

## Benchmarking IE Programs

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### Introduction

Benchmarking is the process of determining what others in the same business as yours are doing. Benchmarking is usually done to determine (and apply) best practices. I have reviewed 101 industrial engineering (IE) programs, by location, size, and other descriptors and I have reviewed the content of their programs. I do not support arguments of the form “we should do it because everyone else does” and I hope that these data will not be used in this way, but these results may provide some ideas for improvement of our programs.

I sought to answer two questions:

- What do we agree that IE is?
- What are the unique courses we have in our programs?

I acknowledge the help provided by seven years of students who have completed an assignment in the introduction to industrial engineering course that I teach. Each student compares our program to an IE program at another university. Their work provided a valuable starting place for this paper.

### Methods

I started with the 104 programs listed at [www.abet.org](http://www.abet.org) as having ABET accredited programs in IE. I made the following three omissions from that list, leaving 101 programs:

- Because we changed our name in 2002, my university was listed twice, so I omitted the listing with the old name.
- While Kansas State University is listed with two programs (Industrial Engineering and Manufacturing Systems Engineering), I could not find the second one at their website, so I omitted that listing.
- While Montana State University at Bozeman is listed with two programs (Industrial and Management Engineering and Industrial Engineering), I could not find the first one at their website, so I omitted that listing.

For each program, I recorded:

- the number of faculty members,
- the department name,
- the degree name,

- the state in which the program was located,
- the date the program was first accredited,
- whether the university or college is public or private, and
- whether the university or college is church affiliated.

I was able to find almost all the above information for all 101 programs. For 5 programs I was not able to determine the number of professors.

I used the following rules:

- Number of faculty: I counted the number of regular faculty members, omitting emeritus, visiting, research, and adjunct faculty, as well as lecturers. I occasionally omitted a faculty member who I knew had moved to another university (after verifying that the person was listed at the new university). I counted deans. For IE programs in ME departments, I counted the number of IE faculty members.
- Level: I recorded the highest degree awarded by the department, not by the university.
- Degree name: I gathered information on the degree closest in name to industrial engineering, so, for example, I chose the IE major, not the manufacturing engineering major at Wichita State (and others).

For each program, I examined the courses required for the IE degree. For most courses I could classify the course by its title, but where the title did not give an obvious indication of its content, I looked at the catalog description. I did not look at any course syllabi so I have certainly misclassified some courses. I recorded the number of credits for each course.

I was able to find the required courses for 92 programs. I could not find all the information on the program (in particular, the number of credit hours for each class) for nine programs (Cornell, Florida A&M/Florida State University, Oklahoma State, Rochester Institute of Technology, Worcester, Marquette, Northwestern, Stanford, and the University of New Haven).

## **Web pages**

We all need to work on our web pages. Errors I found included courses listed twice, addition errors in the number of courses in a semester or in a program, spelling errors, broken links, pages that won't load or won't print, an incredible number of clicks necessary to reach useful information, and so forth. It was often very hard to find the university catalog or bulletin in order to check the course description; if I used the search facility to search for "catalog," most hits were for the library catalog. Sometimes the correct listing was simply "course descriptions."

On the other hand, for some programs I found a clear, one page, semester-by-semester (or quarter-by-quarter) description of the program, with title, number, and credit hours for each course; that page often contained links to the catalog descriptions of the courses. I salute these webmasters.

## University and department characteristics

The ABET listing gives the date of first accreditation of each program. Table 1 summarizes the number accredited by decade. While the rate of additions peaked in the 1970s, IE programs continue to be added at a rate of about one per year. The most recent additions are

- University of San Diego in 2001,
- SUNY Binghamton in 2002,
- Wright State University in 2002, and
- Cal State Hayward in 2004.

Table 1. Decade of first accreditation

1930s	11
1940s	5
1950s	19
1960s	14
1970s	20
1980s	18
1990s	9
2000s	4
Total	100

The thirteen states that have 3 or more IE programs, shown in Table 2, account for 72 (65%) of the programs in the US. There are also 2 ABET accredited IE programs in Puerto Rico.

