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CLEMSON UNIVERSITY SCIENCE MASTER'S PROGRAM IN SUSTAINABLE AND RESILIENT INFRASTRUCTURE: A PROGRAM EVALUATION

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CLEMSON UNIVERSITY SCIENCE MASTER’S PROGRAM IN SUSTAINABLE AND RESILIENT INFRASTRUCTURE: A PROGRAM EVALUATION

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Civil Engineering

by
Elizabeth Eberhart O’Sell
May 2014

Accepted by:
Dr. Leidy Klotz, Committee Co-Chair
Dr. Ronald Andrus, Committee Co-Chair
Dr. Nadim Aziz
ABSTRACT

The Clemson University Science Master’s Program (SMP) in Sustainable and Resilient Infrastructure is a program which aims to link engineering, materials, construction, environment, architecture, business, and public policy to produce graduates with unique holistic perspective and expertise to immediately contribute to the workforce in the area of sustainable and resilient infrastructure.

A program evaluation of the SMP has been performed to study the effectiveness of the SMP and identify areas where the goals and vision of the SMP are achieved and areas where improvements can be made. This was completed by analysis of trends within survey responses, review of Master’s thesis reports, and review of courses taken.

It was found that the SMP has facilitated new interdisciplinary research collaborations of faculty in different concentration areas within the Glenn Department of Civil Engineering, as well as collaboration with faculty in other departments.

It is recommended that a course which provides instruction in all eight competency areas be required for all SMP students to provide a comprehensive overview and ensure all students are exposed to concepts of all competency areas.

While all stakeholders are satisfied with the program and believe it has been successful thus far, efforts do need to be made as the program moves forward to address and improve some items that have been mentioned as needing improvement. The concerns about concentration courses, internship planning, and advising should be addressed.
This evaluation provides benefits to prospective students, current SMP participants, and outside program supporters. The goal of this evaluation is to provide support that the SMP is an effective and worthwhile program for participating students, while attempting to identify any necessary program improvements and provide recommendations for achieving these improvements. This goal has been accomplished.
DEDICATION

I would like to dedicate this work to my family and friends for always providing love, support, and encouragement. I would like to especially thank my parents who instilled in me a desire to learn and have always believed in me.
ACKNOWLEDGMENTS

I would like to express sincere gratitude to my advisors, Dr. Leidy Klotz and Dr. Ronald Andrus, for their support and guidance throughout my graduate and research experience. I would also like to thank Dr. Nadim Aziz for his time and valuable input. Without them, this work would not have been possible.

Thanks go to my internship supervisors, Thomas Suttles and Tony Putnam, and everyone else at Clemson Facilities for providing me with an invaluable learning experience during my time there.

Finally, thanks to the National Science Foundation and Clemson University for supporting this research and graduate program.

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CHAPTER ONE

INTRODUCTION

1.1 Science Master’s Program in Sustainable and Resilient Infrastructure

The Clemson University Science Master’s Program (SMP) in Sustainable and Resilient Infrastructure was implemented in July 2010 with support from the National Science Foundation (NSF). According to the original project proposal, the objective of the SMP is “to link engineering, materials, construction, environment, architecture, business, and public policy to produce graduates with unique holistic perspective and expertise to immediately contribute to the workforce in the area of sustainable and resilient infrastructure.” Graduates with this type of preparation are and will continue to be in demand because “recent events highlight the need for a paradigm shift to look holistically at the nation's infrastructure throughout its life, from the planning stages through design, construction, operation, maintenance, and rehabilitation. The Hurricane Katrina disaster, the general deterioration of the nation's infrastructure, and the need for renewable energy sources are just a few examples highlighting this need for new thinking… Graduates of this program will fill workforce needs in areas of national economic growth that ensures a safe and sustainable infrastructure.”

The project vision is “to create a new and innovative Science Master's Program (SMP) in Sustainable and Resilient Infrastructure that meets a national need to improve the sustainability and resilience of the nation’s infrastructure systems. Graduates of this program will have the technical background as well as the business and professional
skills to become leaders in the field.” The program is an interdisciplinary one that blends civil engineering, environmental issues, business, policy, and architecture to meet a national need. The Clemson project team includes representatives from the areas of Architecture, Civil Engineering, Environmental Engineering & Earth Sciences, Management, and The Graduate School.

External partners of the SMP are from many types of organizations including national government labs, international and national engineering firms, state and local government agencies, and non-profit and professional organizations. The following organizations are external partners of the program: Oak Ridge National Laboratory, City of Charleston, S&ME, FLASH, Kimley-Horn and Associates, Inc., South Carolina Department of Commerce, Fluor, CH2M Hill, Portland Cement Association, SCDOT, Institute for Business & Home Safety, US Army Corps of Engineers, Davis & Floyd, DHEC, Savannah River National Laboratory, FHWA South Carolina, South Carolina State University, and US EPA. Representatives from some of these organizations have also served as Advisory Committee members.

The primary goals of the SMP are to:

1. Prepare STEM (Science, Technology, Engineering, and Mathematics) master’s students to meet the national need for more sustainable and resilient infrastructure

2. Ensure that one-third of the 14 SMP funded students are from underrepresented groups in STEM areas
3. Establish a self-sufficient graduate program in sustainable and resilient infrastructure that will continue after NSF SMP funds end

4. Facilitate internships and research experiences to address industry needs in sustainable and resilient infrastructure

5. Develop and disseminate new knowledge in sustainable and resilient infrastructure through research and publications

The program requirements for students include an internship and minimum of 32 credits of coursework/research distributed as follows:

- 9 of core courses
- 9 of business-related courses
- 6 of thesis research (or 3 of graduate project)
- 6 of concentration (or 9 for project option)
- 2 of seminars (business communication, ethics and leadership)
- Internship for 5 or more weeks

A more detailed list of the minimum program requirements is included in Appendix A. Student fellowship selections were done through a competitive process which included review of short research proposals submitted by the student applicants and their advisors. Students who are selected receive a tuition waiver and support in the form of a stipend for eighteen months. All students receiving NSF funds were required to complete research thesis reports.
In July 2010, the NSF project and creation of the SMP began. The first five SMP students began the program in August 2010. In December 2010, the first advisory committee meeting was held. The first SMP students graduated in December 2011. In September 2013, the NSF project ended and the SMP is moving forward with short-term support from Clemson University. Students have had a variety of experiences in the program thus far, including participating in research, working in interdisciplinary teams, being exposed to business through courses and internships, and learning improved communication skills and methods.

1.2 Program Evaluation

The focus of this thesis is presentation of a program evaluation of the SMP that has been performed. The goal of this evaluation is to study the effectiveness of the SMP and identify areas where the goals and vision of the SMP are achieved and areas where improvements can be made. This was completed by studying survey responses and analyzing trends within, as well as through review of the fifteen Master’s theses that have been written by SMP graduates.

Five different surveys were distributed to different program stakeholder groups in efforts to obtain feedback about the SMP. The five surveys are the Graduate Student Exit Survey, the Internship Supervisor Survey, the Advisory Survey, the One-Year-Out Graduate Student Survey, and the Employer Survey. Blank copies of these surveys are included in Appendix B. Twelve of the fifteen SMP students who had graduated before December 2013 completed the Graduate Exit Survey. As of January 2014, twelve SMP
students had graduated from the SMP at least one year prior and were invited to complete the One-Year-Out Graduate Student Survey. Ten of these graduates returned the survey. Eight SMP student internship supervisors responded to the Internship Supervisor Survey. Nine research project advisors provided responses to the Advisory Survey. So few current employers of SMP graduates returned the Employer Survey that these surveys were not included in this evaluation.

General trends within survey responses were studied and observations made. The conclusions are not statistically significant due to small sample sizes.

The fifteen SMP Master’s theses were reviewed and comparisons made between the SMP theses and Master’s theses of non-SMP civil engineering students completed during the same time frame. Courses taken by SMP students were also studied to determine whether students received adequate course instruction in program competency areas.

This evaluation provides benefits to prospective students, current SMP participants, and outside program supporters. This study provides valuable information for the future of the SMP. The aim was to provide support that the SMP is an effective and worthwhile program for participating students, while attempting to identify any necessary program improvements and provide recommendations for achieving these improvements.
CHAPTER TWO

CORE COURSES

2.1 Background

One of the requirements of the SMP is for each student to complete nine credits of core courses (three three-credit courses), as stated previously. The core courses are courses which have technical content in the following eight fundamental competency areas related to sustainability and resiliency: life cycle assessment, energy efficiency/alternative energy, conservation/resourcefulness, carbon accounting, structural/non-structural protections, rapidity, system analysis, and biomimicry. These courses are intended to provide students with knowledge of sustainable and resilient infrastructure theory and application.

The contents of each core course were mapped to these eight competency areas based on Bloom’s Taxonomy. Bloom’s Taxonomy is a framework used to classify educational goals, objectives, and standards (Krathwohl 2002). The framework consists of 6 cumulative, hierarchical levels in the cognitive domain: 1-knowledge, 2-comprehension, 3-application, 4-analysis, 5-synthesis, and 6-evaluation. Level 1 is the lowest and simplest, and level 6 is the highest and most complex. Achievement of higher learning levels requires mastery of all lower levels.

In order for a course to be added to the list of core courses which students can choose to take, the faculty member teaching the course had to submit a request including a course syllabus and a completed Bloom’s Taxonomy table for the course. The SMP
steering committee then reviewed the request and determined whether the course would be added. Currently, there are eleven SMP core courses. A complete list is provided in Appendix A: Program Requirements. A number of courses pre-existing in the Civil Engineering Department were accepted as core courses for the SMP. Four of the eleven core courses are taught by faculty members not involved in the development of the SMP who saw an opportunity that the topics of their course fit with the program goals. In addition, five new courses were developed within the Civil Engineering Department during the SMP project period and accepted as SMP core courses. These five new courses are: Infrastructure Corrosion, Risk Assessment for Resilient Infrastructure, Structural Health Monitoring, Sustainable Construction Materials, and Sustainable Infrastructure Systems.

2.2 Student Evaluation of Core Courses

The core courses completed by the sixteen SMP students who had graduated by December 2013 are summarized in Figure 2.1. Of these sixteen students, thirteen fulfilled the program requirement by taking three core courses, while three students exceeded the requirement and took an additional core course for a total of four. Also, three students had an approved substitution to take Sustainable Energy (CE 691) as a core course, which is not shown in Figure 2.1, because it seemed to be the only core course which would fit into their last semester schedule.
It appears that the core courses taken most often are the ones that cover topics applicable to a variety of specialty areas. Courses which are more specific to a single specialty area, such as Structural Health Monitoring, Repair and Rehabilitation of Concrete Structures, and Infrastructure Corrosion, were taken by fewer students,
presumably those students with a specific interest in those areas. These data do not account for how often each of these courses has been offered. It is possible that courses which have been taught more often in recent years may have been taken by more students due to availability. Also, the first five courses listed in Figure 2.1 (Sustainable Construction Materials, Sustainable Construction, Risk Assessment, Pollution Prevention, and Environmental Systems) were the original five core courses of the SMP. The other six courses were added to the core course list in semesters after the first SMP students had begun the program. Therefore, the initial students had more limited core course options, and this is likely one reason those five courses have been taken by more students than some of the other courses.

In both the Graduate Exit Survey and the One-Year-Out Graduate Survey, SMP graduates were asked to answer the question “What sustainable/resilient infrastructure core course(s)—Sustainable Construction Materials; Sustainable Construction; Risk Assessment for Resilient Infrastructure; Pollution Prevention and Industrial Ecology; Environmental Systems; Urban Transportation Planning; Structural Health Monitoring; Sustainable Infrastructure Systems—will be/has been most useful to you in your career? Why?” The number of times each course was stated in the responses was tabulated and normalized to a percent based on how many of the responding students took each of the core courses. The normalized percentage results are shown in Figure 2.2 and Figure 2.3, for the Graduate Exit Survey and the One-Year-Out Graduate Survey, respectively. The fractions shown above the bars in these figures represent the number of students who mentioned the course in their response out of the number of students who took the course.
and completed the survey. The complete non-normalized raw survey data are located in Appendix C.

Figure 2.2: Core Course Most Useful to Career – Graduate Exit Survey
In the Graduate Exit Survey, the greatest normalized percentage of graduates predicted that Risk Assessment, followed closely by Sustainable Construction Materials, Sustainable Construction, and Pollution Prevention, would be the core course most useful to their career (Figure 2.2).

Figure 2.3: Core Course Most Useful to Career – One-Year-Out Graduate Survey
In ten responses received to the One-Year-Out Graduate Survey, the answers shifted slightly and Sustainable Construction and Sustainable Construction Materials became the courses mentioned by the greatest percentage of graduates as most useful to their career (Figure 2.3). Five graduates, of the ten who have responded to the survey, named the same course in the One-Year-Out Survey as they did in the Exit Survey, while four more graduates named a different course after working for a year. It can be concluded from their answers that some of the students either did not know for certain what type of career they would start or are not performing the type of work they had expected to be. The Pollution Prevention course saw the largest change in results between the two surveys. The percentage of graduates decreased from 67% mentioning the course as most useful at graduation to 0% mentioning it as most useful after a year.

