
AC 2011-484: DEVELOPMENT OF AN ENGINEERING MANAGEMENT MS OPTION COUPLED WITH UNDERGRADUATE CULMINATING DESIGN

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An Engineering Management MS Option coupled with Undergraduate Culminating Design

Abstract

This article describes a new civil engineering MS management option currently being implemented in our program. The option consists of two new graduate courses that provide a rich experience in leadership, management, and professional practice outcomes. This option also includes a coupling with our undergraduate culminating design class wherein graduate students can gain an effective leadership experience by mentoring undergraduate culminating design projects. It also summarizes preliminary assessment of the class and student evaluations as a means to determine the option's effectiveness. The motivation for this new option comes from 1) a desire to strengthen our undergraduate culminating design experience, 2) a strong recommendation and support from our advisory board to include management issues in the curricula, and 3) the ASCE vision for civil engineering in 2025 to include leadership, teamwork, public policy, and management as educational outcomes.

Some advantages of the MS management option include (a) a structured mentoring experience for graduate students, (b) an effective means to acquire projects for the undergraduate culminating design class, and (c) a forum that allows practicing engineers to share professional expertise directly with students. In addition, students gain an understanding of how technical proficiency must be meshed with business acumen to have a successful career in engineering management.

Introduction

The American Society of Civil Engineers (ASCE) has become a strong advocate for strengthening the capabilities and stature of professional engineers by enhancing their skills in areas of leadership, management, and teamwork. Beginning in 2001 ASCE began publication of the journal *Leadership and Management in Engineering*¹ edited and managed by the committee on professional practice. Areas of interest in this journal include such topics as leadership, teamwork, communications, team building, decision making, partnering, project management, branch and office management, professional practice and development, budgeting, and financial management. The ASCE publication *The Vision for Civil Engineering in 2025*² states that civil engineers must be "entrusted by society to create a sustainable world and enhance the global quality of life." In this document it is stated that "In 2025, civil engineers will serve as master builders, environmental stewards, innovators and integrators, managers of risk and uncertainty, and leaders in shaping public policy." ASCE continues on to challenge educators in that "Colleges and universities must examine their curricula as they relate to the future civil engineer so advancement toward the vision can be realized."

ASCE now prescribes a body of knowledge (i.e. BOK2³) which specifies 24 outcomes needed for professional licensure. Of the 24 outcomes, 9 focus on professional practice. These 9 outcomes are: Communication, Public Policy, Business and Public Administration, Globalization, Leadership, Teamwork, Attitudes, Lifelong Learning, and Professional and Ethical Responsibility. These outcomes are couched in the following six levels of attainment specified with Bloom's Taxonomy.⁴

1. Knowledge - the remembering of previously learned material.
2. Comprehension - the ability to grasp the meaning of material.
3. Application - the ability to use learned material in new and concrete situations.
4. Analysis - the ability to break down material into its component parts so that its organizational structure may be understood.
5. Synthesis - the ability to put together to form a new whole. This may involve the production of a unique communication, a plan of operation (research proposal), or a set of abstract relations (scheme for classifying information).
6. Evaluation - the ability to judge the value of material for a given purpose.

Moreover, in the recent ASCE document, *Achieving the Vision for Civil Engineering in 2025 – A Roadmap for the Profession*⁵ tactics to achieve the stated outcomes are presented. In this document members of the profession are admonished: “civil engineers—as leaders in planning, designing, and constructing the built environment—will have to light the torch and position themselves at the helm of multi-disciplinary, global, collaborative teams that carry out successful projects.”

ABET (the organization formerly known as the Accreditation Board for Engineering and Technology) stipulates eleven (i.e. a-k)⁶ outcomes for all engineering programs including (d) an ability to function on multidisciplinary teams, (f) an understanding of professional and ethical responsibility, and (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. In addition, ABET criteria for Civil Engineering programs include the requirement that “The program must demonstrate that graduates can ... explain basic concepts in management, business, public policy, and leadership; and explain the importance of professional licensure.”

A very large proportion of our graduates (about 80%) obtain graduate degrees and many of them become employees of small to medium sized consulting offices. Our alumni continue to provide us valuable insights and support for our program. The department also has a seventeen member external board (all alumni) that advises us on many critical issues, including curriculum development. The vast majority of these members currently own and manage their own practices, ranging from only a few to several hundred employees. Some of the members are in leadership positions in large civil engineering firms. This advisory board has counseled our department to find ways to include education and experiences in leadership and management within our curriculum. They have offered to assist in developing and teaching any classes. To address this recommendation we have begun a pilot program to offer a management option in our graduate civil and environmental engineering program.

