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Developing Engineering Management Core Competencies

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ABSTRACT

Fast developing countries face many challenges in attempting to harmonize the growth in the various building-blocks of their economies. In particular, educational institutions within emerging economies bear a greater responsibility of providing highly qualified graduates whose academic background and skills are most suited to meet current and future market needs. Fueled by the revenues from large oil reserves, the United Arab Emirates (UAE) is experiencing one of the fastest growing economies in the Middle East. Only small percentage of the UAE population is nationals and the government authorities are counting on this small percentage to run and manage the country's affairs. Engineering students who are UAE nationals are forced to short-cut their progression through the usual engineer's life-cycle to take on management responsibilities in the private as well as the public sectors. Unfortunately, classical undergraduate engineering programs do not prepare engineering students to assume management positions at an early stage in their career. In many cases, concentrated technical training may actually hamper the engineer's efforts from succeeding in management positions if he/she is given this responsibility early in their career path. This paper presents an interdisciplinary engineering graduate program established at the American University of Sharjah (AUS) with a main objective of developing Engineering Management core competencies of engineering graduates in the Gulf region.

Keywords: Engineering Management, Core Competencies, Graduate Education, UAE

1. INTRODUCTION

Soft skills such as communication, teamwork, leadership, motivation and general management are important to the success of engineers. These areas are overlooked in the undergraduate engineering curricula. "Currently, engineers learn leadership and management skills while working – learning soft skills the hard way" (Kumar and Hsiao, 2007). In the workplace, employers prefer engineers with strong soft skills. Even when looking for prmotion and senior management positions, engineers with strong soft skills are prefered. Sommers et al. (2004) found out that engineers are overlooked to senior management positions and attributed that to the lack of education in communication, leadership and management skills (Also Kumar & Hsiao, 2007).

Engineering Management (EM) graduate education is increasing in demand. Universities across the world are implementing new graduate programs in engineering management mainly because they have the potential of generating significant tuition revenue without the corresponding commitment of high-priced university resources and they are attractive to engineers from all disciplines (Westbrook, 2005). Hicks et al. (1999) classified engineering management programs in terms of their focus into three groups: classical manangement, mathematical concepts and behavioural management. Graduate programs in engineering management should maintain a balance between quantative and qualitative concepts. According to the American Society of Engineering Management (ASEM) certification standards, the curriculum requirements include a balance between qualitative and quantitative courses and at least one third of the curriculum to be management or management-

related courses (Westbrook, 2005). Quantitative concepts are required to tie the discipline to the field of engineering (Westbrook, 2005). Botero and Castro (2005) indicated that at the entry level, engineering managers need the quantitative areas such as statistics, finance and accounting while later in their careers, they work in areas that are of qualitative nature such as human resources and policies. A study by Farr and Bowman (1999) indicates that the ability to communicate effectively was ranked the top ABET criteria in engineering management programs followed by the ability to function on multidisciplinary teams. Botero and Castro (2005) realized the need that new engineering management programs must be developed to reflect the local needs and experiences. This is particularily true in the UAE.

Kotnour and Farr (2005) described a potential body of knowledge for engineering managers to include three area: lifecycle issues, core processes and enabling processes (core desiplines). The lifecycle issues include topics such as new product development, value chain management, production and technology marketing. Core processes include strategic management, project/program management, systems engineering, knowledge management and change management. The third area is the core desiplines and includes organizational and workplace design, economics of engineering, quantitative methods and models, quality management and developing engineering management professionals. Eschenbach and Ra (1997) explained that a program mission must balance concepts, skills and knowledge. The concept area emphisize the ability to visuilize the big picture. The skills area include teamwork, communication and analytical skills. The knowledge area includes both managerial and technical knowledge.

Engineering management education is different from the traditional engineering education. Eschenbach and Ra (1997) contend that engineering management education is focused on allowing individuals to achieve a new balance from object-focused engineers to people focused managers, from well-structured to ill-structured problems, from single aspect to multiaspect problems, from certain to uncertain data and from perfectionism to satisfying. This requires a change in the type and the way courses are conducted in Engineering Management programs.

