Developing a Cross-Asset Allocation Mechanism

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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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Kentucky Transportation Center • University of Kentucky
176 Raymond Building • Lexington, KY 40506 • 859.257.6898 • www.ktc.uky.edu

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Research Report
KTC-24-28

Developing a Cross-Asset Allocation Mechanism

Jon Wilcoxson, P.E.
Research Engineer

Bryan Gibson, Ph.D.
Associate Director

and

Bethany Paris, Ph.D.
Research Scientist

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

In Cooperation With
Kentucky Transportation Cabinet
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16. Abstract

The Kentucky Transportation Cabinet (KYTC) has developed several tools and methods to compare the value of proposed projects within specific programs and asset classes, including the Enhanced Bridge Prioritization Index, Enhanced Pavement Prioritization Index, and the Strategic Highway Investment Formula for Tomorrow (SHIFT). Although immensely valuable, these methods and tools do not offer a convenient way of comparing the contributions of individual projects to meeting overall KYTC performance goals. As such, the Cabinet needs a robust mechanism for comparing the impact of projects across its capital, safety, and asset management programs. Following a review of cross-asset allocation frameworks described in academic literature and implemented at state transportation agencies, this report proposes that KYTC adopt the asset sustainability ratio (ASR) to facilitate project- and programmatic-level comparisons for bridges and pavements only; further development is needed to implement capital and safety. The ASR is a ratio that captures the amount of work completed by a program area to the amount of work needed to maintain a transportation network in its current condition. An ASR = 1 means a network is being preserved in its current condition; values < 1 indicate deterioration. Determining the budget levels needed to achieve an ASR of 1 is highly dependent on the types of projects being considered. A worst-first approach that emphasizes replacements will require higher spending levels than a strategy that emphasizes lower cost preservation treatments. With this in mind, researchers analyzed different potential bridge portfolios to determine a reasonable range of budget needs for KYTC's bridge program. Budget needs ranged between $383M and $673M depending on the project portfolio. This range is much higher than the current budget of approximately $189 million. While it is possible to evaluate many combinations of funding levels, the number of potential scenarios should be limited so that decision making is tractable.

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Executive Summary

The Kentucky Transportation Cabinet (KYTC) uses several methods and indices to compare the value of proposed projects within specific programs or asset classes. For example, the Strategic Highway Investment Formula for Tomorrow (SHIFT) process lets KYTC assess the need for and benefits of planned capital projects. However, SHIFT does not effectively assess the value of non-capital projects such as those focused on safety or asset management. Consequently, it is difficult to measure the extent to which a project will help KYTC meet its overall performance goals and compare the impact of different projects.

As part of KYTC's performance management implementation effort, the agency wants to establish a mechanism for comparing the impact of projects across the capital, safety, and asset management programs. Following a high-level review of cross-asset allocation frameworks adopted by other state transportation agencies, researchers worked with KYTC subject-matter experts to generate a set of key performance indicators that can be used to quickly explain performance at a high level (Table E1).

Table E1 Key Performance Indicators

Asset Management	
Pavements	Percentage in Good and Fair Condition
Bridges	Percentage of Deck Area in Good and Fair Condition
Safety	
Number of fatal and serious injury crashes	
Capital Improvements	
Mobility	Travel time reliability (non-Interstate NHS)
Economic Growth	Freight Travel Time Reliability
Congestion	Vehicle Hours of Delay

To mitigate difficulties associated with conceptualizing how safety and capital programs fit within a cross-asset allocation framework, researchers focused on asset management, including pavements and bridges. After testing multiple approaches, researchers concluded that the asset sustainability ratio (ASR) is a robust approach to measure the amount of work completed by a particular program (i.e., bridges or pavements) and the amount of work required to maintain the network in its current condition. KYTC already has a robust ASR for pavements; this report focuses on the development of a similar, yet novel approach for bridges. Other state approaches have focused on proposed budgets or need and are not directly tied to project types or extended life, which our approach attempts to tackle. The ASR is calculated with the following equation:

$ASR = W_a/W_r$ where W_a = Work accomplished by program and W_r = Work required to sustain network condition

Table E2 indicates the relationship between ASR values and network condition.

Table E2 ASR Values

ASR Value	Network Condition
1.0	Remain the same
<1.0	Deteriorate
>1.0	Improve

To maintain KYTC's network in its current condition, one year of life must be restored each year. This depends on the project portfolio and the impact of project types on the network. Because the Cabinet has utilized a sustainability ratio for pavements for some time, researchers focused on bridges in this study and assumed that KYTC's future pavement portfolios would be similar to those of recent years. KTC used data provided by a KYTC subject-matter expert to estimate the additional service life that could be expected from different types of bridge projects which underpinned the expected ASR calculations for various scenarios and was then applied to current budget numbers.

Researchers calculated budget values under different scenarios to determine the amount of funding needed to achieve an ASR of 1 for bridges (hereafter referred to as BSR, or Bridge Sustainability Ratio) as detailed below and in Table E3.

- Maintain Currently Proposed Percentages — This portfolio assumes that the current project percentages are maintained, but the total amount spent for all projects is increased until a BSR of 1.0 is achieved. Since KYTC's current BSR is 0.34, this portfolio requires approximately tripling current spending levels for all treatment types.

- Emphasize Preservation — This portfolio uses "maximum feasible spending levels" for the least expensive option, then increases next least expensive option until a BSR of 1.0 is achieved.

- Conservative Preservation — This portfolio increases the amount of preservation work, but only to 80% of the maximum allowable amount for each project type until a BSR of 1.0 is achieved.

To achieve a BSR of 1 under these scenarios requires an annual budget of $383 million - $673 million. The current budget is $189 million.

Table E3 Proposed Annual Budgets by Portfolio Type

Portfolio Type	Budget	$ Increase from Current	% Increase from Current
Currently Proposed	$188,802,773	$ -	0%
Maintain Currently Proposed Percentages	$ 673,055,516	$484,252,743	256%
Emphasize Preservation	$383,437,439	$194,634,666	103%
Conservative Preservation	$443,227,890	$254,425,117	135%

Table E4 shows potential tradeoffs between pavements and bridges assuming no additional asset management funding is made available. Based on KYTC's currently proposed pavement portfolio, $507 million is needed for non-Rural Secondary pavements. If the Cabinet pursues a conservative preservation program for bridges, $443 million would be needed for the state-owned, non-border bridge network. The percentage of ASR met equals the budget divided by the budget if ASR = 1.0. Limiting the number of scenarios is critical so the number of comparisons decision makers need to evaluate is reasonable. The approaches we analyzed included (1) current budget levels for both programs at $189 and $501 million, respectively, plus the additional funding (shortfall) needed to achieve an ASR of 1.0 for both assets, (2) equal % ASR values for bridges and pavements (this scenario shifts $133 million from the pavement budget to bridges), and (3) an intermediate scenario that moves toward more comparable ASR values, but still slightly favors pavements. In this third case, only $66 million shifts from pavements to bridges relative to the current budget. Other scenarios are possible depending on the number desired and the potential programmatic combinations.

Table E4 Potential Pavement and Bridge Tradeoff Approaches

		Bridges[1]	Pavements[2]	Total
Budget Need for ASR = 1.0 ($M)		$443	$507	$950
Current Funding Level	Anticipated Annual Spending ($M)	$189	$501	$690
	Shortfall	$254	$6	$260
	ASR% Met	43%	99%	73%
Equalize ASR %	Proposed Annual Spending ($M)	$322	$368	$690
	Shortfall	$121	$139	$260
	ASR% Met	73%	73%	73%
Transition to Comparable ASR%	Proposed Annual Spending ($M)	$255	$435	$690
	Shortfall	$188	$72	$260
	ASR% Met	58%	86%	73%

[1] Does not include cost needs for border bridges and bridges not maintained by KYTC.
[2] Does not include cost needs for pavements on Rural Secondary or local-owned routes.

Chapter 1 Introduction

1.1 Overview

The Kentucky Transportation Cabinet (KYTC) manages over 27,000 centerline miles of pavement and 14,000+ bridges (over 9,000 are state owned). Central to the Cabinet's mission is to ensure safe mobility across the transportation network for all users. Kentucky's roads and bridges play a central role in delivering on this mission, from facilitating freight movement to providing safe passage to drivers travelling to school, work, and home. KYTC uses a suite of methods and tools to compare the value of proposed projects across specific programs or asset classes such as the Enhanced Bridge Prioritization Index and the Strategic Highway Investment Formula for Tomorrow (SHIFT). For example, the SHIFT process lets KYTC assess the need for and benefits of planned capital projects. However, SHIFT does not effectively assess the value of non-capital projects such as those focused on safety or asset management. Consequently, it is difficult to measure and compare the contributions of individual projects to meeting overall KYTC performance goals. As part of KYTC's performance management implementation effort, it is necessary to establish a mechanism for comparing the impact of projects across the capital, safety, and asset management programs. This report identifies the appropriate mechanisms for comparisons between pavements and bridges that could be used to implement a cross-asset allocation framework for those assets.

1.2 Research Objectives

- Identify mechanisms for comparing the impact of projects across KYTC's safety, capital, and asset management programs.
- Identify gaps in data and processes.

Table 1.1 Report Structure

Chapter	Material
2	• Literature review
3	• State-level review of challenges and approaches to asset allocation
4	• Kentucky Cross-Asset Allocation methodology for pavements and bridges
5	• Conclusion

Chapter 2 Literature Review

A key challenge state transportation agencies (STAs) face is determining how to allocate limited resources across assets. Porras-Alvarado et al*.* (2016, p. 20) summed up the challenge in this way: “Transportation agencies must determine what funds to allocate by asset type, including roads, structures, safety features, facilities, and other assets, as well as between competing needs for asset replacement, rehabilitation, routine maintenance, and improvement.” The American Association of State Highway Transportation Officials (AASHTO) identified and defined common terms related to cross-asset allocation, tradeoffs, and optimization (Proctor and Zimmerman 2016). The goal of cross-asset allocation is to maximize returns on transportation investments through an explicit consideration of risk. Several methods are available to tackle this issue.

