AC 2009-1190: EM AT NCSU.PDF

Natalie Cherbaka, North Carolina State University

Jerome Lavelle, North Carolina State University

Proposing an Engineering Management Program at North Carolina State University

Abstract

This paper describes an analysis and proposal for starting an Engineering Management (EM) program in the College of Engineering at North Carolina State University (NCSU). We first define EM in the context of current discussions within the discipline, and provide results of a benchmarking survey of existing programs. This sets a context for understanding the discipline and constraints on the design of a proposed program. From this we describe and evaluate potential proposals for an EM program at NCSU.

1. Engineering Management Today

Defining Engineering Management: Engineering Management as a discipline is not tightly defined, as demonstrated by a relatively wide variance among academic EM programs. The discipline is often grouped with Industrial Engineering, Systems Engineering, or Management of Technology. Although very few EM definitions exist, current discipline trends are represented by the following:

- Engineering Management is the art and science of planning, organizing, allocating resources, and directing and controlling activities which have a technological component.²
- Engineering Management is the bridge between the engineering and management disciplines.⁶
- The engineering manager possesses both the ability to apply engineering principles and a skill in organizing and directing people and projects.³

EM programs are distinguished from systems engineering (SE) programs primarily by the management aspect. SE focuses on the development life-cycle from an operational and mathematical perspective with heavy emphasis on decision analysis, structured problem solving approaches, and the interaction/integration of systems. In contrast, an EM program focuses on managing SE efforts and engineering relationships with the rest of the organization. Along the spectrum of programs labeled as EM, those that rely heavily on industrial engineering (IE) tend to focus on management of a process within specific engineering disciplines, and, like SE, are concerned with operational decisions. This is in contrast to management of technology (MOT) programs that focus on traditional management techniques with application to technology assets, not engineering processes as with SE and IE. The opposite approach from SE is an MBA program that teaches pure management theory without application to any specific discipline. EM programs straddle the gap between these approaches, emphasizing the management of all engineering disciplines and overlapping slightly with IE and MOT. Figure 1, adapted from Kotnour and Farr⁶, presents a visual of this overlap.

Figure 1: Definition of EM (adapted from Kotnour & Farr⁶)

Engineering Management Programs: Two general types of EM programs exist that are described here as professional and traditional.

The *professional* type is classified as continuing education and resembles an MBA program more than a traditional engineering program. Characteristics include an interdisciplinary approach; a variety of instructors from fields other than EM, both professionals and academics; a teaching focus; an emphasis on projects over thesis; and minimal research contributions to the general discipline. In contrast, *traditional* programs operate as stand-alone departments or as concentrations typically within a Systems or Industrial Engineering department. They carry the weight of EM research activity and direction for the discipline.

Not unlike other disciplines, but extremely important because of this dichotomy between program types, the discipline relies heavily on professional organizations to provide direction. One of the primary EM professional organizations, the American Society of Engineering Management (ASEM), provides leadership in defining the discipline through certification standards. Additionally, IEEE Transactions on Engineering Management Journal published a special issue focusing on the direction of EM as a profession. Despite the efforts of ASEM and IEEE, a lack of a well-defined body of knowledge and the variety of methods for program execution has generated an EM landscape with enormous variety in program curricula.

Benchmark Study of EM Programs: As part of a benchmarking study to assess current EM programs in the US, data were collected on fifty-five master's level programs based on information available on program websites. The objective was to collect data on graduate EM programs in an attempt to study similarities and contrasts from the varied landscape of program types. Included in the study are the twenty-five institutions granting the most EM degrees in the US. Although some MOT and SE programs are included, only those that possess a clear focus on EM are considered. Available information obviously varies between websites, but most

programs offer adequate information to contribute to the data gathering. In the few cases where website information was insufficient, the program was omitted from the results. Table 1 below displays the programs studied along with a subset of the collected data. This includes the type/mode of course delivery, prerequisites, work experience requirements, host department designation, certificate offerings, and other data.

Program Level Statistics: The large presence of part-time students in EM is an integral part of program design as 83% offer distance, part-time, or continuing education options. The breakdown of these options is displayed in Figure 2, with asynchronous classes, utilizing websites to post lectures from on-campus classes, leading the way with 49%. Over half of the programs are designed specifically for working professionals and 36% require engineering experience for program admittance. Twenty-two percent of the programs cater to professional students by offering certificates; however, all offer complete degree programs in addition to certificates. A few programs offer only seminars, weekend, or week-long courses and not master's level degrees, but to avoid falsely skewing results, these programs were omitted. This is justified because the number of programs is small and the data such outliers relative to the full master's degree programs. The degree length ranges from 30 to 52 credit hours with a median of 33 hours. The relatively shorter program length is one benefit and reason professional students pursue the EM degree over an MBA.

Figure 2: Options for Professional Students

EM is interdisciplinary, combining engineering and management; however, 76% of programs are hosted by an engineering college. Figure 3 displays the breakdown of host colleges. Aside from the host, about one-third of the programs are interdisciplinary in that core requirements reside in both engineering and another program, typically business. This does not account for the programs with EM-specific courses intended to be interdisciplinary by design. Regardless of the execution method, interdisciplinary focus is claimed by most programs.

