



Enhanced Pavement Project Prioritization

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Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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Research Report

KTC-25-01

Enhanced Pavement Project Prioritization

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16. Abstract The Kentucky Transportation Cabinet (KYTC) is responsible for inspecting, maintaining, and improving 27,000 centerline miles of pavement. Given the vastness of the state's transportation network, KYTC needs a robust method for prioritizing pavement preservation projects. The Cabinet has relied on pavement condition ratings, data collected using Laser Crack Measurement Systems, and input from district-level staff to prioritize these types of projects. But this approach overlooks information that should be considered, such as factors related to safety, mobility, and geographic context. To resolve these shortcomings, Kentucky Transportation Center (KTC) researchers worked with KYTC subject-matter experts to develop the Enhanced Pavement Prioritization Index (EPPI). This index, partially modeled on methods adopted by other states, can be used to approach project prioritization more holistically. Potential projects are scored on 10 final factors after testing eliminated two variables due to data issues. The factors are grouped into three categories — Condition, Mobility, and Safety. Weights were assigned to each factor through the Analytic Hierarchy Process. Two factors are included in the Condition category: Pavement Distress Index and Highway Performance Monitoring System (HPMS) Cracking %. The Safety category also has two factors: Mean SCRIM Coefficient (MSC) and Rutting. And the Mobility category includes six factors: Average Daily Traffic, Average Daily Truck Traffic, Snow and Ice Priority System, Truck Route, Functional Classification, and the Criticality Index. The EPPI can be refined by KYTC over the next several budget cycles as it is put into practice ranking potential pavement projects.			
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Executive Summary

The Kentucky Transportation Cabinet's (KYTC) mission is to deliver a safe, efficient, environmentally sound, and fiscally responsible transportation system that provides economic opportunities and enhances the quality of life in Kentucky. KYTC's Department of Highways plays a vital role in achieving this mission by inspecting, maintaining, and improving the state's 27,000 centerline miles of pavement. Currently, KYTC primarily uses pavement condition ratings, Laser Crack Measurement System (LCMS) data, and input from Districts to prioritize pavement projects. However, these factors, sans district input, have generally been assessed in a vacuum and neglect risks associated with poor pavement conditions along specific routes — particularly those that are critical to mobility within a given area. With the assistance of Kentucky Transportation Center (KTC) researchers, KYTC has developed the Kentucky Enhanced Pavement Prioritization Index (EPPI) to prioritize pavement projects. Adopting this new method will strengthen the Cabinet's ability to prioritize pavement projects in concert with other assets as well as improve the resiliency of Kentucky's transportation networks.

Development of the EPPI was informed by a review of prioritization indices used by other state transportation agencies to prioritize pavement projects. Generally, agencies use pavement management systems to compile condition-based data to rank projects. KTC held a series of facilitated workshops with KYTC subject-matter experts to determine what factors should be included in a new pavement prioritization index. Cabinet stakeholders followed the Analytic Hierarchy Process to establish the relative importance of each factor ultimately included in the EPPI. Information on twelve factors grouped into three categories — **Condition, Mobility, and Safety** — are used to calculate the EPPI. Each factor is assigned a weight that denotes its contribution to the overall score. Table E1 lists the initial contribution of each factor within each category to the overall index score. EPPI scores range between 0 and 1, where 0 indicates the lowest priority and 1 the highest priority. However, after testing the index, two variables — Mean Profile Depth (MPD) and Work Order Costs — which were originally considered for inclusion in the calculation were subsequently discarded due to concerns with data quality and efficacy. The original weighting for these variables is assigned proportionally to the other variables within the same category to achieve the final weighting used in the Enhanced Pavement Prioritization Index (EPPI) calculation.

Table E1 Original vs. Final Index Weightings

Category	Variable	Description	Original Weight	Final Weight
Condition	PDI	Pavement Distress Index	34.61%	45.09%
	CRK	HPMS Cracking %	9.97%	12.99%
	COST	Maintenance orders/cost	13.5%	0.00%
Mobility	ADT	Average Daily Traffic	3.16%	3.16%
	ADTT	Average Daily Truck Traffic	2.22%	2.22%
	SNIC	Snow and Ice Priority	0.82%	0.82%
	TR	Truck Route	1.16%	1.16%
	FC	Functional Class	1.69%	1.69%
	CS	Criticality Score	3.26%	3.26%
Safety	MSC	Mean SCRIM Coefficient	10.68%	12.80%
	RUT	Rutting	14.02%	16.81%
	MPD	Mean Profile Depth	4.91%	0.00%

Once the variables are obtained for each pavement section, the EPPI is calculated by summing the products of each variable multiplied by the final weight as shown in the formula below.

$$EPPI = PDI*(0.4509) + CRK*(0.1299) + ADT*(.0316) + ADTT*(0.0222) + SNIC*(0.0082) + TR*(0.016) + FC*(0.0169) + CS*(0.0326) + MSC*(0.128) + RUT*(0.1681)$$

Following successful testing of the EPPI using KYTC data, the Cabinet plans to use it to prioritize pavement projects over the next several budget cycles, giving the agency the chance to review its performance and continue to update it as needed.

Chapter 1 Introduction and Background

The Kentucky Transportation Cabinet (KYTC) manages over 27,000 centerline miles of pavement, the eighth highest total in the U.S. Ensuring safety and mobility are maintained is vital to the transportation network. Kentucky's roads serve as key links in that network by facilitating freight movement and providing safe mobility for network users travelling to school, work, and home.

Currently, KYTC primarily uses pavement condition ratings, Laser Crack Measurement System (LCSM) data, and District input to prioritize pavement projects. However, these factors, sans district input, have generally been assessed in a vacuum and elide risks associated with poor pavement conditions along specific routes — particularly those that are critical to mobility within specific areas.

The current approach omits factors which can justifiably be used to prioritize projects. Additionally, by only focusing on condition, evaluations overlook safety and mobility factors in the prioritization ranking. Failing to incorporate safety and mobility factors may inhibit KYTC's ability to rank the relative importance of assets to the overall network. To address these issues, the Cabinet and Kentucky Transportation Center (KTC) researchers collaborated to develop the Enhanced Pavement Prioritization Index (EPPI). Modeled on approaches taken by other states, the EPPI synthesizes data on pavement condition and other factors to help KYTC make project prioritization decisions. As risk-based method of asset management, the EPPI integrates data on both condition and asset importance into the decision-making process.

This report describes the how KTC and KYTC developed the EPPI. Table 1.1 summarizes its structure and content.

Table 1.1 Report Structure

Chapter	Material
2	Literature review on pavement management systems, pavement performance measures, and general prioritization approaches
3	Background on pavement/roadway prioritization methods from the perspectives of the federal government and state transportation agencies
4	Reviews the methodology undertaken to develop the EPPI
5	Concluding thoughts and application of the Index.

Chapter 2 Literature Review

Pavement projects can take several forms, including preservation, rehabilitation, or replacement. This chapter provides a high-level review of methods and approaches used to identify and prioritize pavement projects, while Chapter 3 discusses procedures used by individual states.

Often, budgetary constraints limit how many projects an agency can undertake, leading to asset deterioration and increasing the cost of rehabilitation or replacement in the future (Hicks et al. 2000). Chang et al.'s (2017) framework attempts to quantify the impacts of limited funding using performance measures and integrating needs, condition, and funding, rather than simply ranking projects based on need alone. Potential factors that could be used to rank assets and their performance include condition, asset design, expected service levels, asset life, factors impacting remaining lifespan, changes wrought by maintenance activities, and causes of deterioration, among others. Preventive maintenance programs (e.g., various forms of pavement preservation) can be cost-effective in the right context, reducing long-term rehabilitation or replacement costs as well as economic costs to the public (Zimmerman and Peshkin 2003; Burningham and Stankevich 2005).

Pavement management systems (PMSs) are databases used to identify and prioritize projects through assessment and optimization (Gurganus and Gharaibeh 2012, Wang et al. 2003). Hudson et al. (1979) provided one of the first definitions of a PMS: “a set of tools or methods that assist decision makers in finding optimum strategies for evaluating and maintaining pavements in serviceable condition over a period of time.” The New Jersey Department of Transportation (DOT) defines a PMS as “a set of defined procedures for collecting, analyzing, maintaining, and reporting pavement data, to assist the decision makers in finding optimum strategies for maintaining pavements in serviceable condition over a given period of time for the least cost.”¹ A PMS generally has inbuilt methodologies that are used to characterize condition, project/treatment options, and predict future conditions (Grivas et al. 1993). It also utilizes algorithms that account for maintenance and rehabilitation costs as well as available funding (Elbagalati and Hajij 2018). PMSs help improve planning, decision making, and analysis of different scenarios depending on the management approach (Zimmerman and Peshkin 2004). All states maintain a PMS that includes pavement data on state primary roads, which are reported to FHWA, as well as other data that have value to individual DOTs. Local/county roads are typically not included in PMSs.

States use PMS software to predict future pavement conditions and make treatment recommendations based on historical pavement health data and anticipated future funding allocations. Software packages apply deterministic (empirical, mechanistic, and mechanistic-empirical) and probabilistic (Markov-chain and Bayesian) forecast models of pavement deterioration at both the network and project levels (Tsai et al. 2019). Input factors for predictive modelling may also include pavement condition data, performance metric thresholds, funding scenarios, decision trees, and construction unit costs.

Other approaches used to prioritize pavement preservation projects are worth highlighting. Pavement management is often challenged by subjective decision making. Decision-making tools have attempted to attenuate the impact of subjectivity. Gurganus and Gharaibeh (2012, p.38) proposed a decision support tool that uses six parameters to prioritize pavement preservation projects:²

1. Visual distress

¹ <https://www.state.nj.us/transportation/eng/pavement/pdf/PMSOverviews0709.pdf>

² For more on pavement scoring methods and performance measures see Papagiannakis et al. (2009).

2. Average daily traffic
3. Current truck average daily traffic
4. Condition score
5. Ride quality
6. Section that receives most in-house maintenance

Elbagalati and Hajij (2018) developed a clustering algorithm to combine pavement segments with overlapping spatial coordinates to maximize budget allocations geographically.

Linear programming (LP) is another method that has been used for decades in pavement maintenance optimization. De la Garza et al. (2011) developed a pavement maintenance optimization LP Excel add-in for state DOTs. The decision-making tool optimizes the amount of funding that should be allocated to different treatment types. In LP, however, the objective and constraint functions require linear relationships. Integer programming has been used when parameters are categorical. Dynamic programming uses multiple stages to simplify complex problems, but state variables increase exponentially with the addition of budget constraints (Hafez et al. 2019).

Other researchers have developed fuzzy logic (Moazami et al. 2011), simulation (Dabous et al. 2020), and neural network (Issa et al. 2022) approaches to pavement performance assessments. Artificial intelligence algorithms are also used to improve data collection rates and processing in PMSs (Peraka and Biligiri 2020; Xu and Zhang 2022).

