

**From:** [noreply@wsu.edu](mailto:noreply@wsu.edu)  
**To:** [curriculum.submit](#)  
**Subject:** 722991 New or Restore Course: CE 516  
**Date:** Monday, October 3, 2022 11:03:14 AM  
**Attachments:** [2022.10.03.10.59.59.43.FormData.html](#)  
[2022.10.03.10.59.53.00.currentFileUpload\\_CertificateCE516LCARationalSyllabus.pdf](#)

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Xianming Shi has submitted a request for a major curricular change. His/her email address is: [xianming.shi@wsu.edu](mailto:xianming.shi@wsu.edu).

**Course Subject:** CE

**Course Number:** 516

**Title:** Life Cycle Assessment of Transportation Infrastructure  
99

**Total Credits:**

**Prerequisite:** CE211 or equivalent

**Catalog Description:** 516 Life Cycle Assessment of Transportation Infrastructure I 3 Sustainability in general; Pavement life cycle; Life cycle assessment; Life cycle cost analysis; Social sustainability. Part of the Pavement Durability & Sustainability Online Graduate Certificate Program. Cooperative: Open to UI degree-seeking students.

**Grading Type:** Letter graded A-F

**Cooperative with UI:** Yes

**Requested Effective Date:** Fall 2023

**Dean:** Krishnamoorthy, Siva - Assoc Dean - VCEA - UG

**Chair:** Xianming, Shi – Interim Chair – Civil and Environmental Engineering

\_\_\_\_\_  
UCORE Committee  
Approval Date

\_\_\_\_\_  
All-University Writing  
Com / Date

\_\_\_\_\_  
Catalog Subcommittee  
Approval Date

\_\_\_\_\_  
AAC, PHSC, or GSC  
Approval Date

\_\_\_\_\_  
Faculty Senate  
Approval Date

Note proposed description:  
**Life Cycle Assessment of Transportation Infrastructure 3**  
Pavement life cycle, life cycle cost analysis, and other issues related to pavement durability and sustainability. Recommended preparation: CE 211 or equivalent. Typically offered Fall. Cooperative: Open to UI degree-seeking students.

**From:** [Shi, Xianming](mailto:Shi, Xianming)  
**To:** [curriculum.submit](mailto:curriculum.submit)  
**Cc:** [Sivakumar, K.](mailto:Sivakumar, K.); [Bevenal, Haluk](mailto:Bevenal, Haluk)  
**Subject:** Re: 722991 New or Restore Course: CE 516  
**Date:** Monday, October 3, 2022 11:58:57 AM

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1. I approve this proposal in its current form.  
As department chair.

Thank you,  
Xianming

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**From:** curriculum.submit@wsu.edu <curriculum.submit@wsu.edu>  
**Sent:** Monday, October 3, 2022 10:59 AM  
**To:** Shi, Xianming <xianming.shi@wsu.edu>  
**Cc:** Sivakumar, K. <siva@wsu.edu>  
**Subject:** 722991 New or Restore Course: CE 516

Xianming, Shi – Interim Chair – Civil and Environmental Engineering,  
Krishnamoorthy, Siva - Assoc Dean - VCEA - UG,

**Course Subject:** CE

**Course Number:** 516

**Title:** Life Cycle Assessment of Transportation Infrastructure  
99

**Total Credits:**

**Prerequisite:** CE211 or equivalent

**Catalog Description:** 516 Life Cycle Assessment of Transportation Infrastructure I 3  
Sustainability in general; Pavement life cycle; Life cycle assessment; Life cycle cost analysis;  
Social sustainability. Part of the Pavement Durability & Sustainability Online Graduate  
Certificate Program. Cooperative: Open to UI degree-seeking students.

**Grading Type:** Letter graded A-F

**Cooperative with UI:** Yes

**Requested Effective Date:** Fall 2023

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Both Chair and Dean approval is required to complete the submission process.  
Please indicate that you have reviewed the proposal by highlighting one of the  
statements below and **reply all** to this email. ([curriculum.submit@wsu.edu](mailto:curriculum.submit@wsu.edu).)  
[Details of major change requested can be found in the attached supplemental  
documentation]

1. I approve this proposal in its current form.
2. I approve this proposal with revisions. Revisions are attached.
3. I do not approve this proposal. Please return to submitter.

If you do not respond within one week, you will be sent a reminder email. If no  
response is received within three weeks of the submission date, the proposal will be  
returned to the submitter.

Thank you for your assistance as we embark on this new process. If you have any  
questions or concerns, please let us know [wsu.curriculum@wsu.edu](mailto:wsu.curriculum@wsu.edu).

**From:** [Sivakumar, K.](#)  
**To:** [curriculum.submit](#)  
**Cc:** [Beyenal, Haluk](#)  
**Subject:** RE: 722991 New or Restore Course: CE 516  
**Date:** Friday, October 21, 2022 12:03:25 PM

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Thanks for following up Blaine. This was approved by Haluk Beyenal (AD for graduate programs and research) and thought that was sufficient.

