Designing Roads for the Test of Time:
Applying Validated Safety Models to Improve Road Standards and Highway Design

Howard Lubliner, Ph.D., P.E.
Managing Director, Infrastructure Services

Cheryl Bornheimer, P.E., M.S.
Project Engineer

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Executive Summary

Standards that protect the safety of motorists and the community are crucial to roadway design. As municipalities update their road standards, leveraging the latest in crash prediction modeling, best practices of design consistency and context sensitivity is essential to developing standards that will serve the community well. While studying at the University of Kansas, we performed research to calibrate and validate crash prediction models for local roads. By applying this research to the update of the road standards for Johnson County, Kansas, we have been able to provide research-proven safety and design recommendations. Additionally, our recommendations uniquely account for deterioration and maintenance factors to improve the way the design standards withstand the test of time while also saving the County money on overlay and re-grading work. This project serves as an example of how academic research, practical safety knowledge and proven roadway design expertise can: improve safety; provide real, long-term cost-savings for all levels of roadway governance; and provide the necessary tools for communicating with the public.
The Highway Safety Manual Ushers in Quantitative Safety Analysis

In 2010, the American Association of State Highway and Transportation Officials (AASHTO) published the first edition of the Highway Safety Manual (HSM). This manual provided transportation professionals and engineers the first comprehensive collection of quantitative safety analysis models and techniques. The goal of the manual is to provide research and information on roadway safety management, methods for safety prediction and crash modification factors. This research can then be applied to project development and design to make more informed decisions on how to improve roadway safety and maintenance.

Prior to the HSM, engineers knew that there were roadway design improvements that would provide a safety benefit, such as widening a road and/or its shoulder, but there was no way to quantify the safety impact. For instance, prior to the HSM, deciding to add 8 feet of shoulder to 1 mile of road or 2 feet of shoulder to 3 miles of road lacked any definitive insight on the impact this would have on reducing crashes and other important safety factors. With the publication of this manual, engineers and roadway designers now have the tools and research to make more informed design decisions and use safety dollars more effectively.

Communication is also important for developing and maintaining public buy-in and support, as well as funding for transportation improvement projects. The safety analyses documented in the HSM provides tools for departments of transportation, and municipal and county governments to communicate the safety benefit of road improvements to the public. By helping the public understand the safety implications of a roadway project or program, transportation agencies have a solid foundation for building consensus of support among the public.
Research on Local Calibration and Validation

The crash prediction models published in the HSM are based on data from sample states and represent national safety trends. They can be used, as published, to determine the relative safety impact of proposed roadway reconstruction projects. For example, if the HSM formulas are used as provided and predict that a roadway reconstruction project would reduce crashes from four crashes per year to three crashes per year, then the actual number of crashes would not necessarily be applicable to a local road in that jurisdiction, but the percent reduction (25 percent) would.

To fully leverage HSM crash prediction models to predict safety benefits with actual crash numbers, calibration to local conditions is needed. In 2010, the Kansas Department of Transportation (KDOT) commissioned a study with the University of Kansas (KU) to calibrate and evaluate the two-lane rural road prediction model for Kansas highways. As graduate students at KU, we led this research and authored the subsequent papers.

For the research, the team modeled nearly 200 miles of in-service, rural, two-lane highways throughout the state of Kansas. For these roads, we compared the actual crash numbers to the HSM’s equation predictions. Based on the difference between the HSM prediction and the actual numbers, we determined a factor that, when multiplied into the formula, would result in more accurate predictions for Kansas’ rural two-lane roads.

Then, because we work with roads that are in the process of being redesigned and reconstructed, we used a first-of-its-kind approach to validate the calibration. To do this, our research team used full reconstruction projects, completed in the previous three to eight years, to validate Kansas-specific calibration factors. The calibrations were then tested and verified on 100 miles of reconstruction projects. The testing demonstrated the calibration factors’ accuracy to be significant and repeatable in predicting the actual safety improvement of road reconstruction projects in Kansas.

By calibrating the model and demonstrating a significant and repeatable ability to accurately predict safety benefit of a specific project, we were able to provide KDOT the confidence to use this national methodology for highway improvement projects large and small on Kansas roadways.
Applying Data and Research to Improve Road Standards

Like many counties across the U.S., Johnson County was working with county road standards they inherited, and in some cases, the background and supporting research for the standards had become outdated. So, the County recently took on the task of updating their standards, which occurs very infrequently. As such, it is essential that the update to these standards are as progressive as possible. To achieve this, we applied our research and integrated the best practices of design consistency, context sensitivity and performance-based design to develop a new set of road standards that will serve the County for the next 20 to 30 years.

A keystone of the new design standard is a typical section for each roadway type. The typical section provides route continuity and applies context sensitivity, which considers the current and future use of the road. Each typical section is optimized using cost-benefit ratio to provide a sustainable safety performance for the County’s entire roadway system. Roadway context was developed by collaborating with County staff to identify routes with similar characteristics. For Johnson County, there are five typical sections – roads anticipated for development and transition to urban street sections, truck routes, bike routes, the Kill Creek Corridor¹ and typical county roads. Then, using GIS and mapping resources, similar corridors were bundled, so continuous corridors would maintain the same typical section throughout. Then, the safety benefit of roadway improvements, such as shoulder width and foreslope angle, were determined for each typical section by using the calibrated two-lane prediction models from the HSM and our research at KU.

