC's. They found the greatest opportunity for improving the closeout process at the district level.

VDOT's quick project closeout is likely a result of providing more explicit steps and details in its project closeout manual, and including checklists for Project Inspector, Construction Manager, Area Construction Engineer, and District Contract Manager.



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CFRP Strengthening of KY 583 Over the Bluegrass Parkway Bridge in Hardin County

The Challenge

The KY 583 Bridge over Bluegrass Parkway in Hardin County, Kentucky required retrofit measures after cracks developed along the vertical and bottom faces of the reinforced concrete beams. Cracks were found on all four beams in one span, the longest of which were nearly 12 feet long and extended across the vertical face longitudinally. The cracks eventually led to concrete delamination and spalling of concrete over the left lane of eastbound Bluegrass Parkway.

The KY 583 Bridge across the Bluegrass Parkway in Hardin County, Kentucky, is a four-span reinforced concrete deck girder (RCDG) bridge. The bridge is 33 feet wide and 230 feet long, with two 14-foot parkway lanes beneath.



Research Project

PCFRP Strengthening of KY 583 Over the Bluegrass Parkway Bridge in Hardin County
KTC-17-19/KHIT88-06-1F

Principal Investigator

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Program Manager

Issam E. Harik, Ph.D.
Professor of Civil
Engineering

Study Timeline

Completed 2018

The Outcome

KTC selected braided triaxial carbon fiber reinforced polymer (CFRP) fabric sheets for the bridge retrofit. The material is one of the CatStrong family of products – flexible, strong, and lightweight CFRP rod panels, fabrics, and wraps used to repair deficient bridges. The products were developed by a joint team of researchers from KTC's Structures Program and the Department of Civil Engineering at the University of Kentucky.

All four cracked beams were wrapped in CFRP fabric, perpendicular to the longitudinal direction of the beam. For best results, the fabric extended a minimum of 6" beyond the end of the repaired region. The retrofit work included the following steps:

- Spalling and loose, deteriorated concrete was removed, which exposed corroded rebars.
- The rebars were cleaned and coated with a zinc primer, and new formwork built around the damaged area.
- A bonding agent was applied to facilitate bonding between the old concrete and repair mortar.
- After sandblasting the repair area, a triaxial CFRP fabric was applied using a high-strength, two-part saturating epoxy.
- After the epoxy cured, a UV protective coating was applied to the outside and bottom faces of the outer beams on either side of the span.
- The Kentucky Transportation Center (KTC) monitored crack movement during the design and planning of the retrofit and for three years beyond the initial repair work.

Why It Matters

The repair work was performed in eight days over a four-week period, including a two-week interval between the application of the rapid-set repair mortar and CFRP material. This retrofit method saved time and minimized traffic disruptions, compared to bridge repairs that require significant concrete work or that involve replacing the entire beam.

Cracks will accelerate the corrosion of reinforcing steel and the deterioration of concrete, eventually leading to loss of bridge serviceability. Thus, the goal of this retrofit was to prevent further crack propagation in the concrete girders.

The repair material was chosen for its fiber orientation that resists 12,000 pounds of force per foot in both the vertical and horizontal plane of the fabric.

The Impacts

The repair work was completed in May of 2014, and the bridge was monitored over a three-year period. A May 2017 inspection revealed no defects in the CFRP fabric in the retrofitted beams. In November 2015, inspectors found an additional crack location away from the first retrofit location. This was retrofitted in a similar manner by the KYTC District 4 bridge crew.



CatStrong products are designed for faster and more efficient application, reducing labor hours and equipment costs that are typically necessary for bridge maintenance projects.



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In-Place Recycling and Reclamation of Asphaltic Concrete Pavements in Kentucky

The Challenge

Full Depth Reclamation (FDR) is a process that rebuilds worn out asphalt pavements by recycling the existing roadway. In this pavement rehabilitation technique, the full thickness of a flexible pavement section and a predetermined portion of the underlying materials are uniformly crushed, pulverized or blended. Pulverization of pavement and underlying road base create a uniform, stabilized base course.



A second preservation technique, in-place pavement recycling, takes the degraded top layer of pavement and restores the roadway to an even surface. Both methods require a new hot mix asphalt (HMA) layer over the stabilized layer, followed by shaping and compaction.



asphalt (HMA) overlay, in-place recycling and reclamation of asphalt pavements is rarely practiced in Kentucky and is not a well-defined process. It is widely known that when pavement sections become too deteriorated, in-place recycling and FDR preservation techniques do not produce good results.

KTC researchers evaluated the potential for implementing in-place asphalt pavement recycling and full depth reclamation on low- to medium-volume roadways throughout Kentucky.

Research Project

In-Place Recycling and Reclamation of Asphaltic Concrete Pavements in Kentucky

Principal Investigators

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Senior Research Engineer

R. Clark Graves
Associate Director

KYTC Contributors

Joe Tucker

Study Timeline

Completed 2018

The Outcome

KTC studied existing literature to answer the following questions:

1. When is HMA reclamation and in-place recycling a viable option?
2. What structural credit should be given to the stabilized layer?
3. What is the optimal modulus/strength to require for the stabilized layer?

KYTC's Pavement Management Group provided KTC with performance data and design information for past pavement projects that used any method of FDR or in-place recycling.

KTC forensically investigated two full-depth reclamation projects to determine the in situ strength of the reclaimed asphalt mixture used in the pavement rehabilitation designs. They also completed a life cycle cost analysis on the projects and confirmed that performing FDR is more cost effective than conventional rehabilitation techniques.

This research established that while KYTC has used full-depth reclamation of asphaltic concrete pavements to address widespread base failures, it has been practiced in Kentucky in the absence of guidelines for preconstruction and design activities.

Based on the study's findings, two draft Special Notes were prepared – the first is a Special Note for FDR-cement, while the second is a Special Note for FDR-emulsified asphalt. These will be implemented to guide the design, construction, and quality control of the FDR process.

Why It Matters

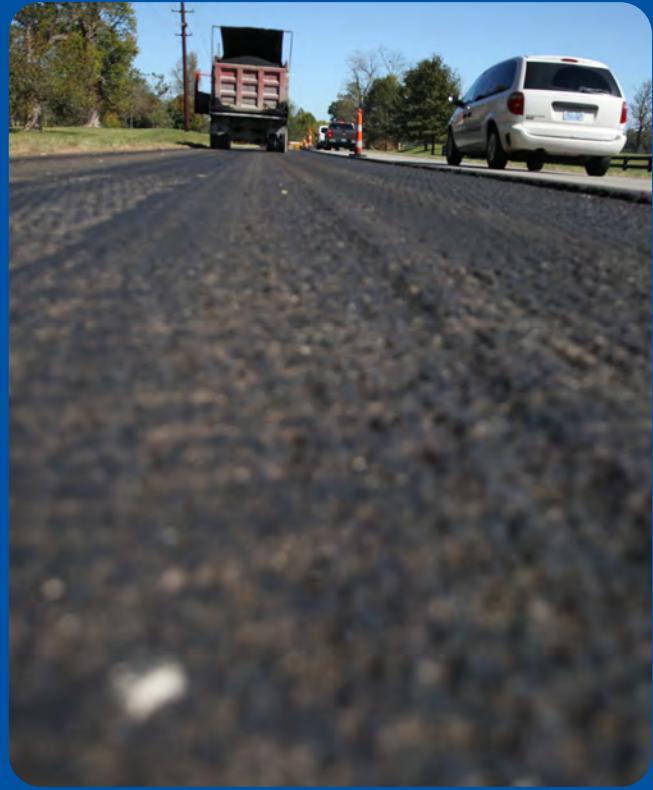
KYTC will realize the following benefits from implementing full-depth reclamation:

- When no millings are produced, there is less stress on the environment
- Less material hauling results in cost savings
- Maintenance activities can be deferred to other critical tasks
- Traffic impacts are reduced

KTC's recommendations and newly-developed Special Notes include a process to identify potential projects for the FDR process, as well as criteria for selecting a suitable stabilizer, the optimum thickness of material to be recycled, and the amount of stabilizer to be added.