Table 1: EM Programs Studied

Institution	Program or Department Name	Inter- active op	Archived online	Remote	Evenings Weekends	Short courses	Degree Prerequisite	Exper Rqmts	Credit Rqmts	Degree	Certifi cates	Interdisci plinary	Host College/Dept	prof or post BS
		18%	49%	33%	35%	11%		36%	30		22%	35%		
Washington State	Engineering and Technology Management Program	x	x	x			BS/BE			MEM	x		Engineering	both
Dayton	Dept of Engineering Management and Systems	x	x	x			BS Eng.Sc.Mth			MS in EM	x		Engineering	both
Drexel	Online Master of Science in Engineering Management		x				BS Eng.Sc.Mth		48	MS in EM	x		Engineering	both
NIJT	Department of Industrial and Management Systems Engineering	x	x	x	x		BS Eng.Sci.Math.Tech		30	MS in EM	x		Engineering	both
Oklahoma State	Engineering and Technology Management						BS in Eng or Sci	3	32	MS in ETM	x	yes	Eng+Tech+Biz+Sci	prof
Purdue	Engineering Management and Leadership Specialization		x				BS Eng.Sc.Mth			MSE with EM conc			Engineering	both
USC	Master of Science in Engineering Management	x	x				BS Eng.Sc.Mth		30	MSEMT			Engineering IE	both
Virginia Tech	Master of Engineering Administration			x			BS Eng.Sci.Math.Tech			MEA			Engineering	prof
Case Western Reserve	Masters of Engineering and Management Degree						BS Eng		42	MEM		yes	Engineering & Business	post-BS
Dartmouth	Master of Engineering Management						BS/BE			MEM		yes	Engineering	both
UNCC	SE and EM Program						BS Eng. Sci		30	MS in EM			Engineering	both
UCF	Department of IE and Management Sys		x				BS Eng		30	MS in IE, EM conc			Engineering IE	both
UCF - 2	Department of IE and Management Sys			x	x	x	BS Eng		30	MS in EM			Engineering	prof
Missouri S&T	EM and SE Department	x	x				BS Eng.Sc.Mth	1	30	MS in EM		yes	Engineering	both
Kansas State	Department of Industrial and Manufacturing SE	x	x				BS in Eng or Sci	2	30	MEM			Engineering IE	prof
U of Minnesota Deluth	Department of Mechanical and Industrial Engineering		x	x	x		BS Eng		30	MS in EM			Engineering	post-BS
U of Mich-Dearborn	MS in Engineering Management		x		x		BS Eng	5	36	MS in EM		yes	Engineering IE	both
Ohio U	EM Program in ISE			x			BS/BE			MS in ISE, EM conc			Engineering IE	both
U of Colorado	EM Program at the COE and Applied Science		x				BS/BE Eng.Sci.Bus.Tech	2	30	ME in EM	x		Engineering	prof
New Mexico Tech	Department of Management		x	x	x		BS Eng.Sci.Math.Tech	2	30	MEM			Management	both
Marquette	EM Program in COE and College of Business Administration				x		BS/BE			MS in EM		yes	Engineering & Business	both
Cal State	Dept of Mfg Systems Engineering and Management		x				BS Eng.Sc.Mth		33	MS in EM			Engineering	prof
UMBC	College of Engineering and Information Technology	x	x	x	x		BS Eng.Sci.Math.Tech			MS in EM	x		Engineering	both
Air Force IT	Department of Systems and Engineering Management						BS Eng. Sci			MS in EM			Engineering & Management	prof/military
Eastern Michigan	EM Program in College of Technology		x	x	x	x	BS/BE Eng.Sci.Bus.Tech		36	MS in EM	x		Technology	prof
U of Kansas	Engineering Management Department		x	x			BS Eng. Sci	2	33	MS in EMGT			Engineering	prof
Duke	Master of Engineering Management Program						BS Eng.Sc	2		MEM			Engineering	both
U of Idaho	Engineering Management Program		x				BS Eng	2	33	M Engr		yes	Engineering & Business	prof
Catholic	Engineering Management Program			x	x		BS Eng			MS in Eng	x		Engineering	both
Colorado State	Department of Mechanical Engineering		x				BS Eng or EIT or PE			MS or ME in ME		yes	Engineering & Business	both
Lamar	Department of Industrial Engineering						BS Eng	2	36	MEM		yes	Engineering	prof
Old Dominion	Department of EM and SE			x			BS Eng. Sci		30	MEM, MS in EM			Engineering & Technology	both
U of Akron	College of Engineering				x		BS Eng.Sci.Math.Tech			MS in EM		yes	Engineering	prof
Florida	Outreach Engineering Management Program			x	x		BS Eng.Sci.Math.Tech	2	32	MS in IE w/Emconc		yes	Engineering	prof
U of Houston - Clear Lake	Engineering Management						BS Eng. Sc		30	MS in EGMT			Engineering	both
USF	Industrial and Management Systems Engineering	x	x	x			BS Eng	2	33	MS in EM			Engineering	prof
MIT	Systems Design and Management			x			BS Eng or MS Eng	5	45	MS in Eng and Mgmt		yes	Engineering	prof
UT Austin	Lifelong Engineering Education Engineering Management				x		BS Eng.Sci.Math.Tech	1.5	36	MS in Eng w/EM major			Engineering	prof
Stanford	Management Science and Engineering		x				BS + prereq courses		45	MS in Mgmt Sc and Eng			Engineering	both
UVA Accel SE	Accelerated Masters Degree in Systems Engineering				x		BS			Accelerated MS in SE		yes	Engineering	prof
St. Cloud State	Engineering Management				x	x	BS/BA			MEM			Engineering	prof
Tufts University	Gordon Institute Engineering Management				x	x	BS Eng.Sci.Math.Tech	3	40	MSEM			Engineering	prof
Stevens Inst. of Tech.	School of Systems and Enterprises EM	x	x				BS Eng. Sci		30	MS in EM	x		Engineering	prof
U of Alabama Huntsville	UAH Masters of Science in Engineering EM option		x				BS Eng	2	36	MSE, EM option	x		Engineering	prof
Portland State	Engineering Technology Management		x				BS Eng. Sci	4	52	ME in EM			Engineering	prof
George Washington	Department of EM and SE			x					36	MS in ETM			Engineering & Technology	prof
Nebraska	Department of Industrial and Management SE	x	x				BS Eng. Sci, Math	2	36	MS in EM		yes	Engineering	prof
U Penn	Executive Masters in Technology Management				x	x	BS/BE	5		MSE		yes	Tech, Innovation, and Bus	prof
Santa Clara	Engineering Management and Leadership Program						BS/MS in Eng or CSC			MS		yes	Engineering	both
Florida IT	Engineering Management						BS in Eng		30	MS in EM		yes	Engineering	both
Southern Methodist	Engineering Management, Information and Systems				x	x	BS in Eng or Tech		30	MS in EM			Engineering	prof
Colorado School of Mines	Engineering and Technology Management						BS in Eng or Sci		36	MS in ETM			Engineering	both
Wayne State	Professional Engineering Management Master's Program						BS Eng	3	42	MS in EM		yes	Engineering	prof
Louisville	Engineering Management in IE				x		BS Eng		30	ME in EM			Engineering	prof
Oregon Health and Science Division of Management			x		x		BS Eng			MS in MST	x		Medicine	prof