Several recent projects have expanded the range of factors incorporated into prioritization, including resilience, socioeconomic factors, and equity. In North Carolina, research is underway on the state's pavement resilience following structural asset damage inflicted by Hurricane Florence. The project will identify characteristics that affect pavement vulnerability and develop a framework for prioritizing pavements using resilient-based improvement plans (Underwood 2023). Louisiana developed a deep reinforcement learning (DRL)-based project system to prioritize and optimize projects following weather-related disasters (hurricanes and flooding). This model uses a PMS plus pavement condition data, traffic data, the pavement network inventory, topographical data, socioeconomic data, and financial information based on damage-related recovery costs. The model produces "an optimal recovery plan of damaged transportation systems by considering social, economic, political, and technical factors and analyzing dynamic interaction flows of communities with transportation infrastructure systems before and after disasters occurrence and effects of disaster mitigation and recovery policies on this system" (Lee et al. 2021).

Chapter 3 Background and State Review

3.1 Background

23 CFR 626 codifies the Federal Highway Administration's (FHWA) pavement design standard as such: "Pavement shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost effective manner."³ As part of the Fixing America's Surface Transportation (FAST) Act in 2015, FHWA published a rule on developing performance measures for pavements and bridges on the National Highway System (NHS) (The National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program Final Rule).⁴ This meets requirements initially defined in Moving Ahead for Progress in the 21st Century (MAP-21) Act in 2012. Pavement measures were defined as:

- Percentage of Interstate pavements in good condition
- Percentage of Interstate pavements in poor condition
- Percentage of non-Interstate NHS pavements in good condition
- Percentage of non-Interstate NHS pavements in poor condition

Pavements rated in good condition do not need major investment beyond standard ongoing maintenance, while those poor condition require significant investment (e.g., major rehabilitation or replacement). State DOTs must set targets for pavement performance — two- and four-year goals for non-NHS pavements and four-year goals for interstate pavements — and issue progress reports. The Infrastructure Investment and Jobs Act (IIJA), also referred to as the Bipartisan Infrastructure Law, passed in 2021 continues the National Performance Management Measures for pavements with additional considerations required for extreme weather and resilience when examining asset management plans. Kentucky's latest pavement report (labelled as mid-2020) documented the following pavement conditions (Table 3.1).

Table 3.1 Kentucky Pavement Progress Determination

	Measure	Data	Baseline	Target	Actual	Progress Made?
NHS Pavements (non-Interstate)	% of pavement in good condition	IRI only	78.9%	--	72.9%	Yes
NHS Pavements (non-Interstate)	% of pavement in good condition	Full distress plus IRI	--	35.0%	48.9%	Yes
NHS Pavements (non-Interstate)	% of pavement in poor condition	IRI only	4.3%	--	3.9%	Yes
	% of pavement in poor condition	Full distress plus IRI	--	6.0%	1.4%	Yes

³ <https://www.ecfr.gov/current/title-23/chapter-I/subchapter-G/part-626>

⁴ <https://www.fhwa.dot.gov/tpm/pubs/PM2PavementFactSheet.pdf>

On the NHS, each state is required to collect pavement condition data at 0.1-mile intervals. States typically collect condition data on public roads every 1 – 2 years. Each year they report pavement conditions and performance to FHWA for the Highway Performance Monitoring System (HPMS).⁵ FHWA has five standard performance metrics:

- International Roughness Index (IRI)
- Present Serviceability Rating (PSR)
- Cracking Percent
- Rutting (flexible)
- Faulting (rigid)

PSR is measured low-speed roads (40 mph or less) where IRI is not obtainable and uses a scale of 0 – 5 to rate pavements. In states that do not collect data on PSR and only use a Pavement Condition Index (PCI), the PCI may be converted to PSR. FHWA's report *Present Serviceability Rating Computation from Reported Distresses* and a companion Excel workbook provide a method to estimate PSR from surface distress data. Thresholds for these metrics are shown in Figure 3.1.

Metric Thresholds for Pavement Condition			
<u>Rating</u>	<u>Good</u>	<u>Fair</u>	<u>Poor</u>
IRI (inches/mile)	<95	95-170	>170
PSR* (0.0-5.0 value)	>4.0	2.0-4.0	<2.0
Cracking Percent (%)	<5	**CRCP: 5-10, Jointed: 5-15, Asphalt: 5-20	>10, >15, >20
Rutting (inches)	<0.20	0.20-0.40	>0.40
Faulting (inches)	<0.10	0.10-0.15	>0.15

Figure 3.1 FHWA Performance Metric Thresholds
Source: Missouri DOT (2019)

Several national studies have resulted in reports, manuals, and tools that provide technical assistance on pavement management and performance,⁶ including *Optimal Timing of Pavement Preventive Maintenance Applications* (NCHRP 14-14), *Quantifying the Effects of Preservation Treatments on Pavement Performance* (NCHRP 14-33) and *Guidelines for the Preservation of High-Traffic-Volume Roadways* (SHRP2 R26 2011). The latter provided an example preservation treatment decision matrix that uses weighted scores to compare treatments categorized by economic factors, construction and materials, customer satisfaction, and agency policies or preferences.

The PCI was initially developed by the United States Army Corps of Engineers to assess airfield pavements and then was standardized for roadways by the American Society of Testing & Materials (ASTM). The international standard is detailed in the *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys* (ASTM 2023). PCI measures pavement surface distress observed while surveying pavement conditions. PCI scaling varies by agency, but a common approach is shown in Figure 3.2.

⁵ <https://www.fhwa.dot.gov/policyinformation/hpms.cfm>

⁶ See <https://www.fhwa.dot.gov/pavement/mana.cfm>

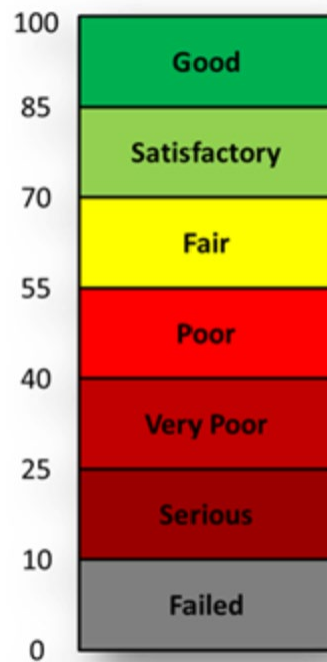


Figure 3.2 PCI Standard Rating Scale

The following method is used to calculate a PCI rating:

- An equation converts the severity and extent of each distress into a deduct value. Individual deduct equations are used for different distress types.
- All deduct values obtained across all distress types are added up and subtracted from 100.
- The result is a PCI on a scale of 0 to 100.⁷

3.2 Pavement Rating and Prioritization Methods

Drawing from information about proposed and implemented methods in 10 states, our synthesis of practices used by other DOTs provides a representative survey of current approaches to pavement ranking and prioritization. However, it should be noted that most of these approaches are focused on large projects such as rehabs rather than routine resurfacing and thus the findings should be viewed in that context. Most states publish asset inventories and pavement management strategies in Transportation Asset Management Plans (TAMPs). They often report long-term performance management targets separately. Pavement management divisions typically publish pavement condition reports detailing pavement performance metrics and methods. While pavement condition data collection methods are available in many of these documents, often pavement project prioritization methods are not rigorously described.

Devices used to evaluate pavements vary among states. Conventional methods include visual inspections and using vehicles equipped with a falling weight deflectometer (FWDs), LCMS, and digital cameras to analyze surface distresses. Newer methods under include Traffic Speed Deflection (TSD) devices for gathering data over short intervals at posted speed limits (Ali et al. 2023), smartphones, and uncrewed aerial systems (i.e., drones) (Afsharnia, 2024).

⁷ <https://www.ucprc.ucdavis.edu/ccpic/pdf/PCI%204-Page%20final%20v2.pdf>

Indiana is currently investigating the feasibility of using crowdsourced data collected by connected vehicles (Bullock and Mathew 2024).

States establish individual pavement performance metrics and thresholds. There are many rating systems used to evaluate pavement conditions, identify distress types, and model project-level deterioration (Tsai et al. 2019). Some DOTs adhere to FHWA's recommendations or make minor adjustments to them (e.g., Caltrans). Others have found FHWA's performance management methods are too general and do not apply to their state's pavement conditions, which has led them to develop their own metrics. Calhoon and Marasteanu (2021) surveyed pavement management processes adopted by 20 state DOTs and found most (14 of the 20 reviewed) use an overall pavement condition metric. They concluded that "Most DOTs use an overall condition metric that makes comparison between pavement sections easier. These metrics are a combination of weighted sub-metrics. A good example of this kind of metric is CTDOT's Pavement Condition Index (PCI) which is calculated from the following weighted metrics [CTDT]: IRI (10%), Rutting (15%), Cracking (25%), Disintegration (30%), and Drainage (20%)." Other states use a metric based on a single data type, such as ride quality (e.g., Missouri DOT has primarily used smoothness). Washington DOT uses metrics and specifies threshold conditions that will trigger a treatment.

Bektas et al. (2015) reviewed of the pavement condition assessment practices in each state, finding that most use deduct values based on distress types, although some employ direct panel ratings or utility methods (distress and condition scores). States may collect additional information (i.e., skid resistance at the New Mexico DOT and Ohio DOT) and data on roadway geometry (KYTC).

Peshkin et al. (2024) detailed survey results on state DOT pavement preservation practices and provided a gap analysis to address state needs. FHWA conducted peer exchanges in 2018 as part of its Every Day Counts Round 4 (*Pavement Preservation When, Where and How*) initiatives, which included topics related to project selection and timing of pavement preservation projects. KYTC was among the participating agencies (Groeger et al. 2018). FHWA's survey of state DOTs found that most agencies perform preservation treatments every 1 – 2 years with pavement condition surveys serving as the primary source of performance monitoring (44 of 50 agencies). Among 49 respondents, only 14 said that their agency has a formal, documented department policy on pavement preservation. An additional 13 said their agency has a policy but that it was not documented, and 22 reported no policy was in place. Most agencies (36) used models for asphalt-surfaced pavement preservation treatments, less than half (20) have models for concrete preservation treatments, and about a quarter (14) do not have any performance models for preservation treatments.

All respondents indicated their agencies will benefit from additional guidance on project selection. When asked how projects are selected, respondents reported a preference for collaboration between the central office and local staff. Nearly all agencies (44) surveyed have pavement management units make recommendations using information from PMSs and local knowledge. About half (24) use a PMS to identify where treatments will be most effective or cluster projects (23) to achieve the highest cost-benefit ratio. Fewer respondents said that when districts are involved (20) decisions are based on funding targets or mileage and condition targets (15). Only 10 reported that targeted cycle time determines treatment projects. Project selection is based on the following (Peshkin et al 2024, p. 37):

- Pavement management system identifies good candidate projects (42).
- Districts/regions select projects based on local knowledge (41).
- Projects recommended locally are matched to pavement management recommendations (24).
- Projects are programmed in clusters to improve cost-effectiveness (23).
- District programming is based on a spending, budget, mileage, or condition target (45).

Figure 3.3 lists the successes and challenges associated with preservation treatments mentioned by state DOTs.