The guidelines contain specifications pertaining to material sampling, testing, mixture designs, structural design parameters, and selection requirements for FDR treatment established through preconstruction planning activities.

KYTC should implement the draft specifications on new rehabilitation projects where the existing pavement exhibits severe base failures, cracking or raveling, and rutting or shoving.



The Impacts

Reclamation of HMA pavements is a viable option when asphaltic concrete pavements exhibit severe cracking or raveling; potholes; high spots or depressions due to base failures; and rutting, shoving, and corrugations.

Many highway agencies and private entities have concluded that adopting FDR yields economic benefits, both during the initial construction phase and across the long-term service life of the pavement.

To validate pavement designs, monitoring and quality control measures should be conducted. These results may be used to modify the Special Notes in the future and to fully develop specifications for FDR design and construction.



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Longer Lasting Bridge Deck Overlays

The Challenge

Bridge deck deterioration produced by delamination and spalling was first observed as a critical problem in the 1970s. Approximately 53% of the 13,000 bridges owned and maintained by the Kentucky Transportation Cabinet (KYTC) have a Federal Highway Administration (FHWA) sufficiency rating of less than 80%. KYTC researchers evaluated the effectiveness of several bridge deck protective and rehabilitation methods, with a focus on improving bridge deck performance.

Various mechanisms result in bridge deck deterioration: corrosion of embedded steel reinforcement, repeated freezing and thawing, scaling from deicing salts, or reactive aggregates. Concrete overlays and waterproofing membrane systems are the most commonly used methods of bridge deck protection.



Research Project

KTC-18-06/SPR14-472-1F
Longer Lasting Bridge
Deck Overlays

Principal Investigator

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Study Timeline

Completed 2018

The Outcome

The objective of this project was to determine the most effective methods for bridge deck overlay construction and rehabilitation, achieved by the following research activities:

- Assessed current bridge protection and rehabilitation practices used in other states.
- Examined new bridge deck overlay products and technologies.
- Reviewed NCHRP (National Cooperative Highway Research Program) guidelines, KYTC standard specifications, and ASCE (American Society of Civil Engineers) infrastructure ratings.
- Took core samples from two bridges to determine if deck overlays maintained the condition of the steel in the bridge decks and if penetration of chloride ions occurred.

This project revealed the importance of using a comprehensive approach when selecting a bridge deck rehabilitation method. Of equal importance is strictly adhering to instructions when installing overlays or waterproofing membrane systems.

Why It Matters



Concrete cores were collected above bridge deck reinforcing steel on KY 32 over Scrubgrass Creek in Nicholas County (built in 1932), and on Old Sonora Road/CR 1189 over I-65 in Hardin County (built in 1959).

- Testing of bridge cores indicated there was no chloride penetration on either bridge deck, although there were signs of corrosion. This confirms the idea that cracks on a bridge deck provide a path for water to reach the steel and initiate corrosion.
- The currently-used latex modified concrete (LMC) overlays perform well, provide a long service life, and are the most commonly used method of bridge deck rehabilitation.
- Based on review and comparison of KYTC specifications to NCHRP recommendations on improving bridge deck performance, it appears that Kentucky is up to date on best practices for new bridge deck construction.

The Impacts

- Other states use a variety of bridge deck rehabilitation methods, though waterproofing membranes and LMC overlays are the most commonly used.
- KYTC should begin experimental use of the following bridge deck alternative rehabilitation methods, expanding the number of options available:
 - MSC microsilica concrete
 - SDC Superplasticized dense concrete
 - FAMC fly-ash modified concrete
 - PMC polymer modified concrete
 - Rosphalt overlays
- KTC recommends developing guidelines for how to select the appropriate bridge deck protection or rehabilitation method for any given project.
- New guidance should document long-term performance characteristics and provide detailed installation instructions.



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Pavements, Materials, Geotechnology, and Infrastructure Assessment

The Program

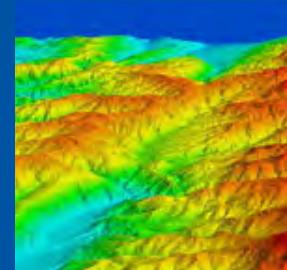
KTC's Pavements, Materials, Geotechnology, and Infrastructure Assessment program utilizes emerging technologies as forensic tools and evaluates high performance materials for new applications. Their work is focused on improving the resiliency and service life of bridges, roadways, and tunnels. A specialty area of interest is preserving and inspecting pavement and guiding any necessary rehabilitation. The group's use of test methods such as GPR, FWD, LiDAR, Pipeline video and drone inspection, and Infrared offer non-destructive methods of diagnosing pavement and structure issues. Compared to conventional techniques, these methods are safer and require less time to find the solution to the problem.



Non Destructive Technology (NDT)

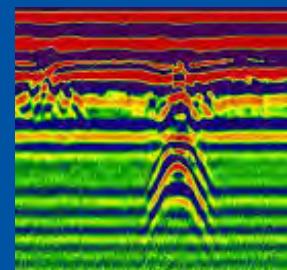
Light Detection and Ranging (LiDAR)

Mobile LiDAR has been used for water flow analysis and to topographically map pavement surfaces, giving a clear picture of how water moves off of the pavement, identifying areas where the pavement is not operating as designed. This technology offers a non-destructive method to evaluate pavement conditions on roadways where there is a high rate of wet weather incidents. LiDAR also offers workers a safer environment in high traffic zones when the technology is utilized to measure bridge and overpass heights. The traditional method of manually measuring overpass heights is time consuming, puts workers at greater risk, and is inconvenient to motorists. LiDAR has been used to inventory current conditions and detect changes in bridge decks and tunnel structures, leading to improved decision making on rehabilitation projects.



Ground Penetrating Radar (GPR)

GPR maps the subterranean cross-section of pavement and measures the pavement layer thickness. Because the technology is vehicle-mounted, gathering data does not disrupt traffic and information is collected in a safer environment. GPR offers a less labor-intensive alternative to coring for diagnosing pavement performance issues, and identifying voids and possible areas with low sub-grade strength. GPR maps may be viewed alongside geology elevations to determine if surrounding topography negatively affects pavement stability. One practical application of GPR is where its cross-section data can provide guidance on choosing overlay and waterproofing materials that protect against corrosion on bridge decks.



Falling Weight Deflectometer (FWD)

The FWD replaces sample coring to test pavement subgrade strength. The test equipment can diagnose multiple areas along a length of pavement without having to stop traffic for an extended period of time. This non-destructive method doesn't require drilling through pavement to the soil and delivers results more quickly.

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Why It Matters

Video and Drone Inspection

Video inspection can often diagnose issues in pipelines, bridges, or other locations where it is unsafe for workers to inspect. Drones are particularly valuable when a bridge exhibits signs of poor structural integrity and there are safety concerns with workers inspecting the bridge in-person. A drone can reach tight locations underneath a bridge and provide information to bridge engineers and inspectors prior to inspections.