This paper describes our efforts to address the need to provide a meaningful education for civil and environmental engineering students in professional skills of leadership and management. We describe a pilot program that incorporates two new graduate level courses and a leadership experience wherein graduate students mentor undergraduate culminating design projects. We report herein the initial findings of the pilot program.

Motivation

There are several factors that combined to encourage us to explore broadening our current MS program to provide a Civil and Environmental Engineering Management option. Previously, our college offered a Master’s of Engineering Management (MEM) degree. This degree was popular

among students of Civil and Environmental Engineering. Alumni with this degree have reported satisfaction with the content of their education and enjoy successful careers. However since few of the other college of engineering programs embraced the degree, the degree was terminated in the late 1990's. At this point, the department created an Engineering Management Option within our program by securing an agreement with the College of Business to provide two MBA courses that could be taken by our students. These two courses provided finance and management instruction to engineering students but did not require prerequisites normal to other MBA curricula. Ensuing retirements and budgetary issues forced the cancelation of those two courses a few years ago and we were left without a business option, despite the fact that it had been successful.

In the summer of 2009, as part of our department's ongoing efforts to assess and improve programs we conducted a large scale alumni survey. Slightly more than 400 of 3300 alumni responded to the survey which covered a large range of topics. While the survey did not specifically target information relative to our MS program, an unintended consequence of this survey did provide an impetus to renew efforts to provide business and project management options. This survey can now provide a baseline for which we can compare the impact of a new MS option. Among other things, the survey included four open-ended questions relevant to this option: 1) What are your perceived weaknesses of the current program? 2) What advice would you give to current students? 3) What advice would you give to faculty? and 4) If you were to go through the program again what would you do differently? While the answers were open-ended, it became apparent as we reviewed them, that certain themes related to technical, professional, and other issues emerged that we could classify them by. We first categorized each and every response to the question about program weaknesses into seven categories: 1) lack of management/business, specific course issues, 2) lack of practical application, 3) lack of design, 4) no weaknesses (just happy with the program), 5) poor development of communications skills, 5) lack of basic theory development, 6) lack of experience with computers, and 7) weak mathematics background. The responses were further divided into groups based on the number of years since graduation being, less than 2 years, 2-4 years, 5-9 years, 10-19 years, and greater than 20 years. The summary of the responses is presented in Figure 1. Note that for each grouping of number of years since graduation, the total response equals 100%.

After the initial categorization, we next grouped the responses into four categories: 1) Professional Development Issues (i.e. previously the Management/Business, Practical Applications, Design, Communication, Computer groupings), 2) Course Issues, 3) Just Happy, and 4) Theory and Basics (i.e. previously the Basic Theory and Math groupings). The new grouping, shown in Figure 2, indicated that the need for greater development in professional aspects was overwhelming compared to the other needs. The finding from the data was consistent across all ranges of years since graduation; essentially, 2 of 3 respondents suggested the need or desire for more development in professional practice issues.

Pilot MS Management Option Overview

With the above information as a baseline, we saw the need to 1) strengthen the overall education of our graduates in the professional development areas and 2) improve the undergraduate culminating design experience. We decided to address these needs with a new MS management option because the undergraduate curriculum is full and the majority (i.e. about 80%) of our students continue on to receive an MS degree. The option consists of two new graduate courses that provide a rich experience in leadership, management, and professional practice outcomes.