2. CORE COMPETENCIES FOR ENGINEERING MANAGERS

Through the natural career-path progression of engineering graduates, engineers pass through the phases of apprentice, professional, mentor, and finally the sponsor phase. During these phases, engineers face many difficulties when they assume management responsibilities within their organizations. Their undergraduate education seldom prepares them to deal with the challenges inherited in managing people. Due the intensive technical training they receive, they become accustomed to making decisions with much information under great certainty, while in the real-world; many decisions are often made with inadequate information and greater uncertainty. In addition, promotion to a management position removes the engineer from the close contact with the details he/she is accustomed to in their technical comfort-zone. In these management positions, engineers soon find out that the management function requires skills and personality traits that are much different from those which are learned in their undergraduate studies.

Engineering managers are best suited to manage either a technical function such as production and design or in a general management function such as marketing management in a technical organization. Performing both jobs requires the engineering manager to develop necessary core competencies which includes a balance of the technical skills with interpersonal and conceptual skills; mastering technical knowledge by itself is not enough to assure the engineering manager's success. To meet the challenges of the 21st century, engineering managers need to manage the inside of the company as well as the outside, to lead from present to future, and to act locally and think globally (Change, 2005).

Core competencies for engineering managers may be divided into four broad categories (Figure 1); technical competencies, financial competencies, managerial competencies, and leadership competencies. Since the engineers are most qualified to work in and manage technical organizations at different levels, technical competencies are a must for engineering managers in order to properly communicate technical issues with customers inside and outside the organization. They must be able to develop organization systems that are efficient and effective as well as robust. Their function requires ability to assess risk and to use state-of-the-art

decision making tools and system optimization techniques to efficiently utilize organization resources including information technology.

Being technically competent must be accompanied by competencies in the management function of planning which includes strategic, operational, as well as tactical planning. Competencies in other management functions such as organizing, staffing, and controlling are necessary in order for the engineering managers to be able to direct organizational resources, in a focused manner, to serve the mission and vision of the organization.