AI/Machine learning

AI/Machine Learning software can scan stock photos of roadway networks and be taught to recognize and pinpoint features such as guardrail and other highway assets. This emerging technology may offer a more efficient, less labor-intensive method of conducting asset inventories. Some assets may require confirmation by inspection, but as the technology develops, it stands to become a valuable tool that increases efficiency and delivers significant cost savings.

ArcGIS Applications

When clients asked for project-level research information to be returned to them using a method that was “better, faster, and cheaper”, researchers developed a real time ArcGIS project data delivery system. The secure database geolocates projects, overpasses and bridges, active landslides, and other historical geologic information. When the user clicks on points on the map, a project information file opens, allowing engineering results to be delivered to the project team quickly and in the field, if needed.

KTC merged several existing GIS databases to act as a field data collector for tracking landslides, rockfalls, and other new geotechnical incidents. The Kentucky Historical Incident Database contains event maps that record visits to a site. The database can be used on computer, iPad, or mobile phone, allowing access at location of an incident.

Future Work

Researchers plan to demonstrate how non-destructive testing can help transportation agencies design and deliver rehabilitation projects more quickly. These technologies may lead to lower maintenance expenditures over time, due to the more accurate and thorough collection of data. Thus, the focus will be on expanding NDT’s usage on critical and aging infrastructure. Researchers will continue fine-tuning LiDAR techniques to inspect pavement, locate challenging grade issues, perform asset inventory, and gather critical information on various structures. Some effort will be directed towards investigating how to collect the most reliable LiDAR data.

Further exploration of AI/Machine learning can be applied, with the goal of tracking many categories of transportation assets. Certain roadway features may need confirmation via in-person inspection. Comparing AI/machine learning to traditional methods will determine if time and cost savings are significant enough to justify widespread use.

Expanding the real-time information delivery concept to include collaborative projects and other bridge, roadway, and structure rehabilitation projects will help communicate results in a timely manner and allow project methodology to adjust, if needed. Projects Using Non-Destructive Technology:

- Longer Lasting Bridge Deck Overlays
- Utilization of Light Detection and Ranging for Quality Control and Quality Assurance of Pavement
- Use of LiDAR to Detect Bridge Clearance Heights
- GPR used to Investigate Deterioration in the Cumberland Gap Tunnel
- Merging Geotechnical Databases to KGS-based Geotechnical Report Database
- Design and Construction Coordination to Facilitate GPS Machine Control
- Forensic Pavement Evaluation using Ground Penetrating Radar (GPR)



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Utilization of Light Detection and Ranging for Quality Control and Quality Assurance of Pavement

The combination of a rainstorm leaving standing water on the roadway, one-quarter inch of pavement rutting, and a motorist traveling over 45 mph can send a vehicle into a dangerous and possibly fatal hydroplane.



Light Detection and Ranging (LiDAR) technology can be used by transportation agencies to inform the design, construction, and maintenance phases of transportation projects. During wet weather, life-threatening pavement grade issues can cause standing water on interstates and state highways, leading to increased crash rates. Kentucky Transportation Cabinet (KTC) researchers demonstrated how mobile LiDAR technology can perform quality control/quality assurance (QC/QA) on pavement sections that have been identified as safety concerns.

Research Project

KTC-18-06/SPR14-472-1F

Utilization of Light Detection and Ranging for Quality Control and Quality Assurance of Pavement

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Research Scientist

Study Timeline

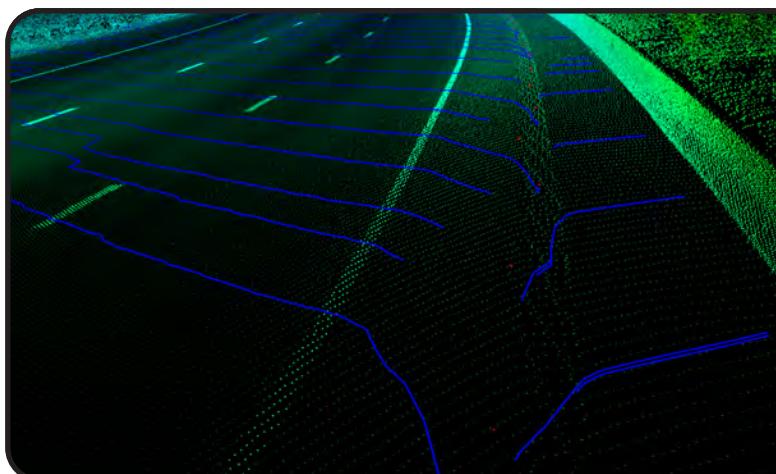
Completed 2018

The Outcome

KTC used LiDAR to evaluate pavement conditions on five roadway sections that have exhibited high incidence rates for wet-weather accidents and to determine if grade issues exist.

Locations were selected based on suspected pavement grade deficiencies and/or discrepancies within the existing data. Mobile LiDAR confirmed unsafe pavement conditions at the following locations:

- o I-471, Kenton Co. KY
- o I-75, Boone Co. KY
- o US-641, Calloway Co. KY
- o I-75, Grant Co. KY
- o I-65, Edmonson Co. KY



LiDAR was used for water flow analysis and to topographically map the pavement surface, giving a clear picture of how water sheds away from the road and follows the path of pavement rutting.

Why It Matters



- Processed survey grade mobile LiDAR data appear to identify where problematic grade issues are located on some of Kentucky's road networks.
- LiDAR provides data that can characterize surface water drainage patterns, identify pavement rutting that accumulates water in the wheel paths, and thus, help reduce the incidence of hydroplaning.
- Based on the results of LiDAR modeling, the Kentucky Transportation Cabinet (KYTC) undertook corrective maintenance to eliminate hazardous conditions on each pavement section, most commonly spot pavement milling, a low cost and effective solution.

The Impacts

- AASHTO has observed that collecting quality data can translate into better decision making for highway projects.
- Collecting thousands of accurate survey data points with mobile LiDAR to understand surface water flow characteristics is a faster and safer method than traditional survey methods.

While using LiDAR to identify and solve transportation-related issues holds promise, several challenges related to data accuracy may occur when collecting and processing mobile LiDAR data. Users should be aware of the following factors that could occur during data collection:

- Solar storms may disrupt data collection.
- Differing LiDAR technology will produce varying results.
- The geospatial accuracy of LiDAR data cannot be improved beyond the geospatial accuracy of the survey control it is tied into.



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Redefining Commercial Vehicle Permitting and Credentialing Violations

The Challenge

Although conviction rates for commercial vehicle violations are on the decline in Kentucky, data shows inconsistencies in adjudication of common offenses from district to district, which creates an equity issue for motor carriers operating in Kentucky. A violation of the state's weight distance tax (KYU) law, is classified as a misdemeanor, and will go on the driver's record even though the carrier is responsible for obtaining the license, filing returns, updating vehicle inventories and paying the tax. Across the state, cases are being dismissed at an increasing rate, which results in a drop in collections of court costs and fines paid by commercial vehicle carriers and drivers. The biggest challenge to Kentucky is the backlog of unresolved cases and the fact that the cost of enforcing commercial vehicle laws exceeds the revenue generated by citations.

The Kentucky Transportation Center (KTC) performed a study that examined violations of the International Fuel Tax Agreement and the Kentucky Intrastate Tax, KYU tax, Unified Carrier Registration, Kentucky size and

weight laws, and federal safety regulations. Researchers first analyzed data from 2004 to 2013 to examine performance trends in the judicial processes and institutions that enforce commercial vehicle laws and regulations. Additionally, KTC determined the financial implications of declining revenue collections, before recommending policy changes that would increase conviction rates and ensure that laws and regulations are applied uniformly throughout the state.



