

**ENGINEERING MANAGEMENT EDUCATION AND ACCREDITATION:
PAST, PRESENT AND FUTURE**

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ABSTRACT

Massachusetts Institute of Technology started Engineering Management Education in response to requests by industry for a degree program that would prepare managers to run the factories of rapidly industrializing North America. This program evolved over time becoming today's Sloan School of Management. The BS, MS, PhD programs in Engineering Management within the Engineering at University of Missouri-Rolla, (Now Missouri University of Science and Technology) was a rebirth for this discipline. Later, many Master level tracks in Engineering Management were launched in IE Departments. Presentation will discuss this academic discipline and its symbiotic relationship with industry and, Compare and contrast it with similar degree programs with a future outlook.

1. Greetings and thanks for the honor of speaking to you this morning. Thank you audience for your attention. Thank you also, for the splendid introduction.

2. What follows is **My story in Engineering** as it happened **in education, work in industry and academia, with a focus on Engineering Management education and practice over the last 60 years**. Most of this was in the United States.

3. How I got into Engineering Management education?

- Observations at Duzici Village Institute Hatay Province where parents taught. First **exposure to learning by doing** as a child!
- METU/ Iowa State University **Mechanical Engineering study with Co-operative training in industry** taught me **practicing your intended profession while studying it**.
- Fenni ve Gamma, part time while serving in the military as a mechanical engineer, and Ankara Mühendislik Ltd, experiences taught me **the need for Managerial skills for running a successful technical enterprise**
- **Setting up the first IE department at METU** along with Drs Omer Benli and Turkan Kumbaraci.
- After the PhD in IE returning to Ankara: METU/IE department chair experience and **the failure to set up on campus a UN funded In Plant Training Center for Engineers taught me the need for this topic to be handled by education systems**. This failure and more caused my return to US and launch my career.
- **Cal State Sacramento business school teaching exposed me to business topics** other than engineering.
- University of Missouri-Rolla (now Missouri Science and Technology University MS&T) Engineering Management Department under **Bernard R. Sarchet, where I served as a faculty member educated me about this new discipline in a university setting**.

4. Engineering Management/Engineering Administration **roots go back to 1914 with the establishment of Program XV at MIT (Massachusetts Institute of Technology)**

- **First IE Department** was at Penn State University in 1909 focusing on efficiency in production (Fredrick Winslow Taylor and his work in machining lead to Scientific Management of work).
- Both IE and EMgt disciplines came about due to **industrial pressures** on academia.
- **The need for rapidly industrializing US for technical managers of the modern factories of the day** was the driving force for EMgt.
- Incidentally, EMgt started in the economics/statistics department but rapidly absorbed into the **engineering school and was presented as Program XV at undergraduate level starting in 1914**.
- Then **came the Master level** offerings at MIT to help educate the existing engineering work force.
- Throughout this process **MIT program evolved with industry encouragement and pressure on the academicians similar to the IE programs elsewhere**.
- **In the mid 60's MIT's EMgt program evolved into the Sloan School of Management** breaking away officially from the Engineering School. The role of several million Dollars gift from the Sloan Foundation (GM) to do this was not insignificant.
- **IE discipline** emerged as a **staff function** where the IEs presented solutions to make production more efficient. **The EMgt discipline** on the other hand emphasized the **line function of optimization of the total enterprise system including the Production, Finance/accounting, Marketing and Human aspects of Management including Planning, Organizing, Leading and Controlling..**

