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A New Industrial and Systems Engineering Program: Benchmarking Results to Determine What and Why

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Abstract

The history of much of Industrial Engineering has its roots in the Industrial Revolution where technologies helped mechanize what had been manual labor. However a lot has changed in the 100 plus years since the Industrial Revolution started, and Industrial Engineering rightly changed along with it. Over time Industrial Engineering has taken different focuses and embodied different instruction by different educational institutions. Is it only just 'gears and wrenches'? Or is there more to it? Are there specific identifiable focuses? If so, how could Industrial and Systems Engineering (ISE) articulate those focuses? If a university was to start a brand new Industrial and Systems Engineering program, what would it look like and why? These topics will be explored in this article focusing on the rollout of a brand new program in Industrial and Systems Engineering at Stevens Institute of Technology.

Introduction – Why an Industrial and Systems Engineering Program?

Modern society depends upon systems of increasing complexity to sustain and advance our quality of life. These systems include technologies that span traditional technology boundaries and have significant human and organizational dimensions. This requires future engineers to be strongly rooted in the fundamentals of engineering and science, while also being equipped to understand, model and impact the human elements of the systems they will develop and evolve. The tools of industrial and systems data analysis thus become an increasingly important element of a core educational experience. Business leaders value engineers who can model business processes, measure and optimize efficiency and effectiveness metrics.

In 2015, the Institute of Industrial Engineers (IIE) changed its name to the Institute of Industrial and Systems Engineers (IISE). The IIE CEO Don Greene explained the reasoning for this by saying; "The name change aligns IIE with the changing scope of the profession that, while keeping its industrial base, has seen more industrial and systems engineers working with large-scale, integrated systems in a variety of sectors. The change also is consistent with department names in many universities, as two-thirds of the top 65 schools ranked in U.S. News & World Report have incorporated 'systems' into their department names".[1]

The following definition of Industrial and Systems Engineering comes from the IISE website: "Industrial and systems engineering is concerned with the design, improvement and installation of integrated systems comprised of people, processes, hardware and software. It draws upon specialized knowledge and skill in the mathematical, physical,

and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems." [2]

Per the Bureau of Labor Statistics, there are over 250,000 ISE jobs in the US. It is one of the largest engineering discipline areas by level of employment and expected to grow by over 10% by 2026. [3] Forbes reports the field as one of the most "in-demand". [4]

In ASEE's 'Engineering by the Numbers' report, the Industrial/Manufacturing/Systems (I/M/S) Engineering discipline area is ranked 7th largest in terms of the number of undergraduate degrees awarded by discipline graduating approximately 5000 students a year.[5] Disciplines ranked higher than 7th are degrees already offered by Stevens (Mechanical Engineering, Chemical Engineering, Electrical Engineering, Computer Science, Chemistry and BioMed). ISE is a very large market currently untapped by Stevens and one that aligns with the mission of the school.

Schools that offer Industrial and Systems Engineering (ISE) programs and are listed in the top 10 by US News and World Report include Georgia Tech, Virginia Tech, Penn State and Texas A&M.[6]

Schools in the North East region of the US on ASEE's 2015 "top 50" list of schools granting the most undergraduate Industrial/Manufacturing/Systems degrees include Cornell University, Columbia University, University of Pittsburgh, Lehigh University, Northeastern University, Rensselaer Polytechnic Institute, State University of New York, Rutgers University and Rochester Institute of Technology. ASEE's 2015 statistics are listed below:

Table 1:Industrial/Manufacturing/Systems Engineering Degrees Awarded by North East Schools

Rank	**School**	**# Degrees Awarded**
10	Cornell	95
20	Columbia	74
26	University of Pittsburgh	67
28	Lehigh	61
29	Northesatern	60
31	RPI	58
34	SUNY	49
36	Rutgers	47
47	RIT	41

Source: https://www.asee.org/papers-and-publications/publications/college-profiles/

The above demonstrates that there is a clear desire for Industrial Engineers by businesses in America and similarly there is a clear indication that Industrial Engineering educational programs are in demand and are graduating a significant number of students from their programs each year. As such, an educational institution would be justified in wanting to start an Industrial Engineering program if it did not already have one. But then comes the question what should be the focus of the new Industrial Engineering program?