Infractions of commercial vehicle laws and regulations included in this study generally fall into three categories:

- 1) offenses related to tax policies,
- 2) fee-based policies, &
- 3) violations of federal safety regulations.

Research Project

KTC-15-17/SPR14-489-1F

Redefining Commercial Vehicle Permitting and Credentialing Violations

Principal Investigator

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Valerie Keathley, Ph.D.
Research Associate

Study Timeline

Completed 2018

The Outcome

In addition to analyzing common commercial vehicle violations, KTC surveyed officials from Kentucky, Florida, Mississippi, and Georgia to determine the commercial vehicle enforcement mechanisms currently in use and each state's issues with current policies. With the goal of creating a more equitable judicial process for motor carriers operating in Kentucky, KTC developed two policy alternatives to the current system, described below.

- The first recommendation allows for only state court systems to preside over commercial vehicle offenses. Alongside this, KTC recommends installing a series of piecemeal reforms that will aim to increase enforcement and boost conviction rates, and generate more revenue.
- The reforms include: 1. Extend weigh station operating hours, 2. Establish a task force to sort through the problems associated with commercial vehicle offenses and create standards that will improve the performance of state agencies, 3. Increase conviction rates and/or fine amounts, 4. Focus on getting final disposition in failure-to-appear cases.
- The second policy recommendation is to create an administrative review board at KYTC, a Motor Carrier Citation Board (MCCB) vested with the authority to adjudicate commercial vehicle offenses in lieu of district courts. The implementation and first year operational costs of MCCB are estimated at \$952,581.
- The MCCB would hold periodic meetings around Kentucky where violators may contest their citations. All offenses under this setup would be pre-payable and the burden of responsibility would be shifted to carriers and away from drivers.

Why It Matters

- The current adjudication process imposes significant expenses on state and local governments, as it involves multiple law enforcement agencies, Circuit Clerk offices, county attorneys, district court judges, and, potentially, public defenders.
- District courts typically are less lenient on motor carriers that do not follow size, weight, and credentialing protocols. Dismissal rates are significantly lower for KYU violations (18.1 percent) and OW/OD violations (12.8 percent), likely due to the factual evidence presented by officers that backs up the charge.
- The civil penalties system used in the MCCB would streamline the adjudication process, restore equity to the system, and because it would generate higher revenue, be a more fiscally responsible alternative to current practices.
- If compliance increases by 20 percent as a result of stricter enforcement and adjudication, establishing a KYTC MCCB should generate revenue estimates of \$19.1 million over 10 years – about \$500,000 more per year than was collected over the 10-year study period.



The Impacts

- Florida has designed a successful civil penalties system for commercial vehicle enforcement that extends beyond weight assessments. As a result, very few defendants protest citations, and the system produces a higher conviction rate and increased compliance(?).
- Implementing a civil penalties system (MCCB) for commercial vehicles would establish a dedicated revenue allocation structure where resources flow back into the activity that generates the collections.
- The study proposes that collections from CV offenses fund the activities of the MCCB, with the remaining revenue deposited into the Road Fund and earmarked for the use of CVE.
- Forming a MCCB would require significant legislative changes that would require the Kentucky General Assembly to deliberate over the specifics of a new system, entailing time and effort to implement new policies and processes.
- Including federal safety violations in the cases handled by the MCCB could encourage more challenges that may be overturned, having a negative impact on safety. Additionally, presiding over these cases increases the oversight responsibilities of KYTC and CVE.



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Implementation of the Real ID Act

The Challenge

The REAL ID Act outlines the minimum standards that must be used to produce and issue driver's licenses and identification cards. By 2020, a person must carry a form of ID that meets REAL ID standards or they cannot visit a military base, enter a nuclear power plant, or board an aircraft regulated by the Federal Aviation Administration.

Real ID Compliance score card

As of 2018, Kentucky remained one of 19 states and jurisdictions not yet fully compliant with the REAL ID Act. It operates under an extension allowing federal agencies to accept state driver's licenses.



Research Project

KTC 15-23/SPR-15-511-1F
Best Practices for Implementing the Real ID Act

Principal Investigator

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Program Manager

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Sr. Research Scientist

Andrew Martin PhD
Sr. Research Scientist

Study Timeline

Completed October 2015

The Outcome

KTC Researchers originally developed and evaluated four scenarios for license printing, shown in the table below. In the solution implemented, however, Kentucky will use Division of Driver Licensing (DDL) field offices to handle REAL ID applications, and production of both Standard ID and REAL ID cards would take place at a vendor. There will be no online renewal option.

Scenario	1	2	3	4
Print Location	Kentucky	Kentucky	Kentucky	Vendor
Print Labor	KYTC	Vendor	KYTC	Vendor
Online Renewal	No	No	Yes	Yes
Standard ID Printing	Clerks	Clerks	Clerks	Vendor
PII Collection for REAL ID	DDL/Clerks	DDL/Clerks	DDL/Clerks	DDL/Clerks

To Develop the Scenarios, KTC:

- Surveyed 10 compliant states to gather information on implementing best practices and public outreach strategies
- Summarized the Department of Homeland Security's eight security requirements
- Analyzed current legislation

Why It Matters

- Governor Bevin signed REAL ID legislation into law in March 2017 (House Bill 410). The federal government extended Kentucky's REAL ID implementation deadline until August 1, 2019.
- In early 2019, the state will begin issuing REAL ID-compliant driver licenses and identification cards, also called a Voluntary Travel ID. Standard Credential, or Standard ID's, will still be available.
- While Kentucky residents will still visit their DDL office or their Circuit Court Clerk locations to apply for a Standard ID or Travel ID, production of the licenses had to be moved from on-demand printing to a secure facility to meet the REAL ID Act's requirements on handling Personally Identifiable Information (PII). Residents receive their new ID within 5-10 business days via mail.
- Shifting a larger percentage of ID production from local offices to a centralized distribution center should lower overall costs, even if the initial cost to KYTC is greater.
- After initial startup costs, eventual savings could be realized by offering an online renewal system.
- Overall, the Cabinet should expect to spend between \$7 million and \$8.55 million implementing REAL ID.

The Impacts

- Kentuckians will need to know the purpose of REAL ID, who will need a Voluntary Travel ID, and the documentation required to obtain one. This information is readily available on drive.ky.gov/confidentKY/Pages/What-is-changing.aspx.
- License fees will increase to \$43 for a standard, 8-year license and will cost \$21.50 for a standard, 4-year license. The Travel ID is \$48 for an 8-year license, and \$24 for a four-year license.
- Both 8-year and 4-year renewals will be available until 2023. After that, only 8-year renewals will be available. This decrease in renewal volumes may mean shorter lines at the DDL and County Clerk Offices.
- Offering Kentucky residents a choice between a REAL ID-compliant card and a noncompliant card may alleviate the privacy concerns some residents may have.



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The Challenge

With an annual budget of \$40-80 million, KYTC's snow and ice removal program is the agency's largest maintenance expense. KYTC contracted KTC to improve the efficiency of snowplow routes, increase safety, and decrease the amount of funding needed to clear roads during each winter.

Existing snowplow routes are county-based, and while high-traffic routes receive highest priority, each county only has a fixed number of trucks and facilities available. Many of the routes have existed for decades.

Snow & Ice Removal in Kentucky

Snow and ice removal continues to be a significant expenditure to all state agencies and with each passing year the cost continues to climb. KTC investigated how to more efficiently provide these services across Kentucky.