The first method is *cross-asset tradeoffs*, which is “the decision-making process by which resources from one asset class are transferred to another in order to maximize perceived utility” (Proctor and Zimmerman 2016, p. 2). This method fosters a simple decision-making process whereby an agency decides which of two asset classes (e.g., bridges, roads) should receive investments, where utility is “any benefit defined by the user.” Consider a scenario in which bridges have met and exceeded performance targets, but roads have not. Assuming revenues remain essentially unchanged, the agency could make a tradeoff by allocating more resources to roads in lieu of bridges, with the goal of improving road conditions while continuing to maintain bridges at target levels by focusing on replacing structures with high maintenance costs. This decision is dictated by performance data but measuring a tradeoff’s results is difficult.

A second method is *cross-asset allocation* which is “the decision-making process by which resources to multiple programs or asset classes are distributed based on the simultaneous quantified prioritization of utility” (Proctor and Zimmerman 2016, p. 4). Under this approach, allocation choices are compared through benefit-cost analysis, multiple-criteria decision analysis, or a risk-versus-reward tradeoff. Benefit-cost analysis is done at the programmatic level rather than the project level. Zeroing in on the project level can introduce issues related to aggregating and/or making more assumptions, however, costs and benefits across asset networks can be compared.

Risk/reward approaches drill down to variables such as safety and mobility. Scenarios are developed to maximize returns based on the amount of risk an agency is willing to accept, where return is a measure of meeting performance targets. Risk is defined as “the positive or negative effects of uncertainty or variability on agency objectives” (Proctor and Zimmerman 2016, p. 6). Risk is also linked to the amount of money spent or allocated to each asset. For example, if less money is spent on pavement, some pavements initially classified as *good* may fall into the *fair* category. This increases uncertainty due to systemic changes in pavement quality. Additionally, reducing pavement expenditures could increase the risk of hazards or other variables, tipping more pavements into a *poor* rating and shortening service lives. Different scenarios can increase performance in one area while bolstering risk in another. Combined, these factors create a spectrum of outcomes, which depends on the level of risk an agency is willing to tolerate for a potential return.

Multiple-criteria decision analysis takes a set of potential allocation options and uses group evaluations to score and prioritize options through weighting. Figure 2.1 provides an example from AASHTO, and displays four options across safety, pavements, bridges, and mobility, with scores for each criterion ranging from 1 to 10. Scores are then summed and multiplied by the weights (Proctor and Zimmerman, 2016, Figure 3, p. 5). Weighted values are summed across the four areas for each option.

Multi-Criteria Analysis Matrix					
		Option 1	Option 2	Option 3	Option 4
Safety Criteria 1		2	1	1	3
Safety Criteria 2		4	3	4	5
Total Safety Value		6	4	5	8
Safety Weight	4				
Weighted Safety Score	(weight X value)	24	16	20	32
Pavement Criteria 1		6	5	7	5
Pavement Criteria 2		8	7	10	3
Total Pavement Value		14	12	17	8
Pavement Weight	2				
Weighted Pavement Score	(weight X value)	28	24	34	16
Bridge Criteria 1		10	9	1	1
Bridge Criteria 2		2	3	4	5
Total Bridge Value		12	12	5	6
Bridge Weight	3				
Weighted Bridge Score	(weight X value)	36	36	15	18
Mobility Criteria 1		3	3	4	5
Mobility Criteia 2		5	7	6	1
Total Mobility Value		8	10	10	6
Mobility weight	1				
Weighted Mobility Score		8	10	10	6
Weighted Ranking of the 4 Options		**96**	**86**	**79**	**72**

Figure 2.1 Multiple Criteria Decision Analysis

Risk can be monetized for use in both benefit-cost analysis and multiple-criteria decision analysis by multiplying the probability of an adverse event by the cost of an event if it were to occur.

Another theoretical framework for multiple-criteria decision analysis is multi-objective decision analysis (MODA). MODA has been widely recommended to address cross-asset resource allocation problems. This approach consists of using preferences to guide project selection through weighting, scaling, scoring, prioritization, and optimization techniques. One framework that uses this approach is the analytic hierarchy process (AHP). 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." In essence, AHP is a decision analysis process that uses expert feedback through pairwise comparisons among a set of factors.

Finally, cross-asset optimization is defined as "the use of recursive mathematical computations to determine the maximum utility for a given set of investments constrained by defined performance parameters" (Proctor and Zimmerman, 2016, p. 9). Cross-asset optimization relies on software to calculate all potential options or outcomes to help users select one that will yield the greatest utility, although data limitations may constrain its usefulness.

Leveraging transportation asset management (TAM) has let STAs approach operations with a business-like mindset (Porras-Alvarado et al. 2016). Applying TAM principles to resource allocation problems can take several forms, including historical/formula allocations, performance based, optimization models (generally one asset class such as pavement management systems), and cross-asset optimization.

However, some concerns exist that TAM's lack of a process for cross-resource allocation may diminish its effectiveness. Porras-Alvarado et al. (2016, p. 19) proposed a framework for "a performance-based, cross-asset resource allocation toward a data-oriented approach to enhancing infrastructure management" through an optimization exercise (Figure 2.2). Other considerations and potential issues when conducting cross-asset allocation include the potential misalignment of performance measures with the cross-asset allocation approach and a lack of equity in decision making when the resource allocation method focuses more on efficiency than fairness. The proposed approach incorporates fairness considerations with utility and envy concepts, and efficiency is introduced by seeking a solution to maximize performance.

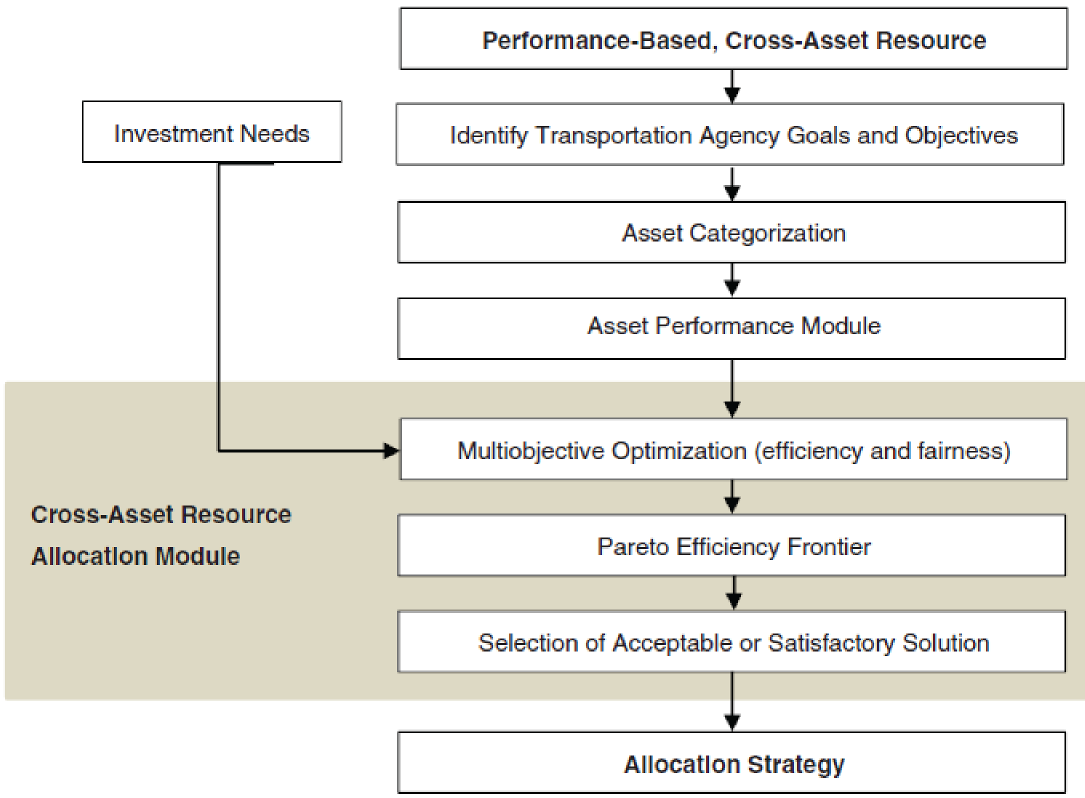

Figure 2.2 Proposed Cross-Asset Allocation Framework
(Porras-Alvarado et al. 2016, p. 22, Figure 1)

Dehghanisanij et al. (2013) proposed a "multi-attribute decision making model that captures the structural and functional integrity of the assets and the corridor, as well as the environmental impacts of maintenance activities on the assets" (p. 13). This framework has "four steps: resource allocation, treatment selection, performance prediction, and overall performance evaluation" (p. 3; Figure **2.3**). Resource allocation determines funding scenarios across assets while the best treatment option is selected given the resources allocated. Performance predictions are made based on the treatment selected and how it may impact performance measures specific to different asset classes, with a focus on measuring how condition changes and/or how well the asset meets its intended function. The overall performance evaluation is an aggregation of underlying performance measures with a set of calculations derived from performance measures that evaluate corridor health based on asset health. The authors recommended incorporating more asset classes in future iterations of such processes while ensuring data availability and reliability.

