2006-282: BENCHMARKING INTERNATIONAL INDUSTRIAL ENGINEERING PROGRAMS

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Benchmarking International IE Programs

Introduction

Fraser[6] compared the 101 ABET accredited industrial engineering programs by location, size, and other descriptors, as well as by the inclusion of different courses in the curricula. Except for two programs in Puerto Rico, all these programs are in the United States.

In this paper, we extend that comparison to include industrial engineering programs in other countries in order to find ideas that US programs (and programs in other countries that use the US model) should consider for adoption from IE programs outside the US. We found differences in total number of credit hours and in number of years required for the IE degree, in the amount of general education included in the degree, and in the strength of ties to industry. We noted trends toward standardization of degrees in certain countries and regions and toward international links among programs. We make two recommendations related to partners: IE programs should seek partnerships with mechanical engineering and with business programs, and IE programs should seek partners with universities in other countries.

Methods for finding IE programs in other countries

We compiled a list of programs to be examined by drawing from the following sources.

Washington Accord Programs. The Washington Accord, signed in 1989, is an agreement among engineering accrediting bodies in Australia, Canada, Ireland, Hong Kong, New Zealand, South Africa, United Kingdom, and the United States. The agreement "recognizes the substantial equivalency of programs accredited by those bodies, and recommends that graduates of accredited programs in any of the signatory countries be recognized by the other countries as having met the academic requirements for entry to the practice of engineering." See www.washingtonaccord.org.

- Institution of Engineers Australia, www.ieaust.org.au
- Canadian Council of Professional Engineers, www.ccpe.ca
- The Hong Kong Institution of Engineers, www.hkie.org.hk
- Engineers Ireland, www.iei.ie
- Japan Accrediting Board for Engineering Education, www.jabee.org
- Institution of Professional Engineers New Zealand
- Engineering Council of South Africa, www.ecsa.co.za
- Engineering Council United Kingdom (ECUK), www.engc.org.uk

The following are not members of the Washington Accord, but were useful websites:

- ASIIN (Germany), www.asiin.de
- CACEI (Mexico), Consejo de Acreditacion de la Ensenanza de la Ingenieria, www.cacei.org.

- National Board of Accreditation (India), www.nba-aicte.ernet.in
- La Commission des Titres d'Ingénieur (France), www.commission-cti.fr. This site is under construction and we could not find a list of accredited programs.
- Universities and Colleges Admission Service (UK), www.ucas.ac.uk, "the central organisation that processes applications for full-time undergraduate courses at UK universities and colleges." Each curriculum at a UK university has a UCAS code.
- All India Council for Technical Education (India), www.aicte.ernet.in.

Substantially Equivalent Programs. ABET describes these programs as "programs that have received substantial equivalency recognition through evaluation by ABET at institutions in countries that are not signatories to the Washington Accord." See www.abet.org/subequi.shtml.

Google and Yahoo. A very efficient way we found to locate programs was to search on "industrial engineering" or "production engineering" while restricting the domain to be searched to a particular country (for example .in for India or .fr for France). Also, Yahoo's list of Industrial Engineering programs includes programs in Canada, Finland, Indonesia, Ireland, Israel, Korea, and Turkey.

For programs located in non-English speaking countries, a big challenge was to find a listing of the program in English. We thank Werner Rutten and Burak Aktas for providing translations for us.

Methods for recognizing an industrial engineering program

We identified a program as being similar to a US degree labeled industrial engineering if it contained most of these components:

- Math and science – calculus, physics, chemistry.
- Engineering – mechanics, thermodynamics, other engineering sciences, computer programming.
- Manufacturing engineering – manufacturing processes, automation, robotics.
- Production engineering – facilities location and layout, production planning and control, supply chain management, quality.
- People – ergonomics, safety, psychology, organizational design, management, work design.
- Money – engineering economy.
- Mathematical methods – probability and statistics, operations research, and simulation.

Names we encountered include:

- industrial engineering,
- industrial and systems engineering,
- Ing. Mecanico Administrador (Mexico),
- production engineering, and
- manufacturing engineering.

Names we found that usually were not industrial engineering degrees include:

- engineering with business studies or engineering with management. These degrees in the UK tend to add business considerations (such as cost and marketing) to a traditional engineering degree so that an engineer designing a product thinks about the business issues.
- industrial engineering. Some programs, especially in the UK, use this label to mean engineering applied in industry. For example, at the University of Wales Cardiff (see www.uwic.ac.uk/new/courses/industrial%5Fengineering/), the phrase Industrial Engineering encompasses electrical and mechanical engineering programs.