Research Project

KTC-17-18/SPR16-529-1F

Snow and Ice Removal Route Optimization in Kentucky

Principal Investigator

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Research Scientist

Erin Lammers
Research Engineer

Eric Green PhD
Research Engineer

Study Timeline

August 2017

The Outcome

KTC researchers optimized snow removal routes for Clark, Montgomery, Grant, and Pendleton Counties (Districts 6 and 7) after completing the following tasks:

- Used a data-driven approach to evaluate KYTC's current snowplow routing procedures.
- Gathered local knowledge about current snow removal practices through interviews with district personnel and snowplow drivers.
- Considered factors such as salt capacity, salt facility and fuel locations, truck type and number of trucks, road width, input from local drivers, and a typical winter storm of 1 inch of snowfall.
- Tested the model routes in Districts 6 and 7, where truck fleets and salt and brine storage barns are shared among neighboring counties.

Why It Matters

The new routes will be implemented during the next winter season and will achieve the following benefits:

- Routes structured around a central high priority road allow drivers to anticipate the many hazards and obstacles along their routes.
- Treating the roads will become a safer and more effective practice as drivers will be more familiar with the roads on their route.
- Drivers will react with more precision to severe winter storms, meaning that routes are more likely to be treated on schedule.
- Fewer trucks will be used in the process, and since a single truck costs \$25,000 per year, counties with optimized routes will see large reductions in costs. The improved routes developed by KTC showed the potential to eliminate 23 of the 93 contract trucks in District 7, & 18 of 67 contract trucks in District 6.

The Impacts

- As implementation in other districts continues, KYTC could save millions of dollars each year.
- To complete route optimizations across Kentucky, KTC researchers will continue interviewing snowplow drivers and district officials so that new route models are tailored to the needs of each district.
- Optimized routes will be delivered to District 3 by the end of February 2018, and Districts 4 and 5 are slated to have optimized snow removal routes by June 2018.
- KTC and district officials can collaborate to prepare drivers for those routes that seem counterintuitive by installing technology that can provide turn-by-turn directions.
- KYTC's Automatic Vehicle Location (AVL) data could be integrated into snow and ice routing so that trucks could adjust in real-time to weather and road conditions.
- KTC could further this research by developing a tool to automate the snow route optimization process for KYTC. Researchers have been communicating with Ohio DOT, as they are currently trying to develop this process.
- Further route improvements and cost savings could be realized if district officials sanction routes that cross county lines.
- Moving salt and brine facilities to a more centralized location may reduce dead head time during some routes. However, this will require a cost benefit analysis of moving the facilities.



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RESEARCH NOTE

Project Managers Boot Camp

July 2018

The Challenge

The role of Project Managers at the Kentucky Transportation Cabinet (KYTC) is to deliver the over 650 new construction projects that are awarded each year. However, frequent staff turnover and lack of experience among Project Managers (PMs) makes it challenging to deliver projects in the Highway Plan on schedule and within the established scope and budget.

KYTC asked the Kentucky Transportation Center (KTC) to develop training for project managers that achieved several goals:

- Accelerate project delivery by learning how to keep schedules intact
- Sharpen the knowledge of PMs and challenge them to take ownership of the whole project
- Provide understanding of the critical role PMs play in building effective teams, acquiring necessary resources, and managing critical path activities



Principal Investigators

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Associate Director

Jeff Jasper PE MPA
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Study Timeline

Ongoing

The Outcome

- Researchers and KYTC leadership assessed the areas where project managers most needed to bolster the knowledge of project management principles.
- KTC studied KYTC's manuals, policies, and guidance to extract critical information to emphasize in the course.
- KTC researchers designed, prepared, and helped deliver Project Manager's Boot Camp (PMBC), an eight-day intensive training course.

PMBC participants explore a range of topics:

Project Management Strategies

Monitoring Budgets

Learning How To Build Harmonious Project Teams

Managing Consultants

Environmental Permitting And Documentation

Utility And Rail Coordination

Structural Design

Right Of Way Acquisition

Professional Ethics

Why It Matters

- As of June 2018, seventy-five KYTC project managers have enrolled in PMBC.
- Lesson plans, training modules, and presentation materials communicate the essentials of project management and the responsibilities of project managers in getting a project to letting.
- Structured group activities reinforce the course material and give attendees the opportunity to translate knowledge into practice.
- Surveys and questionnaires are given each day, allowing instructors to offer immediate feedback and tailor the course to the needs of each Bootcamp class.
- Participants give PMBC a glowing endorsement, stating the course has deepened their understanding of sound project management practices and improved their ability to deliver successful projects.

The Impacts

After PMBC's positive feedback, KTC developed PMBC Xpress, a condensed two-day version of the course that KYTC now requires all consultant project managers to attend. So far, 180 consultant project managers have participated in PMBC Xpress.



KTC researchers continue to refine and update the curricula for both courses and plan to make them available to other state transportation agencies interested in project management training.

PMBC cultivates well-rounded project managers who understand how individual project management activities fit within KYTC's broader goal of delivering the Highway Plan. Over time, PMBC's success will be measured by Kentucky reaping the benefits of an improved and sustainable project delivery process.



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Applicability of Zipper Merge Versus Early Merge in Kentucky Work Zones

The Challenge

Work zones on roadways throughout Kentucky usually require lane closures so that workers can safely perform necessary maintenance and repairs. Recognizing that roadway congestion increases costs and presents safety challenges, KYTC asked KTC to investigate methods for improving traffic flow conditions within work zones. Traditional merging methods have often resulted in driver behavior that compromises the safety of other drivers and workers. A number of state transportation agencies (STAs) have experimented with the zipper merge, or late merge, concept. KTC studied this concept, which encourages drivers to merge at the beginning of the lane taper rather than queuing up in the open lane at the location of the first lane closure sign.

In the zipper merge, vehicles do not merge into the lane that remains open immediately after being notified of a lane closure. Rather, vehicles continue to occupy all lanes until they reach the taper, at which point – and directed by signage – vehicles take turns merging into the open lane, creating a zipper pattern.



Using a blend of quantitative and qualitative data, KTC researchers performed two case studies involving the use of the zipper merge in Kentucky work zones. A more comprehensive study was performed on the I-275 Carroll Cropper Bridge in Boone County, where researchers compared the early merge configuration to the zipper merge. The study done on KY 9 at the Taylor Southgate Bridge in Kenton County focused on qualitative data collection – specifically, driving through the area after the zipper merge had been implemented while collecting GPS/speed data and recording the traffic patterns via a GoPro camera.

Research Project

KTC-17-27/SPR16-526-1F
Applicability of Zipper Merge Versus Early Merge in Kentucky Work Zones

Principal Investigators

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Adam Kirk, PE, PhD Research Engineer

Study Timeline

Completed 2018

The Outcome

Researchers examined several traffic flow indicators, including the average time to pass through the construction zone, average queue time and length, average speed through a queue and through a pass, and average length of a pass.

To assess safety during the four-month construction period, researchers compared crash data of the early merge in place to the crash data with the zipper merge in place. Construction was mentioned as a contributing factor in 4 of 15 crashes before zipper merge, and in 5 of 13 crashes after zipper merge, leading to inconclusive results about safety.

A critical part of the zipper merge evaluation was the use of onsite traffic control devices and advanced signage that advised drivers of the upcoming lane closure, including changeable message boards and fixed signs that read USE BOTH LANES DURING BACKUP.

On I-275, the zipper merge brought about minor, although statistically insignificant, improvements in traffic flow and roadway safety. On KY 9, the zipper merge appeared to improve traffic flow, reduce backups, and minimize the area impacted by construction.