Successes	Challenges
• Equipment certification. • Use of a statewide trainer. • Agency/industry alliances. • Competitive bidding and contracting strategies. • Timing of maintenance before preservation. • Improved specifications. • Innovative use of materials, better control of materials. • Budget commitments. • Innovative construction practices. • Improved crack sealing practices. • Improved design procedures. • Incentives/disincentives.	• Loss of experienced inspectors. • Lack of training. • Contracting and competition. • Lack of contractors. • Aggregate quality, cleanliness, gradations. • Delay between project identification and construction, changes in condition. • Moratoriums. • Small number of available treatments. • Sufficient funding for improvements required by the Americans with Disabilities Act. • Considering surface condition during construction. • Leadership support for preservation. • Modeling preservation in pavement management. • Reflective cracking. • Effect of snowplows. • Agency budgets.

Figure 3.3 Successes and Challenges Extracted from EDC-4 Pavement Preservation Peer Exchanges.
Source: Peshkin et al. (2024, p. 6)

3.2.1 Minnesota

Minnesota DOT (MnDOT) scores pavement projects based on input from district staff, expert guidance from the materials office, and the Highway Performance Monitoring System (HPMS).⁸ The agency uses a trailer-mounted FWD⁹ to evaluate pavements, typically during summer and early autumn to avoid frost and winter-thaw. The vehicle collects data on the outer lane of trunk highways annually. A project is underway to collect shoulder data.

MnDOT calculates four condition indices: Ride Quality Index (RQI), Surface Rating (SR), Pavement Quality Index (PQI), and Remaining Service Life (RSL). The RQI is a ride or smoothness index. Pavement conditions are rated on a scale of 0 (very poor) to 5 (very good). New construction typically has an initial RQI above 4.0. Once the RQI drops to 2.5, a major rehabilitation is triggered. RQI accounts for driver attitudes about road smoothness using a rating panel that involves driving people over selected pavements and sharing their views on rideability, which is a conversion of IRI.

Table 3.2 Minnesota DOT Ride Quality Index (RQI) Performance Categories

Descriptive Category	RQI Range
Very Good	5.0 – 4.1
Good	4.0 – 3.1
Fair	3.0 – 2.1
Poor	2.0 – 1.1

⁸ <https://www.dot.state.mn.us/projectselection/pavement-method.html>

⁹ https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=12277943

Descriptive Category	RQI Range
Very Poor	1.0 – 0.0

The SR is a crack and surface distress index. AutoCrack Software analyzes digital 3D images captured by an inspection vehicle to locate and classify distress types, characterize their severity, and calculate their length and width. Road segments are rated from 0 to 4 (rounded to the nearest tenth). SR is calculated based on the first 500 feet of each mile/section (or 10% sample). The percentage of each distress is weighted according to severity. Percentages are summed to derive the Total Weighted Distress (TWD), which is used in the calculation.

Road sections with a SR rating of 2.5 or less need major rehabilitation, while a 4.0 rating represents a new road with no distress. Prior to 2021, MnDOT lacked a specific standard for a healthy SR score. The standard was established by analyzing trends in all RQI and SR data collected between 2000 and 2018 (Marasteanu, 2021).

Table 3.3 Minnesota DOT Pavement Distress Types Used to Determine the Surface Rating (SR)

Bituminous Surfaced Pavement	Jointed Concrete Pavement	Continuously Reinforced Concrete Pavement (CRCP)
Transverse Cracking <i>Low Severity</i> <i>Medium severity</i> <i>High Severity</i> Longitudinal Cracking <i>Low Severity</i> <i>Medium Severity</i> <i>High Severity</i> Longitudinal Joint Distress <i>Low Severity</i> <i>Medium Severity</i> <i>High Severity</i> Multiple Cracking Alligator Cracking Rutting Raveling & Weathering Patching	Transverse Joint Spalling <i>Low Severity</i> <i>High Severity</i> Longitudinal Joint Spalling <i>Low Severity</i> <i>High Severity</i> Faulted Joints Cracked Panels Broken Panels Faulted Panels Overlaid Panels Patched Panels D-Cracked Panels	Patch Deterioration Localized Distress D-Cracking Transverse Cracking

The PQI is a composite index that measures overall pavement quality. It is used to determine if the state highway system meets performance standards. Table 3.4 summarizes MnDOT rating scales for each pavement index.

Table 3.4 Minnesota DOT Rating Scales Summary for Pavement Indices

Index Name	Pavement Attribute Measured by Index	Rating Scale
Ride Quality Index (RQI)	Pavement Roughness	0.0 - 5.0
Surface Rating (SR)	Pavement Distress	0.00 - 4.0
Pavement Quality Index (PQI)	Overall Pavement Quality	0.0 - 4.5

Finally, RSL is an estimate of the amount of time (in years) until the next rehabilitation. RSL is calculated by first using deterioration curves to predict when the RQI will reach a value of 2.5, then subtracting the present value. RSL values from each year are used to calculate a length-weighted Average Remaining Service Life (ARSL) value for the system and each ATP.

The State of Minnesota requires a Life-Cycle Cost Analysis (LCCA) for all pavement projects in the reconditioning (RD), resurfacing (RS), and road repair (RX) funding categories (MINN. STAT. 174.185). The LCCA compares competing paving materials based on the assumptions of equal design lives and equal comparison periods. If the chosen alternative does not have the lowest life-cycle cost, a justification for its selection must be documented. LCCA is a common approach for determining pavement type.

Matias de Oliveira et al. (2022), borrowing methods created by the Washington State DOT, proposed additional metrics using HPMS data to estimate the Percent Remaining Service Interval (PRSI). The PRSI normalizes RSL across pavement types to predict pavement performance and the effect of funding on pavement condition using an Asset Sustainability Ratio and Deferred Preservation Liability.

Potential pavement projects are identified when the RQI is forecasted to be 2.5 or less, “(Remaining Service Life = 0) in year 10 of the CHIP being developed.” District staff score and select pavement projects using a forecasted length-weighted average RQI. They do not score chip seals, patch, or crack sealing. Scoring methods differ between NHS and non-NHS pavements (see Figure 3.4 and Figure 3.5). Urban non-freeway/non-expressway pavements are scored separately due to complexities in coordinating utilities or local and public involvement.¹⁰

¹⁰ <https://www.dot.state.mn.us/projectselection/pavement-method-urban.html>

NHS pavement scoring

Criteria	Points Available	Scoring Rubric
Timing of the Improvement	60	See table below for detailed scoring information
Network Designation	5	Interstate – 5 points Non-Interstate Freeway – 2 points Other NHS – 0 points
Traffic Volume	10	Projects with AADTs equal to or greater than 25,000 in Greater MN and 120,000 in Metro receive full points. Below those values, points are assigned as a percent of those values rounded down to the nearest point. Example AADT of 14,000 in Greater MN: $14,000/25,000 \times 10 \text{ points} = 5.6 \text{ points}$ rounded down to 5 points.
Truck Volume	10	Projects with HCADTs equal to or greater than 1,000 in Greater MN and 5,000 in Metro receive full points. Below those values, points are assigned as percent of those values rounded down to the nearest point.
Length/Miles Covered	5	< 10 roadway miles - miles/2 = points (i.e. 4 mile project gets 2 points) – round to the nearest half point ≥ 10 roadway miles - 5 points
Other Infrastructure Needs	10	Number of condition 3 & 4 pipes: ≥ 5 – 10 points 1-4 – 5 points 0 – 0 points

Figure 3.4 Minnesota DOT NHS Pavement Scoring

Source: <https://www.dot.state.mn.us/projectselection/pavement-method.html>

Non-NHS pavement scoring

Criteria	Points Available	Scoring Rubric
Timing of the Improvement	60	See table above for detailed scoring information
Traffic Volume	10	Projects with AADTs equal to or greater than 5,000 in Greater MN and 25,000 in Metro receive full points. Below those values, points are assigned as a percent of those values rounded down to the nearest point.
Truck Volume	10	Projects with HCADTs equal to or greater than 500 in Greater MN and 1,000 in Metro receive full points. Below those values, points are assigned as percent of those values rounded down to the nearest point.
Length/Miles Covered	5	< 10 roadway miles - miles/2 = points - round to the nearest half point ≥ 10 roadway miles - 5 points
Other Infrastructure Needs	10	Number of condition 3 & 4 pipes: ≥ 5 - 10 points 1-4 - 5 points 0 - 0 points
Turnback Potential	5	Turnback candidate - 5 points

Figure 3.5 Minnesota DOT Non-NHS Pavement Scoring

Many factors influence why high-scoring projects are not picked or why low-scoring projects are chosen. The lists below provide examples in each category.¹¹

Reasons why a high-scoring project would not be picked:

- Waiting to coordinate with another project
- Cost exceeds the total available budget for the year
- Waiting to avoid simultaneous or multiple years of detours in the same area
- Local partner not currently ready to participate
- Project not identified or prioritized in the metropolitan transportation plan or studies (for projects within MPO planning areas)
- Significant environmental work needs to be completed or more work is required to identify and resolve environmental constraints

Reasons why a lower-scoring project would be picked:

- Model's RQI forecast does not reflect on-the-ground conditions or expectations
- Ongoing maintenance concerns
- City, county, or tribal government has funding for a specific year
- Turnback agreement in place
- To coordinate with the timing of another MnDOT or local project

¹¹ <https://www.dot.state.mn.us/projectselection/pavement-method.html>

3.2.2 Virginia

Virginia offers a case study in best practices for transportation project prioritization. In 2013, the Virginia General Assembly mandated the development of a prioritization process for the Transportation Board. The prioritization process is called the SMART SCALE,¹² which stands for System Management and Allocation of Resources for Transportation: Safety, Congestion, Accessibility, Land Use, Economic Development, and Environment.

The prioritization process requires weighting candidate projects based on safety, congestion, accessibility, land use, economic development, and the environment. Factors are weighted differently across Virginia and within districts based on their characteristics. Only capital and operational projects are eligible for SMART SCALE funding. Asset management projects, including pavement replacement or repair, are not eligible, but the prioritization process captured in Figures 3.6 is notable. Asset management projects may be eligible for funding through the Virginia DOT's (VDOT) State of Good Repair Program. The prioritization process has five steps.



Figure 3.6 Virginia Prioritization Process
Source: <https://smartscale.virginia.gov/how-it-works/>

Scoring is based on six factors, whose weights vary (Figure 3.7).