Figure 3: Host College or Department

Curricula Statistics: To understand what students with EM degrees are learning, the curriculum of each program was investigated to determine the topics covered in core curricula, electives, and capstone requirements. The focus of this part of the benchmark study was on topics covered in the curricula, not simply courses. This approach removes variances caused by the assortment of course structures, traditional semesters, quarters, modules, and short courses. Some programs offer specific core courses, while others allow selection from core offerings. In this latter scenario, the topics covered in core offerings were credited as part of the core curricula. This is justified because choices are often between classes offering variations on the same or similar topic area (e.g., construction project management versus general project management).

Table 2 displays a summary of all topic areas tracked in this study and the percentage of total programs in which the core curriculum covered that topic area. Arguably, other topics could be included and some categories combined; however, the list of topics was constructed from those topics covered in core curricula of EM programs and purposefully does not address general electives. This table provides a view of topic importance as seen by academia, which ideally reflects industry needs and thus helpful in designing a new EM program that is consistent with the accepted EM discipline. For example, 96% of programs offering courses address management of people and organizations, this should clearly be considered for inclusion in any credible EM program.

To clarify the data in Table 2, it is divided into groups based on content – quantitative and qualitative. This grouping is consistent with ASEM certification requirements (with respect to coverage) where courses are categorized as either quantitative or qualitative. In addition, Hicks⁴ categorized topics into three categories: (1) management process/empirical, (2) human behavior/social systems, and (3) mathematical/decision theory. He found that the first and third categories, management process/empirical and mathematical/decision theory, dominated the EM landscape, accounting for 90% of courses. This same trend is visible today where human behavior topic coverage is found in only 10% of the programs. Therefore, in this benchmarking study we inspected programs for quantitative and qualitative content

Table 2: Ranking of Topics by % of Programs Covering in Core Curriculum

Topic	% Programs
Organizational and People Management	96%
Project Management	57%
Finance	55%
Systems Engineering	53%
Statistics	49%
Decision Analysis	45%
General EM Advanced Principles	37%
Strategic Management	37%
Quality (including TQM, 6sig, Lean)	35%
Engineering Econ	35%
OM or MS	35%
General OR	35%
Product Development	33%
Marketing	29%
Cost Analysis	29%
Economics	27%
Accounting	27%
Probability Modeling	24%
Entrepreneurship and Innovation	24%
Leadership	24%
Law	22%
Simulation	20%
Supply Chain and Logistics	20%
Communications	18%
Information Systems	18%
Optimization	16%
Global Issues	16%
General Fin, Acct, Econ	14%
Production and Inventory and Mfg	10%
Human Factors/Behavior	10%
Tech/project Assessment	8%
Reliability	6%
Ethical Issues	6%
Case Studies	6%
Systems Integration	6%
Software	4%
Tech Writing	2%
Design for Mfg	2%

Quantitative Topics: Quantitative topics are clearly important to EM as 90% of programs include at least one course. In this category, topics are classified as based in operations research or in statistics and probability. ASEM certification requires at least one course in probability and statistics and at least two quantitative analysis courses. From the data, in EM programs

- 80% include at least one statistic related topic, and
- 73% include at least one operations research related topic.

