



Introducing Sustainability into the Civil Engineering Curriculum

Dr. Virginia Sisiopiku, University of Alabama, Birmingham

Dr. Virginia P. Sisiopiku is an Associate Professor of Civil, Construction and Environmental Engineering at the University of Alabama at Birmingham (UAB) and the director of the Transportation program. She holds a B.S. degree in Civil Engineering from Aristotelian University in Greece, and M.S. and Ph.D. degrees in Civil Engineering from the University of Illinois at Chicago. Her teaching and research focus on traffic operations and safety, sustainable transportation, and traffic simulation and modeling. She has served as the principal investigator in 80 projects and authored/co-authored over a 160 technical papers. Dr. Sisiopiku has been recognized by many organizations for her professional achievements including the Institute of Transportation Engineers, the Federal Highway Administration, the Illinois Association of Highway Engineers, IEEE, and the Women's Transportation Seminar. She is the recipient of the 2007 President's Excellence in Teaching Award and the 2010 Dean's Award for Excellence in Mentorship, and a Fellow of the Institute of Transportation Engineers.

Dr. Robert W. Peters, University of Alabama at Birmingham

Dr. Robert W. Peters is a Professor of Environmental Engineering at the University of Alabama at Birmingham (UAB) His educational background is in the field of chemical engineering, with his BSChE degree from Northwestern University and his MS and PhD degrees from Iowa State University. He served a Research Area Leader in the Energy Systems Division at Argonne National Laboratory prior to joining the faculty at UAB. At Argonne, he directed research involving treatment of contaminated soils and groundwater. At UAB, Dr. Peters has taught advanced undergraduate/graduate level courses on the topics of sustainable engineering and energy resources. He has led a number of research projects involving energy conservation and sustainability at UAB. He also has had several projects in which he has served either as PI or a co-PI dealing with the transportation field.

Mr. Ossama E. Ramadan, University of Alabama at Birmingham

Ossama E. Ramadan is a Doctoral Candidate at the University of Alabama at Birmingham (UAB). His research interests include work zone traffic control, traffic safety, and, planning and scheduling of infrastructure projects. He received his M.A.Sc. in Civil Engineering from Carleton University, and his B.Sc. (Hons.) in Construction Engineering from the Arab Academy for Science, Technology and Maritime Transport (AASTMT). Selected by UAB School of Engineering as the 2014 Graduate Student of the Year in Civil, Construction and Environmental Engineering. Recipient of the 2002 Carleton University Merit Scholarship. Selected by the President of AASTMT as the 1997 Student of the Year in Construction and Building Engineering. Member of the Golden Key International Honor Society, the Honor Society of Phi Kappa Phi, ASCE, ASEE, and ITE. Currently serves as the President of the UAB ITE Student Chapter.

Introducing Sustainability Design and Assessment Methods Into the Civil Engineering Curriculum

ABSTRACT

While the importance of sustainability is well recognized by professionals and academics alike, Civil Engineering curricula do not typically offer courses covering sustainability design principles and assessment methodologies. To bridge this gap, this paper discusses the development and pilot testing of a new course on Sustainability Design and Rating Systems for upper level undergraduate and master level Civil Engineering graduate students. The course development was the result of close and productive collaboration between one transportation and one environmental engineering faculty member who team-taught the course pilot in the fall semester 2014. This approach can set an example of the benefits of multidisciplinary course instruction that can foster interaction among traditional Civil Engineering disciplines for the benefit of the students. The pilot course focused on sustainable transportation and livable streets, transportation planning and site design for sustainable transportation, sustainability rating systems for neighborhoods and infrastructure, brownfield/greyfield redevelopment options, and sustainability and ethics. The objective was to educate the future engineering workforce about the basic principles for sustainable design and evaluation methods, in an effort to raise awareness and develop expertise on sustainable design options and associated benefits.

Introduction

In October of 2009, the American Society of Civil Engineers (ASCE) adopted the following definition of sustainability: “A set of environmental, economic and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality or availability of natural, economic and social resources”¹. This description is consistent with the 1987 UN World Commission on Environment and Development report that defined sustainable development as “meeting the needs of the present generation without compromising the ability of future generations to meet their own needs”². These definitions and many others offered in the literature, center around three pillars of sustainability namely, economy, environment, and society and suggest a need to consider a global approach when referring to sustainability that considers economic impacts, the ecological view, and a socio-cultural concept for the coexistence of development and the environment³.