The Mexico to UK dimension

As shown in Table 1 (see next page), we tabulated the total number of accredited engineering programs in each country, the total number of accredited IE programs, and the percent of all programs that were IE.

We found four groups, defined by the percent of programs that are IE:

- Mexico, with 15.1% of its engineering programs being IE.
- Turkey, Egypt, Germany, the Arab Gulf States, Hong Kong, New Zealand, India, and Korea, with 4.5 to 9.1%
- The US, Canada, Ireland, South Africa, Japan, and Australia, with 2.9 to 3.7%, and
- The United Kingdom and Malaysia, with almost zero.

Mexico represents one extreme on this scale. IE programs in Mexico were created on US models, often with US professors of IE as advisors. Indeed, Mexico has outdone the US in its embrace of industrial engineering. In Mexico in 2005 CACEI accredited 324 programs of which 49 (15%) were IE. In Australia, by contrast only 4 (1.1%) programs with the IE name are accredited out of 349; even including programs that are IE related, there are only 10 (2.9%). In Mexico, IE is the fifth largest major among all majors, trailing medicine, law, and management.

At the other extreme on this dimension is the United Kingdom (England, Wales, Scotland, and Northern Ireland) where industrial engineering, by name or concept, is almost unknown. The United Kingdom engineering programs are difficult to research. The Engineering Council (ECUK), which accredits engineering programs, lists over 5000 programs on their website, including 2 year to graduate programs. The search is also complicated by the fact that many UK universities do not provide a list of the courses making up the degree program. All students apply to universities in the United Kingdom through UCAS (http://www.ucas.ac.uk/), the Universities and Colleges Admission Services. While the UCAS lists a fair number of programs under the labels industrial engineering, production engineering, production management, and manufacturing engineering many are actually engineering plus business.

Country	Nbr of EN programs	Nbr of IE programs	Percent of programs
Mexico	324	49	15.1%
Turkey	44	4	9.1%
Egypt	145	11	7.6%
Germany	261	19	7.3%
Arab Gulf states	73	5	6.8%
Hong Kong	64	4	6.3%
New Zealand	37	2	5.4%
India	753	35	4.6%
Korea	89	4	4.5%
US	2700	101	3.7%
Canada	295	10	3.4%
Ireland	60	2	3.3%
South Africa	93	3	3.2%
Japan	139	4	2.9%
Australia	349	10	2.9%
UK	5295	2	0.0%
Malaysia	52	0	0.0%

Table 1

We found only two programs in the UK that we would call industrial engineering, one with that name and one called manufacturing engineering.

- The University of Bradford has a bachelor's degree in industrial engineering. They state: “For those wishing to embark upon careers with an international focus, studying Industrial Engineering is likely to have special attraction, as the degree of Industrial Engineering is widely recognised throughout the world, especially in the United States where the Institute of Industrial Engineers is one of the largest professional organisations” (http://www.eng.brad.ac.uk/05/UG_studies/techman/?page=indeng).
- The University of Hertfordshire has a bachelor's degree in manufacturing engineering, which looks very much like industrial engineering, although it appears to lack courses in human factors.

We found quite a bit of evidence that the phrase “industrial engineering” is not used in the UK. Many of the links found through a google search on that phrase, restricted to UK

domains were links to resumes of people with degrees from outside the UK and to journals and conferences described on UK sites but published or held outside the US. The ECUK, which is comprised of the professional engineering organizations in the UK, has no member organization with a content area that is similar to industrial engineering.

In Malaysia we also found little recognition of industrial engineering. We now comment on the situation in some of the other countries, starting at the top.

India has a number of programs similar to US IE programs, most called production engineering. For example, Birla Institute of Technology, Veermata Jijabai Technological Institution, and Pune Institute of Engineering and Technology all offer 4-year degrees in production engineering that are similar to US IE programs. However, the prestigious IITs offer IE primarily at the graduate level, if at all. Only IIT Kharagpur offers an IE program similar to US programs, the Bachelors in Industrial Engineering in the Department of Industrial Engineering and Management. In several universities in India, production engineering is a specialization in mechanical engineering and often it still has a strong ME emphasis.