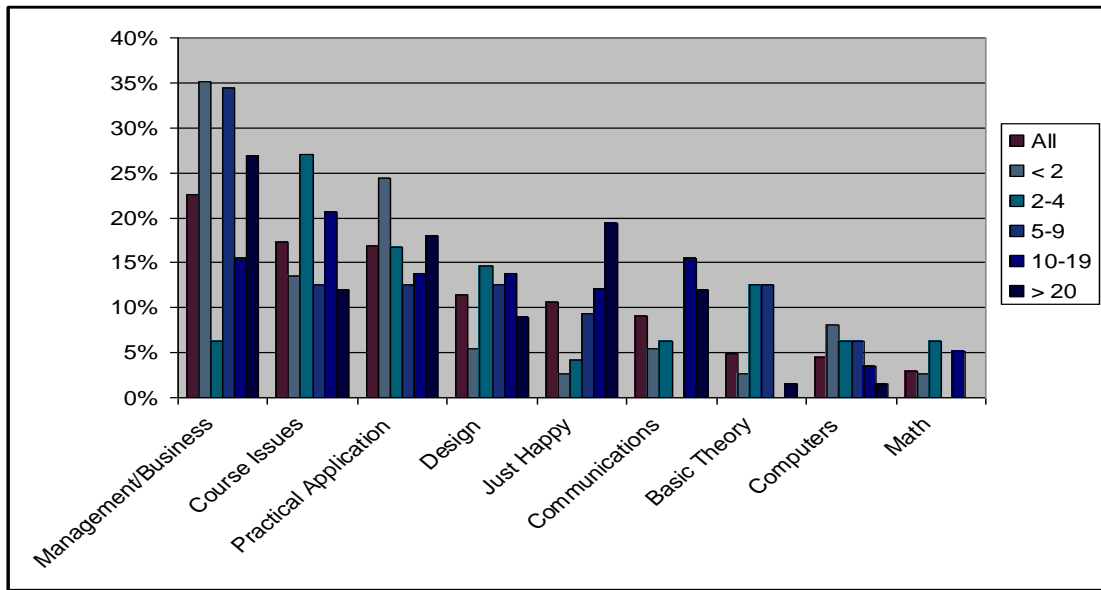


Figure 1: Specific Weakness Areas Identified by Alumni Survey

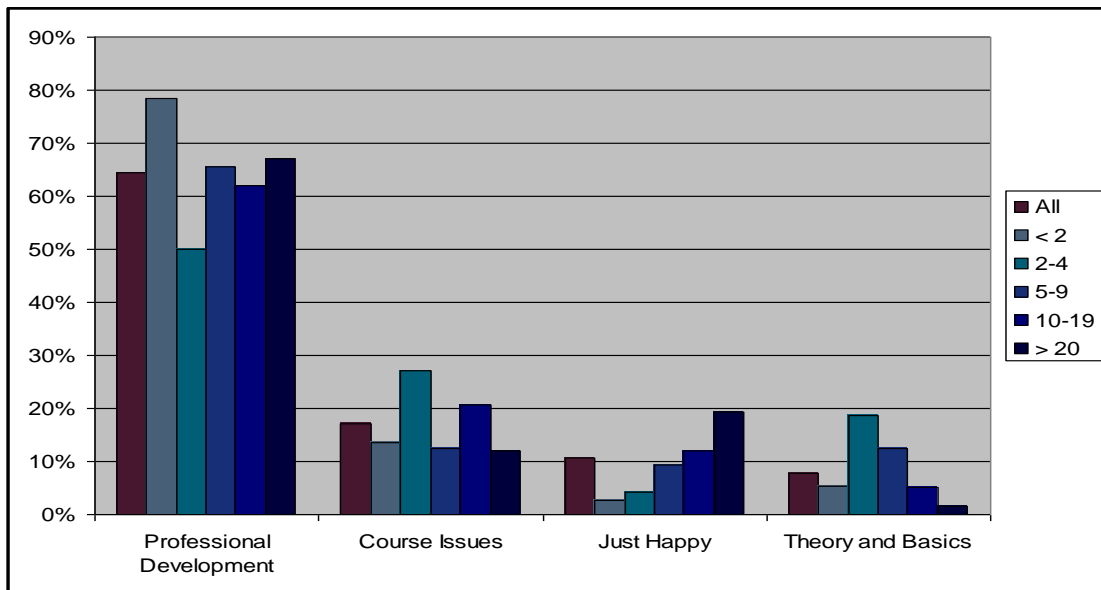


Figure 2: Global Issues Identified by Alumni Survey

This option also includes a coupling with our undergraduate culminating design class wherein graduate students can gain an effective leadership experience by mentoring undergraduate culminating design projects. While some of our faculty question the technical rigor of graduate classes focused on professional skills when compared with other graduate classes that require mathematical depth, the majority of our faculty believe that the more understanding and application of crucial professional skills are equally important for the engineer in today's environment. In addition, we felt that graduate students, being more mature, would better appreciate what the classes would offer, the experiences shared by the invited guest speakers, as well as a very important aspect of the option, the opportunity to mentor an undergraduate design

team. We also felt that the outcomes of the classes would be better achieved if students had completed an undergraduate culminating design experience themselves and had received a brief introduction of professional practice issues.