In doing so, ASCE has made sustainability one of three strategic priorities for the Society, helping professionals to incorporate sustainability principles into their daily practice. ASCE further recommends that civil engineers, as the stewards of society's infrastructure, must take the lead in applying sustainability to planning, design, and construction⁴.

In the recent years, sustainability and livability have emerged as key priority areas at the national level and new policies have been drafted and introduced to advance sustainability practices and investments. As sustainability is growing in importance to Civil Engineering and related disciplines, educating the engineering workforce on issues related to sustainable planning, design, and evaluation is becoming a priority.

In 2003, Robinson and Sutterer published a paper at the 2003 ASEE Annual Conference & Exposition that described their department's experience in integrating sustainability in a Civil Engineering curriculum⁵. The paper concluded that "the initiative to incorporate sustainability into Civil Engineering courses and curricula may begin in each department with a single faculty or a small group of faculty, but it must begin."

Over the past decade, several Civil Engineering programs made sincere efforts to expose their students to sustainability concepts and practices. A review of Civil Engineering curricula indicates that several undergraduate Civil Engineering programs have introduced modules related to sustainability within existing courses and others incorporated new courses covering sustainability design principles and assessment methodologies. In 2009, Allen *et al.* conducted a survey to identify accredited engineering programs at U.S. institutions that incorporate sustainability concepts into engineering curricula⁶. Allen's research team contacted the administrative heads of 1,368 engineering departments at 364 U.S. universities and colleges and asked them to complete a questionnaire about the extent to which sustainable engineering was being integrated into their departments' engineering curricula. Their findings indicated that 59 Civil, Architectural, and/or Environmental departments surveyed incorporated sustainability into their curricula.

Bielefeldt (2011) documented the experience of the Department of Civil and Environmental Engineering at the University of Colorado on incorporating a sustainability module into first-year courses for Civil and Environmental Engineering students⁷. She reported survey results on how the students perceived and interacted with introducing sustainability courses. Her results concluded that a simple course modification can raise the awareness of engineering students about the importance of sustainability.

In 2011, Aurandt and Butler described two approaches to incorporating sustainability into the undergraduate engineering curricula and provided a variety of existing course resources that can easily be adopted or adapted by science and engineering faculty⁸. They concluded that core courses required for engineering majors can be redesigned to introduce concepts of sustainability without compromising the original course objectives.

The literature review offers ample evidence of the value of integrating sustainability into Civil Engineering curricula and provides several case studies demonstrating successful interventions. Building on these efforts, our institution recognized the need to expose Civil Engineering students to sustainability principles and methods through the introduction of new courses into the existing curricula. This paper discusses the development and pilot testing of a new course on Sustainability Design and Rating Systems for combined upper level undergraduate and master level Civil Engineering graduate students.

Literature Review

A number of related research studies have been performed addressing sustainable transportation and rating systems. Samberg *et al.* identify that there is no internationally recognized standard for determining and evaluating sustainable transportation⁹. Mapes and Wolch¹⁰ note that until 2008, there was no comprehensive system in place to measure the sustainability of new community developments. Many projects tend to focus on features that increase community

attractiveness to potential buyers, but fail to address attributes to enhance environmental and socio-economic sustainability¹⁰. In their study, Litman and Burwell describe issues related to the sustainable transport definition, evaluation and implementation of sustainable transportation¹¹. Specific issues addressed included the range of sustainability definitions, the range of issues under these definitions, the range of perspectives, criticisms of sustainability analysis, evaluation of sustainability, transportation impacts on sustainability, sustainable transportation decision making, equity, land use, automobile dependency, community livability, human health, and ecological integrity.

Oswald and McNeil developed a methodology for transportation rating systems and applied the system to transportation investments, specifically urban corridors¹². Their study sought to develop a methodology for development of green rating systems. Indicators were used in existing LEED and Green Globes rating systems. LEED-New Construction, LEED-Neighborhood Development, and Green Globes were evaluated for their potential relevance to a corridor rating system by: identifying the existing credits/objectives that relate to transportation (for their application specifically to corridors); evaluating the existing rating system to determine already established credits/objectives that could be adjusted or refined to relate specifically to transportation corridors, and categorizing credits based on politics/governmental regulations; land use site selection/location of the corridor, usage-utilization of the corridor by drivers; pedestrians, cyclists, transit riders, etc.; infrastructure/corridor physical components (including lanes, sidewalks, signals, etc.); and construction/actual redevelopment or new development process of a corridor.