One important and distinctive element of the new road standards is how our team accounted for time and long-term degradation of the typical roadway section in the design of these standards. To understand how we did this, one must consider how a road ages and is maintained. As a road’s pavement deteriorates over time, instead of reconstructing the road, the pavement will be overlaid with new pavement. Often, the road is overlaid three to six times throughout its 40 to 60 year lifespan prior to reconstruction.
JOHNSON COUNTY, KANSAS
FUTURE MUNICIPAL BOUNDARIES & ROAD CLASSIFICATIONS

LEGEND

Road Classification
- Local (Gravel)
- Collector
- Collector (X < 400)
- Collector (400 < X < 1000)
- Collector (X > 1000)
- Truck Corridor
- Future Municipality Road
- Highway
- Kill Creek Corridor
- Bike Routes
- Park

Future Kansas Municipalities
- De Soto
- Gardner
- Olathe
- Overland Park
- Spring Hill
As the pavement is overlaid, there is a pyramid effect. With each overlay, the new pavement cannot reach to the edge of the road, so the road and its shoulders get narrower, the foreslope becomes steeper, and the ditch capacity may also be reduced. Not only does this increase the likelihood of crashes, but the steep foreslope may also increase the severity of the crash, and the reduced ditch capacity can cause stormwater issues. The inevitable result is that even if a road is built to standard initially, the road will become sub-standard during its lifetime. This is common in counties throughout the U.S., and while most people are aware of this condition, there are very few people setting forth standards and designing to address it.
For Johnson County, the new road standards will be based on a 40-year typical section. This means the recommended design width for the roadway pavement and shoulder will be wider than what the current safety performance standard recommends. Instead, standard road width will account for the reduction in width that happens with maintenance. This way, as the road is overlaid, the reduction of the shoulder will result in it becoming the standards’ optimized width by the end of its lifespan. This allows the crash prediction results to continue to be valid over the entire lifespan of the road and not require increased predicted future crash rates over time.

Another benefit to this approach is a reduction of maintenance costs. One of the most expensive aspects of the pavement overlay is the grading work to tie into the foreslope and re-grade it based on the new road width. With the new design standards, the road is designed to be overlaid, so there is no longer a need for the re-grading work or steepening of shoulders. This commonsense approach to investing in, and maintaining roadways offers tangible benefits to residents and motorists in the way of safety improvements and cost-savings.
Conclusion

As engineers, we work to design roadways that function well and keep the community and motorists safe. County road standards support these two goals by establishing design and maintenance parameters that all roadways must meet. By integrating the best practices of design consistency, context sensitivity and performance-based design, this approach to managing road standards provides a typical section that is consistent for the driver, considerate of the roadway context and is optimized for safety performance. By factoring time, deterioration and maintenance into the typical sections can easily accommodate overlays and ensure the intended safety performance throughout the full lifespan of the road.

The roads we design do not remain in the condition they are originally constructed for long; nor are they reconstructed immediately when they deteriorate. Our design approach aims to employ an innovative and practical perspective by considering the reality of use and deterioration our roads face, as well as the most up-to-date, validated safety standards. In doing so, we have found that we can improve safety over the entire lifespan of a road, prepare counties to make more informed decisions about roadway construction and maintenance, and address the most costly aspects of roadway maintenance. Additionally, the visual tools and quantitative safety data gives local governments and departments of transportation valuable resources for communicating with the public and working with landowners to acquire the needed right-of-way to build roads that meet these safety standards. Most importantly, public works professionals, like the team at Johnson County, can prepare for a safer, more efficient infrastructure design, construction and maintenance program by working with crash prediction and roadway safety experts to develop or update county road standards that will serve their residents and constituents well for the next 40 years.

1 The Kill Creek Corridor is a series of roads in Johnson County that create a through corridor to K-10. Even though there are several roads that make up this corridor, because of its use as a continuous route, we designated these roads as a single typical section for design consistency.
As managing director, Howard leads SKW’s infrastructure services department for planning, construction observation, transportation and structural engineering in the Kansas City metropolitan area and branch offices in Missouri and Oklahoma. In this role, he develops creative solutions for clients to utilize cutting-edge safety and procurement practices to achieve cost-effective solutions. For 16 years, Howard served in various roles at the Kansas Department of Transportation (KDOT). Regarding design, he was involved in both large- and small-scale highway, urban reconstruction, park facility and bridge reconstruction projects. Additionally, he served as KDOT’s Highway Safety Manual (HSM) expert, reviewing and performing crash predictions and writing implementation policy that informed decision-making in project management. Operationally, he oversaw KDOT’s Olathe area office and was responsible for construction and maintenance throughout Johnson and Wyandotte counties. He developed plans, scopes of work, cost estimates, budgets and schedules for the construction phase of pavement preservation, bridge maintenance and facility expansion projects. He coordinated these activities with KDOT staff, elected officials, federal agencies and local members of the community.
As a transportation engineer, Cheryl is responsible for designing comprehensive multi-modal transportation solutions to accommodate automobiles, pedestrians, cyclists and public transit in accordance with local, state and federal policies and standards. Along with leading the design of roadway safety, roadway design, sidewalk and intersection facilities, Cheryl also serves as a project manager defining the scope, schedule and budget of public infrastructure and private development projects.

Cheryl joined SKW in 2016, with five years of experience in highway safety and design, and has added intersection design, as well as traffic studies to her portfolio. She works with local communities to clarify long-term goals and has managed bridge and culvert replacement projects. She also designs plans to rehabilitate pavement, control traffic, widen and improve roads, install guardrails, control erosion and improve sidewalks to meet Americans with Disabilities Act (ADA) standards. She participates on the Transportation Research Board (TRB) Committee, ANB25 – Highway Safety.
COMMUNITIES BEGIN AT SHAFER, KLINE & WARREN

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