For each of these quantitative areas, topics are divided further and displayed in Figures 4 and 5. From the data, there is greater coverage of statistics and decision analysis over OR/MS topics.

Figure 4: Programs with Operations Research Coverage

Figure 5: Programs with Statistics and Probability Coverage

Qualitative Topics: The qualitative category is also divided into two slightly narrower sections: general management and finance/economics. The management category dominates with respect to coverage in EM core curricula:

- 100% of programs include courses that address at least one management topic.
- 90% of programs include courses that cover economic related topics.

The topics and associated coverage are given in Figures 6 and 7 respectively, for the management and economic categories.

Figure 6: Management Topic Coverage

Figure 7: Finance and Economic Topics Coverage

Capstone and Elective Courses: Capstone and elective courses also play an important role in EM curricula. ASEM certification requires a capstone project or thesis and 69% of the programs include one or the other in their curricula. This number does not distinguish between required and optional capstone courses. Typical requirements list a thesis as optional for which a project, or sometimes a series of classes, is an acceptable substitute; however, projects are rarely optional in programs without a thesis option. The breakdown of coverage for capstone offerings is displayed in Figure 8. Included in this figure are seminars and comprehensive exams as they are also considered requirements that address integration of EM concepts by some programs. Clearly, projects dominate as the preferred capstone approach.

Figure 8: Capstone Coverage

The final category addresses electives required in EM programs beyond the core curricula. Figure 9 displays the percentage of programs allowing various elective areas. Electives are heavily dependent on the structure of the core curricula, yet the overall trend of allowing EM and engineering courses is evident.

Figure 9: Disciplines for Electives

2. Engineering Management Directions

Certification Requirements: The lack of consistency in EM programs, combined with growing EM popularity, motivated ASEM to focus on defining the discipline. ASEM has taken significant ownership for the future direction of EM through a certification process that standardizes a quality EM program. Currently, the purpose is different from an undergraduate ABET accreditation in that this certification intends to direct the development of new and existing programs, in addition to recognizing quality programs. The certification process consists of four requirement areas: faculty, curriculum, student admission and support, and administrative support.

Of the four areas, only the curriculum requirements are reviewed here because we are concerned with design, and the other three areas are concerned with implementation. However, all requirements and the certification process are available at the ASEM website (ASEM). The curriculum requirements focus on sufficient balance of coursework between engineering and management. Specifically, the requirements are as follows:

- One-third of the curriculum in management.
- Two courses in quantitative analysis.
- One course in engineering economy.
- One course in probability and statistics.
- A capstone thesis or project.
- An underlying focus on technology, global workforce, and communication skills.

If a program meets the above curriculum requirements and the administrative requirements set by ASEM, they may apply for certification. An evaluation team visits the program to determine compliance with the criteria. Given that the certification is a relatively recent addition to the

field, currently only four universities offer certified programs. However, this does not diminish the value of the process or the standards it sets.

Research and Discipline Trends: The importance of leadership, innovation, entrepreneurship, and analytical techniques stand out for the current EM discipline. In the 2004 special edition of IEEE Transactions on Engineering Management, two papers contribute directly to defining the direction of EM. First, Winston⁹ describes a personal perspective and defense of EM. He defends the education of the engineer in management versus the opposite approach of educating the manager on engineering. Winston's key point is that EM relies on and must focus on leadership. Although he defines leadership as somewhat of an intangible skill, he believes it is possible to train a student as an effective leader through a multidisciplinary program that emphasizes well-roundedness. In the previous section, Table 2 shows that 24% of the programs specifically address leadership. This demonstrates that the trait is considered important, but room for growth exists.

In the second significant paper of the same IEEE Transactions edition, Roberts⁷ addresses the progression of research within EM over the past 50 years, and lays out expectations for future trends. The following are notable with respect to program development: First, despite no increase in the rate of new research, the category of quantitative techniques is a significant contributor within EM. Second, entrepreneurship is a rising area of research that follows industry trends by addressing spin-offs, technology transfer, and financing of these endeavors. New management issues such as these drive the flexible and responsive field of EM. Finally, the quantity of papers with applications of EM to service is increasing. This trend should be considered in a new program based on this research observation as well as the employment trends in the U.S. toward service.

Kotnour and Farr⁶ address current trends in EM and suggest future recommendations. They list current EM concerns as the following: managing teams, leading the workforce, changing culture, using tools and metrics, and developing skills and behaviors. These are consistent skills with Winston's leadership description. Future recommendations are geared toward recommendations for the entire discipline: agility; integration of teaching, research, assistance, training, and service; interdisciplinary evolutions; and participation in professional organizations.