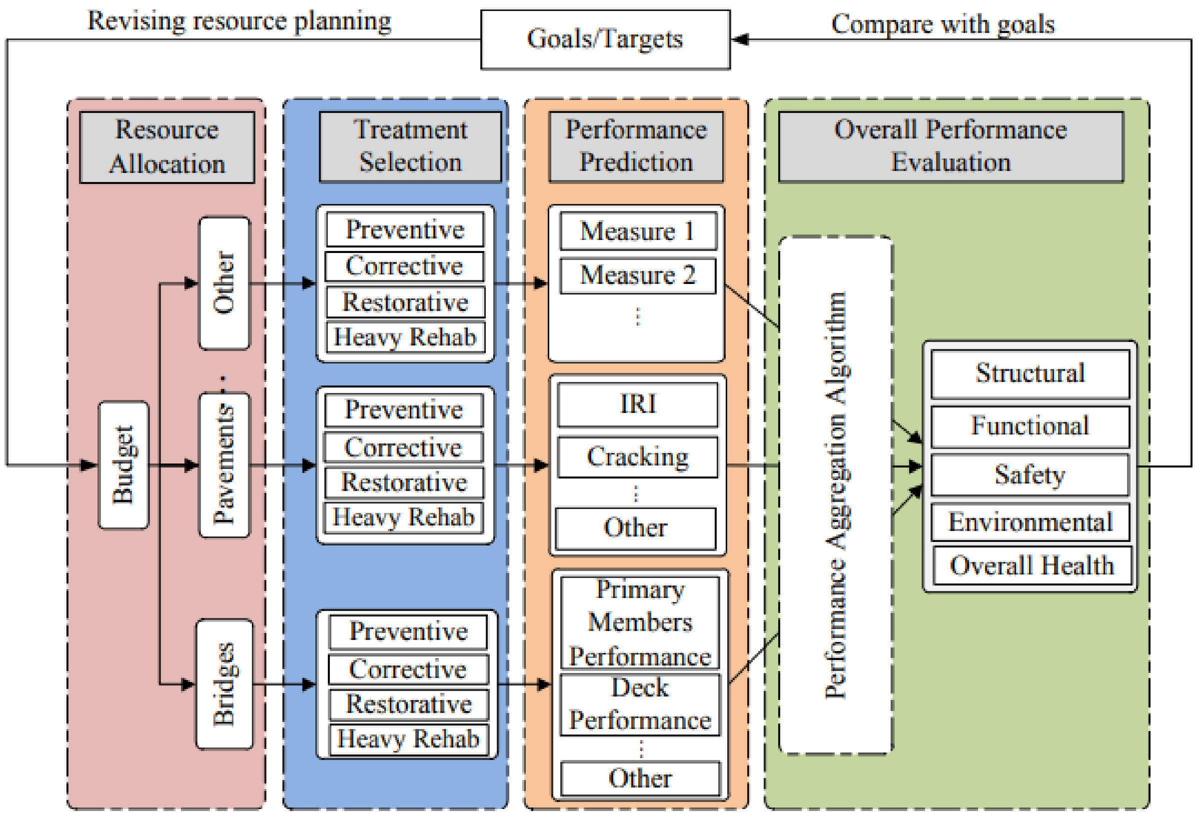

Figure 2.3 Proposed Cross-Asset Allocation Framework
(Dehghanisanij et al., 2013, p. 4, Figure 1)

Using this type of framework can support the budgetary decision-making process across assets. An evaluation and sensitivity analysis of the proposed framework found that an asset's initial condition and priority weightings across functional structural and environmental areas could impact what is deemed an optimal allocation.

Constrained by limited maintenance budgets and competing priorities across asset classes, decision makers must optimize individual asset classes while optimizing overall system maintenance. Fwa and Farhan (2012) proposed a conceptual two-step process that views assets individually to arrive at an optimal Pareto solution. The process uses an algorithm that apportions the overall maintenance budget through cross-asset tradeoffs so budget allocations are optimized based on system goals. The approach is a "holistic multidimensional highway asset budget allocation optimization approach that considers individual asset optimization with multiple objectives and global cross-asset trade-off at the network level while integrating assets with different objectives and performance measures in a manner to avoid subjectivity in the appropriation of funds and resources" (p. 1186).

Chapter 3 State-Level Review

3.1 Background

This chapter reviews cross-asset allocation methods that have been proposed or implemented in several states. Common theoretical approaches that incorporate components discussed in the previous chapter include legacy-driven, fix-it-first, soft-optimization, and performance-based methods (Maggiore and Ford 2015). All states use a weighted ranking system to determine present assets condition (e.g., roads, bridges, multimodal systems). Assets are ranked on quality, and those whose score does not meet a defined threshold are flagged for repair or replacement. Some states also incorporate a risk ratio into calculations. California uses an AI-driven program that integrates aspects of all four approaches (see Section 3.1.5). While these methods have been widely adopted, barriers that can hinder efforts include weak strategic direction, lack of data and tools, institutional constraints, organizational considerations, public/stakeholder issues, and political resistance. SpyPond Partners et al. (2022, p. 2) defined six steps STAs use to develop asset allocation tools:

1. Define the analysis scope
2. Establish Initial Value
3. Determine Treatment Effects
4. Calculate Depreciation
5. Calculate Value and Supporting Measures
6. Communicate and Apply the Results

The subsections below review tools STAs rely on to mitigate challenges associated with cross-asset allocation.

3.1.1 Legacy Driven (Kansas, Louisiana, and Mississippi)

Legacy-driven asset allocation relies on information passing between a research team responsible for collecting data on each component of a system and policymakers who allocate funds based on historical spending patterns. Adjustments to this model are primarily made on the margins based on factors like inflation or emerging priorities (Maggiore and Ford 2015). STAs in Kansas, Louisiana, and Mississippi use this approach, and all three have implemented methods to update allocations across budget cycles:

- The Kansas Department of Transportation (DOT) uses a weighted, four-factor system (preservation, modernization, expansion, and local construction). This system has "…worked well for preservation but not as well for modernization and expansion" (Kansas DOT 2022, p. 14). This system has additional specificity through using engineering factors, regional priorities, economic impact, and other. Preservation is 100% engineering factors, modernization is 80% engineering factors and 20% regional priorities, expansion is 50% engineering factors, 25% regional priorities, and 25% economic impact, and finally local construction is 100% other. An example of a project type prioritization system within preservation is for determining funding priorities for Interstates and non-Interstates both of which are shown in Figure 3.1 (Kansas DOT 2022, p. 26).

Non-Interstate Priority Formula (Attributes /Adjustment Factors)

	Attribute (Need Value)	Relative Weight	Accident Rate (See below) *	Posted Speed (See below) *	Facility Type: Divided	Facility Type: Undivided	Shoulder Type: Stabilized	Shoulder Type: Unstabi-lized	Route Class (See below) *	AADT[1] (See below) *
Driver Expo-sure Attributes	No. Of Narrow Structures Per Mile	0.086	0 to 1	0 to 1					0 to 1	0 to 1
	Shoulder Width	0.089	0 to 1	0 to 1	0.54	1.0	.0607	1.0	0 to 1	0 to 1
	No. Of SSSD[2] Per Mile	0.069	0 to 1	0 to 1					0 to 1	0 to 1
	Lane Width	0.101	0 to 1	0 to 1	0.5	1.0			0 to 1	0 to 1
	No. Of SHC[3] Per Mile	0.099	0 to 1	0 to 1					0 to 1	0 to 1
	Volume/ Capacity (Maximum Default Value = 1.15)	0.091							0 to 1	0 to 1
	Commercial Traffic (Maximum Default Value = 725)	0.065			.037 6	1.0	0.519	1	0 to 1	0 to 1
	Rideability	0.088							0 to 1	0 to 1
	Pavement Structural Evaluation (PSE)	0.208							0 to 1	0 to 1
	Observed Condition	0.104							0 to 1	0 to 1
	Sum of All Weights	**1.00**								

*** Non-Interstate Priority Formula (Adjustment Factors)**

Accident Rate	Adjustment Factor	Posted Speed	Adjustment Factor	Route Class	Adjustment Factor	Capacity –Ad-justed AADT[4]	Adjustment Factor
High	1.0	≥55 MPH	1.0	A	1.0	20,000	1.0
Medium	0.858			B	0.9	10,000	0.925
Low	0.734	≤55 MPH	Varies from	C	0.7	6,000	0.895
			0 to 1	D	0.5	2,000	0.865
				E	0.3	0	0.850

Interstate Priority Formula (Attributes / Adjustment Factors)

Attribute (Need Value	Relative Weight	Facility Type: Divided	Facility Type: Undivided	Shoulder Type: Stabilized	Shoulder Type: Unstabilized	Route Class (See below)	AADT[1] (See below)
Commercial Traffic	0.140	0.376	1.0	0.519	1.0	0 to 1	0 to 1
Rideability	0.189					0 to 1	0 to 1
Pavement Structural Evaluation (PSE)	0.447					0 to 1	0 to 1
Observed Condition	0.224					0 to 1	0 to 1
Sum of All Weights	**1.00**						

[1] **Average Annual Daily Traffic**- The number of vehicles per day on a road -way segment averaged over one year.

Figure 3.1 Kansas DOT Preservation Formulas for Interstate and Non-Interstate Projects

- The Louisiana Department of Transportation and Development integrated the statewide financial management system with an SAP-based, project management system (Louisiana DOTD 2022, p. 19). Project prioritization and selection is based on "District recommendations, technical analysis, customer input, available funding, performance targets identified in the TAMP and the State Long Range Plan" (p. 32). For example, pavements are identified using condition data in the Pavement Management System (PMS) and bridges are identified using life cycle strategies in the AASHTO BrM Bridge Management System, then selection is made based on the criteria above.
- Mississippi DOT uses asset-specific management software systems and integrates changes to allocations based on analysis of previous budget cycles and annual reports with individual asset processes for pavements and bridges. The process for pavements is as follows: inventory based on condition and sections for analysis, generate decision trees, projects are divided by 2-lane, 4-lane, and Interstates, with final approval by leadership. A decision tree for 4-lane flexible pavements is shown in Figure 3.2 (p. 21). Bridges are evaluated based on a Bridge Replacement Index that includes average daily traffic, bypass or detour length, and structural evaluation with factors assigned to each based on the overall impact (Mississippi DOT 2019).