Multiple graduates mentioned in their survey responses that Sustainable Construction was beneficial because of the fact that the concepts taught have many different applications within different fields and that it provided a good overview of sustainability. One graduate mentioned that while Sustainable Construction and Pollution Prevention may be most useful to his/her future career, it was difficult to describe their benefits to potential employers due to lack of technical depth. There were two additional comments regarding changes to the core courses. One graduate stated that it would be helpful if more courses could be added for students focusing on water/wastewater or water resources. Another suggested that Risk Assessment could be taught over two semesters so topics could be covered in greater detail.
2.3 Bloom’s Taxonomy Evaluation of Core Courses

In addition to the results of surveys, the core courses were evaluated using Bloom’s Taxonomy. Each course was rated with regards to each of the eight competency areas using the Bloom’s Taxonomy framework. The core courses were considered individually and as a whole to ensure that students are educated sufficiently in these competency areas of sustainability and resiliency.

Table 2.1 was developed to map the core course contents to the eight desired sustainability and resiliency competencies based on Blooms Taxonomy. The levels determined for each competency indicate the minimum cognitive level of learning achievement which students are expected to reach in the course. The levels are considered cumulative and achievement of higher learning levels indicates mastery of all lower levels.
Table 2.1: Core Course Competency Ratings Based on Bloom’s Taxonomy

<table>
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<th>Course Code</th>
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<th>Life Cycle Assessment</th>
<th>Energy Efficiency/Alternative Energy</th>
<th>Conservation/Resilience</th>
<th>Carbon Accounting</th>
<th>Structural/Non-Structural Protection</th>
<th>Rapidity</th>
<th>System Analysis</th>
<th>Biomimicry</th>
<th>Sum</th>
<th>Average</th>
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<td>CE 893</td>
<td>Sustainable Construction Materials</td>
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<td>Sustainable Construction</td>
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Table 2.1 shows that only one course, Sustainable Infrastructure Systems, provides instruction for students in all eight competency areas. However, all courses provide instruction in at least half of the eight areas. Generally, courses which provide
instruction in fewer competency areas do so at a higher level. The lowest average level for all the eight areas of a course that has been accepted as a core course is 2.4. A reasonable minimum average of 2.0 or 2.5 could be established as a requirement for future courses to meet in order to be considered as core courses. It should be noted that instructors complete these ratings independently for the course(s) which they teach and as a result, there is an amount of variation in ratings due to the subjective nature. It would be beneficial if a brief description of how each course provides instruction at the given level for each competency area were required to be submitted in addition to the ratings. The steering committee could then also judge whether the given ratings are appropriate to maintain some level of consistency between courses.

It is possible for a student to take the three required core courses and not be exposed at all to one of the following five competencies: Energy Efficiency/Alternative Energy, Carbon Accounting, Structural/Non-Structural Protection, Rapidity, and Biomimicry. The same would be true if students were required to take only two core courses, which has been suggested as a means of providing more flexibility to students for taking additional concentration courses.

The competency area of Energy Efficiency/Alternative Energy is not discussed at all in three of the eleven core courses. Carbon Accounting, Structural/Non-Structural Protection, and Rapidity are not discussed in four of the eleven core courses. Biomimicry is not discussed in six of the eleven core courses. The remaining competency areas are discussed at some level in at least nine of the eleven core courses, which is the minimum they should be to ensure all students have at least some understanding of all selected
areas. It is a challenge to balance the need for competencies to be taught in depth and
detail with the need for the full breadth of topics to be taught. Typically, either fewer
topics can be presented in more depth or a wide breadth of topics can be presented in less
depth. It is challenging to achieve both depth and breadth of knowledge.

Conservation/Resourcefulness is the only competency discussed in all core courses and at
a high level in the majority of courses.

There are three competency areas which are discussed in eight or more core
courses at a level of 4-analysis or greater. These are Life Cycle Assessment,
Conservation/Resourcefulness, and System Analysis. As a result, students are highly
likely to have a good understanding of these concepts after completing the SMP. The
remaining five competency areas are only discussed at a level of 4-analysis or greater in
five or fewer core courses, which means students are likely to receive less depth of
instruction on these concepts.

There are two courses which only discuss four of the eight competency areas.
These are Urban Transportation Planning and Biocomplexity Seminar. Therefore, these
two courses may need to be more carefully balanced with other courses which provide
instruction in the remaining areas. All other courses discuss five or more competencies at
some level. There are seven courses (Sustainable Construction, Risk Assessment,
Environmental Systems, Structural Health Monitoring, Biocomplexity Seminar, Repair
and Rehabilitation of Concrete Structures, and Infrastructure Corrosion) which address
four or more competency areas at a rating level of 4-analysis or higher. These courses
provide in depth learning of at least half of the eight competencies.
Next, the Bloom’s Taxonomy ratings for the core courses were cross referenced with the particular core courses each SMP graduate took. For each individual student, the levels achieved of each competency were averaged for all core courses taken. That is, the levels achieved for each area in each course were added together and then divided by the number of courses taken, which was either three or four. These results are displayed in Table 2.2.

Table 2.2: Bloom’s Taxonomy Student Averages

<table>
<thead>
<tr>
<th>Student</th>
<th>Life Cycle Assessment</th>
<th>Energy Efficiency/Alternative Energy</th>
<th>Conservation/Resourcefulness</th>
<th>Carbon Accounting</th>
<th>Structural/Non-Structural Protection</th>
<th>Rapidity</th>
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<td>3.1</td>
<td>5.0</td>
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<td>2.8</td>
<td>2.5</td>
<td>5.4</td>
<td>2.5</td>
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From Table 2.2, it is clear that there were three competency areas, Structural/Non-Structural Protection, Rapidity, and Biomimicry, which a student was never exposed to in courses. There were two different students who were not exposed to one or more of these areas. The fourteen other SMP students received some level of exposure to all eight competency areas in their core courses. Therefore, it is unusual for a student to not receive any exposure in classes to a competency area, but it has happened twice.

![Figure 2.4: Average Bloom’s Taxonomy Levels Achieved by Students](image)

From Figure 2.4, it is clear that as a whole, students received the most exposure overall to the areas of Life Cycle Assessment, Conservation/Resourcefulness, and System Analysis. These are the three competency areas mentioned previously which are
discussed in eight or more core courses at a level of 4-analysis or greater. Students received the least amounts of exposure to Carbon Accounting, Rapidity, and Biomimicry. The majority of students achieved at least a level 3-application in each competency area.

It could be suggested that Sustainable Infrastructure Systems, or another course which provides instruction in all eight competency areas, be required for all SMP students to provide an overview and ensure all students are exposed to concepts of all competency areas. Sustainable Infrastructure Systems would be a particularly good course choice for this because not only does it include all eight competency areas, but it actually does so at a minimum of level 3-application on the Bloom’s Taxonomy scale. According to data shown in Figure 2.1, Sustainable Infrastructure Systems is already one of the core courses taken most often by students.

2.4 Summary

SMP students are required to complete nine credits of core courses, which have technical content in the eight fundamental competency areas related to sustainability and resiliency. In the Graduate Exit Survey, the greatest normalized percentage of graduates predicted that Risk Assessment, followed closely by Sustainable Construction Materials, Sustainable Construction, and Pollution Prevention, would be the core course most useful to their career (Figure 2.2). In the One-Year-Out Graduate Survey, Sustainable Construction and Sustainable Construction Materials were the courses mentioned by the greatest normalized percentage of graduates as most useful to their career (Figure 2.3).
Only one course, Sustainable Infrastructure Systems, provides instruction for students in all eight competency areas of sustainability and resiliency (Table 2.1). It is possible for a student to take the three required core courses and not be exposed at all to one of the following five competencies: Energy Efficiency/Alternative Energy, Carbon Accounting, Structural/Non-Structural Protection, Rapidity, and Biomimicry. In fact, there are three competency areas, Structural/Non-Structural Protection, Rapidity, and Biomimicry, which a student was never exposed to in core courses (Table 2.2). It is unusual for a student to not receive any exposure in classes to a competency area, but it has happened for two students.

There are three competency areas which are discussed in eight or more core courses at a Bloom’s Taxonomy level of 4-analysis or greater. These are Life Cycle Assessment, Conservation/Resourcefulness, and System Analysis. As a result, students received the most exposure overall to these areas (Figure 2.4). Students received the least amounts of exposure to the areas of Carbon Accounting, Rapidity, and Biomimicry.

It is recommended that Sustainable Infrastructure Systems, or another course which provides instruction in all eight competency areas, be required for all SMP students to provide an overview and ensure all students are exposed to concepts of all competency areas. Sustainable Infrastructure Systems would be a particularly good course choice for this because not only does it include all eight competency areas, but it actually does so at a minimum of level 3-application on the Bloom’s Taxonomy scale. According to data shown in Figure 2.1, Sustainable Infrastructure Systems is already one of the core courses taken most often by students.
Moving forward, it would also be recommended that the core course list be expanded when possible. This will allow more flexibility to accommodate the schedules and interests of individual students. Students would like more core courses relating to the six civil engineering specialty areas so they can expand their depth of technical knowledge while still learning applications of sustainability and resiliency concepts. Learning to apply these concepts to specific areas of interest will be more useful to students in future careers. Existing courses should be examined to determine whether there are any that meet SMP requirements but have not been added because the professor has not submitted a request. Also, encouraging professors to incorporate sustainability and resiliency concepts into existing courses when possible would be an easier way to expand the core course list than developing new courses, while benefitting students outside the SMP as well.
CHAPTER THREE

BUSINESS-RELATED AND SEMINAR COURSES

3.1 Business-Related Courses

The second course requirement of the SMP is for each student to complete nine credits of business-related graduate courses (three three-credit courses). The business-related courses are courses which provide instruction to students on various business and policy topics. These graduate courses are intended to provide students with knowledge of the relationship between business and technology, planning, scheduling, contracts, ethics, policy, and social change.

Initially the list of approved business-related courses was limited to the following four courses: Technology and Innovation Management, Policy and Social Change, Construction Estimating and Project Control, and Construction Specifications and Contracts. However, after the first semester, the Steering Committee realized that greater flexibility was needed to accommodate student schedules. Additionally, some students had taken some of the approved courses at the undergraduate level as well, which limited their options even further. Thus, the initial list of approved business classes was expanded to include any business-related class. There is more flexibility for business-related courses to be approved and added than for core courses. Currently, there are sixteen accepted SMP business-related courses, and a complete list of these is provided in Appendix A: Program Requirements.
All business-related courses were pre-existing at the university; none were created for the purpose of the SMP, as some of the core courses were. Additionally, a number of SMP students have received approval to take a total of seven other business-related courses not included on the current list of sixteen and apply these toward their course requirement.

Most of the business-related courses are taught by faculty members not involved in the development of the SMP. Many of the courses are taught in other academic departments, including Business Administration, Sociology, City and Regional Planning, Construction Science and Management, Economics, and Policy Studies. A few of the courses are Civil Engineering courses which teach a business or management component, such as Construction Estimating and Project Control, Construction Specifications and Contracts, Construction Planning and Scheduling, and Project Management Applications.

The business-related courses completed by the sixteen SMP students who had graduated by December 2013 are summarized in Figure 3.1. Of these sixteen students, fourteen fulfilled the program requirement by taking three business-related courses, while two students exceeded the requirement and took additional business-related courses for a total of five each. Also, note that two students took CE 851 and one took EX ST 802, which deal with tools that are used in business.
The first four courses listed in Figure 3.1 were the original four business-related courses of the SMP. The remaining twelve accepted courses were added to the business-related course list in semesters after the first SMP students had begun the program. Therefore, the initial SMP students had much more limited business-related course options, which is probably why those first four courses have been taken by more students than most of the other courses.
It also should be noted that these data do not account for how often each of these courses has been offered. It is possible that courses which have been taught more often in recent years may have been taken by more students due to availability.

In both the Graduate Exit Survey and the One-Year-Out Graduate Survey, SMP graduates were asked to answer the question “What business/management course(s) will be/has been most useful to you in your career? Why?” The number of times each course was named in the responses was tabulated and normalized to a percent based on how many of the responding students took each of the business-related courses. The normalized percentage results are shown in Figure 3.2 and Figure 3.3, for the Graduate Exit Survey and the One-Year-Out Graduate Survey, respectively. The non-normalized raw survey data are located in Appendix C.
In the Graduate Exit Survey, the greatest percentage of graduates predicted that Water Policy and Law and Marketing Foundation would be the business-related courses most useful to their career (Figure 3.2). However, it is necessary to consider that two and one students took these two courses, respectively, so the sample sizes were small.
In the ten One-Year-Out Graduate Surveys that were received, the answers changed and Construction Planning and Scheduling became the business-related course.
mentioned by the greatest percentage of graduates as most useful to their career (Figure 3.3). This course was not mentioned at all in the Exit Survey results. Water Policy and Law and Marketing Foundation, which had been mentioned as most useful in the Exit Survey, were not mentioned at all in the One-Year-Out Survey results.