This program is not meant to compete with traditional MBA programs, rather it is designed to provide Civil and Environmental Engineering graduate students a reasonably complete introduction to some of the basic management skills they will need to understand and more fully develop as an engineering manager and potentially a business owner. In this pilot, any MS student can choose to enroll in the two courses as long as the courses are approved by the student's graduate committee. Though not required for students in this pilot, most of them have had internship, previous, or current engineering work experience. Such work experience adds depth and understanding to the class activities. Students must sign up for and complete both classes in the sequence.

General Structure of the Classes

The two classes being offered are taught by faculty and a variety of professionals with years of practical experience. The classes have two main instructors: a full time and an adjunct faculty. The adjunct faculty is a professional engineer who has a Master of Business Administration degree. The full time faculty administers the courses while the adjunct faculty serves as class facilitator and helps the faculty arrange for additional guest speakers. Typically, one of the instructors will introduce a topic (in one class period) through a presentation or other suitable delivery method. A guest speaker, typically a professional engineer with experience in that topic, then follows up with a presentation to the class. Lectures and presentations are dynamic in their format; meaning, there is significant interaction and participation by the students. Such interaction and participation is best achieved in smaller sized graduate classes than in larger classes that are typical in the undergraduate program. Although the students know that they are partially evaluated based on their class participation, the business nature of the classes and the maturity of the students taking the classes appear to be sufficient motivation to elevate participation to a very high level.

The foundational text for the classes is *Engineering Your Future: The Non-Technical Side of Professional Practice in Engineering and Other Technical Fields*⁷. Four other books were considered for the class: *Civil Engineering Practice in the Twenty-First Century: Knowledge and Skill for Design and Management*⁸, *Developing Managerial Skills in Engineers and Scientists: Succeeding as a Technical Manager*⁹, *A Pocket Guide to Business for Engineers and Surveyors*¹⁰, and *From Engineer to Manager: Mastering the Transition*¹¹. These books have many common topics and any one of them could have been successfully used. The "*Engineering Your Future*" book was selected because the faculty teaching the class felt that that book was slightly more general and at the same time more complete in providing an overview of the topics to be discussed in both classes. The book's approach is easy to read and serves as an introduction to many of the topics. In depth discussion of the topics is achieved through articles from different business and management professional journals, case studies from the Harvard Business School, class discussions, and experiences of the professional practice guest speakers. Reading is assigned in advance and posted on the class web sites; students are responsible to complete the reading prior to coming to class. To further encourage study of the text and reading of articles and case studies, students are randomly selected to make a brief summary of the reading at the beginning of class. The academic form of encouragement appears not to be the

main reason for student's preparation; students appear to be engaged because of a deeper sense of responsibility for their own learning.

Civil Engineering Business Operations (CEBO) Class

This course is taught during the fall semester and provides the students an understanding of a range of considerations required in developing a business plan for a civil engineering firm. Students in this course are taught that a business exists to make a profit and the elements necessary to make a plan so that the business achieves its goal of becoming profitable. Such a point of view is not altruistic but realistic in a business context. The class is divided into groups and each group develops a business plan for a civil engineering firm. Three deadlines related to the business plan are given: 1) the submission of one page summary of the business idea the group will pursue; 2) a first draft of the plan; and 3) the final draft of the plan. Besides the written plan, students make a thirty minute presentation of their plan to a panel of experts. Students receive feedback from the main instructors of the course and from a mentor, who has had the experience of starting his or her own engineering firm.

The topics discussed in the class include different legal forms of business ownership, time value of money, business performance metrics (ROI, IRR, DCF, WACC, EBITDA, and P/E Ratio), balance sheets, income statements, cash flow statement, business development, managing a business for profitability, budgets and cost management, marketing and branding, networking, operations management, supply and demand, market forces, managing a business for growth, competition and game theory, business strategy, managing outside consulting, customer value propositions in business markets, and staffing. The topics were selected by faculty and the department's external advisory board, whose members are professional engineers with many years of experience.

Students in this class are also required to read *The Goal: A Process of Ongoing Improvement*¹². The book was selected because it is an entertaining novel while also being a thought-provoking business book. The author discusses the Theory of Constraints and uses it as a means for an organization to have an ongoing process of improvement. In that process three fundamental questions are explored: what to change?, to what to change?, and how to cause the change? Business performance in today's increasingly competitive market depends on a variety of factors that exist outside the business and being able to answer these questions can help managers, even in Civil Engineering organizations, to make decisions that will influence the bottom line of their business.

