

# SUSTAINABLE PAVEMENTS PROGRAM ROAD MAP



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<b>16. Abstract</b> <p>This document presents a strategic "Road Map" for the Federal Highway Administration's <i>Sustainable Pavements Program</i> that provides focused direction, and stakeholder input of that direction, for the next 5 years. While the gamut of topics that fall under pavement sustainability are much larger than the FHWA's program, the Road Map focuses on the topics and deliverables that are achievable within the scope of the <i>Sustainable Pavements Program</i> and that have a meaningful impact in advancing sustainability considerations within the pavement community.</p> <p>The contents of the Road Map are organized into four broad goal areas: (i) Goal Area 1: Pavement Systems, (ii) Goal Area 2: Assessing Pavement Sustainability, (iii) Goal Area 3: Guidance and Outreach, and (iv) Goal Area 4: Implementation. Recognizing the aspirational nature of a truly "sustainable pavement," each goal area includes processes and actions that advance the state of the practice towards being more sustainable.</p>					
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<b>SI* (MODERN METRIC) CONVERSION FACTORS</b>				
<b>APPROXIMATE CONVERSIONS TO SI UNITS</b>				
<b>Symbol</b>	<b>When You Know</b>	<b>Multiply By</b>	<b>To Find</b>	<b>Symbol</b>
<b>LENGTH</b>				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yard	0.836	square meters	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>
<b>VOLUME</b>				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>
NOTE: volumes greater than 1000 L shall be shown in m <sup>3</sup>				
<b>MASS</b>				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
<b>TEMPERATURE (exact degrees)</b>				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
<b>ILLUMINATION</b>				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>
<b>FORCE and PRESSURE or STRESS</b>				
lbf	poundforce	4.45	newtons	N
lbf/in <sup>2</sup>	poundforce per square inch	6.89	kilopascals	kPa
<b>APPROXIMATE CONVERSIONS FROM SI UNITS</b>				
<b>Symbol</b>	<b>When You Know</b>	<b>Multiply By</b>	<b>To Find</b>	<b>Symbol</b>
<b>LENGTH</b>				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
<b>AREA</b>				
mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<b>VOLUME</b>				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m <sup>3</sup>	cubic meters	35.314	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
<b>MASS</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
<b>TEMPERATURE (exact degrees)</b>				
°C	Celsius	1.8C+32	Fahrenheit	°F
<b>ILLUMINATION</b>				
lx	lux	0.0929	foot-candles	fc
cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
<b>FORCE and PRESSURE or STRESS</b>				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in <sup>2</sup>

\*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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## CHAPTER 1. INTRODUCTION

### Background

In 2010, the Federal Highway Administration (FHWA) launched the *Sustainable Pavements Program* to advance the knowledge and practice of sustainability as related to pavements. With the Program's overarching vision and mission statement (see sidebar) serving as a cornerstone, from 2010 to 2015 the Program developed a number of deliverables designed to assist roadway agencies in the implementation of more sustainable pavement practices using current knowledge and technology; some of those deliverables include<sup>1</sup>:

#### FHWA SUSTAINABLE PAVEMENTS PROGRAM VISION AND MISSION STATEMENT

To advance the knowledge and practice of designing, constructing, and maintaining more sustainable pavements through:

- Stakeholder engagement.
- Education.
- Development of guidance and tools.

- A comprehensive *Reference Document* on sustainable pavement systems.
- A *Framework Document* for pavement life-cycle assessment (LCA).
- A series of 25 technical articles covering a range of sustainability topics.
- A compilation of technical resources on sustainability.
- Five Tech Briefs:
  - *Pavement Sustainability*.
  - *Life-Cycle Assessment of Pavements*.
  - *Climate Change Adaptation of Pavements*.
  - *Strategies for Improving Sustainability of Asphalt Pavements*.
  - *Strategies for Improving Sustainability of Concrete Pavements*.
- A series of webinars focusing on sustainability in all stages of the pavement life cycle.

The *Sustainable Pavements Program* has transitioned into its second 5-year phase, allowing the FHWA to continue its efforts in the pavement sustainability arena. This document presents a strategic “*Road Map*” for the *Sustainable Pavements Program*, providing direction to the program for the next 5 years based on FHWA's goals and pavement sustainability stakeholder input. While the gamut of topics that fall under pavement sustainability is much larger than the FHWA's program, the *Road Map* focuses on the topics and deliverables that are achievable within the scope of the *Sustainable Pavements Program* and that have a meaningful impact in advancing sustainability considerations within the pavement community.

### Sustainable Pavement Context

This *Road Map* articulates some reasonable, yet aggressive targets that the pavement community might consider adopting. The desired end states can be compared with current practices, a necessary first step in identifying the knowledge, technology, and resource gaps that must be

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<sup>1</sup> Deliverables developed under the *Sustainable Pavements Program* are available on the website: <https://www.fhwa.dot.gov/pavement/sustainability/>

addressed to make meaningful advances in pavement sustainability. The underlying philosophy of the goals, strategies, and proposed actions outlined in the *Road Map* is to move the pavement community beyond solely improving upon current practices, but instead to evolve towards the implementation of truly regenerative pavement systems.

Sustainability is not defined by the achievement of a single end. Sustainability can be considered to be a quality attribute best represented by an open-ended continuum where it is always possible to further improve position within the continuum by increasing beneficial impacts (e.g., increased service life or improved ride quality) and reducing negative impacts (e.g., pollutants or extraction of nonrenewable resources). Further progress transitions to designing and constructing pavement systems that are essentially a neutral player in the larger and surrounding systems over their life cycle (i.e., it does no harm). In time, progress should continue so that pavements ultimately contribute to broad positive outcomes (e.g., pavements that produce more energy than they consume or construction that restores more land than it uses). Current efforts focused on reducing the impact and improving efficiency are considered good transitional strategies on the path towards the ultimate goal of producing broadly positive outcomes; some potential additional efforts are to:

- Reduce life-cycle emissions to air, water, and land that negatively affect human and ecosystem health.
- Conserve material resources.
- Reduce waste and landfill needs.
- Produce more comfortable, energy-efficient, and healthy urban ecosystems.
- Reduce pavement life-cycle costs.

## Road Map Scope and Objectives

The *Road Map* scope is summarized in the sidebar, while the overall objectives for the *Road Map* are as follows:

- **Develop a strategic approach to improve the sustainability of pavement systems** that considers each life-cycle stage of a pavement system and identifies challenges, methods, and opportunities for improvement.
- **Provide a framework to identify imminent needs** that are expected to have a lasting impact on the pavement community and eventually lead to more widespread adoption within the United States.
- **Develop a program that balances strategic partnerships, education/outreach, and implementation efforts** to facilitate efforts that enable the pavement community to move towards the development and implementation of truly regenerative pavement systems.

### ROAD MAP SCOPE

The *Road Map* provides a 5-year strategic direction for the FHWA's *Sustainable Pavements Program* that:

- is within the context of the broader pavement engineering and construction community to improve pavement sustainability.
- is guided by the FHWA *Sustainable Pavements Program's* Vision and Mission Statement.
- concentrates specifically on topics and deliverables through which the FHWA *Sustainable Pavements Program* can have a tangible impact given its current scope and authority.



- **Identify priorities that relate to pavement sustainability** that do not fall within the current 5-year scope and mission of the FHWA Sustainable Pavements Program but could be funded by other agencies.

Each proposed action described in this *Road Map* has been placed in one of three implementation target time horizons:

- Short Term: Less than 2 years.
- Intermediate Term: 2 to 5 years.
- Longer Term: Greater than 5 years (for items listed in Appendix A).