Why It Matters

While the case studies could not conclude that zipper merge should be used in all work zones, there is enough potential for the concept to be selectively implemented on several KYTC projects. Future research will study driver behavior at certain sites and use traffic flow models to identify the types of roadways and situations where zipper merge would yield positive benefits.

The zipper merge more fully utilizes roadway capacity leading up to the work zone, as well as reduces potential interference with entrance and/or exit ramps located prior to the work zone. Previous studies found zipper merges well-suited to roadways with heavy traffic, whereas the conventional early merge is preferable for uncongested and low-volume roadways.

Most agencies agree upon the data that should be collected to properly evaluate the zipper merge. These include traffic volumes, queue information, speeds, travel times, merge locations, and crashes. The case studies highlighted the importance of monitoring the area with video cameras and radar guns, and collecting photos and subjective evaluations to create a complete picture.

Further work should identify the characteristics and operational features (number of lanes, AADT, speed limit, and percent trucks) found most suitable for zipper merge applications throughout the state.



The KY 9 zipper merge was implemented based on a suggestion from a Kenton County citizen who was concerned about safety and congestion that backed up far into Cincinnati, blocking other nearby streets. During this case study, researchers focused on qualitative factors such as feedback from the community, insights from transportation officials and other construction personnel, and data collectors who utilized the zipper merge while it was in effect.

The Impacts

Of the alternative merging methods studied in five other states, zipper merge has yielded better flow management and decreased queue length, particularly when condensing three lanes down to one.

Most research proposes that the zipper merge likely improves safety since both lanes travel at the same speed and traffic flows more uniformly; however, this claim cannot be verified due to the challenges of quantifying safety improvements.

Public awareness is one of the most important aspects of implementing a zipper merge. This includes the use of clear signage and public education campaigns. All drivers (including truck drivers) must know how a zipper merge operates and understand that it is utilized to benefit them. The public received information about the zipper merge concept used on KY 9 from a video and writeup posted on the KYTC District 6 website.



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Coaxing Highway Information System Data from Mandli Pavement Scans

The Challenge

The Kentucky Transportation Cabinet (KYTC) Division of Planning's Highway Information Systems (HIS) database contains information on the geometric elements of horizontal and vertical curves for Kentucky's roads. Over time, the data has been collected with varying detail and unknown degrees of accuracy. HIS also lacks information on cross-slope. KYTC asked Kentucky Transportation Center (KTC) researchers to evaluate the accuracy of Mandli pavement scans and determine its potential use in the HIS database. Mandli data is raw and requires processing to determine curve locations, cross slopes and the resulting curve advisory speed. KYTC considered purchase of the Rieker's Curve Advisory Reporting System (CARS) dataset, a commercially available data collection and processing service. KTC evaluated CARS data and compared to the processed Mandli data.

For the past several years, the Division of Maintenance has been collecting pavement scans on all state roads with vans equipped with Mandli software, an updated technology used for highway data collection and pavement 3D technology. The pavement scans provide the latitude, longitude, and elevation data points needed to calculate horizontal curve characteristics such as superelevation, cross slope, and curve radius, and vertical curve characteristics such as grade.



Research Project

KTC 17-26/SPR17 548-1F
Coaxing Highway Information System Data from Mandli Pavement Scans

Principal Investigators

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Teng (Alex) Wang,
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Study Timeline

Completed 2018

The Outcome

This study thoroughly examined how KYTC collects the roadway information that will be used to build up the state's HIS database. By completing the following tasks, KTC researchers developed strategies for processing Mandli data and evaluated its accuracy and value.

- Created a methodology for curve segmentation called University of Kentucky Curvature Automatic Tool (UKCAT) that converts raw Mandli data into HIS horizontal curve data.
- Examined grade and cross slope data and compared to manual field measurements.
- Determined how Mandli pavement scans could be better utilized and how they would improve the HIS database.
- Verified the accuracy of roadway geometry data that KYTC collects.
- Performed a literature review to compare data sources and application methods.
- Estimated the level of cost and effort needed to perform a statewide HIS review and update.

Why It Matters

Of the four data processors tested, KTC researchers found two to be the most efficient at converting raw data into HIS data: UKCAT and Rieker's CARS.

Researchers collected field data on grade and cross slope and compared them to design plans, UKCAT output, and CARS output. Statistical tests used to evaluate data accuracy emphasized the following results:

- Grade data collected by Mandli are accurate for vertical curves on all roads and may be used for HIS.
- The CARS and UKCAT tools perform curve segmentation similarly and accurately, proving that processed Mandli data using UKCAT is a valid method for identifying curve locations.
- Researchers concluded that cross slope data collected by Mandli, while not precise, may be used in curve advisory speed calculations.

The Impacts

- Because Mandli collects data along the vehicle's wheel path which could be affected by driving technique, uneven pavement, or steering wheel mechanics, caution is recommended when using Mandli cross slope data for other HIS purposes.
- Researchers established a method using CARS to convert Mandli cross slope data into a form that can be implemented in HIS.
- For horizontal curves, the team recommends using CARS to identify the location of curves and to utilize the system's calculated advisory speed as a proxy for superelevation.
- For roads where data suitable for CARS data is not collected, or if agencies do not want to use Mandli, UKCAT is a reliable and accurate alternative.
- The curve segmentation process is based on changes in magnitude and sign in the raw Mandli data and may be automated in the future.



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Performance Based Practical Design

The Challenge

State transportation agencies (STAs) have increasingly turned to Performance Based Practical Design (PBPD), a design philosophy that encourages agencies to develop projects to meet the purpose and need with lower project costs. The Kentucky Transportation Cabinet's list of needed projects far exceeds the number it can deliver under the current funding constraints. PBPD can help deliver more projects in a timely manner and at a lower cost, by better allocating transportation funds and prioritizing long-term investment decisions in critical infrastructure. In other words, PBPD "right-sizes" projects.

Implementing PBPD is critical for KYTC's efforts to provide a safe and efficient transportation system and to comply with Federal requirements.

A solid PBPD program can be used to guide the direction of Department of Highway's activities and to improve the overall safety and condition of Kentucky's highway system in a cost-effective manner.



Research Project

KTC-18-03/SPR17-546-1F
Performance Based Practical
Design
Principal Investigator

Principal Investigators

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Study Timeline

Completed 2018

The Outcome

KTC reviewed PBPD concepts and initiatives, along with best practices other states employ to plan projects and achieve more efficient designs. The team offers several recommendations for implementing PBPD in Kentucky.

- The goals and objectives of the project's purpose and need statement should be evaluated periodically to ensure the original intent of the project remains the target.
- For projects to meet only the anticipated capacity needs, maximize design to the point where return on investment does not change with increasing investment – the point of diminishing return.
- Developing a wide range of design options and alternatives allows the project to fit any constraints and helps the design team determine which option yields the best value.
- Evaluate the safety of a solution as compared to existing safety conditions. Considering smaller, incremental safety gains on a project creates savings and will prevent over-designed projects.

Why It Matters

- Championed by the Federal Highway Administration, PBPD has proven effective in Missouri, Indiana, and Oregon.
- One performance measure used consistently across states is project delivery, which is already a focus area in Kentucky.
- Choosing low-cost countermeasures such as striping, signing, and rumble strips, (instead of realignment) is a common PBPD solution and can be easily linked to a performance measure.



The Impacts

- A robust PBPD program will typically require 18 to 24 months of training personnel and promoting the changes in design philosophy before seeing programmatic results.
- For a PBPD initiative to succeed, it is critical for agency leadership to advocate for and learn about how PBPD has been used within other agencies.
- Since KYTC currently has access to the data required to evaluate and monitor all performance metrics recommended by FHWA, PBPD can be implemented in an efficient, cost-effective manner..