Only three graduates named the same course in the One-Year-Out Survey as they did in the Exit Survey as most useful, while six other graduates named a different course after working for a year. Two graduates stated that none of the business or management courses have been useful in their careers thus far, though one of these expressed desire to eventually move into a job involving more of the business sector. Multiple graduates mentioned in their survey responses that though some of the concepts from business courses are difficult to apply at the current stage in their careers, they expect knowledge of these concepts may become more useful in future management positions. It will be useful to follow up with students in the future and see whether this is the case. One graduate stated that the skills taught in these courses were not addressed in the undergraduate curriculum and he/she would have enjoyed taking more of these courses.

These results should be viewed with caution due to small sample size. Because there are many business-related course options available for students, only one or two students have taken many of the particular courses. As more graduates complete the program and each course is taken more times, sample size will increase, and specific results can be considered to be more significant. Continual, regular follow-up evaluations of the business-related courses are recommended.
It is recommended that as the SMP continues the business-related course list continue to be expanded when possible, in order to allow students maximum flexibility to select courses that fit their individual schedules and interests, while still ensuring that students receive instruction on various, relevant business and policy topics. Having more available, approved options allows students to choose business-related courses which cover concepts that align with their specific career goals, which will be more beneficial to students in their futures. Existing courses in departments including Civil Engineering, Business Administration, Sociology, City and Regional Planning, Construction Science and Management, Economics, and Policy Studies should be examined to determine whether there are any that meet the goals of the SMP business-related course requirement but have not yet been added. Also, the seven business-related courses which have been approved previously on a case-by-case basis for students to take and apply toward the course requirements should be added to the accepted list as options for other students to select from.

3.2 Seminar Courses

It is required that all SMP students take two credits of business seminar courses (two one-credit courses). The approved seminars are Business Communications and Ethics and Leadership, which are taught through the MBA program. The goal of these courses is to provide students with professional, business, ethics, communication, and leadership training. The Business Communications course provides “techniques, skills, problems and approaches for effective business communications; strengths and

In both the Graduate Exit Survey and the One-Year-Out Graduate Survey, SMP graduates were asked to answer the question “What seminar course(s)—Business Communications; Ethics and Leadership—will be/has been most useful to you in your career? Why?” The number of times each course was stated in the responses was tabulated and normalized to a percent based on how many of the responding students took each of the seminar courses. The normalized percentage results are shown in Figure 3.4 and Figure 3.5, for the Graduate Exit Survey and the One-Year-Out Graduate Survey, respectively. The non-normalized raw survey data are located in Appendix C.
Of the two business seminar courses, Ethics and Leadership was named by more graduates in the Graduate Exit Survey as the course that would be most useful to their career (Figure 3.4).

Because of a scheduling conflict, one student received approval to take the Biocomplexity Seminar, which is a core course option, in place of the Seminar on Ethics and Leadership. This one student listed the Biocomplexity Seminar as the course that would be most useful to his/her career. For this reason, the Biocomplexity Seminar is the seminar course with the greatest percentage of graduates who had taken the course and predicted that it would be most useful, as shown in Figure 3.4.
In the One-Year-Out Graduate Survey, the two business seminar courses were each chosen equally by seven respondents as most useful to their career (Figure 3.5). Two graduates who returned the survey did not provide an answer for this question. Surprisingly, the seven graduates who responded were consistent and named the same course(s) in the One-Year-Out Survey as they did previously for the Exit Survey. The Biocomplexity Seminar was not mentioned in the results of the One-Year-Out Survey. One student stated that neither course has been particularly useful.

Some reasons that graduates said the Ethics and Leadership course was most useful were that it was better taught, provided several tools to be an effective leader, used

Figure 3.5: Seminar Course Most Useful to Career – One-Year-Out Graduate Survey
useful books, and provided insight on developing individual strengths and how to approach different situations and people.

Some reasons provided by graduates that the Business Communications course was most useful were that presentations and business writing will always be a career requirement and the concepts taught are used every day by graduates. In addition, it provided information on how to effectively disseminate work and communicate with diverse audiences including non-engineers.

A few graduates also commented that several of the topics covered in the seminar courses were also taught in other civil engineering or undergraduate level courses. Another suggested that a management course taught on the main campus would be beneficial to graduate students in many fields.

3.3 Summary

SMP students are required to complete nine credits of business-related graduate courses, which provide instruction to students on various business and policy topics. Currently, there are sixteen approved SMP business-related courses, but nearly any business-related class may be taken.

In the Graduate Exit Survey, the greatest normalized percentage of graduates predicted that Water Policy and Law and Marketing Foundation would be the business-related courses most useful to their career (Figure 3.2). However, it is necessary to consider that two and one students took these two courses, respectively, so the sample sizes were small. In the One-Year-Out Graduate Surveys, Construction Planning and
Scheduling was the business-related course mentioned by the greatest normalized percentage of graduates as most useful to their career (Figure 3.3).

Multiple graduates mentioned in their survey responses that though some of the concepts from business courses are difficult to apply at the current stage in their careers, they expect knowledge of these concepts may become more useful in future management positions. It will be useful to follow up with students in the future and see whether this is the case. These results should be viewed with caution due to small sample size. Because there are many business-related course options available for students, only one or two students have taken many of the particular courses. As more graduates complete the program and each course is taken more times, sample size will increase, and specific results can be considered to be more significant. Continual, regular follow-up evaluations of the business-related courses are recommended.

It is recommended that as the SMP continues the business-related course list continue to be expanded when possible, in order to allow students maximum flexibility to select courses that fit their individual schedules and interests, while still ensuring that students receive instruction on various, relevant business and policy topics. Having more available, approved options allows students to choose business-related courses which cover concepts that align with their specific career goals, which will be more beneficial to students in their futures. Existing courses in departments including Civil Engineering, Business Administration, Sociology, City and Regional Planning, Construction Science and Management, Economics, and Policy Studies should be examined to determine whether there are any that meet the goals of the SMP business-related course requirement
but have not yet been added. Also, the seven business-related courses which have been approved previously on a case-by-case basis for students to take and apply toward the course requirements should be added to the accepted list as options for other students to select from.

It is required that all SMP students take two business seminar courses, Business Communications and Ethics and Leadership taught through the MBA program. The goal of these courses is to provide students with professional, business, ethics, communication, and leadership training.

Of the two business seminar courses, Ethics and Leadership was named by more graduates in the Exit Surveys as the course that would be most useful to their career (Figure 3.4). In the One-Year-Out Graduate Survey, the two business seminar courses were each chosen equally by seven of the ten respondents as most useful to their career.

The seminar courses provide information that is critical for succeeding in a professional environment. While some students may have received the same information elsewhere during their education, many other students spoke highly of the value received by taking the seminars. In addition, the seminars are courses which provide a large amount of benefit, while requiring a much smaller amount of work and time when compared to technical courses. They are taught every semester, so students have multiple opportunities to fit these courses into their schedules. For these reasons, it is recommended that the business seminar course requirement remain as is for future SMP students.
CHAPTER FOUR

INTERNERSHIP

4.1 Background

The internship/traineeship component of the SMP requires each student to complete an internship/traineeship away from the Clemson University main campus, which involves interactions with professionals outside academia and practical engineering experience, and has duration of at least five weeks. As was stated in the original NSF program proposal, “Interns’ assignments will be strategically made with the requirement that the assignments provide interns with hands on experience, appreciation of the skills needed, and broader understanding of sustainability and resiliency from a business point of view.”

SMP students completed internships with a variety of types of organizations, including federal, state, and city government organizations, non-profit organizations, and private companies. Efforts were made to match each student’s research program and interests with the interests of an appropriate organization. The types of internships completed by the sixteen SMP students who had graduated by December 2013 are summarized in Figure 4.1.
The majority of student internships have been with federal government organizations and private companies (Figure 4.1). Some of the SMP external partners and advisory board members assisted in providing and connecting students with internship opportunities. The numbers are approximately even as to how many internship opportunities were found through an advisory board member connection, an advisor connection, or an intern connection. As a result, students gained experience in government labs, foundations, and industry firms. A number of internship institutions provided partial or full support to student interns. SMP educational supplement funds were used as needed to either fully or partially support internship travel/living expenses. Internships were located across the country in various parts of South Carolina, Florida, New Mexico, Tennessee, North Carolina, Illinois, Mississippi, and Georgia.
4.2 Student Evaluation of Internship

In both the Graduate Exit Survey and the One-Year-Out Survey, the SMP graduates were given the statement, “I believe that my internship contributed significantly to my preparation to immediately contribute to the workforce,” and asked to select one of the following answers: strongly agree, agree, neutral, disagree, strongly disagree. The results are summarized in Figure 4.2 for the Graduate Exit Survey and Figure 4.3 for the One-Year-Out Survey.

![Graph showing distribution of responses](image)

Figure 4.2: Internship Contributed to Workforce Preparation – Graduate Exit Survey

At the time of graduation, the majority of SMP graduates either agreed or strongly agreed that their internship prepared them to immediately contribute to the workforce (Figure 4.2). Two graduates selected the “neutral” option, and none disagreed or strongly disagreed with the statement.
One year after graduation, fewer graduates selected the “agree” or “strongly agree” answer choices in response to the same question, and a couple more chose the “neutral” option (Figure 4.3). However, there were still no responses in the “disagree” or “strongly disagree” categories. These results indicate that, in general, graduates believe the internship experience was beneficial in preparing them to start their careers.

Graduates were also asked to respond to the question, “What internship experience(s) will be has been most useful to you in your career? Why?” in each of the two graduate surveys. The results are summarized in Figure 4.4 for the Graduate Exit Survey and Figure 4.5 for the One-Year-Out Survey.
The most common themes in graduate replies for the Graduate Exit Survey were that the internship experience enabled students to learn new skills, showed what it would be like to work for a particular type of organization, and helped students to better understand various applications of concepts learned through class and research (Figure 4.4). All graduates listed at least one benefit of the internship experience and many included multiple specific examples. One student stated, “The internship experience is an excellent requirement in this program…There are a lot of things that cannot be taught in the classroom…This experience definitely makes me feel more prepared for an entry level geotechnical engineering job.” In addition, two students indicated that their internship experience helped them to find a full time job.
Graduates provided similar answers on the One-Year-Out Survey as they did on the Exit Survey. Of the eight graduates who provided answers to this question, six stated the same experience(s) that were most useful as they did on the previous survey.

Common responses include interaction within departments and with coworkers and exposure to a specific task which the graduate now performs regularly (Figure 4.5). One student stated that the internship influenced his/her master’s thesis and provided opportunities he/she would not have had without the SMP program. Another stated, “I am much more confident in both my abilities and the subject matter because of this experience.”
Graduates believe that the internship component of the SMP contributed significantly to their preparation to immediately contribute to the workforce. There are also many experiences that graduates gained from their internships which are useful to their careers. Graduate responses to questions regarding their internships remained very consistent one year after graduation to responses given at the time of graduation.

4.3 Supervisor Evaluation of Internship

The internship supervisors are another valuable source of information regarding the SMP internship component. Eight internship supervisors provided responses to survey questions related to the interns specifically and the SMP as a whole. The supervisors were first asked to “describe the ways in which the intern’s performance benefited your organization.” Their responses are summarized in Figure 4.6.
The most common responses were that the intern conducted research or worked on a project, prepared a report or produced a product, and brought knowledge and/or experience to the organization (Figure 4.6). One supervisor also mentioned that an additional benefit of hosting an intern was “maintaining a recruiting pipeline through sustained relationships with universities such as Clemson.”

Supervisors were asked to “describe the engineering responsibilities that were supervised,” to which there was a wide variety of answers. Examples include conduction of research and experiments, data collection, data analysis and synthesis, preparation and delivery of presentations and conference papers, spreadsheet development, site visits and assessments, design parameter development, test plan development, various calculation,
full project design, materials testing, and report preparation. The specific engineering tasks requested of interns were dependent on the internship organization and supervisor. While each intern had very different responsibilities, all interns had the experience of completing engineering tasks in a professional environment.

Next, supervisors were asked to “describe, if any, the ways in which these responsibilities involved the application of concepts in sustainable and resilient infrastructure.” Again, answers varied, but sustainable and resilient infrastructure concepts and technologies mentioned included pervious pavements; low impact development; wind energy technology; code-plus building practice and application; levee design, repair, and maintenance and flood remediation; water reuse; and LEED rated projects. Two supervisors did not provide a response to this question. However, those who did explained direct ties between intern responsibilities and application of concepts in sustainable and resilient infrastructure.

Supervisors were asked whether the intern was offered a full-time position/employment upon graduation. One supervisor replied yes, the intern is working for the company full-time. Five replied no, either because positions were not available or there was no available funding at that time. Two other responses did not indicate yes or no, but stated that the intern had not yet graduated or the intern had other plans. While it would be ideal for every SMP student to intern at an organization that could offer a full-time position upon graduation, some of the organizations that may be unable to do this offer valuable experiences through internships. Non-profits, government organizations and labs are possible examples.
When asked the question, “Based on your experience, would you supervise other interns in the Sustainable and Resilient Infrastructure Science Master’s Program at Clemson University? Why?” all eight internship supervisors answered positively. Seven replied yes, and one replied perhaps, depending on the student’s desire to learn and participate in the practice of the organization. Comments included statements that previous Clemson interns have been productive and fit in well, came in with exactly the right skill sets, were well-rounded, had confidence in tasks handled, and were high quality participants.