The short- and intermediate-term time proposed actions fall within the scope of the *Sustainable Pavements Program*, and are the primary focus of this *Road Map*. The longer-term time horizon needs are intended to provide a strategic direction for the FHWA and others beyond the 5-year contracting period of the *Sustainable Pavements Program*. While those longer-term needs are not the direct focus of this *Road Map*, they are critical in knowing to help identify short- and intermediate-term actions that support their development.

## Goal Areas

To fulfill the objectives discussed above, four broad goal areas have been developed under the *Road Map*. Recognizing the aspirational nature of a truly “sustainable pavement,” each goal area identifies topic areas and proposed actions under those topic areas that help advance the state of the practice. Because pavements exist and function within much larger systems, practices that support pavement sustainability must contribute to the sustainability of the larger systems as well. Therefore, pavement sustainability is context-dependent and it is necessary to account for surrounding systems and a pavement’s influence on them in order to define the most appropriate sustainability practices associated with a particular pavement system.

These considerations led to the identification of the four key goal areas that support the scope and objectives established for the *Sustainable Pavements Program Road Map*. Figure 1-1 presents the Goal Areas for the *Road Map* and includes an illustrative listing of proposed actions under each goal area.

## Document Organization

This *Road Map* document consists of six chapters (including this introductory chapter), with the bulk of the contents organized by the four goal areas (as shown in figure 1-1):

- Chapter 1. Introduction.
- Chapter 2. Goal Area 1—Pavement Systems.
- Chapter 3. Goal Area 2—Assessing Pavement Sustainability.
- Chapter 4. Goal Area 3—Guidance and Outreach.
- Chapter 5. Goal Area 4—Implementation.
- Chapter 6. Concluding Remarks.

Chapters 2 through 5 are structured similarly, with the scope of each goal area presented first, followed by discussions of the state of practice, goals, challenges, and proposed actions. Chapter

6 presents general concluding remarks, including a brief review of the goals, strategies, and key priorities identified in the *Road Map* and a discussion of the way forward. The document also includes one appendix (Appendix A) that provides a summary of the future needs that are either outside the scope of the *Sustainable Pavements Program* or fall under the longer-term time horizon.



Figure 1-1. *Road Map* goal areas, proposed actions, and their interrelationships.

## CHAPTER 2. GOAL AREA 1—PAVEMENT SYSTEMS

### Scope

The pavement life cycle is comprised of six stages: pavement design, materials production, construction, use, maintenance and rehabilitation, and end of life. Each stage of the life cycle provides numerous opportunities to improve overall transportation sustainability goals, which may include such items as lowering greenhouse gas emissions (GHGs), protecting the surrounding ecosystems, or improving the quality of life in the built environment.

This chapter presents recommended activities for the FHWA's *Sustainable Pavements Program* on the topics of pavement systems (including materials), defined as follows:

- **Pavement systems:** Pavements are considered to be systems, comprised of multiple layers and sometimes interlayers that are designed, constructed, and maintained to fulfill basic transportation needs while meeting sustainability goals. Strategies and decisions affecting pavement systems involve considerations of all life-cycle stages of design, material selection, construction, maintenance and rehabilitation, and ultimately reconstruction at the end of life.
- **Materials:** Materials constitute the layers, interlayers, and other structural elements (e.g., dowels, tie bars, geotextile interlayers, etc.) of the pavement system.. The impact of materials on pavement sustainability is through processes involved in their acquisition (e.g., mining, crude oil extraction), processing (e.g., refining, manufacturing, plant production), transport, and placement or installation. Therefore, each material used in a pavement system is by itself a subsystem having its own life cycle that contributes to the sustainability of the overall pavement system.

In recent years, the pavement industry has made great strides towards improving the quality of constructed pavements while increasing the implementation of asset management practice. These accomplishments have improved the sustainability of many pavement systems. The approach espoused in this chapter is to build upon those accomplishments, focusing on strategies for pavement systems and materials that have the highest potential to improve sustainability in the future.

### State of Practice

A number of significant advancements and improvements have been made over the last several decades in pavement materials and pavement design methodologies. Advancements in asphalt materials include the development and implementation of the Superpave system, the adoption of warm-mix asphalt (WMA) technologies, the increased use of polymerized and rubberized asphalt binders, and continued growth in the use of reclaimed asphalt pavement (RAP). Similarly, advancements in concrete technology have continued, with increased use of supplementary cementitious materials (SCMs) as partial replacements of portland cement, the development of new mixture design strategies that effectively reduce the cementitious materials content of paving mixtures while improving constructability, and significant improvements in mixture durability through improved guidelines for alkali-silica reactivity (ASR) and freeze-thaw susceptibility. Together, these (and other) advancements have resulted in more efficient and economical paving mixtures that have improved longevity, while enhancing the sustainability of pavement systems.

At the same time, the development and adoption of mechanistic-empirical (ME) design methods, as implemented in the AASHTOWare Pavement ME Design software, have provided the opportunity to better design pavements for local materials and conditions. The AASHTOWare Pavement ME Design software predicts pavement performance based on a number of metrics (e.g., ride quality, cracking, rutting, faulting) and, when properly calibrated, can be used to optimize pavement designs for specific locations. Further, the iterative design process allows direct assessment of the impact of specific material choices and layer/interlayer characteristics, including the ability to evaluate the anticipated impact of newly developed materials or the use of recycled, co-product, or waste materials (RCWMs) on pavement performance.

## Challenges

Key challenges and drivers for advancing sustainable practices for pavement systems and materials include:

- Pavement structural response and performance prediction models within the AASHTOWare Pavement ME software need to be validated to ensure they accommodate alternative designs and/or materials.
- The use of RCWMs in pavement systems is very common. However, the impacts of RCWMs on pavement performance are not completely understood, especially as increasing amounts of RCWMs are being used. This lack of fundamental understanding increases risk, and therefore may limit the expanded use of RCWMs in some applications.
- Currently, there is no viable alternative material to partially or completely replace petroleum-based asphalt binder.
- New material test methods and performance-related specifications are available, but their implementation is slowed by lack of acceptance and funding to support implementation.
- Rural and urban roads that are under the control of local governments constitute a significant share of the road network, yet have not benefited as greatly from sustainability advances as have pavements on the National Highway System (NHS).

## Goals, Strategies, and Proposed Actions

Goal Area 1 seeks to address some of these challenges by enhancing (1) pavement design practices and (2) life-cycle cost analysis (LCCA) and LCA data collection. Key strategies under this goal area include:

- Continue development and implementation of Pavement ME design with the goal of incorporating sustainable thinking into the design practice.
- Provide guidance on pavement design- and pavement materials-related data requirements for LCA and LCCA and improve pavement monitoring and data collection procedures to address those requirements.

### Topic Area 1: Pavement Design

Pavements can be designed to be more sustainable through the simultaneous consideration of costs, environmental impacts, and social needs. Traditional pavement design approaches focus primarily on identifying the most economical combination of layer characteristics that meet performance expectations. With the incorporation of properly calibrated models, ME pavement

design has the potential to optimize structural designs for region-specific climate, traffic, and materials.

Although ME design can be used to optimize pavement system designs for a range of conditions, it does not directly consider sustainability goals. Further, the current ME design framework does not explicitly consider use stage impacts, such as excess vehicle fuel consumption due to pavement deflections and pavement surface characteristics (roughness and texture).