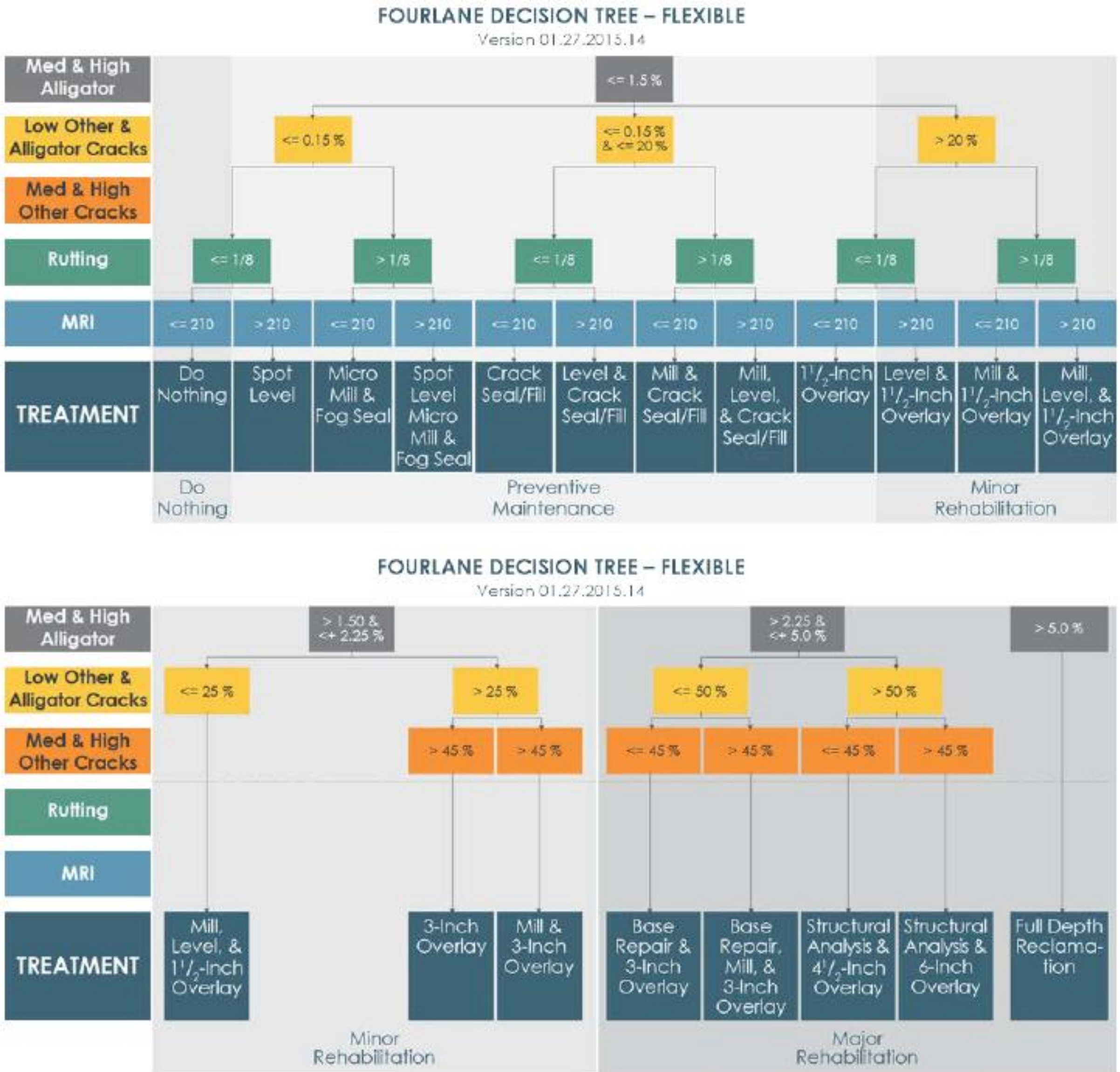

Figure 3.2 Mississippi DOT Decision Tree

3.1.2 Fix It First (Colorado, Georgia)

The fix-it-first approach concentrates on asset preservation. Under this approach, new funding is mostly awarded to maintain existing structures rather than for new construction. New funds are allocated as projects arise, but these projects are a secondary focus during the allocation process. While systems may be in place to rank and measure asset quality (e.g., roads, bridges), maintaining current structures in a condition of fair or better remains the primary driver of funding allocations.

- The Colorado DOT (CODOT) uses an integrated management system — Asset Investment Management System (AIMS) — to integrate all system facilities and track performance targets. CODOT performance measures are divided the key areas of safety, asset management, and mobility. Using this system, the agency assesses the tradeoffs and funding needs required to maintain asset conditions. Figure 3.3 displays the flow of information from facilities to funding (Colorado DOT 2022) while performance measures are in Table 3.1 .

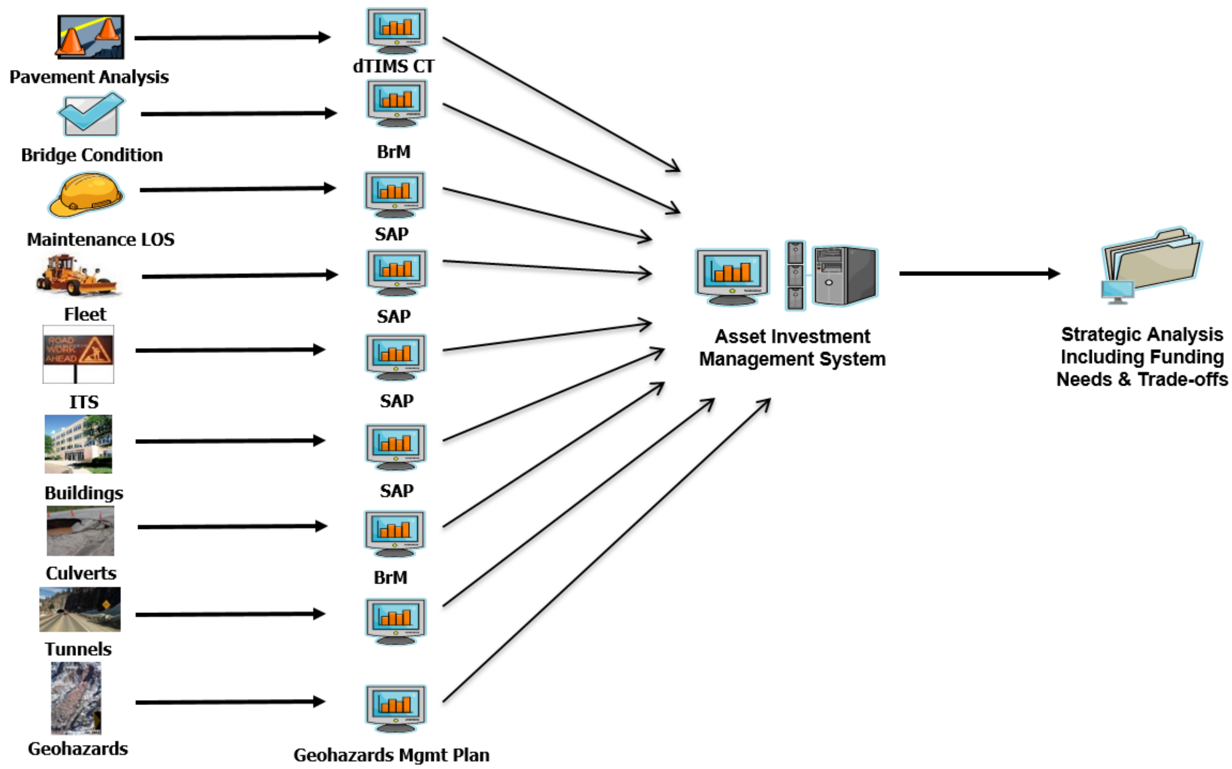

Figure 3.3 Colorado Department of Transportation Asset Investment Management System (AIMS)

Table 3.1 Colorado DOT Performance Measures

Category	Objectives	Target	Current
Pavement	Achieve or maintain 80% high or moderate Drivability Life for Interstates based on condition standards and treatments set for traffic volume categories.	80%	81%
	Achieve or maintain 80% high or moderate Drivability Life for the National Highway System, excluding Interstates, based on condition standards and treatments set for traffic volume categories.	80%	87%
	Achieve or maintain 80% high or moderate Drivability Life for the state highway system based on condition standards and treatments set for traffic volume categories	80%	81%
Bridges	Achieve or maintain the percent of National Highway System total bridge deck area in good condition at or above 40%	40%	38.2%
	Achieve or maintain the percent of National Highway System total bridge deck area in poor condition below 10%	10%	3.43%
	Achieve or maintain the percent of state highway system total bridge deck area in good condition at or above 40%	40%	37.2%
	Achieve or maintain the percent of state highway system total bridge deck area in poor condition below 10%	10%	4.17%
Maintenance Levels of Service	Achieve or maintain an overall MLOS B minus grade for the state highway system	B-	B+
	Achieve or maintain a LOS B grade for snow and ice removal	B	A-
Buildings	Achieve or maintain an average statewide letter grade for CDOT-owned buildings at or above 85% C or better	85%	48%

Category	Objectives	Target	Current
ITS	Maintain or decrease the average percent useful life of ITS equipment at or below 90%	90%	79.4%
Fleet	Maintain or decrease the average percent useful life of CDOT fleet vehicles at or below 75%	75%	68%
Culverts	Maintain or decrease the percent of culverts in poor condition (have a culvert rating of 4 or less) at or below 5%	5%	5.32%
Geohazards	Achieve or maintain the percent of geohazard segments at or above risk grade B at or above 85%	85%	76%
Tunnels	Achieve or maintain the percent of network tunnel length with all elements in equal or better condition that 2.5 weighted condition index at or above 75%	75%	50.5%
Traffic Signals	Maintain or decrease the percent of signal infrastructure in severe condition at or below 2%	2%	6%
Walls	Maintain or decrease the percent of CDOT-owned walls, by square foot, in poor condition (have a rating of 4 or less) at or below 2.5%	2.5%	4.44%
Rest Areas	Achieve or maintain an average statewide letter grade for CDOT rest areas at or above 90% C or better	90%	73%

- Georgia utilizes uses an integrated system housed in AgileAssets that provides a centralized location for flagging assets from different asset groups which may need repair. The system logs data in individual asset-based modules, which are then integrated into the main system to maximize cross-asset return on investment (AgileAssets, 2018). South Carolina uses AgileAssets in a similar fashion.

