Introduction to Sustainable Infrastructure Engineering Design

Edward Neumann

SOURCE

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Preface

LEARNING OBJECTIVES

Introduction to Sustainable Infrastructure Engineering Design is designed as a one-credit component of a one-semester introductory course to civil engineering. Grading rubrics are presented in the appendices which can be used by students as guidelines for preparing three team reports that require the application of critical thinking skills to engineering problem solving as applied to infrastructure design. The rubrics can also be used by instructors to grade the three team reports. One of the major concepts underlying the text is the requirement that students must learn to think about the goals of design and how evidence can be developed that demonstrates the design goals are being met. Students are expected to make this linkage using a matrix presented in the rubric for the third report.

Civil engineering is a profession that has a distinct focus on the design of infrastructure systems. There are major differences between the characteristics of the infrastructure design problems that civil engineers solve and the problems examined by other engineering disciplines, which tend to emphasize the design of smaller items produced for short-term use. Beginning students in civil engineering should be made aware of these distinctions and the types of systems civil engineers design so that they can begin to think about the problems associated with them. This is the starting point for evolving into professional civil engineers whose area of expertise is design of the civil works infrastructure that supports modern societies.

The learning objectives for this textbook are as follows:

1. To introduce students to strategies for using critical thinking to define and solve design problems involving civil engineering systems, components, or processes;
2. To prepare students to function on teams;
3. To develop knowledge of contemporary issues related to civil engineering practice, with emphasis on sustainability;
4. To develop an understanding of public policy that relates to the design of civil engineering systems, with emphasis on Federal Acts and the importance of public acceptability; and
5. To develop skill at communicating effectively in written form.

Chapter 1 of *Introduction to Sustainable Infrastructure Engineering* provides an overview of the role of civil engineering infrastructure systems in today's world, which is becoming increasingly urban, and offers a brief history of civil engineering education. Chapters 2 through 4 provide background information on the growing importance of sustainability in design, climate change, and the federal laws and acts that provide the rationale for, as well as the constraints underlying the design of, many types of infrastructure systems.

Chapters 5 through 9 describe the steps in the civil engineering design process and the role of critical thinking. These chapters challenge the student to think critically when developing designs. The chapters teach the student to raise key questions and develop answers to them when undertaking design. Who is the design being undertaken for? What components will be designed? What design goals are being sought? What constraints and opportunities exist? What constitutes a "good" design and how can alternatives be compared with respect to goal achievement? What recommendations follow from an evaluation of the alternatives? The team reports and their rubrics require students to apply the concepts presented in the chapters.

Grading rubrics are presented that can be used to evaluate team projects in civil engineering design. It is expected that students will begin to develop the skills necessary to write at a professional level, but may not have had previous instruction in report preparation. A two-page diagnostic writing assignment is included, which can be completed before team reports are undertaken to assist in identifying individuals whose writing contains serious deficiencies. Use of the diagnostic writing assignment can help instructors determine which students should be referred to a writing center or other university resources to improve their communication skills.

Chapter 10 provides information on how data bases available over the Internet can be used to develop site maps for team projects. Chapter 11 discusses site evaluation and the use of maps to develop essential information often needed for infrastructure design. Chapter 12 provides a general description of the types of models used in infrastructure design, and Chapters 13 through 15 discuss aspects of career development. These chapters address topics which are relevant to undergraduate program outcomes and ABET accreditation. In Chapter 13, the importance of licensure is emphasized and the paths to licensure are described. Chapter 14 helps students to understand the requirements of the team approach and the importance of communication skills. In Chapter 15, information is presented on student organizations concerned with infrastructure design and the role the professional organizations can play in the development of student abilities, especially management and leadership. It is pointed out that the undergraduate program is not intended to develop a highly experienced professional engineer, but to provide the foundation necessary for the student to evolve into a competent professional as his or her career progresses. Throughout the text, words shown in bold are terms with which the student of civil engineering should become familiar. They are part of the lexicon related to infrastructure systems and their design.

It is assumed that the students who will use the textbook have a good background in high school physics and college algebra, and soon will be ready to take (or possibly are already enrolled in) college level physics and calculus. But the material in the text does not require a background in calculus or statistics. The mathematical solutions required to prepare the final report of the project require only algebra. Most involve the multiplication of numbers, and examples of how to solve the problems are presented in enclosed boxes that have a darker background. The boxes that have clear backgrounds present more advanced information that may be presented at the discretion of the instructor. In nearly all cases, it is not information that is necessary to undertake the project.