Internship supervisors were asked to provide suggestions for improving the internship experience for students in the Sustainable and Resilient Infrastructure Science Master’s Program. The most common response was to ensure there is mutual interest in the internship between the student and the internship organization. A mutual interest is critical for both parties to obtain maximum benefit from the arrangement. It was suggested that coordinating well in advance and having Clemson staff, faculty, and/or advisors more involved in providing input would help achieve this. Another suggestion is to bring students for one to two day site visits in advance so they can better learn the type of work at the organization. These suggestions should be taken into consideration. Advisors should take an active role in helping their students locate internship opportunities that align with their research and career interests and goals. Planning should begin at least a semester ahead of when the internship will occur in order to ensure there is plenty of time to locate and arrange the best possible match. Site visits should be considered, supported, and encouraged when appropriate. Additional comments from
supervisors include having the intern begin background work and planning before arrival onsite and continuing to give students hands-on experiences in real world scenarios.

The last question asked of the internship supervisors in the survey was, “Would your organization be willing to provide financial support for future interns or applied research in Sustainable and Resilient Infrastructure? Describe any financial support that might be provided.” Two supervisors stated that no, their organizations are unable to provide financial support, but they can continue to provide internship opportunities. One supervisor stated he/she is not qualified or authorized to make such commitments. Two supervisors responded that they could possibly provide support. One said project funds could be provided if available. One said the organization could continue to hire future interns. And one replied that his/her organization is already providing support for two students. In total, five organizations of eight surveyed are or may be able to provide some form of financial support to the SMP.

4.4 Summary

The internship component of the SMP requires each student to complete an internship/traineeship involving interactions with professionals outside academia and practical engineering experience. Interns should gain an understanding of sustainability and resiliency from a business point of view. SMP students completed internships with organizations including federal, state, and city government organizations, non-profit organizations, and private companies. The majority of internships were with federal government organizations and private companies (Figure 4.1).
Based on survey results, graduates believe the internship experience was very beneficial. There are many experiences that graduates gained from their internships which are useful to their careers, including the learning of new skills, learning what it would be like to work for a particular type of organization, and gaining a better understanding of various applications of concepts learned through class and research (Figure 4.4). Graduates believe that the internship component of the SMP contributed significantly to their preparation to immediately contribute to the workforce (Figure 4.2 and Figure 4.3).

Interns provided benefit to the internship organizations primarily through contributions of work and knowledge (Figure 4.6). All interns had the experience of completing engineering tasks in a professional environment. Intern responsibilities were also directly related to application of concepts in sustainable and resilient infrastructure.

One possible improvement to the internship component is to connect more interns with companies who are willing and able to consider hiring interns full-time after graduation. However, while it would be ideal for more SMP students to have this opportunity, there are organizations which offer valuable, unique experiences through internships but are not able to hire for full-time positions.

All internship supervisors who completed the survey expressed willingness to supervise other interns in the SMP at Clemson University, because previous Clemson interns have been productive, skilled, well-rounded, confident, and high quality participants. Five supervisors of eight who responded to the surveys said their organizations are or may be able to provide some form of financial support for future
interns or applied research to the SMP. Two organizations are unable to provide financial support but can continue to provide internship opportunities.

Internship supervisors suggested the internship experience could be improved by ensuring there is mutual interest in the internship between the student and the internship organization. Coordinating well in advance and having Clemson advisors more involved in providing input during the internship planning stages would help achieve this. The SMP internship component has proven to be successful thus far, and by taking a few minor steps it should continue to be only more successful in the future.
CHAPTER FIVE

RESEARCH, THESES, AND CONCENTRATION COURSES

5.1 Report Evaluation of Research and Theses

The research experience component of the SMP requires all students receiving NSF SMP funds to complete a research thesis report and all other students to complete a graduate research project report focusing on topics relevant to sustainable and resilient infrastructure. As was stated in the original NSF program proposal, “Research topics will be selected to address a need identified by the partners as well as by the faculty participants. A workshop will be held annually at Clemson where the students, faculty, and representatives of our partners will work together to identify research needs, internship details, and expected outcomes…SMP students’ research topic will be selected in concert with our partners’ needs as well as national priorities.” Topic determination has been primarily faculty advisor driven with input from advisory committee members. Some advisory committee members also served as external readers of research theses.

As of December 2013, sixteen students had completed the program. Of those, fifteen completed a research thesis report. Certain aspects of the SMP students’ thesis reports were compared with those of thesis reports of other students in the Clemson Civil Engineering Master’s program for the same time period. All Master’s thesis reports of students who graduated between December 2011 and December 2013 were considered. This included fifteen SMP student reports and twenty-nine non-SMP student reports.
The first factor compared was the use of the terms “sustainability” and “resiliency” (and all similar forms of those terms such as “sustainable,” “resilient,” and “resilience”) in thesis reports of the two student groups. It was assumed that use of these terms indicated discussion of topics relevant to sustainable and resilient infrastructure in research. The goal was to determine whether SMP student reports included discussion of these topics more frequently than non-SMP civil engineering students. The average number of times these terms appeared in reports for the two groups is summarized in Table 5.1.

Table 5.1: Average Number of Times Terms Appeared in Thesis Reports

<table>
<thead>
<tr>
<th></th>
<th>SMP</th>
<th>Non-SMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>15.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Resiliency</td>
<td>8.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Both terms appeared on average much more frequently in thesis reports of SMP students. “Sustainability” (and similar terms) was used almost twice as often as “resiliency” was in SMP reports and more than three times as often in non-SMP reports. It is possible that this is because students are more familiar with the concept of sustainability than resiliency, especially non-SMP students. Over half (52%) of non-SMP students did not use either term at all in their report, and only 10% used both terms. There was only one SMP student who did not use either of these terms in his/her report, and 40% of SMP students used both terms. In the future, it should be ensured that all SMP students are clearly describing the connection of their research to sustainability.
and/or resiliency concepts since this is a fundamental aspect of the SMP. However, in
general, the data suggest that relevant concepts of sustainable and resilient infrastructure
have been discussed and studied in SMP student research more than in non-SMP student
research, which provides support for the fact that this particular goal of the SMP is being
met.

The SMP has provided a unique opportunity for interdisciplinary research
collaborations. There have been new collaborations of faculty in different concentration
areas within the Glenn Department of Civil Engineering, as well as collaboration with
faculty in departments other than Civil Engineering, including the Department of
Environmental Engineering and Earth Science, the Department of Architecture, and the
Department of Materials Science and Engineering. The frequencies of these various
collaborations are highlighted in Table 5.2 for SMP and non-SMP research theses
completed between December 2011 and December 2013.
Twenty-seven percent of SMP students had research committee co-chairs either from different concentration areas or different departments. Only 10% of non-SMP students had a similar co-chair arrangement. Twenty-seven percent of SMP students had a faculty member from a different department serve on their research committee, while only 10% of non-SMP students had a committee member from a department outside civil engineering. Fifty-three percent of SMP students had research committees comprised of members who were all from different areas. This means over half of SMP students have brought together committees with representatives from three or more different areas of study. Only 14% of non-SMP students have done the same. Committees with all members coming from the same single concentration area have only served 20% of SMP students, while 38% of non-SMP students have had all committee members from a single
area. According to these data, interdisciplinary research collaborations have occurred within the SMP at a much higher rate than within the rest of the Civil Engineering Department at the Master’s level. A high percent of current SMP students have co-chairs from different areas as well.

As of December 2013, publications produced by SMP students included fifteen Master’s thesis reports, one graduate project report, seven peer-reviewed journal papers, eleven conference papers, and seven other professional conference presentations. There are currently five additional thesis reports in preparation. A full list of publications is located in Appendix D.

Based on SMP student research, along with research by PhD students in another Departmental initiative, several new research proposals on sustainability and resiliency topics have been written. This has resulted in two new grants totaling $1.1 million so far.

5.2 Student Evaluation of Research and Theses

In both the Graduate Exit Survey and the One-Year-Out Survey, the SMP graduates were given the statement, “I believe that my research project contributed significantly to my preparation to immediately contribute to the workforce,” and asked to select one of the following answers: strongly agree, agree, neutral, disagree, strongly disagree. The results are summarized in Figure 5.1 for the Graduate Exit Survey and Figure 5.2 for the One-Year-Out Survey.
At the time of graduation, the majority of SMP graduates agreed that their research project prepared them to immediately contribute to the workforce (Figure 5.1). Two graduates strongly agreed and one selected the “neutral” option. None disagreed or strongly disagreed with the statement.

Figure 5.1: Research Project Contributed to Workforce Preparation – Graduate Exit Survey

Figure 5.2: Research Project Contributed to Workforce Preparation – One-Year-Out Graduate Survey
One year after graduation, only one graduate selected the “strongly agree” option and fewer selected “agree” in response to the same question. The number of graduates who chose the “neutral” option increased (Figure 5.2). Four of the graduates who completed both surveys chose less favorable responses to this question on the One-Year-Out Survey than they provided on the Exit Survey. However, there were still no responses in the “disagree” or “strongly disagree” categories. These results indicate that, in general, graduates believe the research experience was beneficial in preparing them to start their careers. Individual opinions certainly depend on specific research topics and career paths.

In the future, it would be beneficial if another question or two about the research experience were asked on the graduate surveys in order to gather more student feedback. Perhaps an open ended question allowing room for individual comment and explanation would be appropriate.

5.3 Advisor Evaluation of Research and Theses

Sixteen out of the twenty-one Civil Engineering tenure or tenure-track faculty served as an SMP research project advisor or co-advisor. These research advisors were another group surveyed, and nine provided responses to survey questions related to the research aspect specifically and the SMP as a whole. The advisors were first asked to “describe the ways in which the SMP funding has benefited your research program.” Their responses are summarized in Figure 5.3.
The most common responses were that the funding allowed research to be started in a new area, allowed for hire of a graduate student, and facilitated collaboration outside the department (Figure 5.3). One advisor stated, “The SMP fund provided an opportunity for me to explore a new collaborative research project with faculty in another area.” Other benefits which SMP funding made possible for advisors include purchase of new research materials and/or equipment, completion of publications, and data generation for future proposals.

Advisors were then asked “How did the SMP funding change or impact your research?” This question yielded similar responses as the previous question. Responses are summarized in Figure 5.4.
Again, the most common responses were that funding allowed research to be started in a new area and facilitated new collaboration (Figure 5.4). Other ways in which funding changed or impacted research for advisors include that it allowed for generation of data to be used in future research, preparation of new research proposals, hire of a new graduate student, and purchase of new materials and/or equipment. One advisor explained, “The SMP program ignited collaboration between the two project advisors…as they were advising the SMP fellow. This collaboration has fostered new concepts of robust design, and its application to both structural and geotechnical engineering are being pursued. As a result, two proposals have been submitted. One of these proposals received funding from the National Science Foundation. [The SMP fellow] has been instrumental in the preparation of both proposals.”
Advisors were asked to provide their opinions on how sustainability and resiliency could be better taught. Their responses are summarized in Figure 5.5. The suggestion provided by the most advisors is to incorporate the relevant sustainability and resiliency aspects into existing courses and provide workshops to faculty with instruction on methods of how to best accomplish this (Figure 5.5). A couple of advisors instead recommended teaching the sustainability and resiliency concepts in a required general seminar course which would provide a broad overview. Both suggestions are valid options and it would actually be recommended to combine the two approaches. A single, required seminar course should be created which would be taken in the first semester in order to provide basic information on the concepts and applications. In addition, incorporation of sustainability and resiliency concepts into all existing courses would allow further instruction and detail for students on how the concepts can be applied in their particular fields of interest.
Advisors were asked the question, “Do you think the Sustainable and Resilient Infrastructure SMP should remain a program where students are also identified with one of the six specialty areas (i.e., Applied Fluid Mechanics, Construction Engineering and Management, Construction Materials, Geotechnical Engineering, Structural Engineering, Transportation Systems)? Or should Sustainable and Resilient Infrastructure become a new and separate specialty area? Why?” Eight of nine advisors think the SMP should remain a program where students also identify with a specialty area, while one advisor believes Sustainable and Resilient Infrastructure should become a new specialty area. Reasons that were provided for maintaining the program as it is currently are summarized in Figure 5.6.
The two primary reasons that advisors believe the SMP should remain a program where students also identify with one of the six civil engineering specialty areas are so students appeal to a broader job market and are sought after by employers and so technical depth of knowledge is not compromised (Figure 5.6).

The next question advisors were asked was, “Based on your experience, would you encourage some of your future graduate students supported on your research or a teaching assistantship to complete the SMP requirements? Why?” Four advisors responded yes, one responded no, and three said it would depend on the individual student’s research interests and career goals. The one advisor who replied that he/she would not explained that the reason was the student would likely lack technical
coursework. Comments provided by the other eight advisors are summarized in Figure 5.7.