Table 2. Thirteen states with three or more IE programs

State	Number of programs.	State	Number of programs.
CA	12	MI	5
OH	8	MA	4
TX	7	PA	3
WI	6	KS	3
NY	6	IA	3
IL	6	AL	3
FL	6		
		Total	72

Ten states and the District of Columbia have no IE programs: AK, DC, DE, HI, ID, ME, NH, NV, UT, VT, WY.

Most of the programs (87) are at public universities and 23 are at private universities.

Four of the programs are at universities or colleges that are church affiliated:

- Marquette, Milwaukee, WI,
- St. Ambrose, Davenport, IA,
- St. Mary's, San Antonio, TX, and
- University of San Diego, San Diego, CA.

Most programs (66%) are in departments that award the PhD, as shown in Table 3.

Table 3. Highest IE degree awarded

Highest IE degree	Number	Percent
PhD	67	66%
Masters	24	24%
Bachelors	10	10%
Total	101	100%

Table 4 shows the most frequent department names. Four department names account for over half the departments and only 8 names have 2 or more departments with that name.

Table 4. Most frequent department names

Industrial Engineering	26
Industrial and Systems Engineering	14
Industrial and Manufacturing Engineering	14
Mechanical and Industrial Engineering	10
Industrial and Manufacturing Systems Engineering	6
Engineering	4
Industrial and Management Systems Engineering	3
Industrial Engineering and Operations Research	2
Total	79

The other 22 departments have unique names, including Decision Sciences and Engineering Systems (Rensselaer), Industrial Engineering and Management Systems (University of Central Florida), Industrial, Manufacturing, and Information Engineering (Morgan State), and Systems Science and Industrial Engineering (SUNY Binghamton).

Table 5 shows the number of IE faculty members in IE departments. I was unable to determine the number of IE faculty for 5 departments, including 3 departments where IE is part of ME. I counted a total of 1153 IE faculty members distributed as follows:

- 49 programs (51%) have 10 or fewer faculty members and account for 317 IE faculty members (27% of the total IE faculty members).
- 83 (86%) have 20 or fewer faculty members and account for 788 IE faculty members (68%).
- 93 (97%) have 30 or fewer faculty members and account for 1025 IE faculty members (89%).

Over half of all IE faculty members (598) are in programs with 14 or fewer faculty members.

Table 5. Size of programs, omitting the three largest programs

Number of faculty	Number of programs	Number of faculty	Number of programs	Number of faculty	Number of programs
1	0	11	7	21	2
2	1	12	7	22	1
3	3	13	6	23	2
4	7	14	3	24	2
5	5	15	4	25	1
6	10	16	1	26	1
7	7	17	1	27	0
8	2	18	1	28	1
9	8	19	1	29	0
10	6	20	3	30	0
				Total	93

Six programs have 25 or more faculty members:

- Georgia Tech, 63 faculty members,
- Stanford University, 34,
- Purdue University, 31,
- University of Michigan, 28,
- Pennsylvania State University, 26, and
- University of Wisconsin-Madison, 25.

These six programs have 207 IE faculty or 18% of all IE faculty members.

### Program content

The information on course content is based on the 92 programs for which I was able to find complete information. *These results depend heavily on my judgment in classifying certain courses as similar.* I converted quarter hours to semester hours by multiplying by 2/3.

We all work within constraints when we design our programs. The total number of credit hours (presumably somewhat constrained by forces outside the department) range from 120 hours (4 programs) to 160 hours (2 five-year programs in Puerto Rico), with 20 programs at 128 hours. The number of hours in general education courses (presumably somewhat constrained by forces outside the department) range from 10 hours to 36 hours with 24 programs at 18 hours.

Tables 6, 7, 8, and 9 show the most frequently required courses in four broad categories: mathematics and science, engineering, industrial engineering, and other. Any course offered by 15% or more of the programs is listed.

Table 6 shows that we agree that math and science (calculus, physics, and chemistry) are required (although two programs omit chemistry as a requirement).

Table 6. Required courses in mathematics and science

Mathematics and Science courses	Number of programs	Percent of programs
Calculus	92	100%
Physics	92	100%
Chemistry	90	98%
Differential Equations, Linear Algebra, or both	68	74%
Science electives	20	22%

The IE programs differ in how they handle the requirements for engineering courses, shown in Table 7. Many programs constrain certain electives so that students select among mechanics, thermodynamics, materials, etc. The University of Michigan, for example, requires students to select a total of 12 credit hours from six groups of courses, with 4 hours in each of three different groups.