3.1.3 Soft Optimization (Arizona, Ohio, North Carolina, and Michigan)

Soft-optimization asset allocation integrates aspects of the fix-it-first and legacy-driven approaches. Changes in funding allocations are made at the policy professional level and may be integrated with other nontechnical inputs (Maggiore and Ford 2015). This impetus may begin with DOT leadership, or professionals may rely solely on the output/results of software analysis.

- Arizona DOT developed its system by surveying the public and agency leadership and determined investment categories from these surveys. DOT leadership prioritized six investment areas (Expansion, Preservation, Safety, Technology, Accessibility, and Operations and Maintenance (O&M)), which were then weighted into a *Baseline Allocation of Resources*. Using a MODA-based process, Arizona DOT generated pairwise comparisons of all investment areas and ranked all assets based on these comparisons (Spy Pond Partners et al. 2019).
- Ohio DOT's method uses "analysis, models, and computerized tools." Its integrated system, with components in AgileAssets and SharePoint, gives district managers and employees easy access to statewide information on assets, and investment and performance targets, which are closely aligned with federal requirements. In addition to software output, Ohio DOT holds "discussions across stakeholder groups to monitor and communicate activities" and integrates feedback into the allocation process (Ohio DOT 2022, p. 29). There is also a focus on aligning capital programs and maintenance to optimize available resources with trade-offs generally focused on life cycle and deterioration analysis in a bid to maximize return on investment through asset treatment longevity.
- North Carolina DOT (NCDOT) distributes available funds as follows: 40% to statewide mobility projects, 30% to regional impacts on connectivity, and 30% to address local needs. To determine priorities across modes NCDOT developed a structured approach for asset allocation, where potential highway system projects are scored in 10 areas that fit into 24 types of improvements. The ten areas include congestion, benefit-cost, safety, economic

competitiveness, accessibility/connectivity, freight, multimodal, lane width, shoulder width, and pavement score. Criteria are categorized as existing conditions or future conditions (AASHTO 2023).

- Michigan DOT prioritizes pavement projects using a decision tree that "sets certain thresholds for remaining service life (RSL), distress index (DI), international roughness index (IRI), riding quality index (RQI), and rut depth for each pavement type to select the appropriate treatment alternatives" (Abukhalil 2019). The results of decision trees for assets are included in a reporting portal/dashboard that is shared with the public on Michigan DOT's website[3] focusing on an integrated asset management approach (Mester 2020). This asset management process includes steps to forecast future condition, measure performance, and use trade-off analysis to identify projects.

3.1.4 Performance-Based Methods (Washington, Utah, Florida, and Oregon)

Performance-based methods are data- and analysis-driven. They integrate a formal performance measurement scale but still require a policy professional to weigh the pros/cons when making final decisions about funding tradeoffs. Most examples below involve agencies developing an in-house cost allocation system that integrates asset-based systems into one, streamlined ranking system.

- Washington DOT (WSDOT) uses a decision lens for pavements, bridges, unstable slopes, and major electrical assets. Dubbed *Practical Solutions*, the system integrates the statewide asset management plan's main goals to assess the condition inventory and determine whether performance measures are met. These are then cross-referenced against the financial plan, risk, and investment strategies to maintain inventory. Drawing from Maggiore and Ford (2015), WSDOT's *Project Delivery Plan* serves as the basis for planned investments during the upcoming six years. The Pavement and Bridge Portfolios were used as well for Performance Scenario Analysis (Washington DOT 2023).
- Utah DOT has adopted a framework that combines all project locations. The system predicts how statewide and project-level performance would vary over time without funding. From this information, the scope of work for the project across performance areas is leveraged to create project impact models using MODA. The system reports performance levels expected for different investment options (Utah DOT 2023).
- Florida DOT created a Strategic Investment Tool, which is "an interactive tool that incorporates output from the Strategic Intermodal System (SIS) highway project selection process" that "allows users to calculate and report performance measures relating to five objectives" (Florida DOT 2013). The objectives are safety, interregional connectivity, economic competitiveness, environmental stewardship, and intermodal connectivity. The system's two components are the Analyzer and the Reporter. The former supports data input and the latter provides streamlined output.
- Oregon DOT compares various scenarios across assets including optimizing current revenue streams, maintaining a state of good repair, and maintaining current condition. To allocate funding, the major investment categories are modernization, preservation, and maintenance. Seeking a balanced portfolio several strategies are compared including targeting more funding for preservation and maintenance over modernization, focusing preservation and preventive maintenance on key routes, provide funding to improve seismic resiliency, or increase funding for both pavements and bridges (Oregon DOT 2022).

3.1.5 California

A focus on enhancing TAM motivated Caltrans to develop a *cross-asset optimization approach* for state system bridges and pavements (Hicks 2021; Figure 3.4.). The new methodology supports prioritization and programming across asset types. Caltrans developed a multi-objective optimization algorithm that integrates an existing MODA

[3] https://www.mcgi.state.mi.us/mitrp/tamcDashboards

model. Optimization is based on identifying the best treatment *and* treatment timing based on performance, what-if scenarios, budget choices across assets, and potential bundling opportunities. The method was developed as part of AssetOptimizerTM software.[4] This approach fosters more efficient program development and management, the identification of optimal resource allocations to better meet long-term performance goals, measurement of tradeoffs, and improvement in the consistency and transparency of project selection.

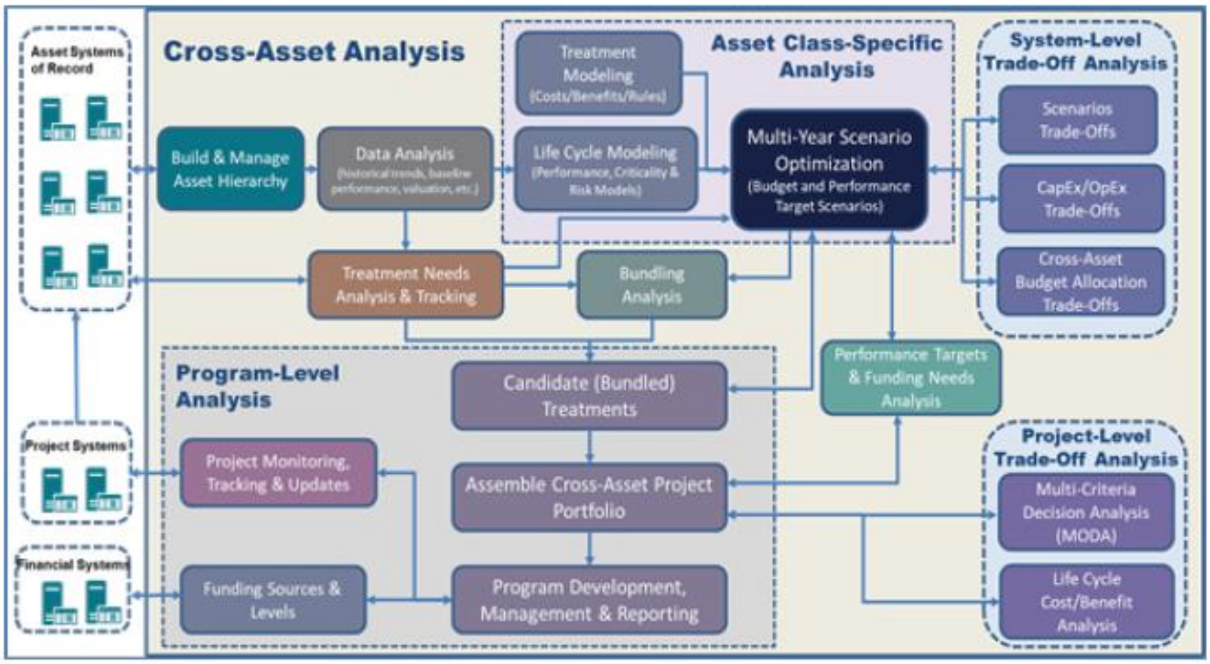

Figure 3.4 Caltrans Cross-Asset Optimization Approach

3.2 Tools for Analysis

Several tools are used to integrate areas monitored and repaired by state DOTs, ranging from in-house systems to those outsourced to companies such as AgileAssets. CH2MHill also created a template that was published alongside NCHRP 806 and NCHRP 08-91,[5] which is a Microsoft Excel–based program for monitoring and evaluating a single asset or integrating several into one system. Users can enter data into the system and choose the weights and methods for applying weights across project types. This is done using a linear or coefficient model and includes tradeoff and risk analysis.

The Multiple Objective Decision Analysis Tool (MODAT) (formerly Cross Asset Resource Allocation Tool (CARAT)) is a cloud-based system that integrates projects and assets and is used mainly for analyzing tradeoffs. Users can select from linear or logistic models and implement a manual ranking system that incorporates risk analysis. The step-by-step interface is less prone to user error than the Excel-based program but output is less succinct. For example, users must drill down within graphs to view individual project rankings. The system creates an integrated system that links project goals and flows to costs and project objectives.

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[4] "Asset OptimizerTM is a cloud-based AI-powered geo-enabled cross-asset optimization and decision analytics platform that implements various components of the proposed methodology" (p. 2).
[5] http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3398

3.3 Key Takeaways

Multiple options are available for creating an effective cross-asset allocation plan. Performance-based methods have risen to the fore and are considered an effective way to streamline several systems. Another system is the cross-asset optimization model created by Caltrans. Regardless of the foundational method, it is critical to build a system that lets users make informed allocation choices based on synthesized data.

