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Project Summary

Technology Transfer Outreach Publication

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Sponsor

Pending

Project Title

An Integrative Framework to Study Sustainability of Road Construction Projects

Economic and Environmental Impacts of Pavement Selection

Problem

This research investigates the factors that lead to building more sustainable pavements, using alternative pavement materials. Long term pavement performance, cost, energy consumption, material wastage, and environmental emissions of alternative pavement designs during the material extraction/manufacturing, construction, and maintenance phases of the pavement life cycle are used to estimate the sustainability of alternative design decisions regarding different pavement types, and use of alternative materials. In addition, an uncertainty analysis is used to account for the high variability of the associated transportation industry cost and maintenance data. This integrated approach will allow decision-makers to understand and compare economic and environmental impacts of the pavement sections in the light of long term and immediate concerns.

Research Objectives

The research objectives include the development and implementation of an integrative decision-making framework founded in the inventory analysis, life cycle assessment, life cycle cost analysis and long-term pavement performance of alternative pavement designs.

Methodology

A life cycle assessment to estimate the environmental impacts are assessed using state-of-the art approaches such as Economic Input Output Life Cycle Assessment (EIO-LCA) (Hendrickson et al. 1998, Cicas et al. 2007), and SimaPro. Specifically, the manufacturing/ extraction phase of the materials used in the pavement sections, and construction and maintenance phase of the design sections are considered. The economic cost benefits are estimated using Life Cycle Cost Analysis (LCCA) methods as described in MDOT and FHWA guidelines (MTC 1992, FHWA 1999). A Monte Carlo simulation method is also used to account for the variability in the prices estimated for the construction and the identified maintenance schedules over the lifetime of the design sections.

Research Findings

The anticipated research findings will include an integrative framework that can be used by transportation agencies to support sustainable pavement design decisions involving alternative pavement types and materials. Recent research findings, using the proposed framework, show that resource inputs, environmental outputs and energy consumption can be significantly reduced by replacing the cement content in JPCP and CRCP design sections with industrial residues like fly-ash and slag (Mukherjee et al. 2006). In addition, a method has been developed to assess net value to construction industry stakeholders due to the adoption of alternative sustainable construction technologies (Muga et al. 2008).

Michigan Tech

MiSTI U.S. DOT University Transportation Center for Materials in Sustainable Transportation Infrastructure

University Facts

Total Enrollment	6,550
Graduate Enrollment	916
Number of Faculty	417
Placement Rate	95%

Michigan Tech is located in Houghton, MI on the south shore of Lake Superior. This rural area is known for natural beauty, pleasant summers, abundant snowfall, and numerous all-season outdoor activities. In addition, the University maintains its own downhill and cross-country ski facilities and golf course. There are numerous cultural activities and opportunities on campus and in the community. Michigan Tech has also been rated as one of the safest college campuses in the United States, and the local community provides excellent resources conducive to an outstanding quality of life.

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MiSTI

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Future Work

Future work will focus on collecting material and equipment inventory data from actual highway construction project scenarios, and further calibrating the proposed decision-making framework to reflect expected and actual long term pavement performance metrics.

Anticipated Implementation

The anticipated implementation will include a software environment that will have two principal components. One component will be a database of the expected environmental impacts from different pavement types that can be easily queried to compare equivalent design sections for alternative materials within typical construction contexts. The second component will allow decision-makers to input particulars specific to their pavement construction and maintenance project – including design requirements, location, site lay-out, maintenance reroutes, lane closures, contract type and delivery system. The inputs will be used to customize the data from the first component and will provide an integrative decision-making approach to identify design decisions that are economically and environmentally most sustainable.

Benefits

The benefits of this research is that it helps to respond to the urgent need to design, construct and maintain sustainable pavement infrastructure. The research equally emphasizes industrial/economic growth, improved environmental performance, and increased value return to societal stakeholders, thus providing an integrative systemic approach that is critical to sustainable design.

Related Studies

Cicas, G., Hendrickson, C. T., Horvath, A., and Matthews, H. S. (2007), "A Regional Version of a U.S. Economic Input-Output Life-cycle Assessment Model." Int. J. of Life Cycle Assessment, 12(6), pp. 367-374

Federal Highway Administration (1999) "Life-Cycle Cost Analysis in Pavement Design." U.S. Department of Transportation, Office of Highway Information Management. Report FHWA-SA-98-079, Washington, D.C.

Hendrickson, C. T., Horvath, A., Joshi, S., and Lave, L. B. (1998), "Economic Input-Output Models for Environmental Life-Cycle Assessment." Environmental Science & Technology, 32(4), pp. 184A-191A.

Michigan Transportation Commission (MTC) (1992), Ad Hoc Life Cycle Costing Task Group 11 "Recommended Method of Pavement Selection Life-Cycle Costing of new or reconstructed pavements," Michigan Department of Transportation, June 1992.

van Oss, H.G., and Padovani, A.C (2002) "Cement Manufacture and the Environmental, Part 1: Chemistry and Technology," Journal of Industrial Ecology, 6 (1), pp: 89-105 (17)

Zapata, P, and Gambatese, J.A (2005) "Energy Consumption of Asphalt and Reinforced Concrete Pavement Materials and Construction" Journal of Infrastructure Systems, Special Issue: Sustainability of Transportation and Other Infrastructure Systems, ASCE, 11 (1) pp: 9-20

Publications

Muga, H., Mukherjee, A. and Mihelcic, J. (2008) An Integrated Assessment of the Sustainability of Green and Built-up Roofs. Journal of Green Building, Vol 3(2), 1-22.

Mukherjee, A., Muga, H. & Van Dam, T. (2006) Towards Building Sustainable Concrete Pavements. In the Proceedings of the 1st. International Construction Specialty Conference, Canadian Society of Civil Engineering (CSCE), May 23-26, 2006, Calgary Canada, 2006.

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