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Transportation System Vulnerability and Resilience to Extreme Weather Events and Other Natural Hazards

The Challenge

Recent federal legislation and Federal Highway Administration (FHWA) have directed state transportation agencies to identify vulnerabilities associated with extreme weather and climate change to develop a risk-based asset management plan, and to incorporate the findings into transportation planning, design, and maintenance practices.

KTC assisted KYTC in its efforts to identify National Highway System (NHS) assets that are at greatest risk from the effects of natural hazards. They identified those highway segments, bridges, and culverts for risks associated with earthquake, flood, landslide and sinkhole.

A pilot project was implemented in District 1 before the work expanded to include a prioritized list of the most vulnerable transportation assets in every district. The results will guide the development of KYTC's risk-based asset management plan, with the goal of improving the resiliency of Kentucky's transportation infrastructure.



Research Project

KTC-18-03/SPR17-546-1F
Transportation System Vulnerability and Resilience to Extreme Weather Events and other Natural Hazards

Principal Investigators

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Candice Y. Wallace, PhD
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KYTC Contributor
Scott Schurman

Study Timeline

Completed 2018

The Outcome

- During the first stage of this project, KTC assisted the Kentucky Transportation Cabinet (KYTC) with developing a vulnerability assessment process.
- Researchers created a modified version of the Federal Highway Administration's Vulnerability Assessment Scoring Tool (VAST).
- The VAST tool organizes indicator-based natural hazard data and their impact on asset vulnerabilities, and calculates a vulnerability score for each NHS segment. Data inputs were categorized by 1) Exposure, Sensitivity, and Adaptive Capacity.
- VAST data were obtained from existing meteorological and geological data, data processed by the project team using GIS, and data produced through KYTC district workshops.
- Transportation experts participated in workshops held at Kentucky's 12 KYTC districts. Participants drew on local knowledge of transportation assets to 1) score the criticality of the roadway and the potential impacts of an extreme weather and/or natural hazard event, 2) perform a mapping exercise to audit flooding events in the District, and 3) identify the greatest challenges to conducting maintenance in each district.

Why It Matters

The output of the vulnerability assessment includes a GIS-based data system capable of producing maps that indicate vulnerable locations. The findings of the vulnerability assessment will guide KYTC's decision-making for planning, design, operations and maintenance. The results were very specific about the assets that could potentially be at risk in each district:

- Of the 287 NHS segments in Kentucky, 83 were found to have high vulnerability to earthquakes, floods, landslides, or sinkholes.
- Of these 83 segments, 13 had high vulnerability to two hazard types, and one other segment had high vulnerability to three hazard types. In terms of hazard types, 4 were vulnerable to earthquake, 27 were vulnerable to flood, 45 were vulnerable to landslide, and 22 were vulnerable to sinkhole.

The VAST scoring revealed a natural hazard-related worst case scenario for each district, as shown in the table below.

District	Worst Case Scenario	District	Worst Case Scenario
1 & 2	Major Earthquake knocking ot bridge or dam	3 & 4	Major Earthquake knocking ot bridge or dam
5	Ohio River flood that closes bridges	6	Ohio River flood that closes bridges
7	Clays Ferry Bridge closure	8	I-75 / US-25 (detour route) closing simultaneously
9	I-64 closure, particularly over Big Sandy River	10	Flood/landslide closing Mountain Pkwy
11	Flood/landslide closing I-75	12	Flood/landslide closing US-23 or US-119

The Impacts

- The VAST assessment is designed to be a screening tool for identifying vulnerability across a large number of assets. For assets with high vulnerability scores, further individual and in-depth analysis is required.
- Because high risk assets have been identified, mitigation strategies can be developed to help offset the effects of natural hazard vulnerabilities and to improve the resiliency of the overall NHS transportation infrastructure across Kentucky.
- Consideration of vulnerability assessments during project planning reduces financial losses that would occur if the system were to fail completely.
- Maintaining a secure and safe transportation system mitigates negative publicity that may arise were the system to fail.
- Several workshop discussions pertained to external factors affecting natural hazard vulnerability, such as land use changes or debris clogging drains and pipes. This information can be folded into an overall risk management plan.



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Optimizing Available Surveying Technology to Streamline Project

The Challenge

Kentucky Transportation Cabinet (KYTC) Project Managers are responsible for preparing all phases of highway projects, from initial concept to letting, while Section Engineers manage all phases of highway construction projects, from letting to completion. Personnel in these positions need to be well-versed in the most current surveying methods as well as the most technologically advanced surveying equipment. Over the past 15-20 years, surveying technologies have undergone rapid advancements — during that same period, loss of staff at the Cabinet has reduced in-house surveying expertise considerably. As a result, contractors frequently undertake their own surveying, creating a further loss of knowledge to KYTC. Many field technicians and engineers who participate in surveying activities receive little formal training in advanced surveying equipment — they either receive a brief training from the equipment vendor or learn to use the equipment on the fly when they are already deployed in the field.

Building Solutions

To understand the challenges related to surveying, KYTC asked researchers at the Kentucky Transportation Center (KTC) to review current surveying practices and recommend ways to bolster in-house surveying expertise. Researchers conducted interviews with KYTC District and Central Office personnel to define current surveying practices and the challenges many district personnel face in their efforts to procure survey data. KTC chose to focus on five major areas: 1) General Issues, 2) Equipment Issues, 3) Digital Terrain Models, 4) Training, and 5) Surveying procedures. Researchers inventoried current surveying equipment by district and produced guidance documents to help project managers determine what survey services are needed on a project.

Research Project

Optimizing Available Surveying Technology to Streamline Project
Delivery
Report #
KTC-18-11/SPR17-544-1F

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Study Timeline

Completed 2018

Finding Solutions

Common difficulties encountered at the district level include equipment shortages, lack of trained survey technicians, misalignments between KYTC- and contractor-generated digital terrain models (DTMs), and an absence of training opportunities focused on surveying. Equipment is shared across multiple crews, which leads to scheduling conflicts and production issues. If only one person has experience operating a piece of equipment, that person must be loaned out with it to ensure proper data collection and/or inspections.



Recommendations

- Improve the quality and usability of in-house DTM's to make them more compatible with the models contractors use.
- Develop trainings geared toward construction inspection and combined design and construction inspection.
- Maintain an adequate number of staff that have surveying experience, train more field technicians, and continue to share knowledgeable people among districts.
- Develop a pocket field guide for construction inspection that describes the process of setting up construction projects, operating equipment, and using GPS surveying equipment on inspections.
- Each district should ideally acquire the GPS surveying equipment needed to outfit each independent field crew with a surveying crew.
- The relative absence of stakes on today's job sites make it difficult for construction inspectors to verify proper placement and elevations of the roadway without employing primary survey equipment.
- While the responsibility for construction surveying on highway projects is now delegated to contractors, Section Engineers still need to be able to perform fairly detailed surveying for Construction Engineering Inspection (CEI).
- To facilitate the development of design bulletins to advertise for contract survey services, Project Development can use the following tools developed by KTC: 1) a survey services decision matrix, 2) a flow chart mapping the process of requesting survey services, 3) a table that provides an overview of different survey methods.
- Establish two survey coordinator positions within the Cabinet, one with a focus on construction inspection, the other with a concentration on project design.
- Implement a process to ensure that software used by the Cabinet and contractors is compatible. All stakeholders involved in surveying should receive similar training on the use of MicroStation.
- Improve internet connectivity to enable more efficient data processing at section offices.