![Figure 5.7: Comments about Encouraging Future Graduate Students to Complete SMP – Advisory Survey](image)

Many advisors stated in support of the SMP that they recognize there is a benefit to taking courses outside of a focus area in order to develop other skill sets. However, most also recognize that there needs to be a balance between this and developing enough technical strength in a focus area. Other comments included that the SMP is a flexible program which matches interests of many students, there is a sense of community which develops between the students undertaking the program, and it provides a good research experience.
One advisor addressed particular instances in which the SMP may not be the best option for some students. This advisor stated, “Yes, I would encourage some of my future graduates to go through the SMP program. The SMP fellows will be able to differentiate themselves from the other MS students by demonstrating that they have the skill sets to address issues in a new frontier in civil engineering. However, depending on the nature of the research topics and students’ future career plan, the SMP program might not be the right option for some of the MS graduates if (1) the particular MS research project or topic requires student to have in-depth technical background in one of the six specialty areas, and (2) the particular student interest and career plan are to become an advanced practitioner in one of the six “traditional” specialty areas.” Another advisor pointed out that the SMP coursework requirements may not be suitable for teaching assistants who have a heavy workload.

The final survey question asked of advisors was, “What other suggestions do you have for improving the Sustainable and Resilient Infrastructure SMP?” There were a variety of good suggestions given. One advisor recommended setting up peer advising where students about to graduate could give advice to students beginning the program regarding the internship portion. This advising could be extended to all aspects of the program. Students could be paired with one another based on their advisor or concentration area. It would be beneficial for first semester students to have a peer they could approach with questions related to courses, internship, research, etc. Another suggestion is to launch workshops or a seminar series in which students and faculty could share and exchange research experiences and ideas. This happens approximately once a
semester in the advisory committee meeting, but perhaps facilitating more frequent, informal opportunities to collaborate would be beneficial as well. One advisor mentioned that the program would become more beneficial if it were extended to a PhD program. Another suggested that a longer duration of funding, such as 4 semesters, would have allowed more flexibility in the curriculum for students. An important statement provided was that the SMP needs to “continue gathering feedback from students, industry, graduates, etc…. & be flexible enough to rapidly make changes based on this feedback.” This point is critical. The program needs to remain flexible and open to change based on the differing needs and opinions of the various stakeholders over time. There should be an ongoing conscious effort to improve the SMP whenever possible.

5.4 Concentration Courses

Students completing a research thesis are required to take a minimum of two three-credit courses from their concentration area. Students completing a graduate research project and report are required to take a minimum of three three-credit concentration courses. These courses are typically those which provide technical knowledge in a specific area, and often are selected to provide students with the necessary skills for completing their research. The student and graduate committee discuss and select which concentration courses will be most beneficial for the student.

In the Graduate Exit Survey and the One-Year-Out Survey, the SMP graduates were asked, “What concentration course(s) will be/has been most useful to you in your career? Why?” Responses to this question varied significantly because students
represented many concentration areas, had taken a wide variety of concentration courses, and had differing career goals. However, there were a few courses that were named more than once on the Graduate Exit Survey. These are Sustainable Energy, Properties of Portland Cement Concrete, and Matrix and Finite Element Analysis. One graduate stated, “I appreciate the diversity of choices available… [My concentration courses] in addition to the sustainability focused courses provided information both by depth and breadth.” Another graduate who had taken an additional concentration course mentioned, “Though it was a lot of extra work to take the extra concentration course I am happy that I did.”

In the One-Year-Out Survey, no course was mentioned more than once in the eight responses. Some graduates said that the most useful concentration courses were technical ones that taught particular concepts which they now use in their careers. Other graduates mentioned that other courses were most useful because they provided broad overviews of topics. For example, one graduate stated, “The sustainable energy course provided me a broad overview of how civil engineers can influence energy consumption for the general population for a long period of time.” Another said, “Materials management has been most useful because it provided a thinking process which has helped me to view my work in a more logical way to better utilize my time and resources.”

The only complaint provided about the concentration course component by both students and advisors is that students should take more of them. When advisors were asked the question, “Are you satisfied with the SMP coursework requirements? If not,
what change would you recommend?” the most frequent suggestion made was that students should take more concentration courses for greater technical depth. “A more flexible curriculum that allows students to take more ‘focus-oriented’ courses would enable the students to obtain more technical depth in their chosen focus area,” was one advisor’s response.

Seven of the nine advisors stated that they were satisfied with the SMP coursework requirements and provided recommendations and comments. The other two advisors did not clearly state whether or not they were satisfied, but did provide suggestions. Other recommended changes were to include more fundamental courses from departments such as economics and math, add an overall course on sustainability and resiliency, and put out a request for new courses. One advisor stated, “Yes, good blend of guidance & flexibility. Continue assessing students to determine courses that should no longer be required.” This brings up the useful point that not only should courses continue to be evaluated for addition to the SMP curriculum, but courses should also be evaluated for removal if students do not find them beneficial.

Half, eight of the sixteen, SMP students who graduated by December 2013 were able to complete additional credit hours of concentration courses above the required program minimum of six hours. The numbers of additional concentration credit hours that students took are summarized in Figure 5.8.
Four students each completed one additional concentration course, two students each completed two additional concentration courses, and two students each completed three or more additional concentration courses (Figure 5.8). There is no correlation between additional courses taken and time to complete the program for these students. Although some students have already elected to take more concentration courses than required, recommendations of ways to increase the concentration course requirement so all students receive appropriate depth of technical knowledge are discussed in Chapter 6.

5.5 Summary

The research experience component of the SMP requires all students receiving NSF SMP funds to complete a research thesis report and all other students to complete a
graduate research project report focusing on topics relevant to sustainable and resilient infrastructure. As of December 2013, fifteen SMP students had completed a research thesis report. When compared to thesis reports of all other students in the Clemson Civil Engineering Master’s program who graduated between December 2011 and December 2013, greater use of the terms “sustainability” and “resiliency” indicated that SMP student reports included much more frequent discussion of topics relevant to sustainable and resilient infrastructure in research.

The SMP has facilitated new collaborations of faculty in different concentration areas within the Glenn Department of Civil Engineering, as well as collaboration with faculty in other departments. SMP students were more likely than non-SMP students to have research committee co-chairs either from different concentration areas or different departments, have a faculty member from a different department serve on their research committee, and have research committees comprised of members who were all from different areas (Table 5.2). SMP students were also less likely to have research committees with all members coming from the same single concentration area.

Interdisciplinary research collaborations have occurred within the SMP at a much higher rate than within the rest of the Civil Engineering Department at the Master’s level.

As of December 2013, publications produced by SMP students included fifteen Master’s thesis reports, one graduate project report, seven peer-reviewed journal papers, eleven conference papers, and seven other professional conference presentations. There are currently five additional thesis reports in preparation.
Graduates generally believe that their research projects contributed significantly to their preparation to immediately contribute to the workforce (Figure 5.1 and Figure 5.2).

Sixteen of the twenty-one Civil Engineering tenure or tenure-track faculty have served as an SMP research project advisor or co-advisor. SMP funding has benefitted advisors’ research programs primarily by allowing research to be started in a new area, allowing for hire of a graduate student, and facilitating collaboration outside the department (Figure 5.3).

Many advisors believe sustainability and resiliency could be better taught by incorporating the relevant sustainability and resiliency aspects into existing courses and providing workshops to faculty with instruction on methods of how to best accomplish this (Figure 5.5). A couple of advisors instead recommended teaching the sustainability and resiliency concepts in a required general seminar course which would provide a broad overview. A combination of these two ideas is recommended. A single, required seminar course should be created which would be taken in the first semester in order to provide basic information on the concepts and applications. In addition, incorporation of sustainability and resiliency concepts into all existing courses would allow further instruction and detail for students on how the concepts can be applied in their particular fields of interest.

Eight of nine advisors believe the Sustainable and Resilient Infrastructure SMP should remain a program where students also identify with one of the six civil engineering specialty areas, so students are sought after by employers and so technical
depth of knowledge is not compromised (Figure 5.6). Almost all SMP advisors would encourage future graduate students supported on their research or a teaching assistantship to complete the SMP requirements depending on the individual student’s research interests and career goals.

Other suggestions provided by advisors for improving the Sustainable and Resilient Infrastructure SMP include setting up peer advising, launching workshops or a seminar series in which students and faculty could share and exchange research experiences and ideas, extending the SMP to a PhD program, providing a longer duration of funding to allow more flexibility in the curriculum for students, and continuing to gather feedback and rapidly make changes to the program based on this feedback.

Students completing a research thesis are required to take a minimum of two three-credit courses from their concentration area. Both students and advisors agree that students should take more concentration courses for greater technical depth. Although half the SMP graduates have already elected to take more concentration courses than required, recommendations of ways to increase the concentration course requirement to ensure that all students receive appropriate depth of technical knowledge are discussed in Chapter 6.

Other changes to the SMP coursework requirements recommended by advisors were to include more fundamental courses from departments such as economics and math, add an overall course on sustainability and resiliency, put out a request for new courses, and continue assessing students to determine courses that should no longer be required.
CHAPTER SIX
OVERALL GRADUATE PROGRAM

6.1 Preparation for Career/Further Education

One critical measure of the effectiveness of a graduate program is the level of preparation students receive for a future career or further education. Graduates of the Master’s program should be well prepared to either join the workforce or continue their education by pursuing a PhD. Graduates were asked questions relating to how well the SMP prepared them for their future on both the Graduate Exit Survey and the One-Year-Out Graduate Survey.

Graduates were asked on the Graduate Exit Survey what their plans were following graduation. The question was asked in a multiple choice format with the following answer choices provided: A. Pursue a career in engineering, B. Pursue a career in engineering that involves sustainable and resilient design, C. Pursue a PhD degree in engineering, or D. Other. The twelve responses received are summarized in Figure 6.1.
The majority of graduates indicated they planned to pursue a career in engineering that involves sustainable and resilient design (Figure 6.1). One graduate planned to pursue a PhD degree in engineering, and one graduate indicated he/she was open to all three options. Others planned to pursue a career in engineering.

In the One-Year-Out Graduate Survey, graduates were asked what they are doing now. The ten responses received were categorized and are summarized in Figure 6.2. Graduates were only categorized as pursuing a career that involves sustainable and resilient design if their response clearly indicated that their job has a sustainable and/or resilient design component.
The majority of graduates who responded to the survey are now pursuing a career in engineering (Figure 6.2). Two are pursuing a career in engineering that involves sustainable and resilient design, and one is pursuing a PhD degree in engineering. The one “other” response represents a graduate who is working part-time in a research group. A couple of the graduates who stated in the Graduate Exit Survey that they planned to pursue careers in engineering that involve sustainable and resilient design, are now pursuing careers in engineering that do not necessarily involve sustainable and resilient design. Although it is possible that some of these may indeed have a sustainable and/or resilient design component to their job, if they did not make this clear in the survey response, they could not be categorized as such. For example, the response “Working for
a full-service civil engineering consulting firm.” was categorized as a career in engineering.

The organizations where graduates are employed have also been categorized by type. These results are summarized in Figure 6.3 for the eighteen SMP students who will have graduated by May 2014.

![Figure 6.3: Types of Organizations Where Graduates are Employed](image)

By far the most graduates, two-thirds, have gone to work for private consulting firms (Figure 6.3). Two work in government and two for non-profit organizations. The one “other” response again represents the graduate who is working part-time in a research group. All graduates are employed.

In both the Graduate Exit Survey and the One-Year-Out Survey, the SMP graduates were given the statement, “I believe that my overall graduate program has
provided me with unique expertise to immediately contribute to the workforce,” and asked to select one of the following answers: strongly agree, agree, neutral, disagree, strongly disagree. The results are summarized in Figure 6.4 for the Graduate Exit Survey and Figure 6.5 for the One-Year-Out Survey.

![Graph showing survey results](image)

**Figure 6.4: Overall Graduate Program Provided Workforce Expertise – Graduate Exit Survey**

At the time of graduation, the majority of SMP graduates either agreed or strongly agreed that the overall graduate program provided them with expertise to immediately contribute to the workforce (Figure 6.4). Only one graduate selected the “neutral” option, and none disagreed or strongly disagreed with the statement.
One year after graduation, fewer graduates selected the “strongly agree” answer choice in response to the same question, but the same number chose the “agree” option (Figure 6.5). Fewer graduates provided responses to the One-Year-Out Survey, which likely accounts for the difference in responses. There were again no responses in the “disagree” or “strongly disagree” categories. The results indicate that, in general, graduates believe the overall SMP was beneficial in preparing them to start their careers.

Graduates were also asked to respond to the question, “What other experience(s) during your graduate program will be/has been most useful to you in your career? Why?” in each of the two graduate surveys. The results are summarized in Figure 6.6 for the Graduate Exit Survey.
The most common replies for the Graduate Exit Survey were that learning the research process, attending and/or presenting at professional meetings or trainings, and working with people in teams were the graduate program experiences that would be most useful to graduates’ future careers (Figure 6.6). Graduates listed many useful experiences they had during their graduate program.

Graduates provided fairly consistent answers on the One-Year-Out Survey when compared to the Exit Survey. Program experiences that were mentioned as useful by at least one graduate include learning the research process, attending and/or presenting at professional meetings or trainings, international volunteer activities, writing a document,
working with supervisors, and having a multidisciplinary approach to classes. Two students listed that experiences with Clemson Engineers for Developing Countries (CEDC) have been the most useful for them. One stated, “I also had the chance to travel to Haiti with CEDC to install a water system and that has been surprisingly relevant to my professional career!” The other said CEDC provided experiences with real-world design, using AutoCAD, and working with clients and budgets.