Kern⁵ tracks EM research trends via content analysis from 1993-2000. Overall, he found a decrease in strategic planning and increases in service applications and innovation. He also recognized performance evaluations and corporate culture as major contributors, despite no significant change in the quantity of research on these topics. The emphasis on service, innovation, and performance measures is consistent with the previous papers discussed. From the above research trends, ASEM standards, and current curricula, a few highlights are visible and should be considered in program design. First, a credible program must consider analytical techniques for managing and decision analysis. This includes courses in decision analysis and project management. Second, the trends of innovation/entrepreneurship, service, and management metrics are rising and an EM program should address these issues to maintain the progressive position EM enjoys as an agile discipline.

Summary of Highlights: Key points from current EM programs, ASEM certification, and EM trends are summarized below. Based on these contributions, a credible EM program should include the following:

- An interdisciplinary approach.
- Collaboration with industry to maintain responsiveness, e.g. through active market outreach or an industrial advisory board.
- A capstone project or thesis that provides and integrative experience within the EM curriculum and topics.
- Accessibility for part-time and professional students.
- Experience requirements for enrolling students.
- Engineering degree required for admission.
- A balance of quantitative and qualitative topics.
- Quantitative courses that cover the following:
 - general operations research techniques for decision analysis and
 - statistical or probabilistic decision analysis.
- Qualitative courses that cover the following:
 - general organizational and people management in technical organizations,
 - project management, and
 - financial, economic, cost decision-analysis.
- Courses or seminars that address EM trends such as innovation, entrepreneurship, technical assessment, global issues, environmental issues, service applications, and leadership.
- Accessibility to a wide range of electives.

3. Why Engineering Management at NC State?

Engineers are pursuing engineering management degrees at an increasing rate, the number of engineering management master's students doubled between 2003 and 2006, while in the same time period, overall engineering master's enrollment decreased by nine percent.¹ According to the Spencer Stuart⁸ CEO profile report, 21% of the S&P500 CEOs have an undergraduate degree in engineering, the most of any discipline. Additionally, two-thirds of engineers spend substantial time in management (ASEM). Engineers clearly must be prepared for management, and an EM program is a natural path to address this need.

With strong current contributions to the overall engineering community, we contend that NC State is well positioned to create and administer a degree program tailored directly to this growing need for management-trained engineers regionally and world-wide. In addition, an EM program at NCSU is aligned strategically with the mission of the college.

Positioning: Currently there are 600 graduate students enrolled in 10 non-thesis distance-based masters programs in the College of Engineering at NCSU. These programs demonstrate that we have the infrastructure and experience to support an EM program. In addition, as one of the largest colleges of engineering in the US we have an annual pool of BS graduates who know our college and programs are thus connected with the university when they seek graduate options. Our physical location in the research triangle region of North Carolina, in the southeast US, continues to bring high-tech companies to the region, and these companies attract engineers and

scientists who are looking for advanced degrees, and means of supplementing and advancing their careers. Too, these companies are looking for skill providers to offer degree programs for their employers. These factors combine to put NC State in a great position to attract students to an EM curriculum.

Mission: The addition of an EM Program is consistent with the current College of Engineering (COE) Mission and effectively stands as an example of this pursuit. Contributing to the long-term goal of remaining a leading public college of engineering, an EM program at NCSU will enhance the breadth of offerings, thereby aligning the COE with many other engineering colleges offering established EM programs. Furthermore, an EM program directly contributes to reaching the stated goals of the COE Mission through both the interdisciplinary structure and the emphasis on leadership, innovation, and globalization:

Image – A unique EM characteristic is the responsiveness to corporate trends. Therefore, the college's commitment to an EM program demonstrates a desire to address current industry concerns. Additionally, NCSU's global impact is enhanced through EM's accessibility and focus. The program will be globally accessible through engineering online distribution and EM's focus on global workforce will produce globally-aware graduates.

Economic Development – Core elements in an EM program are managing the process of innovation and facilitating entrepreneurship. An EM program at NCSU will be positioned to directly assist local companies in this pursuit through education and collaborative projects.

Collaborations – An EM program is designed for the experienced engineer in management. Therefore, the program will generate management-level alumni who become critical industry contacts for future collaborations and partnerships. Additionally, the interdisciplinary nature of EM encourages industry relationships not just for EM, but for all engineering programs.

Infrastructure/Culture/Staff/Faculty –An EM program will facilitate faculty crossing department lines through its interdisciplinary structure. Student diversity will be enhanced by attracting engineering leaders from all areas of expertise. In addition to technical diversity, the presence of experienced engineers in the COE brings invaluable practical perspectives, benefiting both faculty (and therefore traditional students) as well as EM student colleagues.

Research – Current COE faculty who teach EM courses will be exposed to new areas for expanding their current research, and dedicated EM faculty will generate research in a discipline currently not represented at NCSU. Both will benefit from exposure to experienced professional students as a source for industry trends and potential funding. Furthermore, the interdisciplinary EM program facilitates an environment for collaborative research between departments.

Education/Alumni/Outreach/Students – The need for EM is growing nationally as most engineers spend time in management and the overall national workforce is shifting from manufacturing to service and management. The EM program will attract engineers who are currently in management positions and likely candidates for future leaders in their fields;

therefore, educating this demographic enhances the NCSU image of producing alumni who are leaders in industry. Additionally, an EM program administered through engineering online will improve the distance education offerings.