Australia may have followed the UK example. Price[13] states that while the IE and engineering management "degree concepts are well known in other parts of the world, the subjects are not well known in Australia." He argues that IE jobs exist under different names and that the Australian economy needs industrial engineers. He describes the Bachelor of Engineering (Industrial Engineering and Engineering Management) at the University of Monash, a program which we judge to be very similar to US programs. Unfortunately for Price's argument for IE, Grunwald and Pudlowski[7] describe the increasing use in Australia of double degree programs (engineering and business) and make no mention of IE as a possible alternative.

Thailand is not included in our Table because the accrediting organization in Thailand (the Council of Engineers) has no information in English on its web site (www.coe.or.th), but Batty and Thespol[2] reported 31 engineering areas for the BS in Thailand, 20 for the MS, and 11 for the PhD. Industrial engineering is one of the fields with PhD programs, implying the field is well recognized in that country.

A related aspect to this Mexico to UK dimension is the fact that programs in some countries were explicitly modeled on programs in other countries.

- Mexican programs were modeled on US programs.
- Programs in Arab Gulf States were modeled on UK, French, Egypt, and US programs.[1]
- Engineering programs in Egypt were "influenced by the French model, as the process of modernization ... was carried mainly in cooperation with France" in the mid 1800s.[5]
- Engineering programs in Finland were based on German system.[10]
- Malaysian engineering programs began with the 4 year model from Australia.[12]

However, we did not find that these academic roots or geographical groupings explained the results in Table 1. Some of the differences may be due to different economic needs in different countries. Each country is trying to answer, at a global scale, the kind of questions posed by Allen Soyster, as quoted in Khoshnevis *et al*.[8]

> "The same questions have haunted the profession since its inception more than 100 years ago:
>
> - What is the IE passion?
> - What drives the IE economic engine?, and
> - What can we be best at in the world?"

Each country might have different "economic engines" driving industrial engineering. Price[13] argues that Australia needs to develop IE and Engineering Management programs to respond to the growth of services in the Australian economy and the need for productivity improvements in industries associated with traditional engineering fields. Price states that Australian engineers are engaged in "activities carrying titles such as quality improvement, value analysis or business analysis." [13]

Cross cutting issues

Regardless of where countries lie on the Mexico to UK dimension, we found certain cross cutting issues related to the role of higher education in each country. These issues include the number of credits and years for the baccalaureate degree, the amount of general education included in that first baccalaureate degree, and the strength of ties to industry.

IE degrees in the US are nominally 4 year degrees with approximately 128 credit hours.[6] UK degrees tend to be 3 years. In Finland "the first degree is the Diploma in Engineering, equivalent to an MSc, which takes 5-6 years to complete."[10] Some degrees require considerably more credit hours. The Bachelor's degree in industrial engineering at King Abdul Aziz University in Saudi Arabia is a 5-year degree with 155 credits.

The amount of humanities and social courses is driven by the usefulness of such courses first in increasing the understanding by the engineer of the societal context of engineering and second in creating a well educated person, not just a well educated engineer. In the US, a baccalaureate degree is intended to create an educated person, so there are general education or liberal education requirements, typically in the social sciences, humanities, history, and English.

Canada is similar to the US. The CEAB (Canadian Engineering Accreditation Board, a committee of the CCPE, Canadian Council of Professional Engineers) requires programs to include "complementary students that deal with central issues methodologies and thought processes of the humanities and social sciences."[3] The purpose of such courses is to support "understanding of the impact of engineering on society".[3]

While most nonUS degrees in IE that we identified include study of communication skills (in the native language and in English), many lacked the other components of general education. In 1993, Dorato and Abdallah[4] reported on a 1991 survey of electrical

engineering programs at 14 nonUS institutions. They found that 43% had no social science or humanities requirements. In 6 of the 14 countries, "all nontechnical subjects are completed at the high school level".[4] Rao[14] states that, except for some exposure to economics, engineering programs in India do not include humanities and social sciences.

Some European programs are upside down compare to the US model of general education. Such 3+2 programs include specific and applicable career knowledge in the 3 year degree and general education in the ensuing 2-year (Master's) degree.

Programs without a general education requirement and with a large number of credit hours contain an amazing catalog of IE courses. For example, King Abdul Aziz University in Saudi Arabia has 69 credit hours in industrial engineering courses, while a typical US program has 45 such credit hours. We estimate that a US program could add 10 to 36 hours by replacing general education with IE courses. Such an approach might reduce arguments in faculty meetings over which topics are more essential than others.