Request for project proposals and a statement of qualifications are introduced near the end of the semester to help students transition from developing a civil engineering businesses to managing civil engineering projects. Experience in managing a project will be gained by the students in this class by leading an undergraduate student team through their required culminating design experience. Undergraduate students respond to RFPs developed by the graduate students at the beginning of the winter semester in the undergraduate culminating design class.

Civil Engineering Leadership and Project Management (CELPM) Class

This course is taught during the winter semester and topics covered are divided into four groups: 1) management of self, 2) management of others, 3) management of projects, and 4) principles of leadership. Some topics fit within more than one group. The topics covered are diversity at work, building effective teams, effective performance coaching, evaluation, delegation,

utilization, producers and managers, establishing a vision and alignment of purpose, communication skills, managing conflict, developing a contract fee, developing project scopes, engineering projects—from beginning to end, project management approaches, engineering liability, risk management, Microsoft project, critical path, scheduling, partnering, goal setting, professional licensure, public speaking, information sharing, being persuasive, negotiations, family leadership, situational leadership, and the four disciplines of execution (a Franklin Covey program lecture).

Students in this course use the project for which they have previously developed an RFP as the design project for an undergraduate team enrolled in the department's culminating design class. Projects are typically generated from local municipalities, state agencies, or regional engineering companies. The Winter 2010 class had six projects: Fish Passage through Diversion Dams, A City Storm Drain, Analysis of Water Quality Conditions in Veracruz, Mexico - using QUAL2K, Water Quality Monitoring in the Tuxpan River in Veracruz, Mexico, A Pavement Design for State Road 201 Using Cement Treated Rubblized Road Base, and Development of Water Quality and Quantity Information Management System for the State of Veracruz, Mexico. The winter 2011 class has the following eight projects: Engineering Design of Culverts for the State's DOT, Haiti Reconstruction Housing Design, A City Culinary Pipe System Design, Table Rock Gas Plant Concrete Design, Design of a Solar Panel Farm for a Closed Landfill, Bicycle Facility Design and Prioritization for a city, A City Detention Basin Design, and A City Traffic Slowing Management System Design.

Students taking this class help their respective undergraduate teams develop appropriate scope, deliverables, tasks, timeline, and milestones for the project. The students serve as mentors of the multi-disciplinary undergraduate project design team. They help the team manage the project to completion on time, on budget, and to the client's satisfaction; and supervise the preparation and delivery of a design project report. Each undergraduate team has three students and a scheduled weekly project meeting. Graduate students are strongly encouraged to attend their teams' weekly project meetings and to coordinate the activities of the team. Graduate students are encouraged to help but not do the actual work; they are to function as a resource rather than a working hand. They "exist" to facilitate the working of the team and build a cohesive team. Many teams communicate also via e-mail and even using text messages during the week. Graduate students are encouraged to check the progress of the work and provide encouragement and direction when such are needed. A faculty member with appropriate technical background oversees the project and mentors the graduate and undergraduate students. This setup provides hands on experience for the graduate students and an opportunity for the undergraduate students to participate in an actual rather than a contrived design project.

In this course students are required to read two additional books: *Egonomics*¹³ and *The Five Dysfunctions of a Team: A Leadership Fable*.¹⁴ The *Egonomics* book was selected because it points out the pitfalls and strengths associated with ego—a typical human fallacy commonly observed on successful corporate leaders. The author intelligently explains how leaders must learn to manage their ego and use it as an asset rather than a liability to their organizations. The *The Five Dysfunctions of a Team: A Leadership Fable* book was selected because it describes the typical dysfunctions that exist in any team. Leaders and managers success depends on how they make ordinary people join forces to achieve extraordinary goals. The book outlines a model and provides steps that can be used to overcome typical team's hurdles and build a cohesive, high performance team.

Preliminary Assessment

The first pilot course offered was actually the second in the sequence of classes; CELPM which was offered winter semester 2010 and had 6 students enrolled. The CEBO class was initially offered fall semester 2010 with 16 students enrolled and the second offering of the CELPM class is being taught winter 2011 and has 13 of the 16 students from the CEBO class. To date only a limited assessment can be made with anecdotal evidence of success. As these students graduate and move out into professional practice we will be able to track them and compare their experience with the baseline survey of 2009. The average course ratings for the two classes offered were 7.8/8.0 and 6.6/8.0. The most revealing data are some of the student comments.