Soderlund *et al.* described a transportation sustainability rating system, Green Roads, to quantify sustainability practices associated with the design and construction of roads¹³. This rating system rewards credits for approved sustainable choices/practices that can be used to certify roadway projects based on the number of total credits earned. Green Roads consists of 54 possible credits in six categories that can be used to achieve certification. The six categories involve sustainable design (10 credits possible), materials and resources (11 credits), stormwater management (8 credits), energy and environmental control (12 credits), construction activities (9 credits), and innovation (4 credits).

In 2010, Kevern presented a framework for incorporating sustainable design/thinking as a new Civil Engineering course along with experiences from the pilot offering of the course¹⁴. Green building rating systems (focusing primarily on LEED) were used to introduce sustainability concepts in buildings and infrastructure.

Engineering students should become aware of these and other methods that can be used to assess progress toward meeting sustainability goals and objectives.

Course Scope

The scope of the course revolves around sustainability issues related to transportation and infrastructure. Such issues are of great importance as global concerns about climate change, energy use, environmental impacts, and limits to financial resources for transportation infrastructure require new and different approaches to planning, designing, constructing, operating, and maintaining transportation solutions and systems¹⁵.

The effort resulted in the development of educational resources that focus on new paradigms for transportation and community planning with noticeable societal, health, economic, and environmental benefits. The educational objectives and lectures/modules developed for the course reflect discussions and feedback received from the Southeast Transportation Research Innovation Development and Education Center led by the University of Florida and the Sustainable Smart Cities Research Center at the University of Alabama at Birmingham. The educational resources developed were used as classroom training materials in a newly developed course that aimed at educating undergraduate and first year graduate students about sustainability planning concept, design options, and rating systems. Students that completed the course were expected to do:

1. Be able to describe the role of transportation in sustainable development;
2. Be able to identify planning, and design practices for implementing sustainable transportation systems;
3. Be able to describe and differentiate between sustainable, livable, and smart cities;
4. Be able to describe how brownfield and grey field redevelopment/revitalization ties in with livable cities principles; and
5. Be able to describe and apply the different rating systems.

The following paragraphs summarize the course development philosophy and delivery approach and share lessons learned.

Approach

Recognizing early on the multidisciplinary nature of sustainability, we formed a team of transportation engineering and environmental engineering faculty members that collaborated closely in the development of educational modules and delivery of the new sustainability course in our institution.

First, we conducted a comprehensive review of the relevant literature and collected and organized relevant materials for potential use in subsequent tasks. These resources helped us formulate an outline for the course content and an extensive working list of references relevant to the topics of interest. While the topic of sustainability is fairly broad, we focused our attention on sustainable transportation, smart location and linkage, neighborhood pattern and design, and green infrastructure and buildings. More specifically, we examined issues related to smart location selection, brownfields redevelopment options, walkability, compact development, mixed-use development options, and designs promoting accessibility for everyone, elements of certified green buildings, building energy and water efficiency, and stormwater, wastewater, and solid waste management infrastructure.

The next step was to develop instructional materials. The course educational materials were intentionally developed in modules to (a) support instructional needs of the new course offering and (b) allow for select modules to be incorporated into existing courses or be used for training seminars to educate practitioners and agencies on issues related to sustainability. Hundreds of PowerPoint slides and notes, reference listings, and webinar-type presentations were developed by module and became available to use as part of the full-length university course offering or as

stand-alone modules. The intent was to develop a range of education modules that fulfills multiple objectives including training of university students, and professionals on principles of green design, planning, and/or evaluation methods.

Implementation

A 3-hour semester-long course on “Sustainable Design and Rating Systems” has been developed and delivered on our campus during the fall semester of 2014. The class had 19 enrolled students (8 undergraduate and 11 graduate students). The course was team-taught by Transportation and Environmental Engineering faculty members to address both transportation and environmental - related aspects of sustainable design.

A series of course modules were introduced focusing on principles of sustainable transportation and livable streets, transportation planning and site design for sustainable transportation, transportation sustainability rating systems, brownfield/greyfield redevelopment principles, and sustainable design and ethics.

The course modules developed for the course included the following:

- Introduction to Sustainability;
- Sustainable Transport;
- Livable Streets;
- Transportation Planning for Sustainability;
- Site Design for Sustainable Transportation;
- Sustainability Rating Systems – FHWA INVEST;
- Sustainability Rating Systems – LEED ND Introduction;
- Sustainability Rating Systems – LEED ND Smart Location and Linkage (SLL);
- Sustainability Rating Systems – LEED ND Neighborhood Pattern and Design (NPD);
- Sustainable Development Rating Systems (I and II)
- Sustainability at the University Campus level;
- Livable, Sustainable, and Smart Cities;
- Megacities;
- Urban Sprawl;
- Brownfield Redevelopment (I and II);
- Greenfield Redevelopment; and
- Urban Hydrology and Landscape Architecture.