Programs in different countries tend to have different strength of ties to industry, although the strength of ties differs greatly within a country also, as in the US. Some European programs explicitly include one year of "professional practice" in some industry. While such a requirement is similar to a US co-op program, the requirement also often includes close ties between the universities and the companies in order to foster regional development. Some of the local German governments sponsor such programs. IE programs in the Arab Gulf states have close ties, of course, to the oil industry, although some believe the ties should be closer and should include ties to other industries.[1]

Trends

We note two trends: a movement toward standardization in some countries or regions and a growth in international collaborations.

ITESM in Mexico is an example of standardization within a country. ITESM has 33 campuses all over Mexico, but most of the ones that offer IE do so under the identical curriculum. Some private universities in Mexico are doing similar cloning of programs. One reason for this approach is a shortage of PhD degreed professors; a BS degreed professor at an ITESM campus can offer a course that was designed by PhD professors at ITESM/Monterrey, the main campus. In the US, most university systems (for example, the University of Texas) do not have cloned programs; the IE programs at El Paso and Arlington are separate.

Initiatives in the European Union may lead to more standardization among programs in the EU countries. There is a trend to adopt the English 3+2 structure, with the technical part in the 3 year program and the more general education in the 2 year Masters degree. Some countries are having to change their programs because of this EU initiative. According to Svelto,[16] engineering education in Italy, for example, has been based on a

2+3 structure, with the first two years providing a scientific foundation in math, physics, and chemistry, with the following three years on application.

International partnerships are also on the rise. Australia and New Zealand are engaged in "twinning" with institutions in Malaysia, Singapore, and Hong Kong, mainly with Internet-based technologies. For example, as described in Kiattikomol,[9] King Mongkut's University of Technology Thonburi (KMUTT) in Bangkok, Thailand, and the University of Tasmania in Hobart, Australia, began a collaboration in January 1999 to develop a program in civil engineering to be delivered in English in Thailand. KMUTT is also the home of SEACETE, the South-East Asia Centre for Engineering and Technology Education, a UNESCO satellite center established to help the development of engineering education in South-east Asia. KMUTT has a Department of Industrial Engineering.

In 1994 UNESCO founded the UNESCO International Centre for Engineering Education (UICEE), with main headquarters in Melbourne, Australia, and associated centers in Algeria, Denmark, Germany, India, Jamaica, Oman, Poland, Russia, Romania, Rwanda, Scotland, Taiwan, and Thailand (see www.eng.monash.edu.au/uicee/). According to the website, "[t]he key objective in the Centre's operation is the sharing of knowledge and expertise on engineering education through its role as an information broker." UICEE publishes the *Global Journal of Engineering Education*.

Internationalization also takes the form of study abroad. "The Telecom Grand Ecoles in France require every student to spend a minimum of 2 months working abroad at some period of their academic careers."[15]

Stating that "engineering is becoming a global profession," Nguyen and Pudlowski[11] combine the trends of standardization and partnerships by calling for a "global curriculum," that is, a "common engineering curriculum, which can be used globally." The benefits would be time and cost savings for developing countries and reduction in "the need for recognition and accreditation … between countries."

Recommendations for IE programs in the US

We recommend that IE programs in the US find partners, first with their business and ME programs and second with universities in other countries.

In some countries IE is still emerging from ME and in other countries some engineering programs have linked with business majors. Engineering advisory boards in the US often recommend that all engineering programs help graduates understand business imperatives, including quality, customer focus, value engineering, and manufacturing considerations. IE programs should place themselves in the middle of those discussions and should be prepared to help engineering programs add such material and to help business schools add technical material.

Globalization has many meanings, but whatever it means, it cannot be ignored. Even if a graduate of our programs is employed in the US, that graduate will need a global outlook.

We cannot allow students to graduate without exposure to international aspects of engineering practice. One way we can achieve that exposure is through partnerships with nonUS institutions.

Conclusions and future research

While we all often lament the lack of recognition for industrial engineering in the US, this review clearly shows the situation could be worse – and could be better. Perhaps the situation is improving in the US. Price[13] states that industrial engineering accounted for 14% of all engineering jobs in the US in 2000, growing from only 8.9% in 1990.

While we cannot support the statement with numbers, we found that the phrase "production engineering" seems recognized in more countries than the phrase "industrial engineering." The trend we note toward internationalization might push US programs to adopt that term.

We wanted to include many more countries in this comparison, but were stymied by language barriers. We can solve that problem by recruiting native speakers to help us, and such people would also give us more understanding of the nature of the educational system in each country. While the measure we used, percent of IE programs out of all engineering programs, was the easiest for us to find, a better measure would be the percent of IE graduates out of all engineering graduates; such data will be more difficult to find.

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