### *Proposed Actions*

1. Use the current AASHTOWare Pavement ME design framework as the basis for developing a pavement design framework that provides specific guidance and tools for optimizing pavement design that incorporates sustainable thinking.

### Topic Area 2: Pavement Monitoring and Data Collection

Pavement monitoring and data collection are important activities that can provide valuable information for improving pavement design, material selection, and optimization techniques for achieving construction quality, all of which contribute to improved sustainability. Data collection is a continuous process, starting with documentation of pavement construction and continuing throughout the pavement life. Information that should be collected and stored includes pavement layer thicknesses, performance measures (e.g., roughness, distress types and quantities, surface friction), and the use of maintenance/rehabilitation treatments.



### *Proposed Actions*

1. Define performance metrics related to LCCA and LCA, as well as other sustainability metrics (e.g., amount of recycled materials used), determine data that needs to be collected to support the metrics defined, and provide guidance on how to collect the data.
2. Develop a decision-making framework that collectively considers pavement performance, LCCA, and LCA.

## Summary

A summary of proposed actions that are within the scope of the Sustainable Pavement Program is shown in table 2-1. Other possible pavement system action items that were considered under Goal Area 1 but are outside the scope of this program are listed in Appendix A.

Table 2-1. Summary of proposed activities under Goal Area #1.

TOPIC AREA	PROPOSED ACTIONS	TIME HORIZON
 <p data-bbox="289 701 459 730">PAVEMENT DESIGN</p>	<p data-bbox="586 590 1016 653">Develop a sustainable pavement design framework</p>	<p data-bbox="1222 606 1344 636">Short Term</p>
 <p data-bbox="212 1016 540 1045">DATA COLLECTION AND MONITORING</p>	<p data-bbox="586 772 1068 932">Define performance metrics related to LCCA and LCA, and other sustainability metrics, determine data that need to be collected to support metrics defined, provide guidance on how to collect the data</p>	<p data-bbox="1222 840 1344 869">Short Term</p>
	<p data-bbox="586 980 997 1073">Develop a decision-making framework that collectively considers pavement performance, LCCA, and LCA</p>	<p data-bbox="1182 1010 1385 1039">Intermediate Term</p>

## CHAPTER 3.

### GOAL AREA 2—ASSESSING PAVEMENT SUSTAINABILITY

#### Scope

The aim for Goal Area 2 on Assessing Pavement Sustainability is to be able to quantify the environmental, economic, and societal impacts of pavement systems, as well as their interactions with other systems. The desire is to have sustainability considered in the decision-making process where it is relevant and to ensure that decision making is done by informed participants in a data-rich environment.

To achieve this target, the assessment of sustainability must become part of standard decision-making processes, work flows, and specifications, with the ultimate objective being the routine use of sustainability metrics when making decisions for quantifying progress. Achievement of this vision will require incentivization beyond altruistic reasons, meaning inclusion of economic incentives, requirements, and/or other changes by owner agencies that lead to cultural norms that impel improved sustainability.

A particularly important need for measurement of sustainability is to consider the interactions of pavement systems with other systems so that pavement-related decisions, or those made in other systems that affect pavement systems, do not have unforeseen unintended negative consequences. Assessments must include long-term future impacts and interactions that are inevitably influenced by current decisions. This includes consideration of the communities in which pavements are built and function and for which they are intended to serve. It is anticipated that the use of sustainability assessment that considers both long-term impacts and interactions between systems will lead to what has been referred to as “life-cycle thinking.”

Part of the intent is that changes in community and agency goals for quality of life and asset management will lead to changes in standard practices for decision-making processes; this, in turn, creates a beneficial cycle of improvements in sustainability measurement driving better decision making, and the push for better decision making driving improvements in sustainability measurement.

Project-level sustainability assessment approaches considered in this *Road Map* are:

- LCCA.
  - Frameworks, data, models, and tools for LCCA.
  - Processes and methods for using LCCA to support decision making.
  - Applications of LCCA.
  - Implementation issues.
- LCA.
  - Frameworks, data, models, impact indicators, and tools for LCA.
  - Processes and methods for using LCA to support decision making.
  - Applications of LCA for specific purposes, such as environmental product declarations, comparisons, and benchmarking.
  - Implementation issues.

## State of Practice

### Life-Cycle Cost Analysis

The practice of LCCA is simpler and more applied than LCA. Practice typically follows guidance that was provided by the FHWA nearly 20 years ago<sup>1</sup>. The primary gaps, however, are with regard to the development of readily accessible high quality standardized input data for users, identification of where in practice the use of LCCA provides high benefit-to-cost and where it does not, and overcoming institutional inertia and/or lack of resources that prevents the incorporation of a rigorous LCCA into standard practice.

### Life-Cycle Assessment

Creation of a data-rich environment requires access to data and models that are transparent, readily available, regionally applicable, temporally up to date, and financially accessible for the wide range of public and private users. This also requires decision-support frameworks, processes, and tools that are easy to use, time efficient, flexible, context sensitive, and similarly transparent and financially accessible.

While generic LCA has been under development since the 1960s, the first ISO standards for all industrial products are about two decades old. After a few early efforts, the application of LCA to building materials and pavements has begun to develop rapidly in the past decade. While it is currently clear that there are sufficient data, knowledge, models, and frameworks to begin to more widespread implementation of pavement LCA, there are also major gaps in all of the above.

Figure 3-1 shows the elements of successful implementation of LCA organized in the shape of a pyramid to indicate that the elements on the bottom must be substantially completed before moving higher to the next level. The bottom level of the pyramid (shown in dark green) is based on the FHWA Pavement LCA Guidelines, which were published in 2016<sup>2</sup>. The other elements, (shown in light green) indicate that substantial additional work is needed in North America, although several organizations are making rapid progress, and successful initial implementation has been completed in several countries in Europe as well as in Japan.

The data definition level is where the data needed to support different types of decision making are identified in terms of both inputs and outputs for the different contexts in which decisions will be made. Once the overall data needs are defined, the specific data must be identified and made useable and accessible, or created. Data must reside in organized databases and a validation process must be in place to provide credibility of results. These building blocks are needed to produce tools for each of the contexts and different levels of decision making. Finally, specifications and policies can be written based on policy analysis using the data and tools, and written to use data and tools as part of standard decision-making processes.

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<sup>1</sup> Walls, J. and M. R. Smith. 1998. *Life-Cycle Cost Analysis in Pavement Design—Interim Technical Bulletin*. FHWA-SA-98-079. Federal Highway Administration, Washington, DC.

<sup>2</sup>Harvey, J. T., J. Meijer, H. Ozer, I. L. Al-Qadi, A. Saboori, and A. Kendall. 2016. *Pavement Life Cycle Assessment Framework*. FHWA-HIF-16-014. Federal Highway Administration, Washington, DC.