FACTOR AREAS	MEASURE ID	MEASURE NAME	MEASURE WEIGHT
Safety	S.1	Equivalent property damage only (EPDO) of Fatal and Injury Crashes*	70 percent
	S.2	EPDO Rate of Fatal and Injury Crashes	30 percent
Congestion mitigation	C.1	Person Throughput	50 percent
	C.2	Person Hours of Delay	50 percent
Accessibility	A.1	Access to jobs	60 percent
	A.2	Access to jobs for disadvantaged persons	20 percent
	A.3	Access to multimodal choices	20 percent
Environmental quality	E.1	Air quality and environmental effect	100 percent
	E.2	Impact to natural and cultural resources	0 percent - Subtract up to 5 points
Economic development	ED.1	Project support for economic development	60 percent
	ED.2	Intermodal access and efficiency	20 percent
	ED.3	Travel time reliability	20 percent
Land use	L.1	Transportation-efficient land use	50 percent
	L.2	Increase in transportation-efficient land use	50 percent

*100 Percent for transit and Transportation Demand Management projects

Figure 3.7 Virginia DOT Scoring and Weighting

¹² <https://smartscale.virginia.gov/how-it-works/>

Factors are weighted based on geographic location, after which totals for each factor are weighted and summed. The final score is calculated by dividing the benefit score by the SMART SCALE cost.

In terms of assessing pavement conditions, VDOT has seen changes. In the 1980s and early 1990s VDOT used a Distress Maintenance Rating (DMR) which indexed windshield pavement condition data. The DMR deducted scores from 100 (i.e., perfect pavement) based on visible pavement surface distress only (i.e., cracking, raveling, pushing, rutting, flushing, and patching). Distress was rated based on frequency and severity. The DMR was not optimized and did not provide a measure of ride quality. In the 1990s the agency briefly switched to the PCI, but found that it was too general for the state's needs.

Recent approaches have centered around the development of multiple pavement condition indices to address the impact of wheel loads and weathering distresses as well as longitudinal and cross-slope information (including rutting and ride quality) (McGhee 2002). About 90% of the state's road system is comprised of flexible pavements, so those indices receive the most attention. VDOT employs a contractor to collect and process pavement data using vehicles with downward-facing cameras to detect surface cracking and forward-facing cameras to capture images of the right of way for assets and shoulder conditions. The contractor processes images to identify individual distress types, while a third-party rates pavement sections and performs independent quality assurance and validation.

For asphalt pavements, VDOT aggregates individual distress data for two PCIs, a Load-related Distress Rating (LDR) and Non-load-related Distress Rating (NDR). LDR is related to distress types correlated with vehicle loads (e.g., alligator cracking, delaminations, patching, potholes, rutting) while NDR is unrelated to loads (e.g., bleeding, block cracking, linear cracking, reflection cracking). These indices are based on the U.S. Army Corp of Engineer's PAVER method and validated with Long Term Pavement Performance (LTPP) data (VDOT 2022).

VDOT also has a third index, the Critical Condition Index (CCI), which uses LDR or NDR score, whichever is lower. Pavements with a value of 60 or below are considered deficient and receive additional evaluation to determine what the type of maintenance or rehabilitation is required. For the CCI, the slab distress rating (SDR) is used for joined concrete pavements. The Concrete Punchout Rating (CPR) and the Concrete Distress Rating (CDR) are collected for continuously reinforced concrete pavement (CRCP) pavements.

Table 3.5 Virginia DOT Critical Condition Index

Pavement Condition	Index Scale (CCI)
Excellent	90 and above
Good	70-89
Fair	60-69
Poor	50-59
Very Poor	49 and below

Pavement condition data are entered into the PMS. Maintenance and rehabilitation decisions are optimized using unconstrained decision trees, which are used to determine how much work is required on the network if funding were unlimited. Additional input parameters include traffic level, structural condition, and maintenance history. VDOT's online dashboard displays performance measures, including the current statewide pavement condition by road system, historical trends, and forecasted deterioration.¹³

¹³ <https://dashboard.virginiadot.org/pages/maintenance/pavement.aspx>

3.2.3 Iowa

Iowa DOT uses a modified PCI that classifies roads (by type) as good, fair, or poor to describe the overall condition of pavements. However, the agency utilizes more detailed condition data to prioritize projects. PCI thresholds found in the state's 2019-2028 TAMP are shown in Table 3.6.

Table 3.6 Iowa PCI Thresholds

Category	Interstate	Non-Interstate NHS	Non-NHS
Good	76-100	71-100	71-100
Fair	51-75	46-70	41-70
Poor	0-50	0-45	0-40

Iowa DOT performs a cost-benefit analysis using an unconstrained budget scenario for treatments on each pavement section, where the benefit is defined as performance improvement or change in PCI x lane miles over the treatment life. Budget constraints are a factor when selecting projects.

Iowa DOT's Central Office decides which interstate projects are a priority, while district staff provide input for the remaining primary system. District staff typically identify construction and reconstruction projects, after which they are prioritized by the district and Central Office. District offices handle rehabilitation, preservation, and maintenance projects. Decisions are based on pavement conditions and information about "bridges and other structures, safety, traffic volume, capacity and economic benefits."¹⁴ PMIS modelling software data are used to make decisions about potential interstate projects. For non-interstate projects, districts use PMIS data along with field visits, pavement inspections, and local knowledge.

Iowa's long-range TAMP lists several limitations associated with using PMIS and modeling software for decision making:

"There are time lags between data collection, data availability, and the analysis; the models do not perfectly predict future conditions, treatment costs are estimates, treatment selection lengths may not be practical or economical, and local knowledge of pavements is not represented in the model. In addition, Iowa DOT considers other factors such as traffic, system classification and a need for funding flexibility when making project selections" (p. 38).

3.2.4 New York

New York prioritizes pavement projects using a Surface Rating System based on the frequency, severity, and type of cracking and FHWA's IRI ranges for ride quality. The New York State DOT (NYSDOT) *Network Level Pavement Condition Assessment Procedures* (2010) and annual pavement reports outline these methods.

NYSDOT uses an annual windshield survey (Pavement Surface Rating Survey) with raters in each region collecting data on the severity and extent of cracking and distress bidirectionally on travel lanes. The Surface Rating does not include crack type, location, or orientation. Raters assign a condition rating from 1 (impassable) to 10 (new) based on surface distress. They also identify distress types (or Dominant Distresses). Dominant Distresses include alligator cracking, faulting, spalling, and widening drop-off. Table 3.7 lists pavement surface rating categories.

¹⁴ https://iowadot.gov/systems_planning/fpmam/IowaDOT-TAMP-2019.pdf

Table 3.7 New York State DOT Pavement Surface Rating Categories

Rating	Condition/Description
9-10	Excellent — No Surface Distress
7-8	Good — Surface distress beginning to show
6	Fair — Surface distress is clearly visible
1-5	Poor — Distress is frequent and severe
U	Under Construction — Not rated due to ongoing work

NYSDOT uses high-speed profilers to measure IRI, rut depth, and fault height, while curve radius, slope, and grade are measured from digital images. The agency begins at the network level to identify potential pavement projects and then assesses treatment needs.

NYSDOT's PCI uses deduct values subtracted from 100, taking into account surface distress, ride quality, structural capacity, friction, and special considerations for crack seal, thin overlays, and delamination. Table 3.8 shows values associated with each condition type.

Table 3.8 New York State DOT Pavement Condition Index

Asphalt/Overlay Pavements	
Surface Rating	35 pts
IRI	35 pts
Rutting	15 pts
Alligator Crack	15 pts
-or-	
Widening Drop	15 pts
PCC Pavements	
Surface Rating	35 pts
IRI	35 pts
Rutting	5 pts
Faulting	15 pts
Spalling	10 pts

3.2.5 Ohio

Ohio DOT (ODOT) uses a Pavement Condition Rating (PCR) as the primary factor used to determine treatments (Kercher 2021). PCR is computed as the sum of deduct values, which are a function of distress type, severity, and extent: "Deduction for each distress type is calculated by multiplying distress weight times the weights for severity and extent of the distress." The PCR Scale ranges from 0 (all distress present) to 100 (perfect with no detectable distress). The scale is categorized into three levels of severity (low, medium and high) and three levels of extent (occasional, frequent, and extensive) are defined.

Ratings are based on visual inspection of roadway sections. Separate rating forms have been developed for asphalt and concrete pavements (Figures 3.8 and 3.9).

PAVEMENT CONDITION RATING FORM

DISTRESS	DISTRESS WEIGHT	SEVERITY WT.*			EXTENT WT.**			DEDUCT POINTS***
		L	M	H	O	F	E	
RAVELING	10	0.3	0.6	1	0.5	0.8	1	
BLEEDING	5	0.8	0.8	1	0.6	0.9	1	
PATCHING	5	0.3	0.6	1	0.6	0.8	1	
DEBONDING	5	0.4	0.7	1	0.5	0.8	1	
CRACK SEALING DEFICIENCY	5	1	1	1	0.5	0.8	1	
RUTTING	10	0.3	0.7	1	0.6	0.8	1 ✓	
SETTLEMENT	0	0.0	0.0	0.0	0.0	0.0	0.0	
POTHOLE	10	0.4	0.8	1	0.5	0.8	1 ✓	
WHEEL TRACK CRACKING	15	0.4	0.7	1	0.5	0.7	1 ✓	
BLOCK AND TRANSVERSE CRACKING	10	0.4	0.7	1	0.5	0.7	1	
LONGITUDINAL CRACKING	5	0.4	0.7	1	0.5	0.7	1 ✓	
EDGE CRACKING	10	0.4	0.7	1	0.5	0.7	1 ✓	
THERMAL CRACKING	10	0.4	0.7	1	0.5	0.7	1	
*L = LOW **O = OCCASIONAL M = MEDIUM F = FREQUENT H = HIGH E = EXTENSIVE								TOTAL DEDUCT = SUM OF STRUCTURAL DEDUCT (✓) = 100 - TOTAL DEDUCT = PCR =
*** DEDUCT POINTS = DISTRESS WEIGHT x SEVERITY WT. x EXTENT WT.								

Figure 3.8 Ohio DOT Ratings Form (Asphalt)

PAVEMENT CONDITION RATING FORM

DISTRESS	DISTRESS WEIGHT	SEVERITY WT.*			EXTENT WT.**			DEDUCT POINTS***
		L	M	H	O	F	E	
SURFACE DETERIORATION	10	0.4	0.7	1	0.6	0.8	1	
LONGITUDINAL JOINT SPALLING	5	0.4	0.7	1	0.6	0.8	1	
PATCHING	10	0.4	0.7	1	0.5	0.8	1	
PUMPING	15	1	1	1	0.3	0.7	1 ✓	
FAULTING (JOINTS AND CRACKS)	10	0.4	0.7	1	0.5	0.8	1 ✓	
SETTLEMENTS	0	0.0	0.0	0.0	0.0	0.0	1	
TRANSVERSE JOINT SPALLING (CIRCLE IF D-CRACKED)	10	0.4	0.7	1	0.5	0.8	1	
TRANSVERSE CRACKING (Plain Concrete)	15	1	1	1	0.5	0.8	1 ✓	
PRESSURE DAMAGE	5	1	1	1	0.5	0.8	1	
TRANSVERSE CRACKING (Reinforced Concrete)	15	0.1	0.8	1	0.4	0.8	1 ✓	
LONGITUDINAL CRACKING	10	0.5	0.7	1	0.4	0.9	1 ✓	
CORNER BREAKS	10	0.4	0.8	1	0.5	0.8	1 ✓	
*L = LOW **O = OCCASIONAL M = MEDIUM F = FREQUENT H = HIGH E = EXTENSIVE								TOTAL DEDUCT = SUM OF STRUCTURAL DEDUCT (✓) = 100 - TOTAL DEDUCT = PCR =
*** DEDUCT POINTS = DISTRESS WEIGHT X SEVERITY WT. X EXTENT WT.								