Chapter 4 Kentucky Cross-Asset Allocation

4.1 Methodology

We asked a group of KYTC subject-matter experts to provide input on the development of a cross-asset allocation mechanism. The group identified six key performance indicators (KPIs) for asset management, safety, and capital improvements:

- Asset Management
- Pavements — Percentage in Good and Fair Condition
- Bridges — Percentage of Deck Area in Good and Fair Condition
- Safety
- Number of fatal and serious injury crashes
- Capital Improvements
- Mobility — Travel time reliability (non-Interstate NHS)
- Economic Growth — Freight Travel Time Reliability
- Congestion — Vehicle Hours of Delay

These measures communicate overall performance over a period of time and are easy to understand. Initially, the group focused on how funding tradeoffs between these categories would impact KPIs. But members concluded that conceptualizing tradeoffs across safety and capital improvements and quantifying potential changes in KPIs would be too difficult for the initial development of a cross-asset funding mechanism. Some thoughts about future development in these areas were considered. Under the heading of asset management, pavement and bridge condition are well-defined because this is a classic tradeoff decision STAs face. Through trial and error, we arrived at a methodology to determine the impacts of a tradeoff decision between pavements and bridges.

The asset sustainability ratio (ASR) measures the amount of work completed by a particular program (i.e., bridges or pavements) and the amount of work required to maintain, or sustain, the network in its current condition. The following equation is used to compute the ASR:

$$ASR = W_a/W_r$$

where:
W_a = Work accomplished by program
W_r = Work required to sustain network condition

Table 4.1 indicates relationship between ASR values and network condition.

Table 4.1 ASR Values

ASR Value	Network Condition
1.0	Remain the same
<1.0	Deteriorate
>1.0	Improve

To maintain a network in its current condition, one year of life must be restored each year. This depends on the project portfolio and the impact of project types on the network. Work units measured for bridges and pavements are based on the KPIs (Table 4.2).

Table 4.2 KPIs and Work Units

Asset	Key Performance Indicator	ASR Work Unit
Pavement	% Lane-miles in good or fair condition	Lane mile-years
Bridges	% Deck-area in good or fair condition	Square feet-years

4.1.1 Pavement Sustainability Ratio

Maintaining a highway pavement network requires that an agency perform sufficient preservation projects to offset deterioration in conditions that occur as pavements age. Galehouse and Sorenson (2007) described a method of analyzing projects based on the number of years of service life added to pavement that is worked on. Multiplying this number by the project length yields the number of lane-mile-years added to the highway network. To maintain network conditions, transportation agencies must carry out a program of projects sufficient to offset losses due to aging. Galehouse and Sorenson (2007, p.3) provide a more detailed explanation:

> Consider the following quantitative illustration: Suppose your agency's highway network consisted of 4,356 lane-miles. Without intervention, it will lose 4,356 lane-mile-years per year.
>
> To offset this amount of deterioration over the entire network, the agency would need to annually perform a quantity of work equal to the total number of lane-mile-years lost just to maintain the status quo. Performing a quantity of work that produces fewer than 4,356 new lane-mile-years would lessen the natural decline of the overall network but still fall short of maintaining the status quo. However, if the agency produces more than 4,356 lane-mile-years, it will improve the network.

Pavement network size varies by agency. Within an agency, the number of maintained lane-miles changes over time due to construction of new roadways, realignment, transfers of ownership, or year-to-year changes within the agency itself. References to lane-mile-years may be less effective when communicating with stakeholders and decision makers who are not familiar with the scale of pavement networks.

To provide a measure that can be readily communicated, KYTC builds off the lane-mile-years methodology to calculate a Pavement Sustainability Ratio (PSR):

$$PSR = \text{Lane-Mile-Years Added by Projects} / \text{Lane-Mile-Years Lost to Deterioration}$$

A PSR of 1.0 indicates that the pavement treatments delivered in a year offset the deterioration that took place that year (KYTC 2022). PSR values greater than 1.0 signify improving conditions while values less than 1.0 indicate that conditions are deteriorating. Figure 4.1 shows PSR values for KYTC between 2018 and 2022.

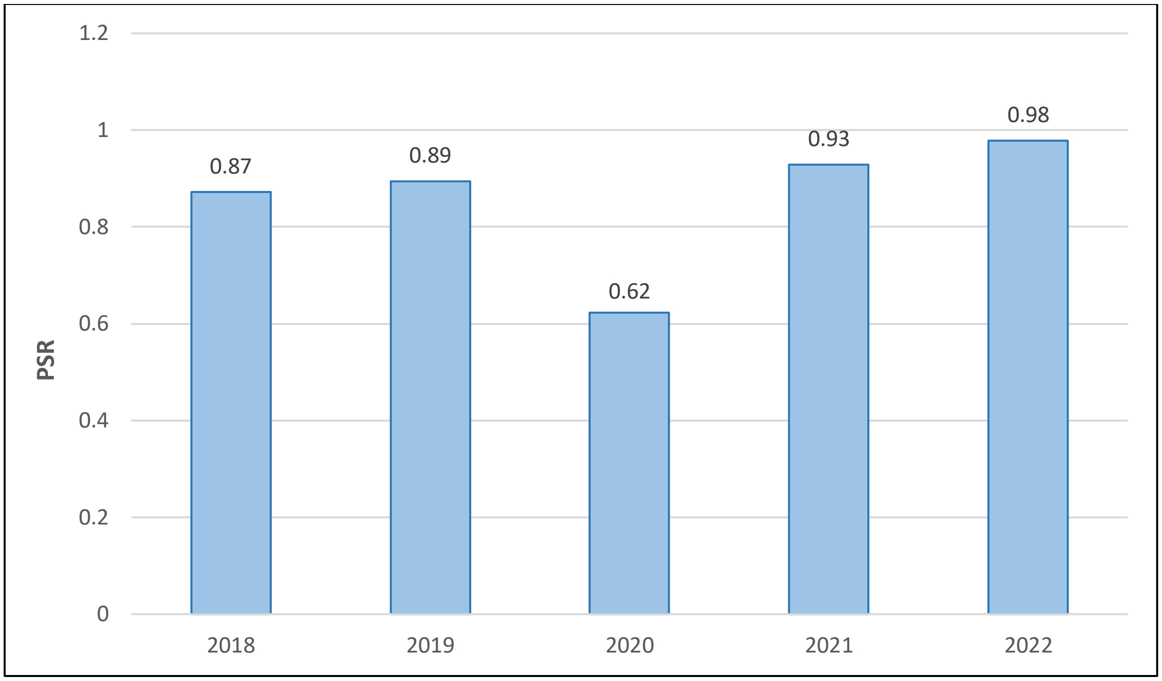

Figure 4.1 KYTC Pavement Sustainability Ratio

Based on KYTC cost data from 2024 and the proposed portfolio of pavement projects over the 2025 and 2026 fiscal biennium, achieving a PSR of 1.0 will require $507 million in funding each year, adjusted for inflation.

Individual agencies can benefit from using a PSR to communicate the effectiveness of their preservation programs over time even if the size of their network changes. The PSR also facilitates cross-agency comparisons as well as comparisons of geographic subunits (e.g., districts, sections, counties) within a single agency. This can be useful in determining appropriate funding allocations for different regions or districts.

The Washington State DOT (WSDOT) also uses the lane-mile-years approach to calculate a PSR, which is reported in the Gray Notebook — the agency's quarterly performance and accountability report. Figure 4.2 shows PSR values for Washington's state highway network from 2018 to 2022. During that time, WSDOT's PSR ranged between 0.47 and 1.01, with a five-year average of 0.68 — falling short of the agency's sustainable range target of 0.9 to 1.1.

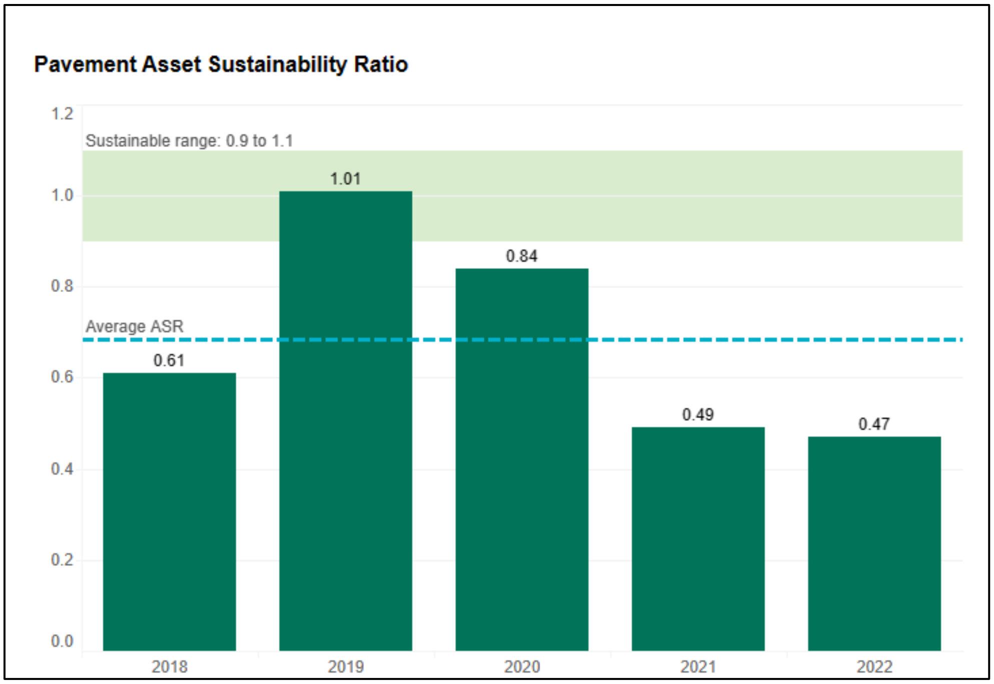

Figure 4.2 Washington DOT Pavement Asset Sustainability Ratio[6]

4.1.2 Developing an ASR for Bridges

To determine how funding should be divided between KYTC's pavement preservation and bridge preservation programs, we had to develop a mechanism for comparing the impact of multiple funding levels on the overall network condition for the two assets. We proposed developing an ASR for bridges (BSR) which would be calculated using the same method as the PSR.