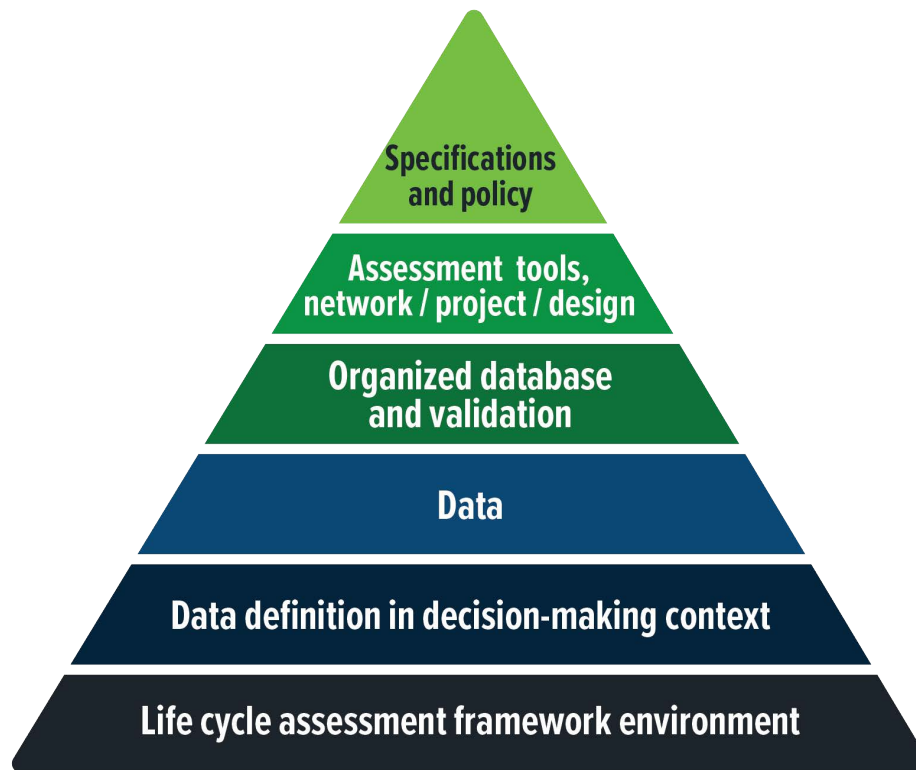


Figure 3-1. Elements required for successful implementation of LCA.

## Challenges

### Life-Cycle Cost Analysis

While LCCA is a mature assessment process and it is generally known what needs to be done to produce a good LCCA system (i.e., collection of data, development of performance models, analysis tools), the challenges for project-level pavement LCCA include:

- While a complete and customizable software, *RealCost*, is available from the FHWA, the major data gaps that agencies must fill to most effectively use the software are:
  - Information regarding costs of pavement rehabilitation and maintenance treatments.
  - Information regarding rehabilitation service lives and the intervals between rehabilitation and maintenance treatments.
  - Information regarding any road user costs the agency may want to consider in the LCCA (including estimated traffic delays caused by construction work zones).
  - Information regarding the discount rate(s) to be used.
- Much of the information required is located in existing agency databases, or needs to be developed from existing databases such as asset management systems and construction cost accounting databases. Methods of either making the information readily available for manual entry into *RealCost*, or the development of approaches to electronically access required data, would make LCCA practice more efficient and less prone to input errors or use of incorrect data.
- Further work is needed to encourage the use of rigorous project-level LCCA practice in standard practice based on the benefits, costs, and appropriate use of LCCA.
- Further work is needed to identify where the use of LCCA provides the most value in the decision-making process so that attention can be focused on those uses.

There is much less use of LCCA at the local government level where there are fewer resources and less analysis of existing data and data systems has occurred to develop inputs; identification of where the costs of using LCCA are justified for local agencies is also needed.

### Life-Cycle Assessment

Although considerable progress has been made in terms of what needs to be done to produce good first-generation LCA data, models and tools, a number of challenges for pavement LCA continue to persist and include:

- Additional work is needed to educate decision makers and pavement practitioners regarding the potential benefits, costs, and appropriate use of LCA and Environmental Product Declarations (EPDs).
- Further work is needed to identify where and how LCA provides the best value in the decision-making processes so that attention can be focused on the optimum use(s).
- Significant need exists to create transparent, affordable, regionally applicable and up-to-date, curated databases. Institutional and financial obstacles to completing this task include:
  - There currently is no single rule maker for PCRs, although there are attempts underway to create forums for building consensus, and the issuance of the FHWA Pavement LCA Framework provides guidance on best practices.
  - The development of EPDs will potentially help fill the data gaps; however, there is a need for standardization of practice in the Product Category Rules (PCR) under which EPDs are produced.
  - The use of EPDs is a subject of discussion in different arenas, including outside the pavement industry, and there may be a push to use EPDs for comparing products for purposes of procurement without consideration of the full pavement life cycle and functional performance.
- LCA needs further standardization to solidify the use of consensus best practices, and to give consumers of LCA confidence to quickly and easily understand LCA and apply the results appropriately.
- As these issues are being resolved, there is a need for the development of LCA tools to facilitate implementation; tools will work best if tied to existing databases within agencies that can easily provide LCA input information, such as pay items.

### **Goals, Strategies, and Proposed Actions**

Goal Area 2 seeks to address some of these challenges by: (1) updating current project-level LCCA guidance specific to pavement systems, and (2) developing simplified guidelines for life-cycle thinking and how agencies can get started with conducting an LCA. Key strategies under this goal area are summarized below.

- Guidance on LCCA is dated and the level of knowledge and experience with LCCA is not consistent across agencies. Better knowledge and experience will add the application of consistent best practices for LCCA to reduce agency, taxpayer, and road user life-cycle costs.
- LCA is a somewhat complex tool used to assess environmental sustainability. There are many applications for its use and a succinct, step-by-step explanation of what LCA is and how agencies can start applying fundamental “life-cycle thinking” practices is needed.

### Topic Area 1: Life-Cycle Cost Analysis

In 1998, FHWA published an interim technical bulletin providing guidance on LCCA for pavements to support better investment decisions. That document is now almost 20 years old and there is a need to provide updated and expanded guidance on the use of LCCA for decision making in today's design and construction environment.

FHWA also developed RealCost, a software tool to perform LCCA for pavement design selection in accordance with the guidelines outlined in the 1998 interim technical bulletin. The current version of the software (Version 2.5) is 6 years old and it does not function properly with the most recent version of Microsoft Excel. The RealCost tool is popular among pavement engineers; therefore, keeping this tool current and functional is important to program users.

#### *Proposed Actions*

1. Develop an updated LCCA guidance document for pavements.
2. Update the RealCost software tool and incorporate the updated LCCA guidance into the tool.

### Topic Area 2: Life-Cycle Assessment

The *LCA Framework Document* published by the FHWA provides detailed guidance on the overall approach, methodology, and system boundaries associated with performing an LCA for pavement systems. However, this guidance can be challenging to interpret and implement for users who are just getting acquainted the fundamentals of LCA. To help users understand and implement LCA concepts at its most basic level, LCA can be applied in the form of “life-cycle thinking” without the use of environmental impact databases and emissions factors. This can be done by identifying the questions to be answered in terms of reducing energy use, waste and emissions, defining the system boundaries and future actions in the life cycle, and calculating flows of materials and energy into the system and waste out of the system. These benchmarking steps alone can often identify inefficiencies to be eliminated and opportunities for reducing both environmental impact and cost. There is a need for simplified guidance for practitioners at highway agencies on how they can apply life-cycle thinking principles and LCA concepts at various levels.



#### *Proposed Actions*

1. Develop guidelines for life-cycle thinking and how to get started with LCA implementation.
  - a) Develop easy-to-follow instructions and other guidance for setting up the processes of goal and scope identification, system definition, quantification of flows, and interpretation to identify changes that lead to improvements.
  - b) Develop information regarding customization of the approach to automate its application by making use of existing agency databases and processes. This will help minimize the cost and human resource requirements of implementing the benchmarking process.
  - c) Pilot the instructions on case studies identified by state and local road agencies.
  - d) Summarize the information and develop information communicating how the information supported better decision making, as well as the costs and effort required.
  - e) Support agencies in applying this approach.
  - f) Develop guidance on getting started with LCA implementation including specific steps to be followed, resources, and available tools.