At the low end, Auburn's engineering requirements outside IE are 2 credits in computing, 3 credits in engineering mechanics, 3 credits in electrical engineering, and 3 credits of engineering elective. At the high end, North Dakota State's engineering requirements outside IE are 3 credits in computing, 6 credits in engineering mechanics, 7 credits in electrical engineering, 3 credits in mechanics of materials, and 3 credits in fluid mechanics.

Table 7. Required courses in engineering

Engineering courses	Number of programs	Percent of programs
Computing	83	90%
Engineering Mechanics	77	84%
Circuits	75	82%
Materials	70	76%
Technical Electives	63	68%
Computer Graphics	58	63%
Introduction to Engineering	52	57%
Thermodynamics	47	51%
Engineering Design	16	17%

Table 8 shows we have agreement about courses on IE tools (e.g., operations research, probability and statistics, and engineering economics), but we teach the integrated IE material (facilities planning and operations planning and control) under very different titles and in different combinations.

While probability and statistics may seem to be mathematics and science courses, 77 of the 90 programs that have such a course (or courses) teach the topics in engineering, mostly in industrial engineering.

Four courses are required in 15 to 25% of our programs:

- Engineering management or project management,
- Information systems,
- Systems analysis and design, and
- Experimental design.

Table 8. Required courses in industrial engineering

Industrial Engineering courses	Number of programs	Percent of programs
Operations Research	92	100%
Probability/Statistics	90	98%
Engineering Economics	88	96%
Work Methods, Human Factors, or Ergonomics	87	95%
Simulation	80	87%
Quality	79	86%
Senior Design Project	79	86%
Production Planning and Control	68	74%
Manufacturing Processes	65	71%
Facilities, Layout, Material Handling	60	65%
Introduction to Industrial Engineering	43	47%
Industrial Engineering Electives	41	45%
Computer Aided Manufacturing or Robotics	38	41%
Engineering Mgt or Project Mgt	21	23%
Information Systems	20	22%
Systems Analysis and Design	18	20%
Experimental Design	17	18%

As shown in Table 9, some programs constrain the general education choices to support IE education by requiring, for example, economics, technical writing, speech, accounting, or ethics. Three of the programs requiring a course in ethics are at church related schools.

Table 9. Other required courses

Other courses	Number of programs	Percent of programs
General Education electives	90	98%
English	79	86%
Economics	38	41%
Technical Writing	36	39%
Speech or Communication	37	40%
Free Electives	26	28%
Accounting	24	26%
Ethics	17	18%

Interesting unique requirements, not shown in any tables, include:

- Anthropology at Wayne State University,
- History of technology at the University of South Florida,
- Business law at Milwaukee School of Engineering,
- Team leadership and facilitation at North Carolina ATSU and Milwaukee School of Engineering,
- Reliability at Cal State Hayward,
- Cognitive engineering at Ohio State University,
- Fuzzy logic at SUNY-Binghamton, and
- Entrepreneurship at South Dakota School of Mines and Technology.

## Conclusions

As a faculty member, I sometimes feel that the field is dominated by large research based departments. I believe we should keep in mind that only 66% of the IE programs are in departments that grant the Ph.D., and over half of IE faculty members are in departments that have 14 or fewer faculty members.

While those outside our field may not have a clear conception of what industrial engineering is, our programs show strong consensus about what courses should be included in an industrial engineering program. In fact, my choice to record courses may overemphasize the differences among programs. I believe that recording topics covered, however they are packaged among courses, would have shown more consensus; such an approach would have involved much more work.

Also not reflected in the information I recorded is variation in the year in which students are advised to take different material. For example, some programs recommend leaving engineering science courses (such as thermodynamics) until the senior year, presumably because no industrial engineering courses in that program build on the material.

## Biographical Information

JANE M. FRASER was on the faculty at Purdue and Ohio State University before moving to Colorado State University-Pueblo in 1998 where she is chair of the Department of Engineering. She holds BA, MS, and PhD degrees.