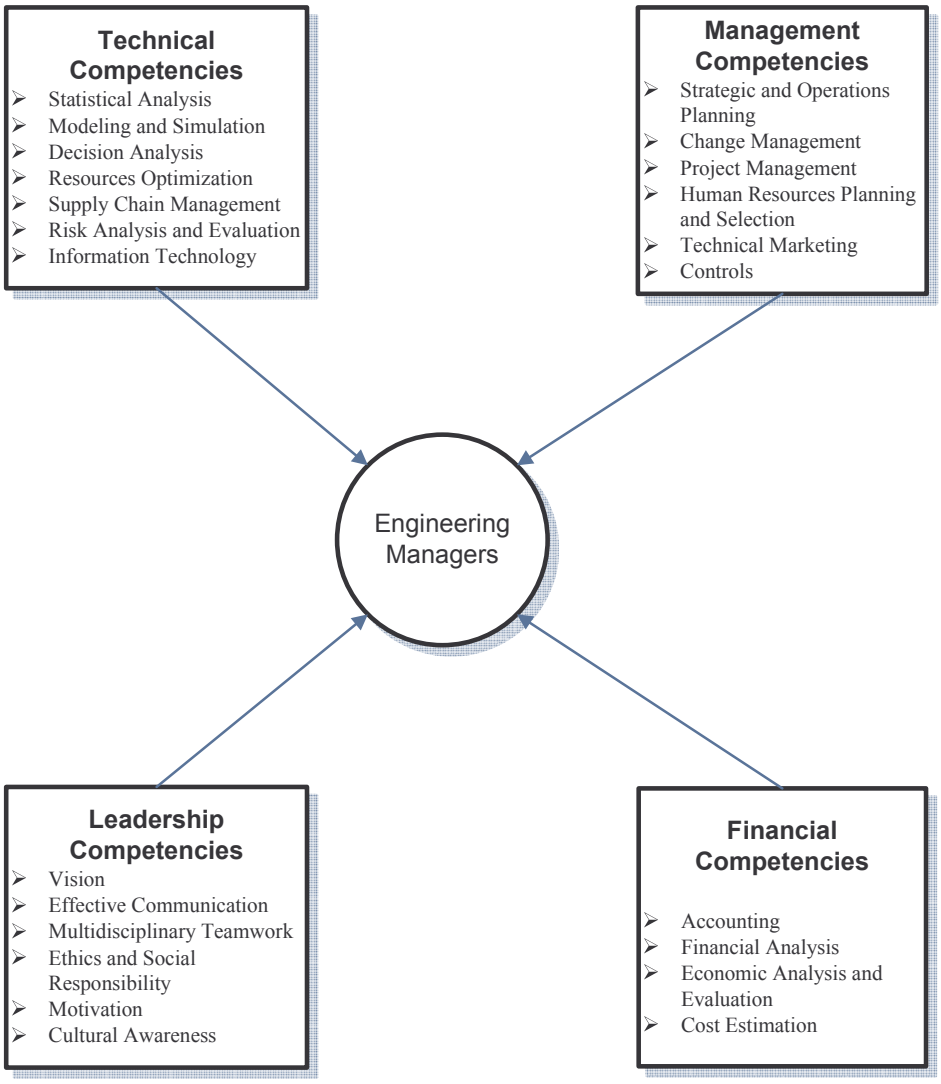

Figure 1. Engineering Management Core Competencies

Developing financial competencies is no longer an option for engineering managers; they must not be concerned only if their designs "will work", they must assure that designs will exceed the needs and expectations of their customers and also "make money" for the organization. This requires understanding of the fundamentals of financial accounting and financial management. Performing economic analysis for projects and choosing between alternatives based on their economic variability and return on investments is a routine part of an engineering manager's job.

By developing leadership competencies, engineering managers learn to do the "right things" rather than "doing things right". Aspiring employees to act willingly and exert high levels of effort toward achieving organizational goals becomes a reality only as a result of effective motivation by their leaders. Engineering graduates must learn how to self develop other leadership traits such as integrity, self-discipline, commitment, and persistence and cultivate natural tendencies towards respecting and valuing others.

When developing a well rounded knowledge in the all four categories of the core competencies, engineering managers will be at a better position to succeed at various levels of managerial positions in technical organizations.

3. ENGINEERING MANAGEMENT AT AUS

The American University of Sharjah (AUS) was founded in 1997 by His Highness, Sheikh Dr. Sultan Bin Mohammed Al Qassimi, supreme council member, Ruler of Sharjah and President of AUS. AUS is licensed in the United States by the Department of Education of the State of Delaware. It is accredited by the Commission on Higher Education of the Middle States Association of Colleges and Schools. The School of Engineering (SOE) offers six undergraduate programs in Chemical, Civil, Computer, Electrical, Mechanical Engineering and Computer Science. All bachelor's degree programs in the School of Engineering have been accredited by ABET. In addition to the undergraduate programs, SOE offers two graduate degrees: one in Mechatronics and the other in Engineering Systems Management (ESM).

The ESM program is a multidisciplinary program that aims to prepare practicing engineers for future management positions. Currently there two themes within ESM: Construction Management and Engineering Management. This paper focuses on the Engineering Management theme. The ESM has three full time faculty members to cover the main courses of the program. Faculty from other department participate on a regular basis to teach courses that are related to their disciplines. Most faculty have North American education and industrial experience. The student body is largely local (from the UAE) with some students from the neighboring countries which enriches the cultural diversity.

The program structure is shown in Table 1. Students are required to take 5 courses at the foundation level (15 credit hours) and 5 courses at the theme level (15 credit hours). The additional 6 hours are for thesis or project. The course descriptions are presented in Appendix A (AUS Catalog, 2006).

Table 1: ESM-EM Structure

Course No.	Course Title	Hours
Foundation Courses (15 Hours)		
ESM 500	Statistical Methods for Engineers	3
ESM 510	Economic Decision Analysis	3
ESM 520	Management for Engineering	3
ESM 530	Strategic Technology Management	3
ESM 540	Modeling and Simulation	3
ESM 550	Information Technology Management	3
ESM 560	Quality Engineering and Management	3
ESM 570	Project Management	3
EM Theme Courses (15 Hours)		
ESM 632	Applied Operations Research	3
ESM 636	Human Resources Management	3
ESM 638	Decision Analysis	3
ESM 640	Supply Chain Management	3
ESM 644	Financial Management for Engineers	3
EM – Thesis / Project (6 Hours)		
ESM 698 / 699	Professional Project / Thesis	6

Table 2 shows a proposed listing of core competencies for engineering managers and how the interdisciplinary program at AUS (described in the following section) attempts to develop these core competencies through the design of its curriculum.