**Summary**

A summary of the proposed activities under Goal Area 2 is provided in table 3-1. Other items that were considered, but are outside the scope of this program are listed in Appendix A.

Table 3-1. Summary of proposed activities under Goal Area #2.

TOPIC AREA	PROPOSED ACTIONS	TIME HORIZON
 <p>LIFE CYCLE COST ANALYSIS</p>	<p>Develop updated LCCA guidance document for pavements</p>	<p>Short Term</p>
	<p>Update RealCost software tool and incorporate updated LCCA guidance into the tool</p>	<p>Short Term</p>
 <p>LIFE CYCLE ASSESSMENT</p>	<p>Develop guidelines for life-cycle thinking and how to get started with LCA implementation</p>	<p>Intermediate Term</p>

## CHAPTER 4. GOAL AREA 3—GUIDANCE AND OUTREACH

### Scope

This chapter presents recommended actions for the FHWA’s *Sustainable Pavements Program* on the topics of guidance and outreach, which are defined as follows:

- **Guidance:** Assistance (in the form of documents, flyers, tools, advice, etc.) in translating information and products from the *Sustainable Pavements Program* into professional practice.
- **Outreach:** Marketing of and education about *Sustainable Pavements Program* products and pavement sustainability in general. This involves communication to the intended audience to establish the profile and perceived value of sustainable pavement solutions.

The FHWA has a history of providing influential guidance and outreach efforts on a range of technical topics, including LCCA, warm-mix asphalt, concrete overlays, and statistical quality control, among many others. The unique position occupied by the FHWA provides an opportunity to influence owner-agencies and practitioners to adopt sustainable pavement practices using guidance and outreach as a bridge between Sustainable Pavement Program products and implementation in practice.

### State of Practice

Awareness of sustainable pavement ideas and practices is growing within the pavement industry (design, materials, construction, research, and owner agencies). Public (e.g., federal, state, and city governments) and private (e.g., trade organizations, nonprofit advocates) entities have produced numerous informational documents, hosted conferences, and formed committees related to pavement sustainability. However this information has difficulty migrating to project-level implementation beyond experimental investigations or demonstration projects chiefly because sustainability concerns tend to have little influence in project decisions beyond initial planning efforts.

### Challenges

Key challenges and drivers for the current state of practice for guidance and outreach are:

- **“Sustainability” remains a specialty subject.** Strong advocates tend to be from the planning and environmental sectors and less so from engineering, contracting, and materials suppliers. Therefore, the reception for sustainability varies greatly based on both speakers and audience.
- **Lack of a high-level message and senior level buy-in regarding the benefits of sustainable pavement practices.** Agencies need a high-level “corporate” message that clearly conveys that sustainable pavement practices help increase safety, improve performance, decrease costs, and reduce the environment impacts of pavement systems. This message should highlight the importance of sustainable pavement systems in asset management and how the adoption of “sustainable” practices is clearly aligned with the performance measures being adopted under the umbrella of [Moving Ahead for Progress in the 21<sup>st</sup> Century Act](#) (MAP-21) and [Fixing America’s Surface Transportation Act](#) (FAST).

- **The definition of “sustainability” remains vague.** Definitions of sustainability are often inconsistent or very general and usually fail to provide much direction at the project level. The generally discussed “triple bottom line” definition (that sustainability incorporates economic, environment, and social components) seems to allow for the inclusion, or exclusion, of just about any common practice. Personal preference, rather than engineering logic, often seems to be the basis for scoping the sustainability of a particular pavement system as a result. Ongoing work in the area of sustainable pavements (including this effort) is slowly converging on a practical, if yet unstated, definition.
- **“Sustainability” is often treated as a communications effort rather than an engineering effort.** Communicating sustainability in pavements is admirable, but such communications often highlight as “sustainable” those practices or actions that are already done for other reasons; thus sustainability can be misconstrued as an effort to rebrand existing practices rather than an effort to advance engineering design and construction.
- **“Sustainability” is often viewed as an add-on feature.** Rather than being integral to a pavement project, sustainability concepts are viewed as optional pavement system qualities. Despite the best intentions, this can lead to their elimination through value engineering and compromise within the design and construction process. They are almost never added as a value engineering proposition.
- **The value of sustainable pavement practices is difficult to quantify.** Sustainability efforts often have nonmonetary values that are difficult to quantify (e.g., clean water, scenic views, lower emissions) or values that are obtained only by trading off a more traditionally understood value (e.g., accepting a shorter service life in exchange for reduced tire-pavement noise).
- **Sustainable pavement qualities and tools are not well understood.** Sustainability considerations tend to highlight nontraditional qualities and use new tools that are not well understood. For instance, while GHG emission reduction in cement production can be quantified, the process for quantification is not well understood by the pavement industry, and the perceived value of that reduction is poorly and inconsistently evaluated.

### Goals, Strategies, and Proposed Actions

The Guidance and Outreach goal area seeks to address these challenges by (1) making the pavement industry aware of “sustainability” and its benefits, and (2) providing guidance on translating knowledge of “sustainability” into tangible actions for pavements. This amounts to efforts in marketing, guidance, and education. Key strategies in this effort are:

- Define sustainability in a practical manner.
- Communicate the engineering value of sustainable practices.
- Position sustainability as a central quality of pavement systems.
- Educate and involve all sectors of the pavement industry in sustainability.
- Quantify the value of sustainable pavement practices.
- Educate the industry on sustainability qualities and tools.
- Provide guidance on how to translate sustainability ideas into project actions.

Based on this list of goals, the following topic areas are proposed for action.

### Topic Area 1: Guidance

Guidance actions assist practitioners in translating information and products from the *Sustainable Pavements Program* into professional practice implementation.

The level of knowledge and experience in applying LCCA is not consistent across the FHWA division offices, nor between or even within state and local agencies. Better knowledge and experience will facilitate the application of consistent best practices for LCCA to reduce agency, taxpayer, and road user costs over the pavement life cycle.

The FHWA has hosted workshops and webinars on LCCA and the National Highway Institute (NHI) has developed training materials and courses on various topics that include education on LCCA, but these courses, workshops, and webinars need to be updated to reflect more recent guidance and to include a sustainability context.

FHWA division offices need comprehensive, complete, and accessible information to be aware of what LCA is and how it can help support decision making so that it is a part of their toolkit for responding to questions and providing guidance concerning recycling, resource and energy use, and the environment.

### *Proposed Actions*

1. Develop updated training materials on LCCA and deliver training for FHWA division offices and state and local agencies (to be undertaken after the proposed actions identified under Topic Area 1 of Goal Area 2 are accomplished).
2. Develop and deliver training for FHWA division offices regarding LCA use on state projects (to be undertaken after the proposed actions identified under Topic Area 2 of Goal Area 2 are accomplished).
  - a) Work with division office staff to identify questions where LCA can fill gaps in decision support.
  - b) Develop frequently asked questions and other information to assist in its use for the applications identified by FHWA division offices.
  - c) Revise and refine the information to ensure that it meets owner agency needs to both understand LCA for pavement, and to communicate and advise in its use.
  - d) Provide training to FHWA division office staff using the information developed, and train FHWA division office staff to provide training to others.

### Topic Area 2: Outreach

Education actions provide information about *Sustainable Pavements Program* products and their potential uses and benefits. They serve an outreach purpose in that they increase industry awareness of pavement sustainability practices.