5. About the time this was happening at MIT (mid 60's) **UM-Rolla was also undergoing some major transformations**.

- Missouri School of Mines a **Land Grant institution focused on mining and engineering became a University.**
 - There was a **need for broadening** the offerings and adding new fields of study.
 - **Addition of Computer science and Engineering Management** technical disciplines along with several Humanities disciplines took place
 - Role of a retired industry executive, **Chemical Engineer Bernard R. Sarchet in shaping the Engineering Management program is very important** as the newest degree offering along with all other engineering disciplines on campus.
 - **Bernie described the Engineering Management program as a “blend of three years of engineering with one year of management”. These topics included Production, Marketing, Finance/Accounting and Management (Planning, Organizing, Leading, Controlling...)**
 - Bernie saw that a lot of Freshman engineering students were dropping out of the demanding **classical engineering disciplines (ME, EE, CE, CHE, etc.)** and not finding a **softer alternative** they were leaving the campus negatively impacting the total enrollment numbers
 - The **BS degree in Engineering Management on campus** was therefore seen as a salvage operation. Some drop outs from classical disciplines would get back in after improving their motivation and grades and some would simply stay and end up with the EMgt degree which turned out to be very marketable in industry.
 - **Major US companies discovered that these graduates were excellent performers in production supervision and technical product or service marketing.** Industry representatives said that they found them to be technically competent enough but also possessed business skills like cost accounting/finance, marketing, production and other management areas. **Proctor and Gamble** was among them that hired EMgt graduates for **production line supervision and technical marketing.**
 - Bernie also opened up a **large market in St Louis**, home of many technology companies employing thousands of engineers, (**Boeing, Monsanto, Emerson Electric, Purina, Anheuser Busch etc.,**) by offering an evening program leading to the **MS degree in Engineering Management.** This program grew rapidly due to an excellent reading of the market by Professor Sarchet.
 - Thus under Bernie’s leadership the department and the new discipline of Engineering Management became a **permanent and significant part of the engineering degree offerings at UM-Rolla but lacked the respectability** among sister engineering departments as **being the only large discipline that was not ABET accredited.**
6. ABET accreditation of the Engineering Management Degree at UM-Rolla:
- What is ABET- (Accreditation Board for Engineering and Technology)?
A US based organization with global mission to develop and maintain quality engineering education at world universities. Largely run by volunteers from Industry and Academia
 - **MUDEK and ABET connection through Washington Accords (Turkey joined in 2011.**
 - Starting in the mid-seventies the expectation of younger faculty with strong academic backgrounds and the alumni pressures for the need to seek and secure accreditation lead to **ABET accreditation of Engineering Management as the first such named degree in the US in 1978.** This leadership position is still maintained to this day.
 - Why you need ABET Accreditation and How it works? In the US engineering programs need accreditation to permit the **graduates to qualify for exams that lead to Professional Registration.**

Thus a team of volunteers from Academia and Industry visit and study a Program and pass a judgement on its quality.

- ABET Commissions & Committees?

EAC- Engineering Accreditation Commission, handles engineering degrees

TAC - Technology Accreditation Commission

CAC - Computing Accreditation Commission

ANSAC- Applied and Natural Sciences Accreditation Commission

- **What are the ABET visitors looking for? General Criteria for Basic Level (Bachelors) Programs:**

Criterion 1. Students: The institution must evaluate, advise and monitor students to determine its success in meeting program objectives.....Must also have procedures and enforce them to assure all students meet all program requirements to graduate.

Criterion 2. Program Educational Objectives:

1. Detailed published educational objectives consistent with the mission of the institution and ABET Criteria
2. A process based on the needs of the program's constituencies in which the objectives are determined and periodically evaluated and modified as needed.
3. A Curriculum that ensures the achievement of these objectives
4. A System of continuous evaluation that demonstrates achievement of objectives and uses the results to improve program effectiveness.

Criterion 3. Student Outcomes: Programs must demonstrate that graduates have

- a. Ability to apply Mathematics, science and engineering knowledge,
- b. Ability to design and conduct experiments and analyze data,
- c. Ability to design systems/parts/process to meet a need,
- d. Ability to function on multidisciplinary teams,
- e. Ability to define and solve engineering problems,
- f. Understand professional and ethical responsibility
- g. Ability to communicate effectively,
- h. Understand the impact of engineering solutions on global, economic...context
- i. Life Long Learning
- j. Knowledge of contemporary issues
- k. Proficiency in modern engineering tools and techniques used in practice

Criterion 4. Continuous Improvement:

- Each program must have an assessment process with documented result and evidence that results are used to improve the process along with other input
- Evidence for this may include: student portfolios with design projects, subject content examinations, alumni surveys documenting career advancements, employer surveys and placement statistics for the graduates....