Other sustainability rating systems were also introduced and briefly discussed. Example of rating systems discussed included: GreenLITES, INVEST, Envision, Green Guides for Roads, STAR Community Index, and EcoDistricts Initiative.

The primary course delivery approach involved lectures by the instructors using PowerPoint presentation visual aids. Instructional technology methods (such as use of YouTube video clips, eBooks and other online study resources) were also adopted in the pilot offering in order to keep students engaged throughout the course and offer them unique and exciting learning opportunities. On occasion, relevant short YouTube video clips were played in the classroom during instruction. After the students watched the video clips, they were requested to answer specific related questions. This technique proved highly effective as it heightened students’

attention, encouraged students' active engagement in classroom discussions, and helped them appreciate the relevance of the course materials. These observations are anecdotal but still consistent with earlier studies that reviewed the impacts of multimedia use on student learning. An example is the work of Berk¹⁶ who examined the use of video clips in college classrooms and provided a detailed rationale and conceptual framework for the practice.

Interactions between students and professional practitioners were also encouraged through the facilitation of two guest speaker seminars featuring sustainability professionals. Experts suggest that there are multiple advantages of having guest speakers in a class including increasing cultural awareness, promoting social cognition, getting students to listen perspectives of other professionals, and validating the relevance of the class content¹⁷. One invited guest speaker discussed sustainability operations on our university campus, addressing recycling activities, environmental and energy management, alternative transportation initiatives, solar powered electric cars on campus, campus community gardens, etc. The second guest speaker shared information about the redevelopment of a small local community into a livable/sustainable community making best use of the topography of the site. The guest speakers were well received by the class and helped students see how professionals in their field are already using sustainability concepts to benefit peoples' lives and the community in general.

As part of the class assignments students engaged in literature review and synthesis; individual and group exercises; design activities; and practiced technical writing and communication exercises. In a class project, students worked in teams of three to four to apply Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) principles for evaluation of proposed Community Development Plans or Redevelopment Projects. The project assignment required teams to:

- a. Develop a proposal,
- b. Perform analysis, interpret findings, and provide recommendations, and
- c. Summarize study and results in a final report and PowerPoint presentation.

Each team conducted an assessment of the principles and resulting LEED-ND scores that would be achieved for the community area plan assigned to them. The selected sites included: Cahaba Heights Community Plan, Calara Comprehensive Plan, Colledgeville Neighborhood Development Plan, Fountain Heights Neighborhood Development Plan, and the Highland Park Neighborhood Plan. Each project team (consisting of two graduate and one to two undergraduate students) presented their results in the form of an oral presentation to the class and as a formal technical report. During the presentation sessions, the students went through a peer evaluation exercise rating each one of their peers (except their teammates) on a scale of 1 to 4 on the basis of a. content; b. presentation style, and c. response to questions. They also turned in a form that provided confidential feedback on each teammate's contribution to the project team effort. Overall, the project provided students the opportunity to gain valuable experience in critical review of reports and documents, data gathering and management, use of performance standards to rate sustainability efforts reflected in plans, practicing technical writing, and communication skills, and working in teams.

Evaluation

In terms of class performance, the mean, median, and standard deviation for the final exam were 85.9%, 82.4%, and 1.8%, respectively. The graded class materials included homework

assignments, two tests, a final exam, and a class project. The overall class performance resulted in a mean, median, and standard deviation scores of 85.9%, 85.5%, and 5.7%, respectively. These scores indicate that the course content satisfactorily met the course objectives. No course pre-test and post-test was given to the students, but such an approach will be utilized the next time this course is taught.

At the conclusion of the course, students provided feedback and comments regarding the pilot offering through the IDEA survey system. Using this input, the teaching effectiveness was assessed based on: a. Progress on Relevant Objectives, a weighted average of student ratings of the progress they reported on objectives selected as "Important" or "Essential", and b. Overall Ratings, the average student agreement with statements that the teacher and the course were excellent. Seven out of eleven enrolled graduate students and 6 out of 8 undergraduate students provided feedback (68.4% response rate).

Table 1 summarizes student ratings of learning on relevant (essential and important) objectives. The feedback from the students is overall very positive with a score of progress toward objectives of 4.8 out of 5.0 reported by graduate and 4.0 out of 5.0 by undergraduate students. As it can be observed, graduate students provided consistently higher ratings than undergraduate students who were less familiar with the course teaching style, and expectations than graduate students and thus more reserved.