Two graduates listed research related experiences as the most useful to their careers. One graduate answered, “My research project was the single most important aspect of my graduate experience. The project forced me to cast vision, find answers and solutions that were unknown and to manage and lead others who assisted with the project. These lessons will continue to serve me well into the future much more than the technical knowledge ever could.” The other wrote, “Research meetings!! Having the opportunity to discuss research problems and goals every week did wonders. I became able to speak with superiors about what needs to be done. It became natural. This has bled over into my current relationship with supervisors and bosses.”

One graduate mentioned courses when stating, “The most useful experience for me, hands-down, was the multidisciplinary approach to my class requirements. I am no longer surrounded by engineers and learning to interact professionally with people from other educational backgrounds was invaluable.”

Advisors should continue to encourage students to attend available training opportunities and attend and/or present at relevant conferences. Weekly research meetings should be required, if they are not already taking place, as they provide many
benefits, including providing a time for problems and questions to be addressed. Teamwork should be promoted through coursework and research whenever possible. Students could also be encouraged to participate in some organization which allows them to practice and apply their engineering training, such as CEDC, Engineers without Borders, or American Society of Civil Engineers. These activities which provide valuable experiences in preparation for a career are important aspects of the graduate program to consider.

Graduates of the SMP feel that the program has provided them with the experiences they need in order to be well prepared to either begin a career or continue their education. The majority of graduates are employed and have started their careers in engineering. There could be some improvement in assisting more graduates with finding jobs in engineering which involve sustainable and resilient design, if that is what graduates are seeking. However, the program has proved to prepare students well for a many of career types.

6.2 Overall Evaluation of the SMP

Graduates were asked a series of questions on the surveys regarding their opinions of the SMP as a whole. In both the Graduate Exit Survey and the One-Year-Out Survey, the SMP graduates were given a series of statements and asked to select one of the following responses to each statement: strongly agree, agree, neutral, disagree, strongly disagree. The first statement given was, “I consider that my graduate program provided me with an adequate understanding of sustainability and resilience.” The responses are
summarized in Figure 6.7 for the Graduate Exit Survey and Figure 6.8 for the One-Year-Out Survey.

Figure 6.7: Program Provided Adequate Understanding of Sustainability and Resilience  
– Graduate Exit Survey

Figure 6.8: Program Provided Adequate Understanding of Sustainability and Resilience  
– One-Year-Out Graduate Survey
In the Graduate Exit Survey, most graduates either strongly agreed or agreed that the SMP provided them with an adequate understanding of sustainability and resilience (Figure 6.7). Two were neutral about the statement. In the One-Year-Out Survey, all graduates either strongly agreed or agreed with the statement (Figure 6.8). No graduates disagreed or strongly disagreed with the statement on either survey. Three graduates who provided responses to both surveys actually provided a more favorable response on the One-Year-Out Survey than they had on the Exit Survey. After a year of working in engineering, these graduates feel more strongly that their understanding of the concepts is adequate.

The next statement given was, “I believe that my graduate program has prepared me to look holistically at the nation’s infrastructure throughout its life.” The responses are summarized in Figure 6.9 for the Graduate Exit Survey and Figure 6.10 for the One-Year-Out Survey.

Figure 6.9: Program Prepared Graduate to Look Holistically at Infrastructure – Graduate Exit Survey
In the Graduate Exit Survey, the majority of graduates strongly agreed that the SMP prepared them to look holistically at the nation’s infrastructure throughout its life (Figure 6.9). A few more agreed, while only one graduate felt neutrally about the topic. In the One-Year-Out Survey, most graduates strongly agreed, while three more agreed with the statement (Figure 6.10). No graduates disagreed or strongly disagreed with the statement on either survey. Responses remained relatively consistent between the two surveys and were very positive in both cases. Any differences in responses can be attributed to change in sample size.

The third statement provided on the Graduate Exit Surveys was, “After graduation, I will continue to study sustainability and resilience.” The responses are summarized in Figure 6.11. All but one graduate indicated they planned to continue studying sustainability and resilience.
The statement provided for response on the One-Year-Out Graduate Surveys was, “I have continued to study sustainability and resilience.” The responses to this statement are summarized in Figure 6.12.
Upon program completion, all but one graduate agreed or strongly agreed that they would continue to study sustainability and resilience after graduation (Figure 6.11). However, after one year, responses indicated that six of the ten respondents had continued studying sustainability and resilience (Figure 6.12). The remaining four respondents answered “Neutral,” which does not clearly indicate whether or not they have continued studying these concepts. Of the ten graduates who provided responses to both surveys, six provided a less favorable response to this statement on the One-Year-Out Survey than they had provided on the Exit Survey, suggesting that new graduates either did not know how to continue studying or were focusing more on other responsibilities, such as developing their technical and business skills.

Perhaps informing graduates of ways they can continue studying these concepts after graduation would make it easier for those who are interested to do so. A list of suggested methods of further study such as books to read, useful websites and articles, or relevant conferences to attend could be provided to graduates.

The last statement of this type that was given to graduates on the two surveys was, “I would recommend this program to a friend.” The responses are summarized in Figure 6.13 for the Graduate Exit Survey and Figure 6.14 for the One-Year-Out Survey.
All students who provided survey responses agreed that they would recommend the SMP to a friend (Figure 6.13 and Figure 6.14). This suggests that the graduates were satisfied with their overall SMP experience.
Graduates were asked to provide other comments about the Sustainable and Resilient Infrastructure SMP in each of the two graduate surveys. The results are summarized in Figure 6.15 for the Graduate Exit Survey.

![Figure 6.15: Other Comments about SMP – Graduate Exit Survey](image)

The comment that was mentioned the most times is that students should take more concentration courses (Figure 6.15). Some graduates felt that they did not receive adequate coursework in their given interest area. More than one graduate mentioned possible difficulty finding employment due to a lack of technical coursework. One suggestion provided for addressing this issue was that an extra semester could be added to the SMP, which would allow time for additional concentration courses to be taken.
Another suggestion was to develop core seminar classes which specifically address the sustainability and resiliency competencies. By requiring these core seminar courses to be taken, the core course requirement could be lowered and students would be able to take additional concentration courses.

Multiple graduates mentioned ways in which the internship could be improved as well. Their suggestions included longer internships, more guidance for obtaining the internship position, and internships which can help progress students’ research.

Another common theme among answers was that advising needs to be improved. Graduates specifically wished that they were better informed by advisors of program requirements and expectations and encouraged to attend and present at conferences.

It was suggested that more SMP student meetings should be held, in which students would give short presentations about what they have done and what steps they plan to take next. The goal would be for these meeting to encourage a better sense of community and accountability among students. A very similar suggestion was made by another graduate on the One-Year-Out Survey also.

Many of the comments about the SMP provided on the One-Year-Out Graduate Survey were similar to those mentioned in the Exit Survey. It was restated that more concentration courses are needed in order to gain a depth of knowledge in a technical focus area. A suggestion provided by a graduate was to either teach the sustainability and resiliency components in seminars and/or to incorporate the concepts into projects and assignments done in concentration courses.
The need for more guidance with identifying and planning earlier for an internship that fits students’ schedules and research was reiterated in the One-Year-Out Survey as well. Other comments included that students should have more interaction with board members than just a single presentation each semester, opportunities to teach an undergraduate class about a topic related to their research, and more instruction on specific technologies and programs used in business. One student stated, “I am familiar with many technologies [of sustainable and resilient infrastructure], but don’t know how to design them, how much they cost, or how to convince municipalities that they perform better than previously-approved technologies.”

On the One-Year-Out Survey, graduates were asked one final question, “What additional course(s) or experience(s) would you recommend for future Sustainable and Resilient Infrastructure SMP students?” Recommendations for students included attending conferences, presenting research, communicating with non-engineers and practicing speaking to non-technical audiences, and taking courses outside their specific discipline. Recommendations for improving the SMP included offering more courses in each discipline of civil engineering, offering a seminar which prepares students for entering the job market by covering topics such as resumes and interviewing, extending the program to two years so students can take more electives and have more time for research, and providing more opportunities for students to work on technical applications of sustainable and resilient engineering.

Overall, all graduates who completed either survey gave very positive evaluations of the SMP as a whole. Their responses indicate that all had good experiences in the
program with few complaints. However, efforts need to be made as the program moves forward to address the items that have been of concern to multiple graduates in order to better the experience for future SMP students. In particular, the concerns about concentration courses, internship planning, and advising should be addressed first.

It seems that allowing students to take more concentration courses will likely require a restructuring of the SMP and options should be discussed by the steering committee and advisory board to determine the best approach. Possible solutions include lengthening the program by one semester, changing the core or business course requirements in some manner that reduces the required credits of these components, or broadening the core course list to include more technical, concentration-specific courses. Lengthening the program would allow graduates more time to take concentration courses without requiring any change to the other program requirements. Teaching the sustainability and resiliency competencies in a few seminar style courses could be one approach to reduce the core course credit requirement, and leave the remaining credits to be taken in concentration areas. Both of these could be a solution, but working to include more technical courses on the core course list is possibly the approach which would require the least amount of change to the program. Requesting or encouraging professors of concentration courses to include relevant applications of sustainability and resiliency in their teaching may qualify a wider variety of courses to be accepted on the core course list. Another option is to work with professors to develop an amended course syllabus for SMP students, which would require them to include sustainability and resiliency aspects on modified class projects or assignments.
6.3 Summary

Overall, graduates of the SMP feel that they were well prepared for their futures to either join the workforce or continue their education by pursuing a PhD. The majority of graduates are employed and have started careers in engineering. There could, however, be some improvement in assisting more graduates with finding jobs in engineering which involve sustainable and resilient design, if that is what graduates are seeking. Few graduates who planned to pursue a career in engineering that involves sustainable and resilient design are now doing so. Most graduates have now gone to work for private consulting firms (Figure 6.3). SMP graduates believe that the overall graduate program provided them with unique expertise to immediately contribute to the workforce (Figure 6.4 and Figure 6.5).

Graduates had many experiences during the program that they believe have been useful to their careers, include learning the research process, attending and/or presenting at professional meetings or trainings, working with people in teams, international volunteer activities, writing a document, working with supervisors, and having a multidisciplinary approach to classes. These types of experiences should be maintained and encouraged for current and future SMP students.

Most graduates believe that the program provided them with an adequate understanding of sustainability and resilience and prepared them to look holistically at the nation’s infrastructure throughout its life.

Nearly all graduates planned to continue to study sustainability and resilience after graduation, but after one year, only about half of graduates stated they had done so.
All graduates who provided survey responses would recommend the SMP to a friend, indicating that graduates were satisfied with their overall SMP experience.

Other comments about the SMP that were provided by graduates include that students should take more concentration courses, internship experience and advising should be improved, more SMP student meetings should be held, students should have more interaction with board members, opportunities to teach an undergraduate class about a research topic should be provided, and more instruction on specific technologies and programs used in business is needed. Additional recommendations for improving the SMP are offering more courses in each discipline of civil engineering, offering a seminar which prepares students for entering the job market, extending the program to two years, and providing more opportunities for students to work on technical applications of sustainable and resilient engineering.

In general, all graduates gave very positive evaluations of the SMP as a whole. Their responses indicate that all had good experiences in the program with few complaints or suggested changes. However, efforts need to be made as the program moves forward to address and improve some items that have been of concern to graduates. The concerns about concentration courses, internship planning, and advising should be addressed first. Possible solutions have been provided, but improvement options should be discussed by the steering committee and advisory board to determine the best approach.
CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Primary Goals of the Science Master’s Program

As was mentioned, there are five primary goals of the SMP. The first goal is to prepare STEM (Science, Technology, Engineering, and Mathematics) master’s students to meet the national need for more sustainable and resilient infrastructure. This goal is being met through the SMP course curriculum, student research, and internships. As of December 2013, sixteen students had graduated from the SMP.

The second goal is to ensure that one-third of the fourteen SMP funded students are from underrepresented groups in STEM areas. This NSF project provided fellowship stipends, for one or more semesters, to twenty-one students. Of these students, seven have been from underrepresented groups in science, technology, engineering, and mathematics fields.

The third goal is to establish a self-sufficient graduate program in sustainable and resilient infrastructure that will continue after NSF SMP funds end. The NSF project ended in September 2013, and the SMP is moving forward with short-term support from Clemson University. A long-term funding solution has yet to be determined.

The fourth program goal is to facilitate internships and research experiences to address industry needs in sustainable and resilient infrastructure. This is being done through collaboration between external partners, the steering committee, advisors, and students. All SMP graduates have completed an internship of five to twelve weeks in
duration. Also, research topics are selected to address a need identified by the partners and/or faculty members. The steering committee reviews student applications and research proposals to ensure that research aligns with the program goals. However, not all students explained and justified the need for their research in their thesis reports. It should be ensured in the future that all students include at least a brief section describing the connection of their research to sustainable and resilient infrastructure and the need for it.

The fifth goal is to develop and disseminate new knowledge in sustainable and resilient infrastructure through research and publications. As of December 2013, fifteen SMP graduates had written a research thesis report and one wrote a project report. Other publications produced by SMP students at that time included seven peer-reviewed journal papers, eleven conference papers, and seven other professional conference presentations. Five additional thesis reports are currently in preparation. Thesis reports are available on the Clemson University Libraries website. See Appendix D for a complete list of SMP publications.