Criterion 5. Curriculum: must contain

1. **One Year of college mathematics and basic sciences** with experimental components appropriate to the discipline
2. **One and one half years of engineering topics of engineering sciences and engineering design** appropriate to the field of study
3. **Major design experience with realistic constraints** including economic, environmental, ethical, health and safety, social, sustainability.....
4. **General education component** complementing the technical content and consistent with program and institution objectives.

Criterion 6. Faculty:

1. Sufficient in number and with competencies to cover all areas of the program
2. Sufficient **faculty availability for student advising and counseling**, university service, professional development, **interaction with industry**.
3. **Faculty must have sufficient control of the program** to direct it..

Criterion 7. Facilities: Classrooms, laboratories and equipment must be adequate to achieve program. Prevailing atmosphere must be conducive to learning and professional development

1. There must be space to foster student-faculty interactions and mentoring
2. Ample opportunities for learning the use of modern engineering tools
3. Computing and information infrastructure must be in place to support student and faculty needs and educational objectives of the institution

Criterion 8. Institutional Support: Must be adequate to assure the quality and continuity of the program, and Sufficient to attract and hold quality faculty and provide for continued development. Adequate to acquire, operate and maintain laboratories and facilities for the program. Adequate support staff and infrastructure to meet program needs

7. ABET Program Criteria for Engineering Management: **Engineering Management criteria for degree programs in Basic level (BS) programs called Engineering Management or a similar name.**

Curriculum – Program must demonstrate that the graduates have an understanding of **engineering relationships between managerial tasks of planning, organizing, leading, control and the human element in production, research and service** organizations as well as **understand the stochastic nature of management** and be able to deal with it. Graduates must be able **to integrate management systems into technological environments....**

Faculty – Professional competence in engineering with **experience in managing technical activities...**

8. Secrets to success in Accreditation:

- Establish and maintain Educational Objectives
- Constituents help set objectives and evaluate their level of achievement
- Outcome Assessment is done regularly, using results to improve programs.....
- A system of processes and procedures is in place and working to meet accreditation requirements.

9. Possible ABET Accreditation visit results:

- **NGR Next General Review (6 years)**
- IR Interim Report
- IV Interim Visit
- NA Not Accredited
- SC Show Cause Why Accreditation should not be denied if previously accredited

10. Some Actions to make UM-Rolla Program a success in Accreditation in 1978:

Before going for accreditation Rolla Program was modified in some areas for example the **design component was modified to be more like an enterprise system design rather than typical business case studies**. Math and science controls were tightened. More analytical content rather than descriptive was built into the usual managerial courses such as technical marketing and financial engineering. **Use of Computer tools and statistical content was expanded in the curriculum. Etc...**

After the initial accreditation in 1978 the BS Program in Engineering Management has received continuous accreditation by ABET every six years, currently coming up for its next evaluation in the year 2020.

11. So **What is Engineering Management? Is it a degree in Engineering or Management?** How does it differ from degrees in Industrial Engineering or at the Masters level How does it compare with MBA?:

Over the years I have answered this question **“What is Engineering Management?”** asked by students, parents, industry personnel and even friends in academia over and over again. The question would be usually followed by other questions such as: **“How does it differ from Industrial Engineering or a degree in general management from a business school”** Or, **“At the Masters level how does it compare with an MBA?”**

Depending on who was asking and for what purpose, I would answer them a number of different ways but **always with the same characteristics. Engineering Management is a new discipline in Engineering**. Its name would have been more accurate if it had been **“Managerial/Enterprise Engineering”**, because that is what these engineers actually do. They do engineering in the managerial realm within an **Enterprise which is a human organization intended to generate more benefits than costs**. While anchored in the principles of science, mathematics and engineering just like other classical disciplines in engineering, **“Managerial/Enterprise Engineering” reaches out to integrate the total enterprise system including its, technical, financial, operational, organizational, marketing and human resource aspects. This integration is the key** to understanding this new engineering discipline of the 21st century.