There might seem to be various, potentially dissimilar, programs in Industrial and Systems Engineering across the country. Some might even go so far are to say the various programs are completely unrelated. However a closer look of the benchmarking done while reviewing these schools' programs and those of the top 10 USNWR, shows ISE programs at leading universities across the country appear to fall into one or more of the following four focus areas:

- Manufacturing – ex. Clemson University
- Supply Chain and Logistics – ex. University of Florida
- Ergonomics and Human Factors – ex. University of Michigan
- Information and Service Systems/ Data Science - ex. University of Virginia

Although some may perceive Industrial Engineering as geared toward manufacturing, this is only one focus of ISE programs as shown above. All the Industrial Engineering Programs demonstrated a strong focus on Operations Research as the core of ISE programs across focus areas. The heart of all the various ISE programs is not traditional manufacturing, but rather optimization of the system, whatever part of the organizational system that may be.

Stevens's Objectives for an ISE Program

With the surge in big data and computer capability, the ability to effectively analyze and utilize data is quickly becoming a critical skill in engineering decision making.[7,8,9] The Stevens' ISE program is targeting this Data Science area. SSE has a faculty with knowledge in this area, which makes having an ISE program with this focus logical to address. The objective of the Stevens ISE program would be to position the school as a regional leader in systems analytics and data science as applied to engineering design. I/M/S Engineering programs tend to focus on one or more concentrations; in areas such as ergonomics, manufacturing, supply chains, information systems, or data science. Columbia focuses on analytics and applied mathematics; with less emphasis on engineering basics, and engineering design in particular than Stevens. Rutgers focuses on manufacturing/reliability. A focus on systems analytics and data science for engineering design would leverage the school's existing reputation, its strong general engineering undergraduate education and expertise in systems engineering.

ISE is not currently addressed at the Undergraduate level at Stevens. Stevens would not pop up for consideration by high school students searching for Industrial/Systems

Engineering at the undergraduate level. Offering an ISE program will expand the addressed market of the school.

Stevens ISE Bachelor of Engineering program graduates would be prepared to assume positions such as Systems Engineer, Application Engineer, Project Engineer, and System Integration Engineer; as well as positions such as Production Engineer, Operations Manager, Project Manager, Reliability Engineer, Quality Engineer, Process Analyst, Supply Chain Analyst and Consultant.

The University of Colorado at Colorado Springs performed an analysis in 2016 to determine the market demand for an Industrial and Systems Engineering bachelors degree. [10] Their report highlights benchmarking that is comparative to what is reported here. For example, the report highlights an 86% growth in ISE enrollments at RIT in the last five years, which is demonstration of the Bureau of Labor Statistics prediction. Additionally, a recommendation from the report was to "consider specializations in Health systems and analytics"; this data focus is the one chosen by Stevens.

Population

The current article takes place at Stevens Institute of Technology, a small, private, urban campus across the Hudson River from Manhattan in New Jersey. Approximately 3000 undergraduate students are enrolled, of whom about 2000 are engineering students. The Engineering Management Program is housed in the School of Systems and Enterprises at Stevens and has been ABET accredited since the early 1990's. It is this School of Systems and Enterprises that has embarked upon the addition of a new undergraduate program in Industrial and Systems Engineering.

Research and Results - Objectives and Curriculum of the New ISE Program

The Stevens ISE program's objective is to provide a rigorous general engineering undergraduate education, with depth in both industrial and systems engineering topics focusing on data, in order to nurture technical leaders of tomorrow who will be able to engineer, develop, and maintain increasingly complex systems with cross-discipline content and socio-technical system dimensions.