Figure 3.9 Ohio DOT Ratings Form (Concrete)

ODOT's pavement project prioritization process is decentralized. The Office of Program Management sends pavement treatment recommendations to districts that are based on PMS decision trees and optimization models. Decision trees account for pavement type, system, PCR ranges, structural deduct values, traffic levels, and specific distress levels from ODOT (Kercher 2021). Some districts use PMS decision trees to select final projects while others primarily use either firsthand field knowledge or a list of deficient roads not included in the PMS's optimized list. Availability of other funding sources may also influence project selection, including safety improvements. Treatment decisions are also influenced by the PMS segmentation rules. The length of each pavement section varies from 1/100th of a mile to 14 miles. Each section receives a treatment recommendation. Districts average the segments, but the PMS recommendations may not be the best fit based on observed field conditions (e.g., poorer pavement conditions, specific traffic types like horse and buggy or heavy haul trucking) and district staff may decide a different treatment is required.

3.2.6 Georgia

Georgia DOT (GDOT) uses two condition ratings to measure pavement performance. The National Highway Performance Program (NHPP) (based on the NHPM) is used for federal reporting, and a GDOT-specific measure called the Overall Condition Index (OCI) is used to set targets and inform decision making.

In 2015, GDOT implemented a State Route Prioritization Plan using a hierarchy based on road function. GDOT policy categorizes state highways into four categories: critical, high, medium, and low (Tsai et al. 2019). Critical highways include interstate and non-interstate highways.

Maintenance prioritization of existing infrastructure are assessed based on the following primary risk rating factors:

- COPACES Rating (Computerized Pavement Condition Evaluation System)
- AADT, Truck Percentage, Population
- State Route Prioritization

GDOT has rated pavement condition using the Pavement Condition Evaluation System (PACES) or computerized data (COPACES) since 1986. PACES ratings are an average of project-level and segment-level condition data for pavement preservation projects on interstate and state routes. COPACES ratings include NHPP Metrics (IRI, cracking, rutting, and faulting) as well as load cracking, edge cracking, block cracking, reflective cracking, raveling, and an adjustment index. Segment-level data are based on cracking distress from a 100-foot sample, or section, of each road mile. GDOT uses distress deduct values to generate a value between 0 [worst] and 100 [best].

Table 3.9 Georgia DOT OCI Pavement Condition Index

Good	OCI of 85 or higher
Fair	OCI between 70 and 84
Poor	OCI less than 70

As of 2019, pavement deterioration models had not been updated in a decade and did not accurately predict maintenance, rehabilitation, and replacement (MR&R) needs. Tsai et al. (2019) explored ways to improve the accuracy and reliability of pavement deterioration models, applying a Bayesian-based method to GDOT's PMS to select MR&R projects. They recommended including factors like environment and pavement design as well as different pavement distress types in the Bayesian pavement deterioration model, while also developing separate models for each type of pavement distress.

3.2.7 Delaware

In 2019, Delaware DOT (DelDOT) developed project prioritization criteria for all public projects in its six-year Capital Transportation Program.¹⁵ Tanked pairwise comparisons were used to create levels of importance consistent with the agency's mission, vision, and goals. The criteria and relative percentages listed below are not specific to pavement prioritization alone:

- Safety – 35.0%
- System Operating Effectiveness – 19.1%
- Multi-Modal Mobility/Flexibility/Access – 11.9%
- Revenue Generation/Economic Development/Jobs & Commerce – 13.1%
- Impact on the Public/Social Disruption/Economic Justice – 8.3%
- Environmental Impact/Stewardship – 6.6%
- State and Local Priority – 6.1%

Each criterion has its own rating scale. Safety criteria are based on a Crash Index, Critical Crash Ratio, and strategies in the Strategic Highway Safety Plan. System Operating Effectiveness is comprised of Existing Congestion Level and Congestion Management. Multi-Modal Mobility/Flexibility/Access accounts for whether a project positively impacts the efficient movement of people and goods across modes (vehicles, bicycle, pedestrian, transit, airports, and marine terminals). Revenue Generation/Economic Development/Jobs & Commerce includes assessments of Economic Impact (Competitiveness) and is based on whether a project is located in a Transportation Improvement District (TID), has cost-sharing support from private or local agencies, or is on a Freight Corridor. Impact on the Public/Social Disruption/Economic Justice involves the extent to which a project invests in existing communities and social- and health-related elements salient to economically precarious or minority populations. Environmental Impact/ Stewardship assesses the degree to which a project mitigates threats to the environment. Lastly, the State and Local Priority rates projects based on whether they have approval and cost sharing by local land use agencies or identified as a priority by the MPOs.

DelDOT uses an internal pavement performance measure, the Overall Pavement Condition (OPC), similar although not identical to FHWA's HMPS condition metrics. The OPC is calculated based on an Individual Distress Index (IDI) that is used to compute a Combined Distress Index (CDI). OPC ratings above 50 are considered in a state of good repair. The OPC includes cracking, rutting, IRI and faulting.

¹⁵ https://deldot.gov/Publications/reports/CTP/pdfs/DelDOT_project_prioritization_criteria_summary.pdf

OPC Index – Pavement Type	CDI – (OPC Component Indices)	IDI – (CDI Component Indices) Note: There are also IDIs for each distress severity used to calculate the total distress IDI.				
Flexible Index	Structural Index	Fatigue Cracking	Patch Deterioration			
	Non-Structural Index	Transverse Cracking	Block Cracking	Surface Defects / Raveling	NWP Longitudinal Cracking	
	Functional Index	Rutting	IRI			
Composite Index	Structural Index	Fatigue Cracking	Patch Deterioration			
	Non-Structural Index	Reflective Cracking	Block Cracking	Surface Defects / Raveling	NWP Longitudinal Cracking	
	Functional Index	Rutting	IRI			
Surface Treated Index	Structural Index	Fatigue Cracking	Edge Cracking	Patch Deterioration		
	Non-Structural Index	Transverse Cracking	Block Cracking	Surface Defects / Raveling	Bleeding	NWP Longitudinal Cracking
	Functional Index	Rutting	Crown > 6%			
Concrete Index	Slab Distress Index	Slab Crack	Patch Deterioration	ASR		
	Joint Distress Index	Joint Seal Loss	Joint Deterioration			
	Functional Index	IRI	Faulting			

Figure 3.10 Delaware DOT OPC Index Components

The PMS uses pavement types and distresses (severity and extent) for optimization of assessments. For each pavement section, severity is categorized as high, medium, or low. Extent ranges from 0 to 100%. The IDI severity then combines for a single IDI value per distress type. The Combined Distress Index (CDI) ranges from 0 (worst) to 100 (best condition). It is comprised of a Structural Index, Non-Structural Index, and Functional Index. It combines similar distress types to create decision trees and performance models. The OPC uses CDI values for each pavement type to determine the overall pavement health and is used for optimization analysis.

3.2.8 Other States

Connecticut

Connecticut DOT uses a composite weighted PCI for each 0.1-mile segment that consists of five individual subindexes, similar to FHWA's metrics (Table 3.10).

Table 3.10 Connecticut DOT PCI Subindexes

Roughness Index [IRI] (10%)
Rutting Index (15%)
Cracking Index (25%)
Disintegration Index (30%)
Drainage Index (20%)

Disintegration accounts for age, traffic, and weather exposure (similar to the ASTM D6433–designated distress Weathering/Raveling). Transverse cross slope and longitudinal grade are used to calculate the drainage measures.

Connecticut DOT uses state-of-the art profiler technology to collect pavement information annually, including pavement distress, wheel path rutting, cracking, patching, raveling, faulting, surface cross slope, and LCMS.

The agency is testing a new index, the Pavement Surface Performance Index (PSPI) (Bernier et al. 2023). The PSPI facilitates monitoring network health and sets lower thresholds for treatments. It “utilizes a relative scale of distresses split by pavement type or functional class and ultimately divided across pavement age, to establish an ‘expected’ performance target for any given pavement section in the state. A particular section can be performing above target or below target, and these target values will be recalculated every 3 to 5 years to ensure the overall network is trending in the right direction.”

Colorado

Colorado DOT adheres to FHWA’s condition metrics and uses a private vendor for data collection on the NHS. The agency does, however, provide a best practice for project optimization on low-volume roads. Most optimization studies have focused on primary roads but have limited application for local PMSs. Colorado DOT sponsored research to investigate best practices for managing low-volume roads (LVRs), specifically maintenance schedule optimization and treatment effectiveness (Hafez et al. 2019). In Colorado, more than half of the state road network is not part of the NHS. LVRs make up about 2,135 of paved miles but have low AADT (less than 2,000) and AADDT (less than 100). Each Colorado DOT region follows its own maintenance policies and maintenance decisions for LVRs and have depended on prior experience, regional practices, and other resources in decision making. Diversity in regional practices and budget allocations impact pavement performance (p. iv). LVRs primarily receive low-cost treatments and light rehabilitations rather than pavement maintenance — chip seals on good-condition roads, thin overlays for roads with low drivability life (DL) values.

Overall pavement condition is measured using five distress indices that make up the DL metric — fatigue cracking, longitudinal cracking, transverse racking, pavement roughness, and rutting. The distress indices are normalized and combined into a single condition index with values that range from 1 (worst) – 100 (distress free).

Table 3.11 Colorado DOT Pavement Performance Category for Each Condition Index

Index Range	Category
Greater than 90	Excellent
80 – 90	Good Condition
70 – 79	Fair Condition
60 – 69	Poor Condition
Less than 60	Very Poor Condition

The DL value is based on performance models for each distress index and is classified by minimum DL (i.e., when the overall minimum time remaining for a road segment is at 50 or below) using the following scale: low (3 years or less), moderate (4 – 10 years), or high (more than 10 years). Hafez et al. (2019, p. 42-43) developed an equation to maximize overall weighted DL (OWDL_t) based on annual network conditions.

Researchers surveyed Colorado DOT’s district staff about decision making on low-volume roads. Districts typically use condition indices and pavement management data (i.e., the most common types of distresses observed based on historical data) to select pavement treatments. The most used indices are DL, Fatigue Index, and Transverse Index.

In many districts, recycling existing distressed pavement before applying a surface treatment (e.g., thin overlay) has increased pavement life.

Idaho

Idaho DOT (ITD) collects pavement data annually and uses IRI, rutting depth, and a performance measure unique to the state, the Overall Condition Index (OCI). The 2017 Idaho *Transportation Pavement Performance Report* recommended switching from the state’s classic method to the OCI, which provides an overall pavement serviceability measure based on a weighted average of performance factors. The classic method uses profiler-collected data on cracking, roughness, and rutting for each roadway functional class. A study comparing the OCI and classic method is underway.