4. Curricular Proposals at NC State

The goal of Engineering Management at North Carolina State University is to fulfill the mission of the College of Engineering by producing well-rounded engineers who can function effectively in their area of expertise as well as possess the skills to assume leadership roles. Engineering Management requires the ability to plan, direct, and systematize technical projects, people, and organizations. Complex business solutions require both analytical and management skills for effective decision-making and leadership. The Engineering Management Program at North Carolina State University incorporates the management discipline into the engineering environment. Designed to assist experienced engineers with advancement into supervisory and decision-making roles, the program is conveniently offered through the Engineering Online department. Students watch classes online at their convenience yet gain access to instructors, fellow students, and classroom materials, via the Wolfware classroom management system. The flexible curriculum options allow students to continue in-depth growth in a specific engineering discipline while focusing on the overlying management decisions faced in today's global, innovative, and technology-dependent corporations.

Admission Requirements: To enroll in the program, students must have an ABET accredited undergraduate degree in engineering and a minimum of two years' experience in an engineering or management discipline.

Curriculum Proposals: Two alternate curricula are presented:

1. *Idea, Invests Required:* The first curriculum proposal accounts for future ASEM certification, addresses research trends, and remains within the strengths and feasibility of NCSU. It consists of 30 hours comprised of six core courses, three electives, and a capstone project. The proposed courses are all new and unique to NCSU, and are proposed to maximize the value of the program to students.
2. *Acceptable, Minimal Investment:* Proposal two attempts to achieve the goals driving proposal one, yet utilizes current NCSU classes.

NCSU EM Curricula Proposal #1:

6 core courses + 3 electives from any engineering dept. + project (30 semester credit hours)

Prerequisites: coursework in statistics and engineering economy, basic business course or experience. (Students without business courses or experience must take BUS390G.)

Capstone Project – The capstone project is an opportunity to demonstrate and practice the integration of engineering management techniques as applied to an industry-based problem.

Core Courses for Proposal #1 (all new courses):

NOTE: In constructing the course descriptions below, capturing the critical topics is top priority. Additionally, the course descriptions are intentionally written to appeal to an engineering manager, ready for use in the language and tone of a course catalog.

Management of Engineering Teams – This course covers management theory applied to the engineering environment. Topics include leadership, strategic decisions, motivation, team decision-making, diversity, infrastructure, performance measurements, global workforce, and ethics.

Technical Project Management – Successful project management is critical to achieving goals via the directing and planning of limited resources. Applications exist throughout the corporate environment from new product development, to production and maintenance of current goods and services. This course covers strategies for success of technical projects under multiple constraints including time, costs, and quality. Topics include current available tools, project selection, work breakdown structures, project scheduling, project budgets, resource management, effective communication, and performance measurements.

New Products, Entrepreneurship, and Innovation – The technology development process is critical for both existing and new businesses. This course emphasizes the process of bringing new ideas and products to life. Topics include legal fundamentals for new technologies, new business development and decisions, intellectual property generation, proposal writing and presenting, government contracts, and patent process.

Managerial Finance in Technical Systems – Financial management involves balancing risk and profitability. Emphasis is on analyzing alternative decisions regarding the selection of projects and actions. Topics include a review of engineering economy, project financing, estimation of costs and value to intellectual investments, investment analysis and selection, reading financial reports, ROI, risk and return, and capital budgeting.

Analytical Decision Analysis – Introduction to modeling and analysis techniques for strategic, tactical, and operational decisions. Students will learn optimization methods and applications to engineering and management problems. Topics include deterministic modeling and solution techniques, sensitivity analysis, network problems, and spreadsheet modeling.

Statistical Decision Analysis – Model and evaluate potential solutions to decisions involving risk and uncertainty. Quantitative and qualitative approaches are studied to describe uncertainty and problem solutions. Topics include probability theory, random variables, and simulation.

NCSU EM Curricula Proposal #2:

5 core courses + 4 electives from any engineering dept. + project (30 semester credit hours)

Prerequisites: coursework in statistics and engineering economy, basic business course or experience. (Students without business courses or experience must take BUS390G.)

Capstone Project – The capstone project is an opportunity to demonstrate and practice the integration of engineering management techniques as applied to an industry-based problem.

Core Courses, Proposal #2 (use of existing courses):

General Management Category:

BUS 530 Managing People in the High Tech Environment - Management of people in organizations. Processes of staffing, motivating, and managing within cultures of technology-intensive organizations. Leadership. Diagnosis of organizational culture. Conflict management and negotiations. Innovation and change management.

Quantitative Category:

OR 501 Introduction to Operations Research - OR Approach: modeling, constraints, objective and criterion. Problems of multiple criteria, optimization, model validation and systems design. OR Methodology: mathematical programming; activity networks; dynamic programming; Markov processes; queuing theory. Examples, OR Applications: production planning and scheduling; service systems; health care delivery; Waiting line problems: single and multiple servers with Poisson input and output. Project management through PERT-CPM.

Project Management Category (one of the following):

CE 561 Construction Project Management - Construction project management and control using network based tools, time-money analysis and other quantitative and qualitative techniques. Planning and scheduling, critical path, lead-lag, resource allocation, uncertainty, cash flow and payment scheduling, change orders, project acceleration, coordination and communication, record keeping. Emphasis on computer-based techniques.