Table 2. Relationship Between EM Core Competencies and Program Courses

	Program Courses												
Core Competencies	**500**	**510**	**520**	**530**	**540**	**550**	**560**	**570**	**632**	**636**	**638**	**640**	**644**
Technical Competencies													
Statistical Analysis	●	○			◑		◑	○	○		○	○	
Modeling and Simulation					●			○					
Decision Analysis			◑					◑	◑		●		
Resources Optimization			○			○		○	●			◑	
Supply Chain Management												●	
Risk Analysis and Evaluation	◑				◑	○		◑			◑		○
Information Technology						●	○	○		○			
Financial Competencies													
Accounting		◑										○	●
Financial Analysis		○											●
Economic Analysis and Evaluation		●		◑									○
Cost Estimation		◑						◑			○	○	○
Management Competencies													
Strategic and Operations Planning			◑	●		○		○		○		○	
Change Management			●	○				○		◑			
Project Management			○					●					
Human Resources Planning and Selection			○					○		●			
Technical Marketing			◑										○
Controls			●	○		○	◑	◑		○			
Leadership Competencies													
Vision			◑			◑							
Effective Communication	○	○	●	○	○	○	○	○	○	○	○	○	○
Multidisciplinary Teamwork	○	○	●	○	○	○	○	○	○	◑	○	○	○
Ethics and Social Responsibility	○	○	○	○	○	○	○	○	○	●	○	○	○
Motivation			●			○		○		●			

Cultural Awareness			◑					○		●			

Level of relationship between core competencies and courses: ● high; ◑ medium; ○ low

4. SUMMARY AND CONCLUSIONS:

Academic institutions have an obligation to meet the needs of prospective employers of their graduates. This can only be met if universities do not develop their educational programs in a vacuum where the needs of its customers are not the driving force behind the programs curriculum structure. This is particularly true in fast-paced developing economies such as the one of the UAE where the government is attempting to run the public as well as the private sectors using its UAE nationals. Engineers who are nationals are expected to take on managerial responsibilities especially in the public sector at an early stage of their career without adequate managerial background from their undergraduate studies.

In this paper we presented an example of an interdisciplinary graduate engineering program at AUS that is designed to develop core competencies of engineering graduates to meet the needs and market demands in the Gulf region. We presented descriptions of four categories of engineering management core competencies and showed how the ESM graduate program at AUS attempts to develop these core companies of its graduates by structuring the curriculum to balance the quantitative and the qualitative courses offered as well as developing the courses while keeping in mind the needs of its external customers.

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APPENDIX A (AUS CATALOG 2006-2007)

ENGINEERING MANAGEMENT SELECTED COURSE DESCRIPTIONS

ESM 500 -- Statistical Methods for Engineers (3-0-3)

Covers the principles and methods of statistics as applied to engineering systems and management. Topics include probability, sample statistics, confidence intervals, and introduction to quality control for product acceptance and process control.

ESM 510 -- Economic Decision Analysis (3-0-3)

Covers economic decision analysis and accounting/finance fundamentals for engineering projects and management. Also covers time value of money and the effects of interest, project cost estimation, alternative evaluation methods, make/buy decisions, replacement studies and project selection under limited budget. In addition, fundamental principles of accounting, indirect cost distribution and financial analysis are covered. Includes extensive use of spreadsheets and case studies

ESM 520 -- Management for Engineers (3-0-3)

Treats a range of integrated topics for individuals in both public and private sector organizations who coordinate and manage engineering projects, personnel, resources and systems. Professional practice topics include human resources, communication skills, leadership styles, team building, total quality management, principles of project management, and the fundamentals of organizational development and performance evaluation. Management needs in multicultural and multinational environments are also considered. Integrate core management principles with engineering experiences using case studies and applications.