I approve this curriculum proposal.

Siva

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**From:** curriculum.submit <[curriculum.submit@wsu.edu](mailto:curriculum.submit@wsu.edu)>  
**Sent:** Friday, October 21, 2022 11:46 AM  
**To:** Sivakumar, K. <[siva@wsu.edu](mailto:siva@wsu.edu)>  
**Cc:** curriculum.submit <[curriculum.submit@wsu.edu](mailto:curriculum.submit@wsu.edu)>  
**Subject:** FW: 722991 New or Restore Course: CE 516

Siva,

Apologies if it was missed, but I do not see that we received your approval for the attached curriculum proposal. Can I advance this through the Senate approval process?

Thank you,  
Blaine

Blaine Golden, Assistant Registrar  
Curriculum, Graduations, Athletic Eligibility

**From:** [noreply@wsu.edu](mailto:noreply@wsu.edu) <[noreply@wsu.edu](mailto:noreply@wsu.edu)>  
**Sent:** Monday, October 3, 2022 11:00 AM  
**To:** curriculum.submit <[curriculum.submit@wsu.edu](mailto:curriculum.submit@wsu.edu)>  
**Subject:** 722991 New or Restore Course: CE 516

Xianming Shi has submitted a request for a major curricular change. His/her email address is: [xianming.shi@wsu.edu](mailto:xianming.shi@wsu.edu).

**Course Subject:** CE

**Course Number:** 516

**Title:** Life Cycle Assessment of Transportation Infrastructure

## **Rationale for the Requested CE 516 New Course**

This course titled “*Life Cycle Assessment of Transportation Infrastructure*” was identified as a key mandatory course to be incorporated in the graduate certificate program of *Pavement Durability & Sustainability*. The certificate program will provide education and workforce development (E&WD) opportunities for practicing engineers and some on-campus graduate students, by specifically addressing a prioritized need identified by the Advisory Board members of the Department of Civil and Environmental Engineering (CEE) in a CY2021 survey. This program is designed to contribute to a skilled, diverse, informed and practice-ready transportation workforce, by offering mandatory and optional courses customized to bridge the gap between conventional CEE curriculum and emerging industry needs.

Note there is an existing in-person course, *CE 504 Sustainability Engineering* that covers topics related to green building and sustainable development, including low impact development (LID) stormwater design and environmental life cycle assessment (LCA). Yet, the new course (CE 516, see Syllabus attached) is focused on the LCA of pavements and covers not only the environmental dimension but also the economical and societal dimensions of LCA. Furthermore, CE 516 will be a Global Campus course and the mode of delivery will be asynchronous, online instruction.

### **How this impacts other units in Pullman and other branches**

This new course has been designed to supplement existing graduate courses in CEE department and should positively impact other units in Pullman and other branches. Specifically, practicing engineers and graduate students with their concentration area in transportation engineering and structural engineering may be the main audience. This course will be offered remotely for online access; as such it would benefit other WSU branches as well.

# ***CE 516: Life Cycle Assessment of Transportation Infrastructure***

## **Syllabus**

### Module 1: Sustainability in General

1. Introduction to Sustainability - definitions; environmental, economic, social aspects. UN definition. Tradeoffs. Sustainability as a continuum. Lifecycle thinking. The idea of 'you can't improve what you don't measure'. Metrics and methods to assess sustainability: LCA, LCCA, Social LCA, green rating systems- general overview.
2. How sustainability fits into transportation decision making process.

#### **Learning outcomes for Module 1**

Upon the successful completion of Module 1, students should be able to:

- Understand the sustainability definitions
- Identify 3 pillars of sustainability and examples of considerations under each
- Provide the examples of lifecycle thinking and tradeoffs for transportation infrastructure
- Explain the phases of transportation decision-making process and how more sustainable decisions can be made in each phase

### Module 2- Pavement Life Cycle

3. Pavement life cycle in general + material production phase
4. Secondary materials
5. Pavement design, construction, maintenance & preservation
6. Use phase, EOL

#### **Learning outcomes for Module 2**

Upon the successful completion of Module 1, students should be able to:

- Identify pavement life cycle stages
- Identify the key consideration in each life cycle stage that should be used to collect proper data and inform LCA and LCCA
- Discuss the tradeoffs of different strategies and context-specificities
- Comment on potential social, environmental and economic benefits of different strategies (e.g. use of different secondary materials, longer life pavements, permeable pavements etc.)