BUS 564 Project Management - Life cycle view of organizing and managing technical projects, including project selection, planning, and execution. Methods for managing and controlling project costs, schedules, and scope. techniques for assessing project risk. Use of popular project management software tools. Application of project management tools and methods to product development, software, and process reengineering projects.

Economic Analysis Category (one of the following):

ISE 510 Advanced Engineering Economy - Engineering economy analysis of alternative projects including tax and inflation aspects, sensitivity analysis, risk assessment, decision criteria. Emphasis on applications. 3 credit hours.

ISE 711 Capital Investment Economic Analysis - Analysis of economic merits of alternatives including interest and income tax considerations. Risk and sensitivity exploration techniques. Introduction to analytical techniques for multiple objectives or criteria. Use of mathematical programming and computers for capital budgeting.

BUS 520 Managerial Finance - Investment and financing decisions by businesses with emphasis on technology-driven organizations in rapidly changing environments. Cash as the basis of asset valuation. Time value of money. Capital budgeting decisions under certainty and uncertainty. Capital market theory. Cost of capital. Capital structure theory and dividend policy. Cash management. Options and managerial implications. Derivatives and risk management.

Innovation, Entrepreneurship Category (one of the following):

MSE (BUS) 576 Technology Evaluation and Commercialization Concepts - Commercialization potential of new technologies, products and processes. Marketing, organizational, financial, operational and manufacturing issues. Strategic assessment and planning. Innovation management. Entrepreneurial transfer mechanisms including spinoffs, licensing and high-technology start-ups. Practical application with project and team management skills development.

MSE (BUS) 577 Technology Evaluation and Strategy - Theoretical and practical team-based application of systematic evaluation techniques for assessing commercial potential of technologies, products and processes. Prioritization and selection based on technology strategy.

MSE (BUS) 578 High Technology Entrepreneurship - Development of strategies to commercialize technology based on prioritized assessments. Investigation of various commercialization approaches. Business plan development. Practical application of technology management skills to actual cases with commercial potential.

BUS 579 Entrepreneurship - Elements and application of the entrepreneurial process. entrepreneurship, business and strategies, structuring and financing a venture, managing growth and risk, plan.

BUS 500 Strategic Management - Theory and practice of business, global, and corporate strategy for high technology firms and firms in industries affected by advancements in information technology. Alignment of technologically intensive organizations' strategies and structures with their macro and industry environments.

5. Evaluating the NCSU EM Proposals

Considering the proposals described above, we ask where would the NCSU program fall in the spectrum of EM programs? Here we attempt to answer that question.

EM bridges engineering and management programs and often overlaps slightly or borders Systems Engineering (SE) and Management of Technology (MOT) programs – SE and MOT are the extreme points in the EM landscape. In Figure 10 the EM programs evaluated in this study are compared based on curriculum emphasis. To rank the programs, each was assigned a weighted score indicating their respective emphasis toward SE or MOT. The score is calculated

from the topics covered in required curricula and if those topics are found primarily in SE, EM, or MOT programs. For example, programs with heavy focus on decision analysis techniques lean towards the SE end of the figure; those with heavy focus on general management and information systems are on the bottom of the figure representing a lean towards MOT.

The intended point of Figure 10 is the general positioning of each program. The specific rankings could certainly be argued based on the ranking system. However, the overall trend and positioning is sound. Note that the two proposed NCSU programs fall appropriately in the middle of the landscape. Locating in the middle portion of this graph is the goal for the proposed curricula as they are designed for consistency with the accepted EM discipline.

Figure 11 is intended to look more specifically at how well the two NCSU proposed curricula compare to other EM programs in strength of EM topics. The topic areas and the percent of programs that cover each area, as displayed in Table 2 are the starting point. The percentage associated with each topic maps directly to the weight of that topic. A program is credited with that weight if the topic is included in the required curriculum. A weighted EM score is then calculated for each program. Mathematically, the EM score, $EMscore_j$, for each program j , is calculated as

$$EMscore_j = \sum_{i=1}^n w_i t_{ij}$$

where n is the number of topics, w_i is the weight of each topic i (the percent*100 from Table 1), and $t_{ij}=1$ if topic i is included in program j , and 0 otherwise.

For an example in calculating the score, consider the topic Organizational and People Management with a 96% participation rate. In this case the topic weight, $w_i = 96$ when $i = \text{org/people mgmt}$. If a program j covers this topic, then $t_{ij}=1$ and $EMscore_j$ is incremented by 96. For all programs, each topic is checked for inclusion, and $EMscore$ is incremented accordingly. In Figure 11 this EM score is represented by the red line, with the programs in the top left scoring higher.

What can be learned from this figure and the EM score? This EM score represents two concepts:

- The level at which a program conforms to other EM programs.
- The topic coverage of an EM program.

A higher score indicates a program that includes a large quantity of common EM topics in the required curriculum. With respect to calculating the score, a program receives the most points toward its score by including topics that are found in many other EM curricula, while gaining a minimal score increase for topics that fall outside of common EM curricula. This method of calculation is slightly biased toward programs that include many topics in their curricula, but one could argue the greater number of EM specific courses and topics offered implies a better EM program, and the bias is minimal.