TEAM PROJECTS

The decision to use teams and a project site is up to the course instructor. What is described in the following paragraphs has been found to work in actual classrooms, but the decision on how best to use the material will depend on individual course needs. The textbook has been designed for use in conjunction with introductory team projects. It utilizes feasibility studies as a means for introducing civil engineering design and presenting information about the role that major infrastructure systems play in urban areas. The project requires students to identify the design problem, define design objectives, generate alternatives, evaluate alternatives, and make recommendations concerning follow-on studies and design work.

An effort is made to provide a "top down" experience, rather than the "bottom up" experience that students will obtain in subsequent courses. The "top down" approach is based on a belief that beginning students are interested in gaining exposure to the functioning of experienced professionals early in their program. This awareness of the "big picture" provides them with a model to evolve toward and also provides a framework for much of the more detailed coursework presented in the typical undergraduate curriculum. The feasibility study offers an opportunity to introduce students to the purpose and design rationale for different major infrastructure systems. The need to complete the team reports and apply the steps in critical thinking provide the motivation for team members to apply the steps of infrastructure engineering problem solving as they learn about major civil engineering infrastructure systems.

Objective 2 listed above, preparing students to function on teams, can be achieved by assigning each individual student to a team that is tasked with undertaking a design feasibility study for a specific type of infrastructure system. This works well if the team project involves the development and evaluation of alternative ways of meeting the major civil engineering infrastructure needs of a large site that could be the location of a future urban community.

When a site is selected for the team project, site infrastructure design teams can be established. If development of a community design is selected as the team project, the systems can include land use, transportation, water supply, storm water management, and waste management. Geotechnical and structural design problems can be added if the instructor wishes. Students who are assigned to apply the problem solving concepts for the land use, transportation, and storm water management systems can be asked to work together as a composite team since all three systems are closely linked together with respect to community layout. Once students have been assigned to a "community design" team, team members can decide among themselves who to assign to the three sub-teams that develop feasibility design concepts for land use, transportation, and storm water management. The remaining teams, water supply and waste management, can work independently of the community design teams since the major design concepts for these systems are not as strongly linked to community layout. Ideally water supply and waste management system design teams would be sub-teams functioning as part of a site design team, but the number of students required for this could make the size of the community design teams unwieldy for the learning objectives and it would become difficult to complete team design requirements and project reports within a single semester. The organizational concept proposed for the teams is shown in Figure P.1 that follows.

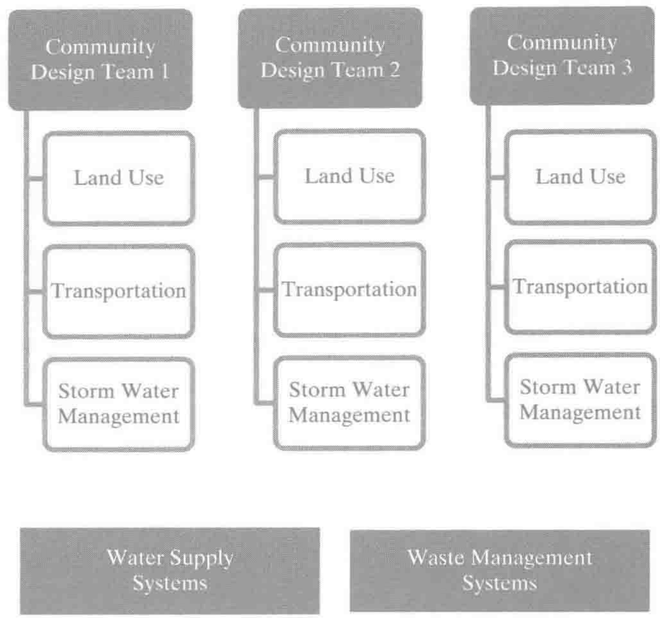

Figure P.1
Team organization.
Community Design Teams consist of six to seven individuals and water supply and waste management teams consist of three to four individuals.

The number of community design teams will depend on the size of the class. Normally at least six to seven students per community design team is optimum because it allows the land use, transportation, and storm water management sub-teams to consist of at least two and possibly three students. Single teams can undertake the feasibility design of the waste management and water supply systems and may consist of three or four students each. If a class is very large, additional teams can be identified to undertake the feasibility design of structural and geotechnical systems. Additional community design teams can also be added, keeping in mind that if more than three or four students are assigned to a water supply or waste management system or community design sub-system team, it becomes hard for team members to communicate effectively among themselves. Control within the team may be lost.

It is a philosophy of the course that the instructor should grade the reports promptly and return them to the teams by the next meeting period, if possible. This ensures rapid corrective feedback and helps motivate the team. The first two reports may be considered as leading up to the third report, which should be viewed and graded as a report that would stand by itself. For this reason, students may need to be given a chance to revise the third report to correct errors and omissions before it is turned in for grading.