In general, education materials are likely to be more impactful if they include discussion of actual guidance and guidance products rather than just general information. Therefore, they may be most effective once guidance products become available.

### ***Proposed Actions***

1. Continue offering webinars on sustainability-related topics. It is worthwhile to continue the webinar series that began with the publication of *Towards Sustainable Pavement Systems: A Reference Document*. As new products emerge from the *Sustainable Pavements Program*, it is appropriate to conduct companion webinars to introduce the products and discuss their envisioned uses.
2. Develop online learning modules for just-in-time training. These are training solutions that are available when needed rather than on a scheduled basis. Evidence suggests these are more readily consumed than extensive reports or scheduled short courses and workshops. These modules may have the most impact if the FHWA can work with industry partners for delivery (e.g., National Center for Asphalt Technology, CP Tech Center, ASCE, ACI, AAPT, APWA, etc.).
3. Train instructors for instructor-led training. It may be worthwhile to develop a course on pavement sustainability and train a set of instructors for delivering instructor-led training. This would involve a 2-3 day instructor-led session covering key *Sustainable Pavements Program* products.

### **Topic Area 3: Case Studies**

Case studies provide an outreach marketing channel for increasing awareness of pavement sustainability practices. The main effort in case studies should be implementation (getting a lead agency or group of agencies to implement practices), with the outreach component being the marketing of these implementation efforts.

A set of case studies should be prepared that identifies and illustrates “best” sustainable pavement practices that can be used as models for other agencies. The FHWA *Sustainable Pavements Program* can incorporate into its Sustainable Pavements web site a series of short technical reports (e.g., similar to the Asset Management case studies) documenting successful implementations, complemented by short web videos describing the example, results of the assessments (when available) and links to the specification used.

### ***Proposed Actions***

1. Develop best-practice case studies on:
  - a) Sustainable pavement use. Careful documentation of efforts in actual constructed (or under construction) pavements with multiple sustainable features. The highest impact would come from projects that agree, in advance, to feature best practices that have emerged from the *Sustainable Pavements Program* and have them documented. This is best accomplished as a combined implementation/guidance effort.
  - b) FHWA *Sustainable Pavements Program* output. Case studies of organizations that have used or implemented the program’s products complemented by short web videos describing the example, results of the assessments (when available) and links to the specification used.



### Topic Area 4: Support Media

Support media provide an outreach marketing channel for increasing awareness of pavement sustainability practices. They should be undertaken by organizations competent in the required media (e.g., online delivery, video, etc.) and not limited to pavement experts.





#### *Proposed Actions*

1. Prepare conference presentations. Continue the practice of creating conference-ready presentations of key *Sustainable Pavements Program* products.
2. Develop and disseminate Tech briefs. Continue the practice of creating succinct summaries of key *Sustainable Pavements Program* products in the form of FHWA Tech briefs.
3. Develop web-based videos, animations, infographics, and testimonials. Professionally produced videos and animations on specific sustainability-related topics, featuring projects, owners, and contractors that have participated in an implementation pilot program.
  - a) High-level message on pavement sustainability. One of the critical gaps identified includes a short mission statement that clearly conveys that sustainable pavement practices help increase safety, improve performance, decrease costs, and reduce the environmental impacts. To bridge this gap, the FHWA *Sustainable Pavements Program* can develop a short and catchy “sales pitch” that agency champions can use to promote the message to their executive leadership and decision makers. The message can be transmitted through the identification of the champions and the development of customized short videos, handouts, and presentations customized for different audiences.
  - b) Develop a “10 Minute Elevator Speech” on what LCA is and how it is best used. This will be a succinct and to-the-point explanation of LCA (using animations and infographics), including why and how it can best be used.

## Summary

A summary of the proposed activities under Goal Area #3 is provided in table 4-1.

Table 4-1. Summary of proposed activities under Goal Area #3.

TOPIC AREA	PROPOSED ACTIONS	TIME HORIZON
 <b>GUIDANCE</b>	Develop and deliver training on LCCA	Short and Intermediate Term
	Develop and deliver training on LCA	Short Term
 <b>OUTREACH</b>	Webinars on sustainability-related topics	Short Term
	Online Training modules for just-in-time learning	Short Term
	Train instructors for instructor-led training	Intermediate Term
 <b>CASE STUDIES</b>	Develop best practice case studies on: <ul style="list-style-type: none"> <li>• Sustainable pavement use</li> <li>• FHWA <i>Sustainable Pavements Program</i> output</li> </ul>	Intermediate Term
 <b>SUPPORT MEDIA</b>	Conference presentations	Short Term
	Tech Briefs	Short Term
	Web-based videos, animations, infographics, and testimonials: <ul style="list-style-type: none"> <li>• High-level message on pavement sustainability for executive leadership and decision makers</li> <li>• “10” minute elevator speech” on what LCA is and how it is best used</li> </ul>	Intermediate Term

## CHAPTER 5. GOAL AREA 4—IMPLEMENTATION

### Scope

The aim of this goal area is to provide the means by which State DOTs can implement and transform pavement practices to achieve a sustainable pavement system that best serves society and is synergistic with the surrounding ecosystems.

This chapter presents recommended implementation strategies for the FHWA's *Sustainable Pavements Program* to help agencies adopt and deploy more sustainable pavement practices. These recommendations include efforts to accelerate the deployment of the most promising sustainable pavement technologies as well as technical support to agencies that are working to adopt those technologies in their day-to-day practices.

### State of Practice

Agencies are increasingly becoming aware of the benefits of adopting more sustainable pavement practices, with several early adopters leading the way. However, widespread adoption and implementation are still in its infancy and there are gaps that are hindering the implementation of innovations that would otherwise result in more sustainable pavement systems. These gaps include the definition of the audience for the technology transfer and implementation efforts, which should include local agencies, state DOT, policymakers, consultants, and industry. There are also significant deficiencies that exist in terms of:

- Educational opportunities for agency personnel (state DOT staff, FHWA personnel in the Division Offices, and other stakeholders).
- Reliable data for agencies to use for benchmarking their practices.
- Tools for quantifying the impacts of adopting more sustainable pavement practices.
- Incentives for agencies to include life-cycle thinking into their decision-making process.
- Specifications that reflect “best” sustainability practices.

Finally, there is an ongoing need to effectively communicate the benefits of adopting more sustainable pavement practices to all stakeholders, including policymakers, state DOTs, industry, and FHWA Division Offices.

### Challenges

Some of the challenges that state DOTs and other stakeholders are facing include the following:

- **Risk aversion of many highway agencies.** Agencies tend to be risk averse, sticking with strategies that they have commonly used in the past. This can create a barrier to innovation and stifle the implementation of more sustainable practices, which may seem “risky” because they are unfamiliar.
- **Lack of tools to support changes in agency internal policies.** The reluctance to adopt sustainability pavement practices is partially due to the lack of tools to support agencies as they consider changing internal policies required to allow and promote these innovations. Agencies and local FHWA offices often do not have the resources to educate their engineers and mid-level managers or to develop the needed standards and specifications. Examples of the type of resources that may facilitate the transition include

the creation of a centralized knowledge base that can be customized to local conditions and the development of benchmarking tools to compare practices within their organization and potentially with other agencies.

- **Building up institutional sustainability knowledge requires long-term commitment.** Implementing sustainability is not something an agency can do overnight but instead requires education, nurturing, hiring people, instituting practices, and consistently trying to build an internal knowledge base. Most agencies do not have dedicated staff with the authority and means to integrate sustainability in a structural way within the organization.