### Module 3: Life Cycle Assessment

7. Introduction to LCA: 4 phases of LCA, purpose of LCA, different LCA types (attributorial, consequential, screening LCA).
8. Goal and scope definition. Different implementations and goals of LCA, functional unit. Scope of the analysis and life cycle stages. Making informed comparisons when using LCA.
9. Phase 2: Life Cycle Inventory and data in LCA. Unit processes.
10. Phase 3: Life Cycle Impact Assessment Methods. Phase 4: Interpretation. Normalization, weighting, end-point indicators
11. Environmental impacts- Part 1: Global Warming Potential
12. Environmental impacts- Part 2: Acidification, Smog creation, Ozone depletion.
13. Environmental impacts- Part 3: Eutrophication, Ecotoxicity, Human Health Impacts.

14. Methodological choices in LCA: allocation methods for co-products and recycling.
15. Overview of LCA tools and data sources.
16. Environmental Product Declaration (EPDs)- Part 1. Eco-labels in general and EPDs.
17. EPDs of construction materials- concrete.
18. EPDs of construction materials- asphalt and other materials.
19. Sustainability policies: Buy Clean acts and green public procurement.
20. Sustainability standards: ISO standards and Product Category Rules.
20. LCA examples- concrete studies
21. LCA examples- asphalt studies
22. LCA examples- transportation and fuels

### **Learning outcomes for Module 3**

Upon the successful completion of Module 2, students should be able to:

- Identify and explain phases of LCA
- Explain the potential environmental impacts and the key life cycle inventory items that are the outputs of LCA
- Based on the select problem from the domain of transportation infrastructure, create a detailed outline of the LCA by doing the following:
  - o selecting the most appropriate LCA type
  - o defining the functional unit and system boundaries
  - o creating the meaningful scope of the analysis
  - o outlining the product system and the key unit processes
  - o selecting and justifying the allocation type (where appropriate)
  - o defining the data needs
  - o providing the recommendations for the meaningful comparisons
- For an LCA analysis from the literature, perform informed interpretation by:
  - o Analyzing the comparisons postulated through the goal and the scope of the study
  - o Comment on various potential environmental impacts in the context of the goal and scope of the study
  - o Commenting on data quality
  - o Commenting on the appropriateness of comparisons (where appropriate)
  - o Providing the constructive critique of the study and areas of future work
- Conduct a simple LCA for pavement design alternatives using LCAPave tool, create the report and provide the recommendations.
- Find EPDs for relevant materials and products, read EPDs, provide simple recommendations based on the content of EPDs
- Explain the basic concepts related to the green public procurement and the role of EPDs and LCA in it

## Module 4: Life Cycle Cost Analysis

23. LCCA- basic concepts (setting up design alternatives, basic differentiation between agency and user costs, salvage value, discount rate), benefit-cost analysis.
24. LCCA- agency costs and user costs in all life cycle stages
25. Computations and decision making with LCCA. Statistics and stochastic LCCA.
26. LCCA Exercise using RealCost tool.

### Learning outcomes

Upon the successful completion of Module 4, students should be able to:

- Establish the design alternatives for LCCA
- Outline the activities for design alternatives, relevant agency and user costs in each life cycle stage and the data needs
- Perform LCCA computations and analyze the results
- Conduct a simple LCA for pavement design alternatives using RealCost tool, create the report and provide the recommendations.

## Module 5: Social Sustainability

27. Sustainability rating systems and green building codes (LEED, INVEST, GreenRoads)
28. Social LCA and equity in transportation projects

### Learning outcomes

Upon the successful completion of Module 5, students should be able to:

- Identify the key social considerations related to pavements
- Outline the key element of social LCA

## Knowledge checks

29. Test 1: Lessons 1-13
30. Test 2: Lesson 14-26

Finals: a project based on the LCA and LCCA as a pavement design decision-making support. (There can be Test 3 as well as the final project).

## Recommended Literature

- Simonen, Kathrina. *Life cycle assessment*. Routledge, 2014.
- Schenck, R. and White, P. eds., 2014. *Environmental life cycle assessment: measuring the environmental performance of products*. USA: American Center for Life Cycle Assessment.
- Van Dam, T.J., Harvey, J., Muench, S.T., Smith, K.D., Snyder, M.B., Al-Qadi, I.L., Ozer, H., Meijer, J., Ram, P., Roesler, J.R. and Kendall, A., 2015. *Towards sustainable pavement systems: a reference document* (No. FHWA-HIF-15-002). United States. Federal Highway Administration.
- Harvey, J., Meijer, J., Ozer, H., Al-Qadi, I.L., Saboori, A. and Kendall, A., 2016. *Pavement life cycle assessment framework* (No. FHWA-HIF-16-014). United States. Federal Highway Administration.
- Federal Highway Administration. 2002. *Life Cycle Cost Analysis Primer*.

## Recommended Tools<sup>1</sup>

- [LCA Pave by FHWA](#)
- [RealCost by FHWA](#)
- [OpenLCA](#)

## Recommended Database

- [Federal LCA Commons](#)

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<sup>1</sup> More tools will be presented to the students and included list provides only select few. The listed tools are public, free and fully transparent and as such deemed as the most appropriate for this class.