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In-Service Evaluation of High Tension Cable Barrier Systems

The Challenge

Cable median barrier (CMB) is a safety innovation installed primarily to prevent crossover crashes. KYTC authorizes three types of high-tension CMB for use: Brifen, Trinity, and Gibraltar. Some cable barrier systems have lost tension across their whole length after experiencing a single vehicular impact, leading KYTC officials to question whether all CMB products perform at a similar level. Vehicle impacts with cable barrier typically result in damaged steel posts, which require replacement because posts hold the cable wire ropes in place, providing the necessary high tension. If a second vehicle were to strike the cable barrier system somewhere other than the area of the first crash, the high-tension cable barrier system is designed to maintain much of its tension and continue to prevent vehicles from crossing the median.

KTC completed a study of cable barrier systems installed across Kentucky, with the goal of comparing each vendor product's performance and determining the safety effectiveness of high-tension cable barrier. Researchers conducted a literature review of several state DOT's best practices that apply to cable barrier and inspected cable barrier on-site in over 100 locations. Through these activities, analysis of crash data and case studies, and interviews with KYTC and contract personnel, the project team evaluated the installation, routine maintenance of, and crash maintenance of each vendor's cable barrier product. Seven Kentucky interstate segments were selected for analysis because median crossover crash data from previous studies was available, and these roadways use both Gibraltar and Brifen, the most frequently used systems in the state.

Research Project

In-Service Evaluation of High Tension Cable Barrier Systems
Report #
KTC-17-17/SPR16-526-1F

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Study Timeline

Completed 2018



In a crossover crash, a vehicle departs the roadway on the left shoulder, crosses the median, and enters the opposing lane(s) of traffic, often resulting in a head-on collision.

The Outcome

Vendor Comparison

- Brifen, the most commonly-installed system in Kentucky, offers the more desirable outcome of a lesser degree of lateral deflection, even with increased post and anchor spacing.
- Brifen maintains cable tension better after an impact, even when the crash occurs near the end treatment. The high cable tension does make maintenance more complex, particularly for vehicle extractions.
- There are more concerns over crashes that occur near the end treatment of Trinity or Gibraltar systems.

The Outcome (cont.)

Safety Effectiveness

- When researchers analyzed crashes before widespread cable barrier installation occurred (2004-2008) and after (2011-2015), they found that while total crashes increased from 2004 to 2015, median crossover crashes declined significantly.
- The few instances in which a vehicle traveled through the cable barrier system usually involved a large truck, not a passenger vehicle. CMB was not designed to redirect large trucks.
- When passenger vehicles travel over or through the cable median barrier, it is often due to cable barrier that was installed at a lower elevation than where the vehicle exited its travel lane. Cable barrier should be installed on the high-elevation side of divided median roadways when the difference in elevation is significant.

Maintenance Considerations

- The Trinity CASS system offers the lowest maintenance cost per crash and per mile due to larger post spacing. Brifen maintenance costs are the second lowest; Gibraltar has the highest costs, despite its ease of repair.
- Field observations and interviews found that contractors typically completed cable median barrier repairs within the time frame specified in the district maintenance contracts.
- Damaged in-line posts accounted for nearly 89 percent of the total maintenance costs for cable median barrier between 2010 through 2015.
- Installing a concrete mow pad along the length of cable barrier increases the overall strength of the system, and has resulted in fewer maintenance issues compared to cable barrier with no mow pad.

Why It Matters

The benefit cost analysis demonstrated that cable median barrier installations have resulted in high value in both economic and comprehensive terms.

Quality assurance during installation is needed to ensure cable median barrier meet all guidelines for appropriate post spacing, post vertical angles, and end post weakening cuts. Training and guidelines should be provided to KYTC inspectors to aid construction inspection during CMB projects.

Additional CMB specifications and tolerances in the specifications should be provided in future KYTC district installation and maintenance contracts.

In recent years, the installation of additional CMB systems coupled with districts relying extensively on posts "furnished by vendor" have led to increasing costs for in-line post repairs. If KYTC were to furnish posts, there could be a potential savings opportunity.

The Impacts

National guidance has confirmed that as post and anchor spacing increase, deflection distances during crashes increase; therefore, Kentucky should continue to follow this guideline.

Most state DOTs check cable median barrier rope tension following major or minor repairs; thus, a recommendation from this study is for KYTC District Offices to institute a tension-monitoring program for both annual inspections and after repairs. Ideally, contract personnel would document tension readings at set distance intervals and take readings within 72 hours following repairs.

KYTC could consult manufacturers to inquire about improved end treatments or methods to mitigate system tension loss when crashes occur near the end treatment.

If KYTC is interested in studying the performance of CMB systems following crashes, consideration should be given to collecting tension data prior to repairs of CMB systems.

For this study, the research team did not employ the use of Kentucky-derived safety performance functions, or SPF. Kentucky currently lacks a suitable SPF for use in this study and the data collection effort required to produce relevant SPF were outside of the scope and resources of this project.



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KTC RESEARCH NOTE

KYTC Maintenance Overview and Budget Analysis

December 2018

The Challenge

The Kentucky Transportation Cabinet (KYTC) manages over 27,500 miles of the state's roadways and is responsible for maintaining transportation assets in a good state of repair, including bridges, traffic signals, lighting features, traffic signs, and guardrails. Maintenance refers to the routine care of infrastructure (e.g., patching potholes, repainting roadway lines and markings, cleaning bridges, mowing), while operations refers to tasks that keep traffic moving (e.g., plowing and salting roadways; keeping signs, traffic signals, and roadway signals functional). The Cabinet's maintenance and operations are the responsibility of the Department of Highways' Maintenance units, which include the Division of Maintenance, the Division of Traffic Operations, and the district staffs dedicated to preservation.

In 2018, roughly \$350 million was budgeted for maintenance and operations. Without adequate funding, pressing maintenance issues are sometimes left unattended, and when unpredictable maintenance events occur, other critical scheduled roadway maintenance tasks may receive less funding. When these activities are deferred to another time period, there are often unintended consequences.



Research Project

KYTC Maintenance Overview and Budget Analysis
Report #
KTC-17-21/SPR18-56-2-1F

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Study Timeline

Completed 2018

Building Solutions

Researchers at KTC analyzed trends in KYTC's maintenance budget and – with KYTC's input – quantified the need and importance of maintenance funding. Additionally, KTC reviewed core maintenance functions and rated their importance for preserving Kentucky's roadway networks. Among the maintenance topics explored were potholes; guardrails, signs, and striping; roadside vegetation; and snow and ice removal.



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Finding Solutions

Baseline spending for snow and ice removal typically accounts for nine percent of the overall maintenance budget, however, since the cost depends on the amount of precipitation, up to 27 percent of the maintenance budget may be used during a severe winter, applying significant pressure to the overall budget. In 2017, the total for the combination of the maintenance budget and the RS allotment to maintenance was \$404 million. However, the purchasing power gap for both the maintenance budget and the RS allotment topped \$100 million. By 2022, that gap is expected to grow to \$134 million. Even if modest increases in funding are programmed for maintenance, the purchasing power will continue to decrease.



Recommendations

According to TRIP, Kentucky drivers incur \$4 billion in costs each year from driving on poor roads and suffering through congestion. Many of these issues can be mitigated through performing routine maintenance to keep roads and bridges in a state of good repair over longer periods of time. A starting point to improve maintenance outcomes is keeping maintenance funding on pace with inflation. Improving maintenance outcomes can result in streamlined freight movement, improved driver experience and better traffic flow, reduced safety hazards, better pavement conditions, and longer service life of transportation assets.



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