Figure 11: Landscape of Emphasis Among Engineering Management Programs

Figure 12: EM Program Comparison by Weighted EM Score

The two proposed NCSU curricula score high on the EM weighted chart. Therefore, we learn that they are both consistent with current existing EM curricula and that they provide excellent EM topic coverage with respect to other programs.

Based on these two above figures and the rankings that motivate them, we can see the potential for the NCSU program to compare to other EM programs, and understand which programs with which the curriculum will align most closely. Table 3 lists the fifteen programs that conform the most closely to the NCSU proposal #1. This ranking is based on the combined proximity in the above two rankings, EM landscape and EM score. Certainly other programs are useful resources, but these programs should be considered as effective benchmarks.

The proposed curricula are potential starting points for EM at NCSU. To increase the quality, future evolutions of the programs need to consider other issues outside of simply course work. Leadership is targeted as a key quality in EM and needs to be addressed through specific courses, seminars, or collaborative work that transcends multiple courses. In addition to the project, a capstone preparation course is a natural step towards capturing the extra skills such as leadership, communications, teamwork, and integration of knowledge that can be lost in traditional single-topic courses.

Organization of the courses and students should be considered as an avenue for change. The concept of cohorts, or starting and completing the program with the same group of students, is an effective method of capturing the intangible skills. Additionally, a program consisting of 8-12 topic modules instead of 4-6 multi-topic courses is an approach some universities utilize.

Table 3: Proximity to NCSU Proposal #1

Proximity	EM Program
1	SMU executive
2	OK State
3	Wayne
4	Michigan Dearborn
5	Tufts
6	Marquette
7	Air Force
8	Florida
9	Wash State
10	Case West Reserve
11	Drexel
12	UCF
13	UT Austin
14	MIT SDM
15	ODU

Because no EM on-campus program exists, NCSU has the opportunity to maximize the EM student experience by specifically tailoring each new class to EM goals. Modules also allow for a greater number of faculty involved at a lower commitment level.

For NCSU to achieve continued growth and accurate direction, it is critical to define ownership of the program. ASEM certification requires at least one full time EM faculty member and this is an obvious approach for directing ownership.

Target Audience and Feedback: The target audience for an EM program at NSCU is anticipated to be engineering alumni, regional engineering managers, current engineering online students, and colleagues of current engineering online students. A missing piece in this study is input from these potential students. This input is critical to design a program that meets the needs of the target audience. Without the support of engineers and corporations who intend to utilize this program, it will struggle to support the university mission as described in the opening section. Therefore, once the program is accepted internally, it should be proposed to current industry professionals and contacts for feedback and adjustment. Market research should determine (1) demand for the program, (2) need for skills, and (3) design of the program.

5. Conclusions:

The college of engineering should seize the opportunity to enhance its current prominent standing with the addition of an EM program. An EM program will appeal and attract an

untapped market of students and provide financial benefit to the college. It will allow NCSU to align and compete with leading engineering programs. Finally, an EM program addresses the COE mission with specific benefits to each area: image, economic development, collaborations, infrastructure/culture/staff/faculty, research, and education/alumni/outreach/students.

An EM program is achievable at NCSU through the strong and varied capabilities across the engineering departments. Current courses can provide the starting point, with new course added as the program grows. The physical needs of an EM program are minimal, and engineering online is posed to support such a program. A program that attracts predominately part-time students, with no laboratory requirements, is well-suited for online distribution.

What needs to be done? This study addresses the structure of an EM program, relative to the overall discipline of EM. Curricula are proposed that align with current programs, research trends, and discipline trends, and position the program for future certification. What remains to be completed is a study on the specific EM needs of the NCSU target audience. Beyond this, the program requires ownership for effective execution. Although engineering online can administer the program, it will need designated leadership and support to be accepted by faculty and future students.

Finally, the college of engineering must determine the next path. In light of this study, there is a clear argument for moving forward with an EM program. It is consistent with the COE mission and will bring financial benefit. Therefore, I highly recommend that this program receive the college-level direction and support necessary for success.

6. Bibliography

1. ASEE. (2008, March). Databytes-Future Engineering Managers. *Prism* , 17 , 7.
2. ASEM. (2008). *American Society for Engineering Management*. Retrieved October 2008, from <http://www.asem.org/>
3. Babcock, D., & Morse, L. C. (2002). *Managing Engineering and Technology*. Prentice Hall.
4. Hicks, P. C. (1999, March). What are we teaching our engineering managers? *Engineering Management Journal*.
5. Kern, C. D. (2002). Content and Trends in Engineering Management Literature. *Engineering Management Journal* , 14 (1).
6. Kotnour, T., & Farr, J. V. (2005). Engineering Management: Past, Present, and Future. *Engineering Management Journal* , 17 (1).
7. Roberts, E. B. (2004). A Perspective on 50 Years of the Engineering Management Field. *IEEE Transactions on Engineering Management* , 51 (4).
8. Spencer Stuart. (2008). *Route to the Top*. Annual CEO Profile Report, Chicago, IL.
9. Winston, A. W. (2004). Engineering Management--A Personal Perspective. *IEEE Transactions on engineering management* , 51 (4).