Table P.1 shows a possible syllabus for a one-credit course or the one-credit portion of a two- or three-credit course. Other ways of integrating the text material into a course can be developed to meet the needs of individual programs.

Table P.1 One-Credit-Hour Course

	1 Credit Hour Lecture
Week	**Lecture Topic and Assignment**
1	Civil Engineering Infrastructure Systems Introduction and Chapter 1
2	Sustainability and Design Chapter 2
3	Climate Change Chapter 3
4	Federal Laws and Acts Chapter 4
5	The Phases of Design Chapter 5
6	Needs Assessment and Problem Definition Chapter 6
7	Establishment of Design Goals Chapter 7
8	Synthesis and Generation of Alternatives Chapter 8
9	The Evaluation of Alternative Solutions Chapter 9
10	Development of Site Maps and Data Bases Chapter 10
11	Site Evaluation and Use of Contour Lines Chapter 11
12	Abstraction and Modeling Chapter 12
13	Ethics, Liability, Licensure Chapter 13
14	Team Management, Communications, and Leadership Chapter 14
15	Undergraduate and Graduate Curricula and Programs Chapter 15

The proposed syllabus covers the phases of engineering problem solving and materials related to sustainability, climate change, federal laws and acts, professional orientation, and career development. Topics can be omitted at the discretion of the instructor.

Acknowledgments

I would like to thank my past and present colleagues in the departments of civil engineering and colleges of engineering at West Virginia University and the University of Nevada Las Vegas. They have all inspired me to prepare this manuscript. I began learning about the challenges of teaching an introductory course to engineers at the beginning of my teaching career over 43 years ago. Special thanks are due the current chair of the Department of Civil and Environmental Engineering and Construction at UNLV, Dr. Donald Hayes, and Provost Michael Bowers, who graciously supported me as I prepared the manuscript for this text. The author also expresses gratitude to Dr. Bea Babbit for instruction and guidance on the development of the rubrics which evolved into those presented in the appendices. Thanks are due to Drs. David Shields and Bonnie Bukwa for the discovery of omissions or incorrect statements, and providing the necessary information to add material and make the corrections. The drafts of the manuscript were used for several years by students in the Introduction to Civil Engineering Design course at UNLV, and a debt of gratitude is owed especially to them. The students provided me with much insight into what was important and what was extraneous. Lastly, I wish to thank the staff of Pearson Education for the editing, preparation, and publishing of this manuscript.

About the Author

Edward S. Neumann earned his PhD in the Urban and Regional Planning program in the Department of Civil Engineering at Northwestern University, where he received a Resources for the Future Doctoral Fellowship. Following the awarding of his PhD, he fulfilled an ROTC obligation at the US Army Corps of Engineers Waterways Experiment Station. He served as Director of the Harley O. Staggers National Transportation Center at West Virginia University. He also served as Chair of the Department of Civil and Environmental Engineering for ten years, and as Director of the Transportation Research Center at the University of Nevada Las Vegas (UNLV). A licensed civil engineer in Nevada, he is a recipient of the James Laurie Prize from the American Society of Civil Engineers, the Wayne T. VanWagoner Award from the Institute of Transportation Engineers, and was named Outstanding Engineer in Government/Education by the Southern Nevada Branch of the American Society of Civil Engineers. He has taught capstone design in civil engineering and introduction to engineering courses for over 42 years.

Contents

CHAPTER

1 Civil Engineering Infrastructure Systems

Objectives

After reading this chapter, you should be able to:

- Provide an overview of the history of infrastructure systems and the evolution of civil engineering
- Explain systems concepts
- Explain the concept of the feasibility assessment
- State eight major categories of civil engineering design goals

HISTORICAL PERSPECTIVES

The Infrastructure of Civilization

Your life depends on civil engineering systems that function effectively and so do the lives of nearly everyone else on the planet. **Infrastructure** can be defined as the physical facilities which sustain and support the community, and often incorporate engineering materials which include concrete, steel, or other construction materials which may be subjected to loads of high magnitude. Civil engineers design the infrastructure of our urban megacenters and surrounding metroplexes, our large and medium-sized cities, our smaller communities, and our more remote developments such as parks and sites where natural resources are extracted or food is grown. They also play a significant role in the design and construction of sea and space infrastructure. "Infrastructure" includes the systems that provide water for drinking and industrial needs (designed by civil engineers who have specialized in environmental and water resources engineering), systems that prevent the risk of flooding after rain storms (designed by civil engineers who have specialized in water resources and hydraulics),