## Goals, Strategies, and Proposed Actions

The implementation goal area seeks to address these challenges by promoting governance, programmatic, and project level changes leading to more sustainable pavement solutions. Key strategies are to: (1) provide tools to support agencies deploying these practices and policies, (2) establish a program to support pilot implementation efforts, and (3) develop a benchmarking mechanism to help promote and communicate sustainable pavement practices and policies.

### Topic Area 1: Sustainable Pavement Project Development Toolbox

An important topic for accelerating the implementation of sustainable pavement practices is the development of tools to support the implementation efforts.

#### *Proposed Actions*

1. Develop project-level assessment process and tools. A series of simple tools that uses concepts and methods developed in Goal Areas 1 through 3 can be developed to allow agencies to assess individual projects. The program can produce guidelines and software tools for the establishment of benchmarks, quantification of the benefits, and quantification of the value.
2. Educate decision makers on EPDs. A program needs to be implemented to help educate decision makers on EPDs and provide guidance on their use.

### Topic Area 2: Pilot Programs

It is recommended that the FHWA *Sustainable Pavements Program* establish a technical support program for sustainable pavement practices, which could focus on such items as conducting LCAs, preparing EPDs, evaluating novel materials and/or pavement systems, and documenting their economic, environmental, and social impacts. This program can include not only the provision of the technical support but could also help defray some of the additional costs associated with the activity (e.g., DOT travel support).

#### *Proposed Actions*

1. Develop pilot program guidelines and application procedures. Prepare guidelines that detail the objectives and scope of a proposed pilot program, and describe the requirements and procedures for agencies to participate in the program.
2. Identify lead states, industry champions, and initial pilot projects. Select and support the initial pilot projects for implementation, identifying lead states and key industry partners in each of the key sustainable pavement practices targeted, and support their deployment.

3. Conduct training and outreach. Conduct training to facilitate the development and implementation of the pilot projects and outreach efforts to highlight the lessons learned and recruit pilot participants.
4. Establish structure for a centralized data repository. Create the structure and requirements for a database that will store relevant project information, including design, construction, costs, and environmental impacts. This repository should include relevant specifications, documented benefits, and other information that could be useful for other agencies to analyze and replicate the pilot.
5. Document benefits and assess and improve frameworks and tools. Work closely with the early adopters to capture key data and use the results from the pilot projects to document the benefits and test and assess the frameworks and tools developed by the FHWA *Sustainable Pavements Program*, propose improvements, and implement those improvements when possible.
6. Prepare pavement sustainability application guidebook. Develop a concise and simple-to-use guidebook that summarizes the knowledge gained through the pilots, and provide practical guidance for activities such as applying LCA, developing and using EPDs, and adopting more sustainable pavement materials and systems.

### Topic Area 3: Pavement Sustainability Report Card

The FHWA *Sustainable Pavements Program* can develop an approach that allows agencies to benchmark and communicate uniformly the degree of implementation of sustainable pavement practices and policies within the agency and provide support for implementation efforts. The benchmarking can be facilitated by a pavement sustainability “report card” that tracks the evolution of the agency in the adoption of sustainability practices for their pavement systems. The report card should be practical and consider regional differences.

#### *Proposed Actions*

1. Report card development. Develop the framework for comparing and tracking sustainable pavement practices and policies. This implies defining goals of the effort and preparing a plan to achieve these goals, the format for the report card, and the elements that should be included and how they can be assessed. For example, the report card may establish an implementation level (e.g., basic, proficient, advanced) for a series of key elements (e.g., life-cycle thinking, recycling, sustainability goals included in the agency’s mission statement, and so on).
2. Training and initial self-evaluation. Once the report card is developed, it is necessary to train agencies and other stakeholders on how to apply it and conduct an initial self-evaluation. This initial evaluation will require support from the FHWA *Sustainable Pavements Program*.
3. Implementation support program. Continuing efforts should include periodic self-evaluations and documentation of best practices that can be used for benchmarking and as examples for other agencies.

## Summary

A summary of the proposed activities under Goal Area #4 is provided in table 5-1.

Table 5-1. Summary of proposed activities under Goal Area #4.

TOPIC AREA	PROPOSED ACTIONS	TIME HORIZON
 <b>SUSTAINABLE PAVEMENT PROJECT DEVELOPMENT TOOLBOX</b>	Develop project-level assessment process and tools	Short Term
	Educate decision makers on EPDs and provide guidance on their use	Short Term
 <b>PILOT PROGRAM</b>	Develop guidelines and application procedures	Short Term
	Identify lead states, industry champions, and initiate and support pilots	Short Term
	Conduct training to facilitate development and implementation of pilot projects	Short Term
	Establish structure for centralized data repository to store relevant project information including design and construction information, costs, and environmental impacts	Short Term
	Document benefits; assess and improve framework and tools	Intermediate Term
	Prepare pavement sustainability application guidebook	Intermediate Term
 <b>PAVEMENT SUSTAINABILITY REPORT CARD</b>	Develop report card	Intermediate Term
	Conduct training and assist agencies with initial self evaluation	Intermediate Term

## CHAPTER 6. CONCLUDING REMARKS

### Summary

The role that sustainability considerations play in the highway and transportation community continues to grow and evolve. In this context, addressing sustainability is not the achievement of a single end point, but rather a continuous journey that must confront an evolving assortment of technical issues and topics.

This document presents a strategic “*Road Map*” for FHWA’s *Sustainable Pavements Program* that provides direction for this journey over the next 5 years. With an emphasis on pavements, the *Road Map* is divided into the following four goal areas:





- Goal Area 1—Pavement Systems and Materials.
- Goal Area 2—Assessing Pavement Sustainability.
- Goal Area 3—Guidance and Outreach.
- Goal Area 4—Implementation.

As described throughout the document, the focus of the *Road Map* is on the topics and deliverables that are achievable within the scope of the *Sustainable Pavements Program* and that have a meaningful impact in advancing sustainability concepts and considerations within the pavement community. Chapters 2 through 5 provide comprehensive lists of goals, strategies, and proposed actions within each of the four strategic goal areas that can be accomplished under the FHWA *Sustainable Pavements Program*. A high-level summary of the proposed actions is presented in table 6-1.

However, in recognition of the many pavement-related issues that are longer term in nature or require groundbreaking or more fundamental research, an appendix is included that presents a summary of some of those needs in anticipation of their conduct outside of the FHWA *Sustainable Pavements Program*.

It is acknowledged that this *Road Map* represents only the first step towards the implementation of truly regenerative pavement systems by identifying both the short- and long-term actions needed to promote sustainability in the pavement field. As a whole, this area is in its infancy and there will be a number of new and emerging topics that materialize as pavement sustainability begins to take root. This *Road Map* document should therefore be regarded as a dynamic document that should be updated regularly to reflect new developments and changes.

Table 6-1. Summary of needs identified under each Goal Area.