Four of the five primary goals of the SMP have been and continue to be met by program participants. Goal three is being met for the short-term, but a long-term plan to meet this goal is still being developed. It should continue to be ensured that all program stakeholders, including faculty, students, advisors, student support personnel, internship supervisors, and external partners, are familiar with these goals. This can be accomplished through widely distributing goals and program materials via the SMP website, an annual catalog, and/or newsletters.
7.2 Conclusions

The effectiveness of the SMP has been studied and areas where the goals and vision of the SMP are achieved and where improvements can be made have been identified. This was completed by analysis of trends within survey responses, review of Master’s thesis reports, and review of courses taken.

The greatest normalized percentage of graduates believe that Risk Assessment, Sustainable Construction Materials, Sustainable Construction, and Pollution Prevention are the core courses most useful to their career. The greatest normalized percentage of graduates believe that Construction Planning and Scheduling has been the business-related course most useful to their career. Graduates believe both of the two business seminar courses, Ethics and Leadership and Business Communications, are useful. They each provide information that is critical for succeeding in a professional environment.

There are three competency areas of sustainability and resiliency, Structural/Non-Structural Protection, Rapidity, and Biomimicry, which a student was never exposed to in core courses. Students received the most exposure overall to the competency areas of Life Cycle Assessment, Conservation/Resourcefulness, and System Analysis and the least exposure to the areas of Carbon Accounting, Rapidity, and Biomimicry.

Sustainable Infrastructure Systems is the only core course which provides instruction for students in all eight of the competency areas.

Graduates believe there are many experiences gained from their internships which are useful to their careers, including the learning of new skills, learning what it would be like to work for a particular type of organization, and gaining a better understanding of
various applications of concepts learned through class and research. Graduates believe that the internship component of the SMP contributed significantly to their preparation to immediately contribute to the workforce.

Internship supervisors expressed willingness to supervise other interns in the SMP at Clemson University, because previous Clemson interns have been productive, skilled, well-rounded, confident, and high quality participants. Five supervisors of eight who responded to the surveys said their organizations are or may be able to provide some form of financial support for future interns or applied research to the SMP.

As of December 2013, fifteen SMP students had completed a research thesis report. When compared to thesis reports of all other students in the Clemson Civil Engineering Master’s program who graduated between December 2011 and December 2013, greater use of the terms “sustainability” and “resiliency” indicated that SMP student reports included much more frequent discussion of topics relevant to sustainable and resilient infrastructure in research.

As of December 2013, publications produced by SMP students included fifteen Master’s thesis reports, one graduate project report, seven peer-reviewed journal papers, eleven conference papers, and seven other professional conference presentations. There are currently five additional thesis reports in preparation.

The SMP has facilitated new collaborations of faculty in different concentration areas within the Glenn Department of Civil Engineering, as well as collaboration with faculty in other departments. Interdisciplinary research collaborations have occurred
within the SMP at a much higher rate than within the rest of the Civil Engineering Department at the Master’s level.

In general, advisors believe the Sustainable and Resilient Infrastructure SMP should remain a program where students also identify with one of the six civil engineering specialty areas, so students are sought after by employers and so technical depth of knowledge is not compromised. Almost all SMP advisors would encourage future graduate students supported on their research or a teaching assistantship to complete the SMP requirements depending on the individual student’s research interests and career goals.

Overall, graduates of the SMP feel that they were well prepared for their futures to either join the workforce or continue their education by pursuing a PhD. The majority of graduates are now employed and have started careers in engineering. However, few graduates who planned to pursue a career in engineering that involves sustainable and resilient design are now doing so.

Program experiences which graduates believe have been useful to their careers, include learning the research process, attending and/or presenting at professional meetings or trainings, working with people in teams, international volunteer activities, writing a document, working with supervisors, and having a multidisciplinary approach to classes. Most graduates believe that the program provided them with an adequate understanding of sustainability and resilience and prepared them to look holistically at the nation’s infrastructure throughout its life.
It is important to note that these results are not statistically significant due to small sample size. However, as more graduates complete the program and sample size increases, significance may be determined.

7.3 Recommendations

In general, all graduates gave very positive evaluations of the SMP. Survey responses indicate that all had good experiences in the program with few complaints or suggested changes. However, efforts do need to be made as the program moves forward to address and improve some items that have been of concern to graduates. The concerns about concentration courses, internship planning, and advising should be addressed first. Possible solutions have been provided, but improvement options should be discussed by the steering committee and advisory board to determine the best approach.

Both students and advisors agree that students should take more concentration courses for greater technical depth. Possible solutions for this include lengthening the program by one semester, changing the core or business course requirements in some manner that reduces the required credits of these components, or broadening the core course list to include more technical, concentration-specific courses. Lengthening the program would allow graduates more time to take concentration courses without requiring any change to the other program requirements. Teaching the sustainability and resiliency competencies in a few seminar style courses could be one approach to reduce the core course credit requirement, and leave the remaining credits to be taken in concentration areas. Both of these could be a solution, but working to include more
technical courses on the core course list is possibly the approach which would require the least amount of change to the program. Requesting or encouraging professors of concentration courses to include relevant applications of sustainability and resiliency in their teaching may qualify a wider variety of courses to be accepted on the core course list. Many advisors believe sustainability and resiliency could be better taught by incorporating these aspects into existing courses and providing workshops to faculty with instruction on methods of how to best accomplish this. Another option is to work with professors to develop an amended course syllabus for SMP students, which would require them to include sustainability and resiliency aspects on modified class projects or assignments. A single, required seminar course could be created, in addition, which would be taken in the first semester in order to provide basic information on the concepts and applications.

A different approach is to allow students to take any courses they wish as core courses, but require the students to make connections to sustainability and resiliency concepts either throughout the course or at the end. This could be done through a simple brief narrative describing the applications of sustainability and resiliency to course concepts or another method of presentation of the findings. In this case, a seminar course providing weekly SMP student meetings would provide a forum for collaboration and discussion which would aid development of ideas. No change to current course curriculum by professors would be required, and students would have greater flexibility to take courses within their concentration area.
It is recommended that Sustainable Infrastructure Systems, or another course which provides instruction in all eight competency areas, be required for all SMP students to provide a comprehensive overview and ensure all students are exposed to concepts of all competency areas.

It is also recommended that the core course and business-related course list be expanded when possible. This will allow more flexibility to accommodate the schedules and interests of individual students. Existing courses should be examined to determine whether there are any that meet SMP requirements and goals but have not yet been added.

Graduates, advisors, and internship supervisors all agree that there are improvements that could be made to the internship planning. Internship supervisors suggested the internship experience could be improved by ensuring there is mutual interest in the internship between the student and the internship organization. Coordinating well in advance and having Clemson advisors more involved in providing input during the internship planning stages would help achieve this.

Other comments about the SMP provided by graduates include that more SMP student meetings should be held, students should have more interaction with board members, opportunities to teach an undergraduate class about a research topic should be provided, and more instruction on specific technologies and programs used in business is needed. Additional recommendations for improving the SMP are offering more courses in each discipline of civil engineering, offering a seminar which prepares students for
entering the job market, and providing more opportunities for students to work on
technical applications of sustainable and resilient engineering.

Additional suggestions provided by advisors for improving the Sustainable and Resilient Infrastructure SMP include setting up peer advising, launching workshops or a seminar series in which students and faculty could share and exchange research experiences and ideas, extending the SMP to a PhD program, providing a longer duration of funding to allow more flexibility in the curriculum for students, and continuing to gather feedback and rapidly make changes to the program based on this feedback. Other changes to the SMP coursework requirements recommended by advisors were to include more fundamental courses from departments such as economics and math, add an overall course on sustainability and resiliency, put out a request for new courses, and continue assessing students to determine courses that should no longer be required.

In the future, the graduate surveys could include more questions and space for comment on the research experience. Graduate surveys could also allow space for graduates to comment on multiple or all of the courses they took, rather than just mentioning the ones they believe are most useful to their career. Opportunity to follow up with respondents through oral interviews to gain more detail about particular answers would be helpful. More in-depth answers may provide for better evaluation of the program given that there have been too few participants for statistical testing.
Appendix A

Program Requirements

Science Master’s Program in Sustainable and Resilient Infrastructure

Minimum Program Requirements (32 credits)

September 2012

• Nine (9) credits of core courses. Choose three courses from the following list:
  1. Sustainable Construction Materials (CE 893)
  2. Sustainable Construction (CE 636)
  3. Risk Assessment for Resilient Infrastructure (CE 893)
  4. Pollution Prevention and Industrial Ecology (EE&S 686)
  5. Environmental Systems (ARCH 873)
  6. Urban Transportation Planning (CE 612)
  7. Structural Health Monitoring (CE 893)
  8. Sustainable Infrastructure Systems (CE 893)
  9. Biocomplexity Seminar (EE&S 883)…must be taken three times for 3 credits.
  10. Repair and Rehabilitation of Concrete Structures (CE 828)
  11. Infrastructure Corrosion (CE 893)

• Nine (9) credits of business related courses. Choose three course from the following list:
  1. Technology and Innovation Management (MBA 845)
  2. Policy and Social Change (SOC 614)
  3. Construction Estimating and Project Control (CE 634)
  4. Construction Specifications and Contracts (CE 837)
  5. Managerial Economics (MBA 862)
  6. Introduction to Accounting and Finance (MBA 819)
  7. Water Policy & Law (CRP 845)
  8. Planning Process and Legal Foundations (CRP 801)
  9. Site Planning and Infrastructure (CRP 802)
  10. Construction Business Strategy and Marketing (CSM 864)
  11. Introduction to Econometrics (ECON 605)
  12. Rural sustainable Development: Evolution of Public Policy (PO ST 851)
  13. Ethics and Public Policy (PO ST 842)
  14. Planning & Scheduling (CE 633)
  15. Project Management Applications (CE 840)
  16. One of the following: EX ST 802 or higher, Reliability (CE 851)

• Six (6) credits of thesis research (CE 891) or three (3) credits of graduate project (CE 889). Students receiving NSF SMP funds are required to complete a MS thesis.
• Six (6) graduate credits of concentration; or nine (9) graduate credits for project option students.

• Two (2) credits seminar courses. Take both of the following seminar courses.
  1. Business Communications (MBA 850)
  2. Seminar on Ethics and Leadership (MBA 881)

• An internship/traineeship. The following are minimum requirements for the internship/traineeship: a) the duration must be at least 5 weeks (the length of one summer term); b) it must involve significant interactions with non academics and emphasize practical aspects of engineering; c) it must involve leaving Clemson’s main campus; d) the student must submit a short plan to their MS program advisory committee before starting the internship; and e) the student must submit a short report of the experience signed by the internship supervisor to their advisory committee.

• At least 12 credits (if you do a thesis) must be non-research, 800-level courses.
Appendix B

Blank Surveys
Clemson University, Department of Civil Engineering  
Science Master’s Program (SMP) in Sustainable and Resilient Infrastructure

**GRADUATE EXIT SURVEY**

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I believe that my overall graduate program has provided me with unique expertise to immediately contribute to the workforce.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. I believe that my research project contributed significantly to my preparation to immediately contribute to the workforce.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3. I believe that my internship contributed significantly to my preparation to immediately contribute to the workforce.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4. I consider that my graduate program provided me with an adequate understanding of sustainability and resilience.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5. I believe that my graduate program has prepared me to look holistically at the nation’s infrastructure throughout its life.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6. After graduation, I will continue to study sustainability and resilience.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7. I would recommend this program to a friend.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

8. What sustainable/resilient infrastructure core course(s)—Sustainable Construction Materials; Sustainable Construction; Risk Assessment for Resilient Infrastructure; Pollution Prevention and Industrial Ecology; Environmental Systems; Urban Transportation Planning; Structural Health Monitoring; Sustainable Infrastructure Systems—will be most useful to you in your career? Why?

9. What business/management course(s) will be most useful to you in your career? Why?

-- Continued on back side --
10. What concentration course(s) will be most useful to you in your career? Why?

11. What seminar course(s)—Business Communications; Ethics and Leadership—will be most useful to you in your career? Why?

12. What internship experience(s) will be most useful to you in your career? Why?

13. What other experience(s) during your graduate program will be most useful to you in your career? Why?

14. After graduation, I plan to:
   A. Pursue a career in engineering
   B. Pursue a career in engineering that involves sustainable and resilient design
   C. Pursue a PhD degree in engineering
   D. Other:

15. Other comments about the Sustainable and Resilient Infrastructure SMP:

   Thank you for taking the time to complete this survey!
INTERNSHIP SUPERVISOR SURVEY

Part A: TO BE COMPLETED BY THE GRADUATE INTERNSHIP STUDENT

Name of Graduate Internship Student: __________________________

Name Internship Institution: __________________________

Dates of experience: __________________________

Total weeks at Internship Institution: __________________________

Name of Internship Supervisor: __________________________

Wavier of Rights
I, __________________________, hereby authorize to provide to the Project Team evaluating the Sustainable and Resilient Infrastructure Science Master’s Program at Clemson University the information requested in this survey. I hereby wavier my rights to access and to view the completed survey.