Engineering embodies analysis and design. **Without design activity there is no engineering**. Electrical engineers design electrical systems. Similarly, mechanical engineers design mechanical systems and so on. **What is the design element in the engineering management discipline? They design the enterprise systems with the help of staff in engineering and business topics**, the whole system, as opposed to the components of the whole as is in the classical disciplines of engineering or business. That is why graduates of these engineering management programs are so capable of fitting in any and all areas of our modern technology infused enterprises. Their education, focused on all aspects of an enterprise allows them to excel as a contributor to the goals of any organization public or private.

How does it compare with Industrial Engineering and at the graduate level with the MBA? Industrial engineering programs usually prepare graduates to be **staff analysts** to operational managers. They are not intended to run an organization but provide supportive services to the people who run them. They analyze problems as defined by top management and make recommendations to the executive managers. Engineering management graduates on the other hand, can do both the analysis and the execution of what emerges as the right answer to a tactical, operational or strategic problem. Since they have a strong connection to engineering they are capable of interpreting the technological implications of the situation and the solutions being implemented. In this regard they are better prepared than the **MBA graduates who tend to excel in Finance or Marketing areas (among others) in managing an enterprise** but, may fall short on fully comprehending the technological implications of their managerial actions.

In the earlier part of an engineering career the MS degree in Engineering Management is more effective for advancement, but during the latter part an MBA from a good name school may be better for entering the corporate managerial ranks

Engineering Management degree is available at the **undergraduate level in a few universities in the United States. Among the top programs are the University of Missouri-Rolla and the Stevens Institute of Technology in Hoboken, New Jersey.** Another excellent undergraduate program is available at the **US Military Academy at West Point in New York.** Engineering Management degree is found to be **more popular in the United States at the Masters level.** There are **over one hundred fifty such programs in the US, many of them are located in the IE departments along with the MS in IE degree offerings.**

Students who seek the Masters degree in Engineering are usually interested in gaining **depth in a focused area** of the types of enterprises they wish to work in, **or** they often seek additional **breath to understand better the modern technical organizations.** Through the MS in Engineering Management education they aim to broaden their career options or increase their rate of progress within the ranks in their own organizations. This is the more common reason, typically around eighty percent of the applicants mention when they first inquire about these programs. In many cases this degree helps them adjust to the leadership roles they aspire in their organizations for which they were inadequately prepared during their undergraduate engineering education.

It is well known that engineers who join the world of work upon graduation with their BS degrees find within 3-5 years that technical problems they were prepared to solve were not that difficult. It is the enterprise skills related problems, such as: teamwork, people related problems, communications, meeting dead- lines, staying under budget and on schedule, overcoming financial and organizational barriers, etc,.. often frustrates them. These skills are not normally taught in the classical engineering programs. The undergraduate or the Master degree recipient in Engineering Management thus has an advantage in the ever so competitive job market when compared to those who do not have the integrative skills of Engineering Management/Managerial or Enterprise Engineering.

In our global economy, mastering the enterprise analysis and design skills along with a sound foundation in engineering, mathematics and sciences, as provided by an engineering management education, at any level, should lead to challenging and satisfying techno-managerial careers anywhere in the world.

12. Growth and expansion of Engineering Management at Rolla:

After serving briefly as the Department Head of Industrial Engineering at Wichita State University in Kansas, I returned to Rolla in mid-eighties to serve as the Department Head of Engineering Management where I inherited a mature department. Our earlier fund raising efforts ably led by Bernie Sarchet in getting an Engineering Management Building bore fruit and our building was being built. Entry into the electronic distance education had already begun at Rolla but was accelerated with the new and excellent technology classroom facilities in the new building. Dr Mac Daily soon became another shining star in the [NTU] National Technological University global distance education programs through courses offered from our department. By the way distance education is now a fast growing reality. Already there are at least 2 on line ABET accredited programs

Engineering Management curriculum was expanded to include a set of internal tracks in Manufacturing Engineering, Packaging Engineering, Industrial Engineering, Quality Engineering and Management of Technology in addition to the tracks in classical engineering disciplines. These were lined up from left to right on a Technical Depth versus Managerial Breadth coordinates. Thus the Manufacturing and Packaging engineering were tracks that were more technical in content with equipment based labs following an educational paradigm based on the concept of **Learning Factory**. The idea of Learning Factory was based on the **land grant tradition of learning by doing**. Thus the **Engineering Management education would be provided using an educational model more similar to the way in which physicians are trained**. Learning by doing would be at the basis of this process. Learning factory would be the comprehensive labs for this purpose. In the early years Engineering Management did not have equipment based labs which was a distinguishing feature of engineering disciplines.