Student comments from the winter 2010 CELPM class include:

“It has been one of the best classes I have taken since I started.. The instructors are great, even outside the classroom, they're awesome”

“This class was refreshing because it taught concepts not found in the regular civil engineering curriculum. Mentoring my own team proved to be invaluable practical experience to learn leadership and management. Most of the time, the speakers used engaging methods to effectively teach their topic. The small class size and high professor-student ratio helped me be an active participant in class to feel close contact with the professors. For me, close contact with professors has been one of the most important elements of my development. They are so inspiring! Being able to talk one-on-one has motivated me to work harder and be better--even more than external motivators like getting good grades.”

Student Comments from the Fall 2010 class (Civil Engineering Business Management) include:

“I think that this course is extremely valuable for students about to enter their careers. The guest speakers and lecturers were great and I was amazed that (the professors) were able to secure such valuable and high-profile people to come and lecture on various topics. That was probably my favorite part of the class: great lectures.”

“great class. exactly what I think has been lacking. I recommend it to all in the major.”

“I didn't like that the course was so varied in subject matter. I didn't have a chance to learn or apply what was being taught by the guest speakers. I recommend that homework be assigned more.”

“This is a great class that needs to continue. It really helped to round out my engineering education. I consider it one of the most beneficial classes I have taken.

“I felt that the business operations course was an awesome course. I really loved how we got the opportunity to interact with professionals all semester long. I also really liked that the focus of the course was mainly on creating a business plan, and everything else that we did was in reference to that and to help us develop an effective business plan. ... One thing I would recommend is to let the speakers know beforehand when the class ends (5:50, not "whenever you want"). ... I really did love hearing all of the speakers. I felt that that was something really valuable to my education. I felt that was really worth the money I paid for tuition. ... Thanks for a great semester”

Since only a portion of the undergraduate design teams had graduate student mentors we also surveyed the undergraduate students from the CELPM class. Not surprisingly students seemed to like their experience whether they had a mentor or not so it was difficult to fully identify the benefit. However, while few of the undergraduate students who did not have graduate mentors wished they would have, almost all of them said that given the choice they would choose to take

the business operations and project management MS option to further develop their professional skills and have the opportunity to mentor an undergraduate team.

Summary

We feel that advantages of the MS management option described above include: (1) an effective treatment of issues faced in the management of a civil engineering company, (2) a valuable structured leadership/mentoring/management experience for graduate students enrolled, (3) a forum that allows practicing engineers to share professional expertise directly with students, and (4) a strengthening of our department's undergraduate culminating design experience

The breadth and depth of the subjects covered in this two class sequence provides an adequate coverage of the issues faced by graduates whose careers result in leading team efforts and managing an engineering office. Our current ABET accredited curriculum coupled with the broad general education and other requirements of our institution does not allow for adequate treatment of these subjects in the undergraduate program. In addition, with a significant number of our graduates obtaining MS degrees and their likelihood of leading and managing civil engineering companies, this graduate option is a good fit for our department's program. Student comments and advisory board reviews have been positive.

The structured mentoring experience for graduate students is one of the strongest components of this option. Here a graduate student is able to mentor a group that has a real project to complete. The graduate student is able to observe and participate in team building events, project planning and completion, as well as observe and deal with personality issues that arise in a real project management experience. In some cases the graduate student continues this effort as his or her MS project option.

Our advisory board and other alumni are anxious and willing to support efforts to strengthen and build our department's program. They willingly provide not only advice, but significant amounts of time and resources to assist us. They recognize that, in many ways, they have superior knowledge and experience in some of the professional required in managing civil engineering operations and are willing to share that experience with students. We recognize that strong alumni support is strength for a department.

The capability to acquire real, focused and doable senior capstone projects is a continuing issue. This program places some of the responsibility to secure these projects on graduate students. With this responsibility graduate students are motivated to approach public engineering organizations and engineering companies to identify, support and possibly fund meaningful projects. Outside entities are often very supportive of such efforts of mature students. We believe this aspect is a win-win for our department and the entities that provide projects. Although over the years it has been a struggle to find strong faculty or outside mentorship for the senior design projects; this new option has the positive aspect of providing strong mentorship from motivated graduate students to all design project teams.

We would move this pilot effort to a formal option within our department if current successes continue.

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