Graduate Internship Student Signature: __________________________
Date: ______________

Dr. Ronald Andrus
Project Team Chair, Sustainable and Resilient Infrastructure SMP
Clemson University, Department of Civil Engineering
109 Lowry Hall
Clemson, SC 29634-0911
Tel. 864-656-0488; Fax 864-656-2670

Instructions to Internship Supervisor
The purpose of this survey is to help us evaluate the effectiveness of the Sustainable and Resilient Infrastructure Science Master’s Program at Clemson University, and not evaluate the Intern. After completing this survey, seal it in an envelope, sign across the seal, and return the envelope to the Intern or mail to the above address.

PART B: TO BE COMPLETED BY THE INTERNSHIP SUPERVISOR

Describe the ways in which the intern’s performance benefited your organization—

Please describe the engineering responsibilities that were supervised--

-- Continued on back side --
Describe, if any, the ways in which these responsibilities involved the application of concepts in sustainable and resilient infrastructure--

Was the intern offered a full-time position/employment upon graduation?
_____________________________________

Based on your experience, would you supervise other interns in the Sustainable and Resilient Infrastructure Science Master’s Program at Clemson University? Why?

What are your suggestions for improving the internship experience for students in the Sustainable and Resilient Infrastructure Science Master’s Program?

Would your organization be willing to provide financial support for future interns or applied research in Sustainable and Resilient Infrastructure? Describe any financial support that might be provided.

Thank you for taking the time to complete this survey!
Clemson University, Department of Civil Engineering
Science Master’s Program (SMP) in Sustainable and Resilient Infrastructure

PROJECT ADVISOR SURVEY

Part A: TO BE COMPLETED BY THE GRADUATE STUDENT

Name of Graduate Student: _____________________________________________

Name of Project Advisor(s): ____________________________________________

Waiver of Rights
I, ______________________________________, hereby authorize to provide to the
Project Team evaluating the Sustainable and Resilient Infrastructure SMP at Clemson
University the information requested in this survey. I hereby waive my rights to access
and to view the completed survey.

Graduate Student Signature: __________________________________________
Date: _________________

Dr. Ronald Andrus
Project Team Chair, Sustainable and Resilient Infrastructure SMP
Clemson University, Department of Civil Engineering
109 Lowry Hall
Clemson, SC 29634-0911
Tel. 864-656-0488; Fax 864-656-2670

Instructions to Graduate Project Advisor
The purpose of this survey is to help us evaluate the effectiveness of the Sustainable and
Resilient Infrastructure SMP at Clemson University, and not evaluate the Graduate
Student. After completing this survey, seal it in an envelope, sign across the seal, and
return the envelope to the student or mail to the above address.

PART B: TO BE COMPLETED BY THE PROJECT ADVISOR

Describe the ways in which the SMP funding has benefited your research program.

How did the SMP funding change or impact your research?

How could sustainability and resiliency be better taught?

-- Continued on back side --
Are you satisfied with the SMP coursework requirements? If not, what change would you recommend?

Do you think the Sustainable and Resilient Infrastructure SMP should remain a program where students are also identified with one of the six specialty areas (i.e., AFM, CEM, CM, GE, SE, TS)? Or, should Sustainable and Resilient Infrastructure become a new and separate specialty area? Why?

Based on your experience, would you encourage some of your future graduate students supported on your research or a teaching assistantship to complete the SMP requirements? Why?

What other suggestions do you have for improving the Sustainable and Resilient Infrastructure SMP?

Thank you for taking the time to complete this survey!
Clemson University, Department of Civil Engineering
Science Master’s Program (SMP) in Sustainable and Resilient Infrastructure

**ONE-YEAR-OUT GRADUATE SURVEY**

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I consider that my graduate program provided me with an adequate understanding of sustainability and resilience.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. I believe that my graduate program prepared me to look holistically at the nation’s infrastructure throughout its life.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3. I believe that my overall graduate program provided me with unique expertise to immediately contribute to the workforce.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4. I believe that my internship contributed significantly to my preparation to immediately contribute to the workforce.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5. I believe that my research project contributed significantly to my preparation to immediately contribute to the workforce.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6. I have continued to study sustainability and resilience.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7. I would recommend this program to a friend.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

8. What sustainable/resilient infrastructure core course(s)—Sustainable Construction Materials; Sustainable Construction; Risk Assessment for Resilient Infrastructure; Pollution Prevention and Industrial Ecology; Environmental Systems; Urban Transportation Planning; Structural Health Monitoring; Sustainable Infrastructure Systems—has been most useful to you in your career? Why?

9. What business/management course(s) has been most useful to you in your career? Why?

10. What concentration course(s) has been most useful to you in your career? Why?

-- Continued on back side --
11. What seminar course(s)—Business Communications; Ethics and Leadership—has been most useful to you in your career? Why?

12. What internship experience(s) has been most useful to you in your career? Why?

13. What other experience(s) during your graduate program has been most useful to you in your career? Why?

14. What addition course(s) or experience(s) would you recommend for future Sustainable and Resilient Infrastructure SMP students?

15. What other suggestions do you have for improving the Sustainable and Resilient Infrastructure SMP?

Thank you for taking the time to complete this survey!
EMPLOYER SURVEY

Part A: TO BE COMPLETED BY THE SMP GRADUATE

Name of SMP Graduate: ____________________________________________

Name of Employer: ________________________________________________

Dates of employment: _____________________________________________

Total years of employment: ________

Name of Employer Supervisor: _______________________________________

Waiver of Rights

I, ________________________________________, hereby authorize to provide to the
Project Team evaluating the Sustainable and Resilient Infrastructure Science Master’s
Program at Clemson University the information requested in this survey. I hereby wavier
my rights to access and to view the completed survey.

SMP Graduate’s Signature: _________________________________________

Date: ______________

Dr. Ronald Andrus
Project Team Chair, Sustainable and Resilient Infrastructure SMP
Clemson University, Department of Civil Engineering
109 Lowry Hall
Clemson, SC 29634-0911
Tel. 864-656-0488; Fax 864-656-2670

Instructions to Employer Supervisor

The purpose of this survey is to help us evaluate the effectiveness of the Sustainable and
Resilient Infrastructure Science Master’s Program at Clemson University, and not
evaluate the Graduate. After completing this survey, mail it to the above address.

PART B: TO BE COMPLETED BY THE EMPLOYER SUPERVISOR

Please describe the engineering responsibilities of the Graduate--


Describe, if any, the ways in which these responsibilities involved the application of
concepts in sustainability and resilience—

-- Continued on back side --
What additional training would you recommend to the Graduate?

Based on your experience, would you hire other graduates of the Sustainable and Resilient Infrastructure Science Master’s Program at Clemson University? Why?

Do you have any suggestions for improving the Sustainable and Resilient Infrastructure Science Master’s Program at Clemson University?

Would your organization be willing to provide financial support for summer interns or applied research in the Sustainable and Resilient Infrastructure? Describe any financial support that might be provided.

Thank you for taking the time to complete this survey!
Appendix C

Non-normalized Raw Survey Data

8. What sustainable/resilient infrastructure core course will be most useful to you in your career?

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students Who Named Course in Response</th>
<th>Number of Students Who Took Course and Survey</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable Construction Materials (CE 893)</td>
<td>3</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>Sustainable Construction (CE 636)</td>
<td>4</td>
<td>6</td>
<td>67</td>
</tr>
<tr>
<td>Risk Assessment (CE 893)</td>
<td>4</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Pollution Prevention (EE&amp;S 686)</td>
<td>2</td>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>Structural Health Monitoring (CE 893)</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Environmental Systems (ARCH 873)</td>
<td>1</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Urban Transportation Planning (CE 612)</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Sustainable Infrastructure Systems (CE 893)</td>
<td>0</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Repair and Rehabilitation of Concrete Structures (CE 828)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Infrastructure Corrosion (CE 893)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No Response</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure C-1: Student Exit Survey Question 8
9. What business/management course(s) will be most useful to you in your career?

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students Who Named Course in Response</th>
<th>Number of Students Who Took Course and Survey</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting &amp; Finance (MBA 819)</td>
<td>2</td>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>Business Seminars</td>
<td>3</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Contracts &amp; Specifications (CE 837)</td>
<td>2</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Site Planning &amp; Infrastructure (CRP 802)</td>
<td>3</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Water Policy &amp; Law (CRP 845)</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Construction Estimating &amp; Project Control (CE 634)</td>
<td>1</td>
<td>4</td>
<td>25</td>
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<tr>
<td>Marketing Foundation (MBA 829)</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Infrastructure Project Planning (CE 691)</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Technology and Innovation Management (MBA 845)</td>
<td>0</td>
<td>5</td>
<td>0</td>
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<tr>
<td>Managerial Economics (MBA 862)</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Planning Process and Legal Foundations (CRP 801)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Intro to Econometrics (ECON 605)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ethics and Public Policy (PO ST 842)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Construction Planning and Scheduling (CE 633)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Infrastructure Management (CE 893)</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>No Response</td>
<td>0</td>
<td>12</td>
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</table>

Figure C-2: Student Exit Survey Question 9
<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students Who Named Course in Response</th>
<th>Number of Students Who Took Course and Survey</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethics &amp; Leadership</td>
<td>7</td>
<td>11</td>
<td>64</td>
</tr>
<tr>
<td>Business Communications</td>
<td>4</td>
<td>12</td>
<td>33</td>
</tr>
<tr>
<td>Biocomplexity</td>
<td>1</td>
<td>1</td>
<td>100</td>
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<tr>
<td>No Response</td>
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<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure C-3: Student Exit Survey Question 11
8. What sustainable/resilient infrastructure cores course have been most useful to you in your career?

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Number of Students Who Named Course in Response</th>
<th>Number of Students Who Took Course and Survey</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable Construction Materials (CE 893)</td>
<td>2</td>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>Sustainable Construction (CE 636)</td>
<td>3</td>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>Risk Assessment (CE 893)</td>
<td>1</td>
<td>3</td>
<td>33</td>
</tr>
<tr>
<td>Pollution Prevention (EE&amp;S 686)</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Structural Health Monitoring (CE 893)</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Environmental Systems (ARCH 873)</td>
<td>1</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Urban Transportation Planning (CE 612)</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Sustainable Infrastructure Systems (CE 893)</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Repair and Rehabilitation of Concrete Structures (CE 828)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infrastructure Corrosion (CE 893)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No Response</td>
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<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure C-4: One-Year-Out Graduate Survey Question 8
9. What business/management course(s) have been most useful to you in your career?

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Number of Students Who Named Course in Response</th>
<th>Number of Students Who Took Course and Survey</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting &amp; Finance (MBA 819)</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Business Seminars</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Contracts &amp; Specifications (CE 837)</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Site Planning &amp; Infrastructure (CRP 802)</td>
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<td>6</td>
<td>17</td>
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<tr>
<td>Water Policy &amp; Law (CRP 845)</td>
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<td>1</td>
<td>0</td>
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<tr>
<td>Construction Estimating &amp; Project Control (CE 634)</td>
<td>1</td>
<td>3</td>
<td>33</td>
</tr>
<tr>
<td>Marketing Foundation (MBA 829)</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Infrastructure Project Planning (CE 691)</td>
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<td>3</td>
<td>33</td>
</tr>
<tr>
<td>Technology and Innovation Management (MBA 845)</td>
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<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Managerial Economics (MBA 862)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Planning Process and Legal Foundations (CRP 801)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Intro to Econometrics (ECON 605)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ethics and Public Policy (PO ST 842)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Construction Planning and Scheduling (CE 633)</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Infrastructure Management (CE 893)</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Policy and Social Change (SOC 619)</td>
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</tr>
<tr>
<td>Construction Business Strategy &amp; Marketing (CSM 864)</td>
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</tr>
<tr>
<td>Rural Sustainable Development: Evolution of Public Policy (PO ST 851)</td>
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<tr>
<td>Project Management Applications (CE 840)</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>EX ST 802 or higher or Reliability (CE 851)</td>
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<td>0</td>
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<tr>
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<td>10</td>
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</tr>
<tr>
<td>None</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure C-5: One-Year-Out Graduate Survey Question 9
11. What seminar course(s) have been most useful to you in your career?

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students Who Named Course in Response</th>
<th>Number of Students Who Took Course and Survey</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethics &amp; Leadership</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Business Communications</td>
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<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Biocomplexity</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>None</td>
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<td>10</td>
<td>10</td>
</tr>
<tr>
<td>No Response</td>
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<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure C-6: One-Year-Out Graduate Survey Question 11
Appendix D

List of SMP Publications

Journals


Thesis/Dissertations


• Machmer, B.M. (2012). *Understanding the behavior of a pile foundation in unsaturated soils subjected to lateral loading*. Clemson University.


**Conference Papers and Presentations**


  Status = PUBLISHED
  Status = PUBLISHED

  Status = PUBLISHED

  Status = PUBLISHED

  Status = PUBLISHED

  Status = AWAITING_PUBLICATION

  Status = PUBLISHED

  Status = PUBLISHED

  Status = PUBLISHED

  Status = PUBLISHED

  Status = ACCEPTED
Other Publications


Status = PUBLISHED
REFERENCES