GOAL AREA	NEEDS
 <p><b>PAVEMENT SYSTEMS</b></p>	<ul style="list-style-type: none"> <li>• Development of “sustainable pavement” design framework</li> <li>• Define performance metrics related to LCCA and LCA, and other sustainability metrics, determine data that need to be collected to support metrics defined, provide guidance on how to collect the data</li> <li>• Develop a decision-making framework that collectively considers pavement performance, LCCA, and LCA</li> </ul>
 <p><b>ASSESSING PAVEMENT SUSTAINABILITY</b></p>	<ul style="list-style-type: none"> <li>• Development of updated LCCA guidance for pavements and update RealCost software tool</li> <li>• Development of guidelines for life-cycle thinking and how to get started with LCA implementation</li> </ul>
 <p><b>GUIDANCE AND OUTREACH</b></p>	<ul style="list-style-type: none"> <li>• Guidance: Training on LCCA and LCA for FHWA division offices, state, and local agencies</li> <li>• Outreach: Webinar series, online-learning modules, instructor-led training</li> <li>• Case studies on sustainable pavement use and organization that have used or implemented products from the <i>Sustainable Pavements Program</i></li> <li>• Support Media: Conference presentations, Tech Briefs, web-based videos, animations, infographics, and testimonials for communicating the message on pavement sustainability</li> </ul>
 <p><b>IMPLEMENTATION</b></p>	<ul style="list-style-type: none"> <li>• Simple tools for project-level assessments</li> <li>• Pilot program for sustainable pavement practices</li> <li>• Pavement sustainability report card</li> </ul>



## The Way Forward

The information presented in this *Road Map* sets the framework for moving ahead in understanding, adopting, and applying sustainability concepts to pavement systems. The critical factors in prioritizing and implementing the proposed actions are summarized below.

- **Champions at the national, state, and local levels.** Champions should be identified at the national, state, and local levels to help drive and advance the key priorities identified in the roadmap. These champions can help in promoting widespread adoption of best practices and promising technologies through revisions to their agency standards and specifications and by communicating the success stories.
- **Partnership between stakeholders.** Strategic collaborative partnerships between the industry, academia, and transportation agencies are key factors in implementing and promoting sustainability concepts.
- **Education and outreach.** The development of simple, useful resources will play an important role in communicating the importance of improving pavement sustainability to the decision makers and the consumers. Tools and resources—such as guidance documents, technical briefs, websites, software tools and web-based applications—are critical to this effort.
- **Pilot Support Programs.** Establishment of a support program for sustainable pavement practices, such as conducting LCAs, preparing EPDs, and implementing new materials and design techniques, can help motivate more agencies to get involved.

With a clear path and a partnered approach to these issues, the opportunities in promoting and implementing sustainability concepts become more clear and manageable.



## APPENDIX A. NEEDS AND PROPOSED ACTIONS OUTSIDE THE SCOPE OF THE SUSTAINABLE PAVEMENTS PROGRAM

A summary of the needs and proposed actions outside the scope of the *Sustainable Pavements Program* is presented in table A-1.

Table A-1. Summary of needs outside the scope of the *Sustainable Pavements Program*.




TOPIC AREA	FUTURE NEEDS
 <b>CONSTRUCTION QUALITY</b>	Develop relationships between construction quality records and pavement performance
	Evaluate and document benefits of improved quality on life-cycle impact using LCCA and LCA methods
	Summarize best practices for quality construction
	Develop easy-to-use tools and guidance to facilitate archiving construction quality records and incorporation of these records into the existing inventory systems owned and operated by the agencies
	Evaluate the potential benefits and trade-offs of alternative contracts and project delivery methods that enhance sustainability using case studies documented in the literature
	Evaluate and demonstrate the capabilities of existing sensor technology to monitor construction processes
	Evaluate and demonstrate the capabilities of new performance tests that improve quality of construction processes
 <b>CONSTRUCTION SCHEDULING</b>	Develop tools or improve existing ones to incorporate capabilities of calculating environments impacts due to work zone
	Demonstrate the sustainability benefits of implementing effective road and lane closure strategies that can result in accelerated construction
	Develop performance goals and measures for work zones to eliminate work zone delays, reduce queue lengths, and minimize GHG emissions
	Develop guidance for effective road and lane closure strategies applicable to different class of roads with varying traffic volumes
 <b>MECHANISTIC-EMPIRICAL PAVEMENT DESIGN PROCEDURES</b>	Conduct a round robin between the available ME procedures for model evaluation and comparison of the most sustainable solutions
	Develop a framework to incorporate statistical methods into predicting pavement performance
	Evaluate optimized design practices and pavement structures for rural and urban roads for local government
	Develop a design framework for pavement structures that are more compatible with natural cycles of water, air and thermal energy in urban areas
	Evaluate and document sustainability benefits and tradeoffs of permeable pavement systems designed for stormwater management
Evaluate and document sustainability benefits of high friction and low noise surface layers for high volume roads from a perspective of safety, cost, performance, and environmental impact	

Table A-1. Summary of needs outside the scope of the Sustainable Pavements Program (continued).








TOPIC AREA	FUTURE NEEDS
 <p><b>ALTERNATIVE MATERIALS</b></p>	Evaluate the impact of alternative materials on the long-term performance of pavements, LCCA, and LCA
	Investigate the effect of new nanotechnology materials on pavement capacity, LCCA, LCA
	Development of binders from renewable sources that can still serve the pavement purpose
	Understand the mechanism and deterioration of new pavement constructed using alternative materials
	Develop reliable and accurate prediction model to estimate pavement remaining life that can be used in pavement LCA
	Incorporate developed pavement performance prediction models in PMS to allow developing a more robust LCA
	Identify alternative materials that can be used for both asphalt concrete and portland cement concrete pavements.
 <p><b>SUSTAINABLE PAVEMENT PROJECT DEVELOPMENT TOOLBOX</b></p>	Specification framework for sustainable materials, pavement systems and preservation and renewal techniques
Project level assessment process and tools	
 <p><b>SUSTAINABILITY RATING SYSTEMS</b></p>	Improve ratings approaches based on more quantitative analysis and metrics, making them less technology prescriptive and more outcome based; provide alternative paths to achieve goals
Benchmark ratings systems on same projects	
 <p><b>GUIDANCE</b></p>	Develop sustainability guide specifications that will give pavement owners the ability to incorporate ideas into actual contract documents
Develop and maintain a pavement PCR to assist in organizing how emerging materials EPDs can be integrated into pavement system evaluation	

Table A-1. Summary of needs outside the scope of the Sustainable Pavements Program (continued).

TOPIC AREA	FUTURE NEEDS
 <p><b>LIFE CYCLE ASSESSMENT</b></p>	Improve LCA databases, models and tools—Develop data and indicators for societal and economic impacts
	Improve LCA databases, models and tools—Complete bridging of major gaps in use stage research
	Improve LCA databases, models and tools—Develop software tied to databases for project-level LCA
	Improve LCA databases, models and tools—Identify approaches and framework for the expansion of pavement LCA system boundaries to consider
	Education and outreach—Include life-cycle thinking in academic curricula and professional training
	Production of PCRs and initial production of EPDs for most major pavement materials
	Identify decision points in pavement process (PMS, Conceptual, Design, Postconstruction) and LCA needs
	Develop national and regional databases for materials and construction
	Review mandates and processes (FHWA, State, Other) that are reactive and replace where possible with proactive considerations from LCA type results and community values (goal set, system definition, data driven metrics, decision-making process)
	Develop recommendations for specifications and procurement practice requiring EPDs, What is required to be able to include in Procurement, risks (Unintended Consequences), benefits, costs
 <p><b>LIFE CYCLE COST ANALYSIS</b></p>	Identify and recommend a system for reviewing and reconciling PCRs to avoid conflicts, provide data accessibility, credibility, transparency
	Implement a system for reviewing and reconciling PCRs to avoid conflicts
 <p><b>LIFE CYCLE COST ANALYSIS</b></p>	Document case studies from states who are using LCCA to identify added value, and approach to implementation (good and bad experience)