ESM 530 -- Strategic Technology Management (3-0-3)

Gives students a broad overview of the main topics encompassed by management of technology. Includes technical managerial challenges which are presented by new technologies in the context of engineering systems, and development and implementation of technological strategies to create competitive advantages. Presents innovative activities beginning with research and development and extending through production and marketing. Focuses on the emergence of the knowledge economy and technology as a key knowledge asset. Technological innovation, technological forecasting, technological impact identification, technology assessment and evaluation and case studies.

ESM 540 -- Modeling and Simulation (3-0-3)

Covers the concepts and principles associated with systems modeling and simulation using contemporary software such as simulation with ARENA. Topics include probability and statistics review, modeling techniques including problem formulation and queuing theory; discrete event simulation modeling. Students become experienced with the state-of-the-art simulation and modeling software reflecting the joint nature of these activities in good simulation studies, and continuous simulation of industrial and manufacturing systems using ARENA Team project included.

ESM 560 -- Quality Engineering and Management (3-0-3)

Covers the techniques and applications of quality control, total quality management and reliability engineering. Topics include sampling procedures; data patterns; product quality and control of engineering materials, Statistical process control (charts and troubleshooting), product acceptance sampling plans, process capability analysis, an introduction to total quality management, reliability principles and analysis, time-to-failure, failure rate, and reliability determination, and component and system reliability.

ESM 570 -- Project Management (3-0-3)

Covers the application of management techniques related to the unique nature of projects. Examines the elements of project management critical to the success of projects; project management framework, project life-cycle, scope management, time management, cost management, project controls and earned value, use of project management software. The principles and tools are integrated and clarified through case studies from a variety of disciplines and through creation of project management plans developed by students working in teams.

ESM 632 -- Applied Operations Research (3-0-3)

Covers formulation of mathematical model, solution using linear programming, sensitivity and cost analysis of developing alternative optimum solutions, inventory control, production planning and control, management resource planning, forecasting and stochastic modeling. Includes a team-based design project.

ESM 636 -- Human Resources Management for Engineers (3-0-3)

Introduces current trends, practices and methodology of Human Resources Management (HRM) and planning as related to the engineering profession and conduct of business. Topics include: human resources planning process, tools and techniques, job specification and methods of job analysis, Legal requirements and ethical context of HRM; Methods of recruitment, evaluation, career training and development programs, salary systems and employee benefits, HR information systems, and international HR issues. HR management practices and methodologies are integrated with engineering experiences.

ESM 638 -- System Optimization and Decision Analysis (3-0-3)

Covers theory and practice of analyzing decisions in the public and private sectors. Multiple objectives, influence diagrams, decision trees, sensitivity analysis, probability assessment, multi-attribute utility and human biases are covered. Practical applications through real world systems model building are described and conducted. Uses case studies to examine the use of decision analysis software and spreadsheets to solve real-life problems.

ESM 640 -- Logistics Management (3-0-3)

Offers an overview of supply chain management (SCM), an integration of purchasing, operations, logistics, management of physical warehouse, documentation and information flows within the supply chain cycle. Topics include supply chain management purposes and processes; supply chain design, evaluation and measurement models; trends in strategic operations, procurement, and logistics within the supply chain. Includes case studies in logistic modeling for diverse distributors.

ESM 644 -- Financial Management for Engineers (3-0-3)

Helps students in understanding, recording and analyzing financial information, cost concepts, cost behavior and cost accounting. Covers cost-volume-profit analysis and leverage, capital budgeting for profit planning, financial planning and forecasting, risk and return, portfolio theory and asset pricing models, multinational and international finance.

ESM 698 – Professional Project (6 credit hours)

Requires an approved professional project for completion of the MS degree. A selected area of engineering management and systems engineering is chosen for the project. Requires a report and final presentation to the advisory committee.

ESM 699 – Research (6 credit hours)

Comprises research in the disciplinary areas that encompass systems engineering and engineering management. Taken during the planning and completion of the thesis for the MS degree. Completed under the supervision of the faculty member serving as a thesis advisor. A thesis and final defense to the advisory committee are required.