Where the PSR calculation uses the lane-mile-year as its underlying unit to measure the benefit of a project or group of projects, the BSR requires a unit more appropriate for bridges. Since bridge network conditions are based on deck area rather than lane-miles, the underlying unit of measurement for the BSR is the square foot–year.

For bridges, consider a basic example similar to Galehouse and Sorenson in the prior section, where the only type of work done on bridges is replacement and each replacement adds 60 years of service life. The total network deck area is 60 million ft^2. So, every year, replacement should be done on bridges totaling 1 million ft^2; (60 years x 1 million ft^2 = 60 million ft^2-years). Incorporating different treatment types that provide less service life such as rehabilitation and preventive maintenance projects will change the amount of work needed to sustain the network.

Each bridge preservation treatment is first assessed in terms of the average number of years of improvement it confers to a structure. This value is multiplied by the deck area of the structure to which the treatment is applied to obtain the square foot–years added by a project. Summing this value for all projects in a given year provides the total square foot–year for the bridge preservation program. This number is then divided by the total deck area of the bridge network to arrive at the BSR:

6 https://public.tableau.com/app/profile/gnb.transportation.safety.and.systems.analysis.performance.manag/viz/PR-PAV-AssetSustainabilityRatio/PR-PAV-AssetSustainabilityRatio

BSR = Square Foot–Years Added by Projects / Square Foot–Years Lost to Deterioration

A BSR of 1.0 indicates the bridge projects delivered in a year offset the deterioration that took place that year. BSR values greater than 1.0 denote improving conditions while values less than 1.0 signify deterioration.

To calculate the BSR, we needed to estimate how many years of improvement are added by different treatments. To do this, KTC asked a KYTC subject-matter expert to estimate the additional service life that could be expected by completing different bridge projects (Table 4.3). In most cases, the estimated Years of Improvement were determined entirely based on the type of project being performed. However, KYTC determined that Preservation projects on Interstate and Parkway bridges (INPK) would likely not provide as much benefit as those on non-INPK bridges due to higher traffic volumes and increased trucking.

It is important to note that our approach considers the sum of all the costs (design, right of way, utilities, and construction, or DRUC) and calculates the percentage of DRUC spent in each year, this percentage is then multiplied by the "years of improvement" associated with the project type to determine the overall benefit in a given year. So, if a replacement project is evenly split across two years, we assume 37.5 years of improvement in each year. As this is the approach used by KYTC, we follow it here, however this methodology could be applied in different contexts and with different variations on costs. These values underpin the different portfolios and associated BSR calculations.

Table 4.3 SME-Recommended Improvement Values

Work Description	Years of Improvement	# of Bridges	Deck Area
Replacement	75	75	410,539
Superstructure Replacement	32-60	9	14,701
Major Rehabilitation	27.5	14	87,632
Painting	27.5	1	44,033
Deck Rehab	25	1	6,403
Non-INPK Preservation	22.5	14	157,200
INPK Preservation	12.5	4	72,229
Minor Repairs	15	4	155,852
Riverside Expressway Repair Project	10	9	1,029,629

Kentucky's state-owned bridge network consists of 9,090 structures greater than or equal to 20 feet in length. Of these, 35 are approaches or crossings of the Ohio River, which forms Kentucky's northern border with the states of Ohio, Indiana, and Illinois. Another 15 cross the Big Sandy and Tug Fork rivers which are Ohio River tributaries that form Kentucky's border with Virginia and West Virginia. Due to the size of these structures – particularly those crossing the Ohio River – border bridges represent over 9% of the total deck area of state-owned bridges in Kentucky. In many cases, these bridges also have distinctive structural elements that differentiate them from non-border bridges. Additionally, Kentucky's border bridge crossings often represent critical infrastructure which carry increased risks as compared to other bridges.

Because of the unique issues related to maintenance and border state agreements regarding varying percentages of responsibility of Kentucky's border bridges, KYTC subject matter experts recommended that border bridges be excluded from the analysis. The variability in structure design, condition, and criticality of border bridges introduced a level of complexity that could not be readily accounted for within the scope of this project. Instead, it was assumed that – at a minimum – the estimated cost of currently programmed projects for border bridges would need to be added to the calculated budget need for state-owned, non-border bridges.

Similarly, Kentucky's 2025-2026 bridge program includes a unique non-border bridge project on an elevated section of I-64 in Louisville. The Riverside Expressway Repair Project includes minor repairs to 9 bridges comprising over 5 million square feet of deck area – similar in size to the total border bridge network. However, in this instance, the design of the bridges in question and the repairs under consideration are relatively straightforward. Consequently, KYTC recommended including these structures in the analysis along with an assumption of ten years of improvement for the project.

4.2 Results

Using the various project portfolios, a range of budget values can be obtained that could potentially provide a BSR of 1.0. However, program managers must be aware of the assumptions underlying the calculations and how well each portfolio would translate into reality if implemented. These assumptions, along with the real-world considerations that must be addressed are discussed below.

<u>Assumption 1</u>

There will always be enough suitable projects for any chosen portfolio.

BSR calculations for a portfolio are based on the cost per square foot of each treatment type and the number of years of life added. Using these values, the cheapest portfolio can theoretically be determined by limiting all treatments to the least expensive type based on the cost per square foot–year. However, this assumes enough bridges in the network are in such a condition that the cheapest treatment type is a viable solution.

In reality, each treatment type will be appropriate for a limited number of bridges. Applying preventive treatments to bridges in need of replacement or replacing bridges only in need of minor repairs would not provide the life-extending benefits assumed in Table 4.3. Therefore, a portfolio consisting of a single treatment is unlikely to be effective. As such, portfolios must be adjusted to match actual network conditions.

<u>Assumption 2</u>

Good project selection will ensure that performance matches expectations.

Assuming the values in Table 4.3 are accurate, program managers should expect that — on average — a portfolio of projects should achieve the anticipated network-level life extension if they carefully select projects to align conditions with treatments. For instance, if a bridge cannot achieve the expected life extension of a repair treatment, it will be deferred for replacement.

Critical local needs sometimes require that a bridge undergo emergency repairs that will not provide the expected life extension of a typical repair project. Maintaining access for first responders, industry, and residents may require immediate repairs until a longer-term solution can be implemented. Conversely, safety or mobility needs may require the replacement of a bridge that is still in relatively good condition. While such projects do not provide the network-level benefits assumed by the BSR model, they represent a reality which bridge managers must frequently address.

<u>Assumption 3</u>

KYTC and the contracting industry can scale up to match any portfolio.

BSR calculations assume that the program size for any treatment type can be increased or decreased to the precise level necessary to meet sustainability needs. If necessary, an infinitely large program of projects could be performed without economic or logistical impact.

However, as the bridge program's size increases beyond a certain threshold, resource limitations will likely increase contract costs for labor and materials, reducing the overall portfolio's effectiveness. KYTC could also face challenges retaining enough staff to provide effective inspection and contract oversight. Thus, it may be advisable to incrementally transition to a larger bridge program rather than making dramatic changes that cannot yet be supported.

For example, applying these criteria to a preservation-only portfolio compels decision makers to answer questions listed in Table 4.4 to determine the feasibility of such a portfolio.

Table 4.4 Consideration of a Preservation-Only Bridge Program

Question	Consideration	Conclusion
Are there enough potential projects?	Preservation is currently 15% of the total program.	It is unlikely that enough suitable projects could be identified to develop a 100% preservation program
Would it address critical needs?	A preservation-only program would include no replacement or rehabilitation of poor structures.	Many critical needs would not be met.
Can KYTC and industry meet the level of work?	A preservation-only program would require dramatic increases in labor, materials, and oversight.	Unlikely. Industry and KYTC are not currently structured for this level of preservation work.
Is the budget level reasonable?	Moving to a preservation-only program would only slightly increase the overall program budget.	Total budget is probably reasonable.

Addressing these questions would help decision makers quickly conclude that a preservation-only portfolio would be impractical. Applying the same approach to a replacement-only portfolio would yield similar results, although the budget level would likely yield an unreasonable scenario given the expense of replacements versus preservation-only. Taking underlying assumptions into account when analyzing tradeoff options generates a more realistic set of options.

KYTC's 2025 – 2026 proposed state-maintained bridge project list yields BSR values of 0.22 and 0.46, respectively, and an average of 0.34 based on the proposed composition of project work types. BSR is calculated by dividing the deck area years of work by the total deck area for non-border bridges (59,232,499 ft^2). Applying the values from Table 4.3 to each year of proposed work yields the BSRs in Table 4.5.

Table 4.5 Bridge Sustainability Ratio by Year

Year	Deck Area Years	BSR	Total Cost
2025	12,950,096	0.22	$136,557,321
2026	27,194,685	0.46	$241,048,224
Biennium Average	20,072,390	0.34	$188,802,773

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Table 4.6 shows the distribution of project types by costs over the 2025-2026 biennium.

Table 4.6 Current Project Cost Breakdown

Work Description	Percentage of Total Budgeted Costs
Replacement	77%
Superstructure Replacement	5%
Major Rehabilitation	8%
Painting	2%
Deck Rehab	1%
Non-INPK Preservation	3%
INPK Preservation	1%
Minor Repairs	1%
Riverside Expressway Repair Project	2%

Based on project cost breakdowns,
Table 4.7 shows the proposed portfolio of the highway plan by work description, total deck-area years, and total project costs along with the cost per deck area-year. The latter metric is the total deck area-years divided by total project costs for each project work type.

Table 4.8 shows the average annual impact of the proposed portfolio for FY25 and FY26.