Table 1. Student Ratings of Learning on Relevant Objectives

Description of Objective	Importance Rating	Graduate (5-point Scale)	Undergraduate (5-point Scale)
1. Gaining factual knowledge (terminology, classifications, methods, trends)	Essential	4.7	4.2
2. Learning fundamental principles, generalizations, or theories	Essential	4.7	4.2
3. Learning to <i>apply</i> course material (to improve thinking, problem solving, and decisions)	Important	4.7	3.8
4. Developing specific skills, competencies, and points of view needed by professionals in the field most closely related to this course	Important	4.9	4.2
5. Acquiring skills in working with others as a member of a team	Important	4.7	4.0
6. Developing creative capacities (writing, inventing, designing, performing in art, music, drama, etc.)	Important	4.7	3.3
7. Gaining a broader understanding and appreciation of intellectual/cultural activity (music, science, literature, etc.)	Minor/None		
8. Developing skill in expressing myself orally or in writing	Important	4.7	4.3
9. Learning how to find and use resources for answering questions or solving problems	Important	4.9	4.3
10. Developing a clearer understanding of, and commitment to, personal values	Minor/None		
11. Learning to <i>analyze</i> and <i>critically evaluate</i> ideas, arguments, and points of view	Important	4.9	3.5
12. Acquiring an interest in learning more by asking my own questions and seeking answers	Important	4.9	4.2
Progress on Relevant Objectives		4.8	4.0

Table 2 provides a summary evaluation of teaching effectiveness based on the IDEA survey report. It can be seen that students provided excellent ratings in their evaluations of both the teacher and course. These overall ratings serve as another indication of student satisfaction with the course content and delivery and as an expression of their support for the new course offering.

Table 2. Summary Evaluation of Teaching Effectiveness

	Average (5-point scale)	
	Graduate	Undergraduate
A. Progress on Relevant Objectives (See Table 1 for details)	4.8	4.0
Overall Ratings		
B. Excellent Teacher	5.0	4.2
C. Excellent Course	4.6	3.8
D. Average of B & C	4.8	4.0
Summary Evaluation (Average of A & D)	4.8	4.0

Anecdotal comments provided by students were also positive. One of the evaluations indicated “This was a great class to take. I really liked the format being broken up into two categories taught by two different professors with different specialties. Their knowledge from different disciplines helped me learn.” Another student commended: “This class was great. The instructor did a good job bringing her strengths to the class” and “The project schedule was well planned. Content after each class was available immediately.”

In summary, the student evaluations were overwhelmingly positive, with more than 83% rating the course as “very good or excellent” and stating that the course met the stated learning objectives and demonstrated substantial effectiveness toward providing students with factual knowledge (terminology, classifications, methods, trends) and teaching them fundamental principles, generalizations, or theories related to the topic of the course.

Observations and lessons learned from the first offering of the course included having more “hands-on” field activities (e.g., field trips, sustainability design assessments, discussion of other sustainability design assessment methodologies, etc.) to further enrich the learning experience in future offerings.

Summary and Conclusions

This paper documented the need for introducing sustainability related courses in the Civil Engineering curricula and the steps taken at our institution to research, develop, and pilot test such a course in fall semester 2014. The new course demonstrated a successful integration of sustainability concepts within a Civil Engineering curriculum. The pilot course combined knowledge and expertise in transportation and environmental engineering disciplines and fostered a successful interaction between faculty members and students with interests in these fields. This approach addresses best the multidisciplinary nature of sustainability and expands training and career opportunities for students in Civil Engineering fields.

The recently introduced “Sustainability Design and Rating Systems” course reviewed planning and design practices for implementing sustainable transportation systems and helped students to better understand and appreciate the role of transportation in sustainable development. Moreover, it introduced and contrasted principles of various sustainability rating systems for transportation and neighborhood development and provided students the opportunity to implement aspects of the LEED-ND rating methodology as part of a group project. Further information regarding the course can be found in the website of the sponsoring University Transportation Center¹⁸.

Overall, the work described in this paper builds the foundation for assessment and adoption of sustainable and green urban development and transportation options that would improve quality of life and result in measurable economic benefits. The education modules developed as part of this effort are expected to help traditional and non-traditional students to understand appropriate criteria for selecting projects that meet sustainability and livability priorities, as well as basic design principles that can be used in developing more sustainable project alternatives for consideration in the future. The effort documented in this paper opens new avenues for the dissemination of information on sustainable design options to engineering students while simultaneously supports training needs of Civil Engineering professionals, who can benefit from future adoption of developed educational modules into short courses and seminars.

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