The OCI quantifies the extent and severity of pavement distresses using a scale from 0 (poorest pavement) to 100 (best). It does not account for speed. Values are used to calculate an Individual Distress Index (IDI) and entered into the OCI formula. The AgileAssets Pavement Management System Engineering Configuration Document describes the calculations and is available upon request.

Table 3.12 Idaho OCI Pavement Distress Types

Flexible	Rigid
Fatigue Cracking	Slab Cracking
Edge Cracking	Joint Seal Damage
Transverse Cracking	Joint Spalling
Block Cracking	Faulting
Patch Deterioration	Map Cracking
Raveling	Studded Tire Wear

There are also two subindices for each pavement type: “Rigid pavements have the Slab Index and the Joint Index computed, while flexible pavements have the Structural Distress Index and the Non-Structural Index computed” (IDT 2022 p. 14).

Indiana

Indiana DOT (INDOT) follows FHWA’s approach to pavement performance measures. INDOT uses a third-party contractor to conduct annual inspection of NHS roads and implement a quality assurance process (e.g., remove duplicates) and field verification prior to entering data into ArcGIS Roads and Highways. Indiana collects IRI, rutting, faulting, and cracking data on all state-maintained highways annually, including the right (RWP) and left wheel path (LWP) zones, two non-wheel path zones (NWP), outside pavement edge zone, and the outside shoulder zone of the roadway. The data includes a portion of the shoulder. The pavement condition threshold values are categorized in Table 3.13.

Table 3.13 Indiana Pavement Condition Thresholds

Performance Measure	Good	Fair	Poor
IRI (inches/mile)	<95	95-170	>170
RUT (inches)	<0.20	0.20 - 0.40	>0.40
Faulting (inches)	<0.10	0.10 - 0.15	>0.15
Cracking (percent)	<5	5 – 20 (asphalt) 5-15 (JCP)	>20 (asphalt) >15 (JCP)

Performance Measure	Good	Fair	Poor
		5-10 (CRCP)	>10 (CRCP)

INDOT outlines steps for determining pavement project priorities in its TAMP¹⁶ and Strategic Asset Management Plan (SAMP).¹⁷ INDOT's Pavement Asset Management Team (PAMT) utilizes the PMS to assess pavement network conditions and model treatment recommendations based on cost-benefit ratios. The dTIMS' pavement management system simulates deterioration over a 20-year period and provides cost estimates based on the known budget allocation to make project recommendations. The PAMT generates a candidate list for the state's five-year capital plan based on years 6 – 10 of the 20-year pavement asset management plan. The PAMT team then meets to score projects based on pavement cracking, roughness, roadway category, truck volume, and cost-effectiveness. Preliminary project rankings are reviewed, and the scoring may be modified based on knowledge from the field. The candidate list is further evaluated based on available revenue and project costs, with the scoring system updated annually. Figure 3.11 shows each step of INDOT's pavement project prioritization process from the 2020 SAMP (p. 43):



Figure 3.11 Indiana DOT Pavement Project Prioritization for the Capital Program

¹⁶ <https://www.in.gov/indot/files/2022-TAMP.pdf>

¹⁷ https://www.in.gov/indot/engineering/files/INDOT-SAMP_Graphical-Refresh_v14_Final.pdf

Chapter 4 Kentucky Enhanced Pavement Prioritization Index

4.1 Current Approach and Potential Issues

KYTC collects pavement condition data on the state primary system every two years. The Operations and Pavement Management Branch began collecting PDI data around 2016 for state primary, secondary, and supplemental routes, but not RS routes. PDI is evaluated approximately every three years.

When the FD05 resurfacing program is prepared each year, projects are addressed within each District's project delivery and preservation (PD&P) branches in order of priority based on PCI. Projects are programmed to the extent funding allows, and the remaining projects are deferred to the next year, at which point they are ranked again based on new PCI data.

Because KYTC's Pavement Management staff visually evaluates Maintenance Priority (MP) system pavements on a three-year cycle, PCI calculations in any given year include a mix of data from the current year and the previous two years. To equate current-year evaluations with those conducted in prior years, older datasets are adjusted using an assumed average rate of deterioration.

Since some pavements deteriorate slower or faster than average rates, District PD&P staff identify any pavement sections not scheduled for the current year's evaluation which seem to be deteriorating faster than the assumed rate of deterioration. When these sections are identified, Pavement Management staff conduct off-schedule evaluations to obtain more accurate condition data.

Often, projects which just miss the cutoff for FD05 programming in a given year will not make the list in the following year based on the newly available PCI data. District staff expressed concern that the current prioritization process does not adequately address District needs related to roadway maintenance and public expectations. The following issues were identified as concerns with the current methodology:

Internal Constraints

- District personnel lack the familiarity with pavement deterioration models needed to properly assess whether a pavement section should be reevaluated during an off-schedule year.
- Competing responsibilities within the maintenance and construction programs leave District PD&P personnel without enough flexibility to identify projects which may be deteriorating more rapidly than the models would suggest.
- To accurately compare all pavement projects, Pavement Management staff should reevaluate pavements that are deteriorating more rapidly than expected as well as those deteriorating more slowly than expected. Such pavement sections would be even more challenging for District personnel to identify.

Impacts on Maintenance Planning

- Often, the ability to make long-term pavement maintenance plans is hampered by uncertainties about the resurfacing schedule.
- Other non-pavement work, such as cross drain replacement, minor embankment repairs, the annual striping program, and safety improvements, should be coordinated with resurfacing and would be more efficient if there were better clarity on project timelines.
- Maintenance needs addressed through resurfacing can sometimes be deferred with less pushback from the public if they can be sure the anticipated resurfacing year is accurate.

Maintaining Public Trust

- Greater certainty about resurfacing schedules can enhance KYTC's relationships with the public and local officials in ways that improve the Cabinet's ability to achieve goals outside of the pavement and maintenance programs.
- While addressing the most deteriorated pavements in a given year certainly has merit, the public often expects that pavements which have been in need of resurfacing for a longer period of time will be fixed before those that have only recently been added to the list.

The objectivity of the FD05 prioritization process has built confidence in the program among KYTC leadership. This has increased support for the overall pavement preservation program, which has allowed the Cabinet to expand its treatment options and obtain additional funding. As such, any changes to the process should be made with care to ensure confidence in the program is not lost. Additionally, while many current District PD&P engineers have a lot of experience maintaining pavements, it is likely that the overall level of experience at the District level will decline in the coming years. Central Office oversight and guidance will continue to be critical to the success of the pavement preservation program. To introduce a newer, more comprehensive approach, KYTC partnered with KTC to develop an Enhanced Pavement Prioritization Index (EPPI).

4.2 Methodology

KTC collaborated with a working group of KYTC subject-matter experts to develop the EPPI. KTC's team of facilitators guided Cabinet stakeholders through the Analytic Hierarchy Process (AHP) to determine the relative importance of each factor included in the EPPI. Vargas (2010) described AHP as "a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternatives or projects." Applications of AHP are abundant (e.g., Saaty 1990, Saaty 1987, Saaty 1994, Saaty 2008, Vaidya and Kumar 2006, Vargas 1990, Vargas 2010, Hummel et al. 2014, Yap et al. 2019). Forman and Gass (2001) observed that AHP can be used for prioritization and other applications.

Saaty (2008, p. 85) identified AHP's four steps:

- Define the problem and determine the kind of knowledge sought.
- Structure the decision hierarchy from the top down beginning with the goal of the decision, then the objectives from a broad perspective, through intermediate levels (criteria on which subsequent elements depend), and on down to the lowest level (which usually is a set of the alternatives).
- Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare elements in the level immediately below with respect to it.
- Use priorities obtained from the comparisons to weight priorities in the level immediately below. Do this for every element. Then, for each element in the level below add the weighted values to obtain its overall or global priority. Continue this process of weighting and adding until the final priorities of the alternatives in the bottom most level are obtained.

The research team adopted a modified version of AHP for this project:

- Identify factors to be included in the index through facilitated workshops.
- Group factors based on commonality and assign category labels.

- Use individual pairwise comparisons to assign relative importance using the Fundamental Scale for Pairwise Comparisons, or Saaty’s Fundamental Scale (Table 4.1).¹⁸
- Generate a comparison matrix from a group aggregation of pairwise comparisons.
- Normalize the matrix by dividing each column entry’s value by the total column value.
- Determine each factor’s relative contribution to the index by calculating the Eigenvector, which is the sum of the rows in the matrix divided by the number of columns.
- Multiply the Eigenvector values (Eigenvalues), or independent weightings, for the category labels by each group factor’s Eigenvector. This yields global priorities where scores range between 0 and 1. The sum of the global priorities equals one.
- Check data consistency using Consistency Ratios.

Table 4.1 Saaty’s Fundamental Scale

Magnitude of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Moderate importance	Experience and judgement moderately favor one factor over another
5	Strong importance	Experience and judgement strongly favor one factor over another
7	Very strong importance	One factor is favored very strongly over another and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one factor over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	Used when a compromise option is necessary

4.2 Results

After identifying factors to include in the proposed index, the working group placed factors into three categories — Condition, Mobility, and Safety. Groupings and the factors comprising each are shown in Figure 4.1. Each of these variables is defined in Appendix A, including the source of the data, the file location in Dropbox, the methodology, and considerations for future improvement.

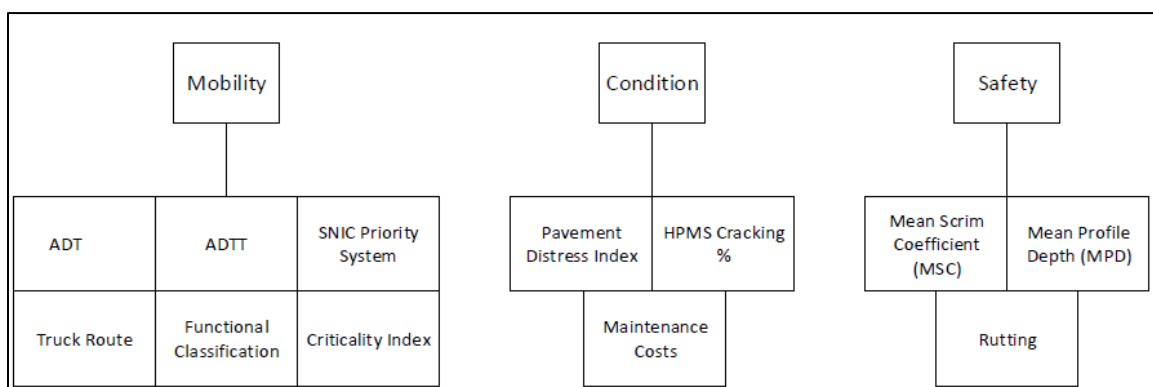


Figure 4.1 Index Factors

¹⁸ This approach and table are also cited by FHWA for bridges: https://www.fhwa.dot.gov/bridge/abc/dmtool/survey_form.cfm

Using a pairwise comparisons approach, each factor and category was assigned an independent weight derived from the scoring matrices. As a group decision-making process,¹⁹ AHP often follows one of two approaches — (1) Aggregation of Individual Judgements (AIJ) (Saaty 1989) or (2) Aggregation of Individual Priorities (AIP) (Ramanathan and Ganesh 1994, Forman and Peniwati 1998). Researchers conducted two rounds of rankings and found that AIP was the best approach to retain individual preferences. AIP aggregates individual priorities using the geometric or arithmetic mean so alternatives can be ranked based on group outcomes (Yap et al. 2019). Forman and Peniwati (1998) noted that “the geometric mean is more consistent with the meaning of both judgements and priorities in AHP” (p. 169). Once aggregated priorities were calculated for categories and factors, category weights were multiplied by the weight of each factor in that category to arrive at its contribution to the overall score, or global priority. For example, the Pavement Distress Index accounts for 34.61% of a structure’s score. EPPI scores range from 0 to 1, where 0 indicates the lowest priority and 1 the highest priority. Tables 4.2 – 4.4 show the index’s initial global priorities for Condition, Safety, and Mobility, respectively.