Table 4.7 Current Proposed Portfolio Impacts

Work Description	Total Square Feet-Years	Total Project Costs	$ / Square Feet-Year
Replacement	18,975,226	$316,112,424	$16.66
Superstructure Replacement	765,079	$5,283,731	$6.91
Major Rehabilitation	1,959,528	$21,491,563	$10.97
Painting	1,210,908	$5,500,000	$4.54
Deck Rehab	160,084	$1,526,574	$9.54
Non-INPK Preservation	3,537,010	$10,830,405	$3.06
INPK Preservation	902,869	$4,147,418	$4.59
Minor Repairs	2,337,787	$4,213,430	$1.80
Riverside Expressway Repair Project	10,296,291	$8,500,000	$0.83
Total	**53,531,623**	**$427,446,250**	

*Major Rehab Work excludes Superstructure Replace

Table 4.8 Average Annual Project Impacts (FY 2025 and 2026)

Work Description	Total Deck Area-Years	Total Project Costs	$ / Square Feet-Year
Replacement	9,487,613	$158,056,212	$16.66
Superstructure Replacement	382,539	$2,641,865	$6.91
Major Rehabilitation	979,764	$10,745,782	$10.97
Painting	605,454	$2,750,000	$4.54
Deck Rehab	80,042	$763,287	$9.54
Non-INPK Preservation	1,768,505	$5,415,203	$3.06
INPK Preservation	451,434	$2,073,709	$4.59
Minor Repairs	1,168,894	$2,106,715	$1.80
Riverside Expressway Repair Project	5,148,145	$4,250,000	$0.83
TOTAL	**26,765,812**	**$213,723,125**	

The cost per deck area-year for each treatment type provides an estimate of the level of funding required to add one year of life to one square foot of bridge deck. Total replacements and major rehabilitation projects are the most expensive, while preventive treatments are cheaper.

The current BSR based on the average annual impact for KYTC's proposed program is 0.34. This indicates that current bridge funding levels are insufficient to maintain the network in its current condition. To understand the range of funding levels that could yield a BSR of 1 for bridges, we developed several theoretical budget needs based on the following portfolios:

- Maintain Currently Proposed Percentages — This portfolio assumes that the current project percentages are maintained, but the total amount spent for all projects is increased until a BSR of 1.0 is achieved. Since KYTC's current BSR is 0.40, this portfolio more than doubles spending for all treatment types.

- Emphasize Preservation — This portfolio uses "maximum feasible spending levels" for the least expensive option, then increases next least expensive option until a BSR of 1.0 is achieved.

- Conservative Preservation — This portfolio increases the amount of preservation work, but only to 80% of the maximum allowable amount for each project type until a BSR of 1.0 is achieved.

Table 4.9 summarizes proposed portfolios that would yield an BSR of 1. Each portfolio requires that the total Deck Area Years provided by all projects is equal to the total deck area for the entire state-owned non-border bridge network (59,232,499). Note that while the benefits of the Riverside Expressway Project are included in the calculations to determine total BSR, these benefits could not be readily achieved elsewhere in the state due to the unique nature of the project. Consequently, the Total Project Costs and Deck Area Years provided by the Riverside Expressway Project remain constant in each of the proposed portfolios. Unique projects such as the Riverside Expressway Project may need to be considered on an case by case basis when looking at a portfolio of projects.

Table 4.9 Annual Budget Needs for BSR=1 with Various Project Portfolios

Using Existing Project Portfolio Percentages				
Work Description	**Deck Area Years**	**Total Project Costs**	**$ / SF-Year**	**% of subtotal**
Replacement	34,382,403	$572,783,952	$16.66	86%
Superstructure Replacement	1,386,294	$9,573,924	$6.91	1%
Major Rehabilitation	3,550,592	$38,941,913	$10.97	6%
Painting	2,194,120	$9,965,795	$4.54	1%
Deck Rehab	290,065	$2,766,096	$9.54	0%
Non-INPK Preservation	6,408,931	$19,624,291	$3.06	3%
INPK Preservation	1,635,965	$7,514,966	$4.59	1%
Minor Repairs	4,235,984	$7,634,578	$1.80	1%
Subtotal	**54,084,354**	**$668,805,516**		100%
Riverside Expressway Repair Project	5,148,145	$4,250,000		
Total	**59,232,499**	**$673,055,516**		
Emphasize Preservation Portfolio				
Work Description	**Deck Area Years**	**Total Project Costs**	**$ / SF-Year**	**% of subtotal**
Replacement	9,487,613	$158,056,212	$16.66	42%
Superstructure Replacement	14,425,183	$99,622,158	$6.91	26%
Major Rehabilitation	979,764	$10,745,782	$10.97	3%
Painting	14,310,727	$65,000,000	$4.54	17%
Deck Rehab	80,042	$763,287	$9.54	0%
Non-INPK Preservation	4,898,723	$15,000,000	$3.06	4%
INPK Preservation	4,353,884	$20,000,000	$4.59	5%
Minor Repairs	5,548,419	$10,000,000	$1.80	3%
Subtotal	54,084,354	**$379,187,439**		100%
Riverside Expressway Repair Project	5,148,145	$4,250,000		
Total	**59,232,499**	**$383,437,439**		
Conservative Preservation Portfolio				
Work Description	**Deck Area Years**	**Total Project Costs**	**$ / SF-Year**	**% of subtotal**
Replacement	11,223,689	$186,977,890	$16.66	43%
Superstructure Replacement	11,583,915	$80,000,000	$6.91	18%
Major Rehabilitation	5,470,598	$60,000,000	$10.97	14%
Painting	11,448,581	$52,000,000	$4.54	12%
Deck Rehab	2,516,750	$24,000,000	$9.54	5%
Non-INPK Preservation	3,918,978	$12,000,000	$3.06	3%
INPK Preservation	3,483,107	$16,000,000	$4.59	4%
Minor Repairs	4,438,735	$8,000,000	$1.80	2%
Subtotal	54,084,354	**$438,977,890**		100%
Riverside Expressway Repair Project	5,148,145	$4,250,000		
Total	**59,232,499**	**$443,227,890**		

A summary of each portfolio indicates the budget required to attain an BSR of 1 and the increase from the current budget both in dollars and percentages (Table 4.10). To achieve a BSR of 1 requires a budget of $387 million – $528 million. The current budget is $213 million.

Table 4.10 Proposed Annual Budgets by Portfolio Type

Portfolio Type	Budget	$ Increase from Current	% Increase from Current
Currently Proposed	$188,802,773	$ -	0%
Maintain Currently Proposed Percentages	$673,055,516	$484,252,743	256%
Emphasize Preservation	$383,437,439	$194,634,666	103%
Conservative Preservation	$443,227,890	$254,425,117	135%

Table 4.11 shows potential tradeoffs between pavements and bridges assuming no additional asset management funding is made available. Based on the currently proposed project portfolios, $443 million is needed for bridges and $842 million for pavements, as shown in the column Budget for ASR=1.0. The percentage of ASR met is the budget divided by the budget for ASR=1.0. Limiting the number of scenarios is critical so the number of comparisons decision makers need to evaluate is reasonable. The approaches we analyzed included (1) current budget levels for both programs at $233 and $700 million respectively plus the additional funding (shortfall) needed to achieve an ASR of 1.0 for both assets, (2) equal % ASR Met values for bridges and pavements (this scenario shifts $78M from the pavement budget to bridges), and (3) an intermediate scenario that moves toward more equitable ASR values, but still slightly favors pavements. In this third case, only $50 million is shifted from pavements to bridges from the current budget. Other scenarios are possible depending on the number desired and the potential programmatic combinations.

Table 4.11 Potential Pavement and Bridge Tradeoffs at Current Funding Levels

		Bridges[7]	Pavements[28]	Total
Budget Need for ASR = 1.0 ($M)		$443	$507	$950
Current Funding Level	Anticipated Annual Spending ($M)	$189	$501	$690
	Shortfall	$254	$6	$260
	ASR% Met	43%	99%	73%
Equalize ASR %	Proposed Annual Spending ($M)	$322	$368	$690
	Shortfall	$121	$139	$260
	ASR% Met	73%	73%	73%
Transition to Comparable ASR%	Proposed Annual Spending ($M)	$255	$435	$690
	Shortfall	$188	$72	$260
	ASR% Met	58%	86%	73%

[7] Does not include cost needs for border bridges and bridges not maintained by KYTC.
[8] Does not include cost needs for pavements on Rural Secondary or locally owned routes.

Chapter 5 Conclusion

Using a performance-based method for cross-asset allocation can be effective but any approach must provide insights into different datasets that underpin individual programs. Through trial and error, we identified the ASR approach as having the most promise when addressing the question of how to allocate limited funds among asset classes. The ASR measures the amount of work completed by a particular program (i.e., bridges or pavements) and the amount of work required to maintain, or sustain the network in its current condition. By comparing current budget allocations, ASR values were calculated and different options compared to generate a range of budgets necessary for certain programmatic decisions and to achieve particular ASR values. We looked at different tradeoffs based on potential ASR goals. With current asset management funding levels, reaching an ASR value of 1 is currently not feasible.

Additional considerations include whether sustainability, rather than asset improvement, should be the goal that is measured in this context. Greater investments in the bridge and pavement programs would yield improvements in ASR rather than a focus on what can be sustained given the status quo.

Finally, while the ASR approach provides a mechanism for comparing existing physical asset classes like pavements and bridges, additional work is needed to determine the best way to integrate safety and capital projects into the tradeoff equation to develop a true, holistic cross-asset allocation scheme. Both project type impacts are difficult to understand from a true cross-asset allocation viewpoint. For capital projects, SHIFT does help assess the need and benefits, but it does not help in this context. Potentially, SHIFT data could be used but expected project life and a methodology to calculate an ASR for capital projects are two significant hurdles. For safety projects, the use of safety "targets" could help generalize current conditions and the levels needed to maintain those, but establishing expected life values for safety projects presents another potential barrier as potentially some of these could be considered to have an infinite life. Finally, a general consideration for all project types was a conversion to dollars which could dilute the usefulness of the overall approach.

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