Developing new fields such as the Artificial Neural Networks was another development I encouraged. Dr Cihan Dagli deserves a lot of credit in making UM-Rolla a leader in this area with the ANNIE conferences he launched in the eighties. My only role in this may have been that I brought Cihan to Rolla and coined the term Artificial Neural Networks in Engineering [ANNIE].

Packaging engineering developed as a great opportunity for us but later on it was not well supported by faculty and lost its luster. I believe that Packaging Engineering remains an area to be developed in an Engineering Management academic environment and hope that some school somewhere will take up this opportunity as there is a great need for such engineers in the work environment. I believe that Engineering Management discipline is the best academic discipline for it.

Expanding the MS program to off campus locations to industry was one of my accomplishments that I take great pride in. Particularly the negotiated cooperative program with the nearby US Army Engineering School at Fort Leonard Wood, Missouri where Army Engineer officers would complete their MS degree in Engineering Management in a 16 weeks period was noteworthy. These officers were given 15 Credits for the work they did at the Army courses supplemented by our evening classes and the remaining 18 credits were taken during a 16 week period as the base commander allowed them to stay in place until they completed their degrees. We had an interesting problem in working out this 18 credits during a sixteen week semester. Our Graduate Dean objected to such a compact delivery arguing that maximum number of credits allowed in a semester was 15 and that raising it to 18 would lower the quality. We then changed the format to two 8 week summer session equivalents where up to 10 credits were regularly allowed. I argued that we allowed them only 9 credits per 8 week term in the interest of quality! This is how the eight week sessions came about in Rolla. This format is now very common in other schools.

13. Robert Morris University Experiences in Starting a School of Engineering and Science from scratch:

After achieving national and international prominence in Engineering Management Education at Rolla I took up early retirement and moved on to Robert Morris University near Pittsburgh, PA. This private College wanted to develop a School of Engineering and Science as it planned to grow from its current status as a regional business school into a more comprehensive university that embraced science and technology. Being the Founding Dean for such a school really appealed to me so I went there and in 6 years developed ABET accredited BS degree programs in engineering that in content had the Engineering Management character but without the name. The degrees in Software, Logistics (now Industrial), and Manufacturing Engineering were set up with several key business courses in the required part of the programs. The education was based on the concept of the Learning Factory where integrated teams of students would work on projects often acquired from industry in the region. Also a Masters degree program was established in Engineering Management. With only three required courses in Project Engineering & Management, Financial Analysis, and Engineering Systems Design and the rest coming from many pre-approved elective areas in engineering, business, information systems, and sciences. This has been a strong program responding to the needs of the working engineers and industry in the region.

14. Closing Comments:

I believe that Engineering Management discipline has infinite potential to be the **educational paradigm of engineering in the future**. It is more synthesis oriented than analysis where the classical engineering disciplines are focused. It also **integrates across disciplines from technical to human and managerial**.

I believe that **communication skills are very important for engineers** and Engineering Management discipline does a better job in this than our sister disciplines. **The students work in teams on open ended problems that have softer dimensions as well as hard analytical and technical**.

I also believe that the current engineering education based on Mathematics and Physical sciences (Physics and Chemistry) will have to embrace equally well the **Life sciences** as increasingly these sciences merge at the basic level. **Health and environmental sustainability related topics also need to be embraced by all engineering disciplines** including engineering management.

I believe that current Schools of Engineering have to evolve into Schools of Enterprise Engineering & Management where all engineers will have exposure to **Production, Finance, Marketing, Human and Organizational areas and leadership skills in addition to technical areas**. I believe that a **synthesis between the Business side and Engineering side of the enterprise must be achieved** in a successful future educational paradigm which is waiting to be realized. When this happens I believe we will have a more humanistic engineering education benefiting all mankind.