Table 4.2 Kentucky Enhanced Pavement Prioritization Index Weights — Condition

Factor	Contribution to Overall Score
Pavement Distress Index	34.61%
HPMS Cracking %	9.97%
Maintenance Costs	13.50%

Table 4.3 Kentucky Enhanced Pavement Prioritization Index Weights — Safety

Factor	Contribution to Overall Score
Mean SCRIM Coefficient (MSC)	10.68%
Rutting	14.02%
Mean Profile Depth	4.91%

Table 4.4 Kentucky Enhanced Pavement Prioritization Index Weights — Mobility

Factor	Contribution to Overall Score
ADT	3.16%
ADTT	2.22%
SNIC Priority System	0.82%
Truck Route	1.16%
Functional Classification	1.69%
Criticality Index	3.26%

Data inconsistencies were evaluated to ensure people participating in the decision-making process made consistent choices. To measure consistency, a consistency index was calculated using Eq. 9 (e.g. Saaty 1994, Saaty 1987).

$$\text{Consistency Index} = \frac{\text{Max.Eigenvalue}-n}{n-1}; \text{ where } n = \text{number of criteria} \quad (\text{Eq. 9})$$

The maximum Eigenvalue is the sum of each Eigenvector in a category multiplied by its respective column total. The consistency ratio is calculated with Eq. 10.

$$\text{Consistency Ratio} = \frac{\text{Consistency Index}}{\text{Random Consistency Index}} \quad (\text{Eq. 10})$$

¹⁹ For a scan of literature on group aggregation techniques see Ossadnik et al. (2016).

The Random Consistency Index (RI) is a function of the number of criteria being evaluated with values in Table 4.5.

Table 4.5 Random Consistency Index

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 4.6 provides consistency ratios for each index category along with the category labels. Saaty (1987) proposed that a 10% ratio threshold is acceptable, which the ratios for all categories are well below.

Table 4.6 Consistency Ratios

Category Label	Consistency Ratio
Condition, Safety, Mobility	0.36%
Condition	0%
Safety	2.87%
Mobility	0.42%

After testing the index, two variables – Mean Profile Depth (MPD) and Maintenance Order/Costs – which were originally considered for inclusion in the calculation were subsequently discarded due to concerns with data quality and efficacy. The original weighting for these variables is assigned proportionally to the other variables within the same category to achieve the final weighting used in the Enhanced Pavement Prioritization Index (EPPI) calculation.

Table 4.7 Original vs. Final Index Weightings

Category	Variable	Description	Original Weight	Final Weight
Condition	PDI	Pavement Distress Index	34.61%	45.09%
	CRK	HPMS Cracking %	9.97%	12.99%
	COST	Maintenance orders/cost	13.5%	0.00%
Mobility	ADT	Average Daily Traffic	3.16%	3.16%
	ADTT	Average Daily Truck Traffic	2.22%	2.22%
	SNIC	Snow and Ice Priority	0.82%	0.82%
	TR	Truck Route	1.16%	1.16%
	FC	Functional Class	1.69%	1.69%
	CS	Criticality Score	3.26%	3.26%
Safety	MSC	Mean SCRIM Coefficient	10.68%	12.80%
	RUT	Rutting	14.02%	16.81%
	MPD	Mean Profile Depth	4.91%	0.00%

Once the variables are obtained for each pavement section, the EPPI is calculated by summing the products of each variable multiplied by the final weight as shown in the formula below.

$$EPPI = PDI*(0.4509) + CRK*(0.1299) + ADT*(.0316) + ADTT*(0.0222) + SNIC*(0.0082) + TR*(0.016) + FC*(0.0169) + CS*(0.0326) + MSC*(0.128) + RUT*(0.1681)$$

Details on each variable including sources, methodology used to calculate the variable, and considerations for future improvements are in Appendix A.

4.3 District Input

In cases where segments are closely ranked, the best option may be to utilize additional screening criteria to aid decision makers. District perspectives can be valuable for improving the process, their input was solicited as part of the working group and individually to gather feedback on overall process improvements. The considerations listed below can be used as needed, alone or in conjunction with others, to improve the overall prioritization process.

- Allow districts to prioritize all FD05 projects from the candidate list.
 - In this scenario, the current process of evaluating and scoring projects would remain the same, but Districts would be able to provide prioritization input on projects as they see fit as long as Pavement Management staff had identified the project as a current-year need. EPPI scores would still inform this process and Districts could choose to simply default to the Central Office list. There is a small risk that projects could be indefinitely deferred/ignored by a District, and a mechanism to mitigate this risk should be explored.
- Allow district prioritization of some percentage of FD05 projects from the candidate list.
 - Projects appearing within some percentage of the top of each year's prioritization list (based on EPPI) would be programmed automatically, while the District would have the authority to program some other projects identified as a current-year need. Since the level of funding each District receives may be unknown when prioritization occurs, the split between Central Office and District prioritization should be close to 50% to ensure at least some District priorities are addressed.
- Incorporate the amount of time a project has needed resurfacing into the prioritization calculation.
 - Each project would receive additional points based on the number of years it has been identified as a current-year resurfacing need. While this method is more objective, it could prove difficult to determine the appropriate level of priority to apply. Also, the method could lead to unforeseen consequences which may not be an improvement over the current situation. A significant amount of uncertainty about project scheduling would likely still exist.
- Allow districts to protect some number of projects just missing the current year's list which would be guaranteed for resurfacing the next year.
 - Districts would flag critical projects missing the cut to be placed at the top of the next year's program. In situations where additional mid-year FD05 funding becomes available, such projects may be completed earlier but in no case would they be excluded beyond the second year. Budgetary constraints may need to be established, but generally this would be limited to the top 1 – 4 projects within a branch.
- Follow the Preventive Maintenance Alliance model.
 - KYTC's Preventive Maintenance Alliance (PMA) consists of District and Central Office Maintenance professionals focused on advancing pavement preservation throughout the state. PMA members meet regularly to review pavement preservation research, identify training needs, and evaluate the performance of past projects. Each fall, the PMA also reviews proposed projects for the upcoming construction season. This model represents a good example of cooperation between Central Office and District PD&P engineers to achieve a healthy preservation program and could be expanded to include other preservation treatments such as resurfacing. Under this scenario, the individual EPPI values would serve as a guide to a prioritization process that also considers distinctive local demands.

While some of these suggestions represent a significant departure from the current FD05 prioritization process, using the EPPI in coordination with some of these additional criteria would still situate the role of Central Office

Pavement Management as critical to the process. In all cases, projects to be programmed would be limited to those identified as current-year needs by Pavement Management engineers. This should alleviate concerns that outside factors could lead to the advancement of unnecessary projects.

Chapter 5 Summary and Conclusion

KYTC manages over 27,000 centerline miles of pavement across Kentucky. These links provide vital connectivity and help to move people and freight safely and efficiently. Historically, KYTC has used pavement condition ratings, LCMS data, and District input to prioritize pavement projects. But these approaches, with the exception of District input, have been applied without additional context such as consideration of the risk of poor pavement conditions along specific routes, particularly those critical to mobility within a given geographic area.

To strengthen pavement prioritization practices and improve the data points available to decision makers, KTC's team, in collaboration with KYTC subject-matter experts, developed the EPPI. Cabinet stakeholders identified index components and assigned them ranks during several brainstorming sessions. EPPI values are calculated using data on 12 factors, which are grouped into three categories — **Condition, Mobility, and Safety**. Because the sum of weights assigned to each factor equals 1, EPPI scores range between 0 and 1, where 0 indicates the lowest priority and 1 the highest priority. Utilizing the information could help decision makers identify pavements that are a priority when funding is limited.

Applying the EPPI methodology to analyze other transportation assets would improve cross-asset comparisons. With the EPPI being used to rank projects over the next several budget cycles, KYTC will have the opportunity to review its performance and update it as needed.

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Appendix A Explanation of Index Variables

Pavement Sections

KYTC's pavement evaluation sections represent the base data to which the enhanced prioritization process is applied. Below are descriptions of the associated fields.

ROUTE_NAME

Seventeen-character alphanumeric field identifying the county, system, route number, and roadway segment for a pavement section.

LANE_DIR

One-character numeric field identifying direction of traffic flow for the pavement section.

0=both directions on an undivided section,

1=cardinal direction of a divided section,

2=non-cardinal direction of a divided section, `

9=route no longer exists on the state network.

BMP

Beginning milepoint for the pavement section.

EMP

Ending milepoint for the pavement section.

EFF_DATE

Date the condition survey was conducted for the pavement section.

Source:

MMS_PMS_CONDITION_SURVEY where year of the EFF_DATE is within the previous three years. KYTC conducts visual surveys on a three-year cycle, so this approach ensures that all pavement segments are included. For the sample, surveys used included those conducted in 2021, 2022, and 2023.

Duplicate records may exist for some sections when pavements are evaluated more than once. This may occur when a district requests that a pavement be re-evaluated due to excessive deterioration. Duplicate records were identified and older records were discarded.

Gaps in records may occur if a pavement was resurfaced at some point during the 3-year period, but these would generally not be candidates for resurfacing anyway.

Prioritization Variables

The variables used to prioritize pavement segments are listed below along with the data source and methodology for processing the data. The filenames used for the variables are also listed, as well as considerations for improvements or alternative methods for applying the variables.

Pavement Distress Index (PDI)

Source: CAL_pdi from KYTC's existing Pavement Distress Index calculation, which assigns the PDI value based on visual distress scores and pavement rideability (using the International Roughness Index). Values range from 0.0 to 1.0 where 0.0 represents no distress and 1.0 is the highest distress index possible.

Dropbox File: PV COND,ADT,PDI.xlsx

Methodology:

CAL_pdi was obtained directly from the pavement condition query for each pavement segment. KYTC's weighting for PDI was multiplied by the PDI value to assign the PDI prioritization.

Considerations for Future Improvement:

None identified.

HPMS Cracking Percentage (CRK)

Source: AVG_CRK_PERCENT across the entire pavement section using the most recent values in MMS_LCMS_DATA_HPMS_LOC.

Dropbox File: PV AVG RUT, CRACK.xlsx

Methodology:

The AVG_CRK_PERCENT value ranges from 0% to 100%. For each pavement section, KYTC's full weighting was assigned to pavements where AVG_CRK_PERCENT = 100% and was reduced linearly to zero for sections where AVG_CRK_PERCENT is equal to 0%.

For records where AVG_CRK_PERCENT is NULL, the average across all pavement sections statewide was assigned.

Considerations for Future Improvement:

For NULL records, consideration should be given to using the previous year's values if available.

Maintenance Work Orders Cost (COST)

Source: KYTC Operations Management System report on work order costs associated with pavement repair activities (A-series activities).

Dropbox File: PV MAINT COSTS (A).xlsx

Methodology:

For each pavement segment, the average A-series activity costs (those associated with pavement maintenance) over the previous three years are calculated. This value is scaled against the highest average value for all pavement segments under consideration for resurfacing. KYTC's weighting is applied fully for those segments having the highest cost and is reduced linearly to zero for pavements having no A-series costs over the previous three-year period.

A review of the work order costs revealed significant data quality concerns. Approximately 20% of pavement segments in the sample dataset had zero costs for A-series activities. Excluding sections with zero costs, the per-mile annual costs ranged between \$0.74 and \$197,349.31. Further, while a correlation between PDI and pavement maintenance costs should be expected, a review of the data revealed no correlation between these two variables. KYTC staff posited that while cost data at the county- or route-level is generally reliable, the data input process for

work orders does not provide sufficient granularity to assess costs for individual pavement sections. As a result, the Maintenance Work Order Cost variable is excluded from the EPPI calculation.

Considerations for Future Improvement:

If the Maintenance Work Order Cost variable is to be included in the EPPI calculation, KYTC must first address the data quality issues to ensure reliability at the pavement-section level.

Average Daily Traffic (ADT)

Source: LAST_CNT from `kytc-its-2020.kytc\_data.HIS\_HIS\_TF`

Dropbox File: PV COND,ADT,PDI.xlsx

Methodology:

LAST_CNT value is used to calculate a length weighted average for ADT across each pavement evaluation section. These values are scaled using the maximum statewide ADT where the full KYTC weighting is assigned to sections with the highest ADT. The weighting is scaled linearly to zero for ADT values of zero.

Considerations for Future Improvement:

None identified.

Average Daily Truck Traffic (ADTT)

Source: ADTSINGLE and ADTCOMBO from `kytc-its-2020.kytc\_data.HIS\_HIS\_TF`

Dropbox File: PV COND,ADT,PDI.xlsx

Methodology:

ADTSINGLE and ADTCOMBO were summed together to obtain ADT Total. These values are scaled using the maximum statewide truck traffic within the resurfacing dataset. The full KYTC weighting is assigned to sections with the highest truck traffic. The weighting is scaled linearly to zero for records where the truck traffic is zero.

Considerations for Future Improvement:

None identified.

Snow & Ice Priority (SNIC)

Source: kytcsnwIcePriority from `kytc-its-2020.streaming.enriched\_weather\_roadway`

Dropbox File:

PV SNIC.xlsx

Methodology:

The kytcsnwIcePriority value(s) are obtained for each pavement segment and the percentage occurring within each snow and ice priority category is calculated. Each percentage is multiplied by the corresponding values in the table below and the products are summed together to obtain the overall SNIC prioritization for the pavement segment.

Snow and Ice Priority Category	% of Weighting Applied
IP*	100%
A	80%
B	60%
C	40%
U	20%

* Interstate and Parkway: Not applicable to resurfacing program.

Considerations for Future Improvement:

None identified.

Truck Route (TR)

Source: KYTC Truck Route file (TR.dbf) from KYTC Division of Planning HIS website.

Dropbox File: PV TRUCK.xlsx

Methodology:

TR.dbf file was downloaded and opened in Excel. Truck Route records were merged with Pavement Segment records to determine the length overlapping a truck route network. This was divided by the total length of the pavement segment to determine the Truck Route Percentage. Because the Truck Route data does not separate segments by cardinality, non-cardinal pavement segments were calculated based on the cardinal direction.

KYTC's Truck Route weighting was multiplied by the Truck Route Percentage so that pavements with a Truck Route Percentage of 100% receive the maximum prioritization.

Considerations for Future Improvement:

None identified.

Functional Classification (FC)

Source: KYTC Functional Classification (FS.dbf) file from KYTC Division of Planning HIS website.

Dropbox File: PV FUNCTIONAL CLASS.xlsx (PV Sections with FC tab)

Methodology:

The FC (Functional Class) and D_FC (Functional Class Description) fields from the FS.dbf file are used in conjunction with the table below to establish the FC rating for calculating EPPI.

FC	D_FC	KYTC Weighting
1	Interstate	1.0
2	Principal Arterial – Other Freeways and Expressway	0.8
3	Principal Arterial – Other	0.8
4	Minor Arterial	0.6
5	Major Collector	0.3
6	Minor Collector	0.2
7	Local	0.1

Functional class segments often do not align perfectly with pavement segments. Rather, they each have beginning and ending milepoints that are frequently independent of the other dataset. In cases where a pavement segment contains more than one functional classification, KYTC requested that the relative lengths of each functional class be used to assign a weighted functional class to the pavement segment.

To calculate the percentage of each functional class within pavement segments, the pavement and functional class datasets are merged into one table so that all breaks can be identified. The lengths associated with each functional class were then summed for every pavement segment. The individual percentages associated with each functional class were then multiplied by KYTC's weighting, which assigns higher priorities to higher functional class roadways.

Considerations for Future Improvement:

None identified.

Criticality Score (CS)

Source: The Criticality Score is used as a measure of a pavement segment's importance in providing network connectivity – particularly in rural areas where alternative routes may be limited. Zhang and Chen provide a method of defining segment criticality based on two metrics – betweenness centrality (BC) and detour importance (DI), where “BC measures a segment's importance in providing regional connectivity and accessibility, while DI quantifies a segment's significance as a detour route when other roadways in a region face disruptions.”

The formula and data sources for calculating the Criticality Score are shown below:

$$\text{Criticality Score} = [(BC)^{\dagger}_{\text{Scaled}} + (DT)^{\dagger}_{\text{Scaled}}]^{\dagger}_{\text{Scaled}}$$

Measure	Description	Data Source
BC	The centrality of a road, calculated as the percentage of OD pairs using the road within its 1-hour travel time neighborhood.	HIS, HERE data, KYSTDM TAZ, Census block group
DT	The importance of the road as detour to other highways with top 5% BC values. $DT_a = \sum_{i=1}^k BC_i \times p_i \times w_i$ where DT_a is the detour score of link a; BC_i is the BC value of the segment i whose detour will include link a; p_i is the percent trips originally using segment i that rerouted through link a when segment i is disrupted; w_i value varies by functional classification: 1 for FC1, 0.95 for FC2, 0.8 for FC3, 0.7 for FC4, 0.5 for FC5, 0.4 for FC6, and 0.2 for FC7.	HIS, HERE data, KYSTDM TAZ, Census block group

[†]Scaled - Converts value to a score of 0 to 100 by dividing the value with the maximum value of all projects.

Dropbox File: PV CRITICALITY.xlsx

Methodology:

The Criticality Score was calculated for each cardinal direction pavement segment. Non-cardinal segments were assigned the same value as the cardinal direction. Some records have a zero value for the Centrality or Detour Importance fields. Future iterations of the Criticality Score will address this issue; for now, the data is interpolated using adjacent sections.

Considerations for Future Improvement:

None identified.

Mean Scrim Coefficient (MSC)

Source: MEAN_SCRIM_COEFFICIENT from kytc-its-2020.kytc data.traffic pavement friction enriched, which contains the most recent SCRIM values based on MAX (CYCLE_YEAR) for each PVSECT_ID.

Dropbox File: PV SCRIM MPD.xlsx

Methodology:

Once the MEAN_SCRIM_COEFFICIENT (MSC) was obtained for each pavement section, the field value was modified so that it falls within a range established by KYTC. Currently, the maximum value for MSC ($MSC_{\max}$) is set to 60, while the minimum value ($MSC_{\min}$) is set to 25. MSC values falling within this range are maintained. Those that are less than $MSC_{\min}$ were raised so that they equal $MSC_{\min}$, while those that were greater than $MSC_{\max}$ are lowered to equal $MSC_{\max}$.

The purpose of establishing maximum and minimum values is to (1) ensure that pavements do not receive higher prioritization for resurfacing when existing MSC values already exceed those which might be reasonably achieved through resurfacing; and (2) establish a lower threshold below which all pavements would receive the maximum possible prioritization. The weighting for MSC is fully applied for pavements with MSC values less than or equal to MSC_{min} and drops linearly to zero for pavements with MSC values greater than or equal to MSC_{max} .

Approximately 12% of pavement segments did not have an MSC value available. In these instances, the average MSC value across all pavement sections was used.

Considerations for Future Improvement:

It may be appropriate to establish a more detailed process for estimating values when MSC data is not available for a given pavement section. Some options to consider may include average MSC value for district, average MSC value for county, or average MSC value by pavement age.

Rutting (RUT)

Source: RUT_AVG across the entire pavement section using the most recent values in MMS_LCMS_DATA_HPMS_LOC.

Dropbox File: PV AVG RUT, CRACK.xlsx

Methodology:

The RUTTING_AVERAGE value for each pavement section was obtained and capped to a value of 0.5". The full prioritization weighting was assigned to sections where RUTTING_AVERAGE is greater than or equal to 0.5". The weighting was reduced linearly to zero for sections where RUTTING_AVERAGE is equal to zero.

For records where RUTTING_AVERAGE is NULL, the average across all pavement sections statewide was assigned.

Considerations for Future Improvement:

KYTC has considered using a maximum average value across a given length of pavement within each section. For example, instead of using the average across the entire pavement section, the maximum average rutting might be measured in 100' increments. Appropriate length for consideration has not yet been determined, and modifications to the SQL or subsequent calculations would be required.

For NULL records, consideration could be given to using the previous year's values if available.

Mean Profile Depth (MPD)

Source: MPD_MM from kytc-its-2020.kytc data.traffic pavement friction enriched, which contains the most recent MPD values based on MAX (CYCLE_YEAR) for each PVSECT_ID.

Dropbox File: PV SCRIM MPD.xlsx

Methodology:

Initially, a maximum MPD value of 0.25" was used for scaling individual section scores. However, after further consideration, it was determined that MPD value should not be considered for prioritization of resurfacing projects. Analysis of existing MPD data revealed that MPD values in Kentucky generally increased (improved) as pavements age. Consequently, it should not be expected that pavement segments would realize any improvement through resurfacing.

The weighting previously assigned to MPD was distributed proportionally to the other two safety variables (MSC and Rutting).

Considerations for Future Improvement:

More research into the impacts of MPD on safety may be needed to establish meaningful processes for assigning prioritization based on MPD.

NOTE: The data source had errors in the RT_UNIQUE field. KYTC staff indicated that the ROUTE_UNIQUE_IDENTIFIER field should be used instead.