An analysis of the US News and World Report (USNWR) top 10 ISE programs was completed to determine a set of core components common to leading ISE programs. [6] These components were used to align the Stevens ISE curriculum with these leading programs, and with what is commonly accepted as required for ABET purposes in ISE programs. The table below lists these core components and the manner in which they will be incorporated in the Stevens ISE program.

Common Components of Top 10 ISE Programs as ranked by USNWR	Stevens Proposed ISE Program Course Equivalent
Programming	E 115 Introduction to Programming*
Linear Algebra	MA 227 Multivariate Calculus (includes a linear algebra component)*
Probability	SYS 501 Probability for Systems Eng's
Statistics	EM 365 Statistics for Engineering Managers
Optimization	ISE 357 Elements of Operations Research I
Stochastics	ISE 4XX Elements of Operation Research II
Discrete Event Simulation	ISE 345 Modeling and Simulation
Engineering Economics	E 355 Engineering Economics*

* These courses are part of the core curriculum that all engineers take regardless of discipline.

The coursework specific to ISE programs entails specialized courses in areas such as probability, stochastic modeling, simulation, optimization, and engineering economics as can be seen from the table above. Industrial and Systems engineering elective courses then vary based on the more specialized focus areas previously mentioned: Specifically:

- Manufacturing
- Supply Chain and Logistics
- Ergonomics and Human Factors
- Information and Service Systems/ Data Science

Given there was no ISE program currently at Stevens, only an ad-hoc analysis of employers who currently hire Stevens students could be done about the prospects of hiring of Stevens' ISE graduates several years from now. The Director of Career Services was brought into the discussion as well. The Director voiced that she believed there would be a large proportion of employers who would want to employ ISEs. The Stevens's employers spoken to on an ad-hoc basis corroborated this belief as well as provided other input regarding the new program and its' focus.

Given the above and the data centric focus of the intended ISE program, the Industrial & Systems Engineering program-specific content at Stevens will be delivered via the following courses.

Course Number	Required Course Name	Credits
ISE 224	Informatics & Software Development	3
ISE 225	Data Infrastructures	3
ISE 322	Engineering Design VI	2
SYS 501	Probability & Statistics for Systems Engineers	3
ISE 345	Modeling & Simulation	3
EM 365	Statistics for Engineering Managers	4
ISE 357	Elements of Operations Research I	3
ISE 350	Logistics and Supply Chain Management	3
ISE 385	Innovative System Design	3
ISE 4XX	Elements of Operations Research II	3
ISE 4XX	Data-Mining & Applied Machine Learning	3
ISE 451	Analysis of Networks and Strategies	3
ISE 423 & 424	ISE Senior Design	3 & 3

The typical ISE curriculum also includes a broad core math and science foundation spanning chemistry and physics, calculus, statistics, thermodynamics, computer science, and electronics/circuits. These portions of the curriculum for the ISE Program will be from the standard engineering curriculum that all engineering programs are required to follow at Stevens (i.e the ISE program has very little say on modification of the remaining courses).

Looking Toward Accreditation – Program Objectives and Evaluation

The program objectives of the Bachelor of Engineering in Industrial and Systems Engineering at Stevens can be summarized as follows:

- Industrial and Systems Engineering graduates will develop, implement and improve systems comprised of people, processes, hardware and software elements that are innovative, reliable and cost-efficient.
- Industrial and Systems Engineering graduates will provide leadership of, and communicate effectively within, team-based environments in dynamically changing organizations.
- Industrial and Systems Engineering graduates will continue to develop skills in engineering, technology management, business and other Industrial and Systems Engineering related fields.

Progress towards the achievement of these Program objectives will be assessed using the standard Stevens program and course assessment tools for engineering programs (including use of direct student feedback, results from student grading, and accomplishments in Senior Design). Post-graduation outcomes will be assessed based on graduate placement information collected, as well as Advisory Board feedback, and feedback from employers on hired student performance and progress. Yearly program reviews will be conducted to drive iterative improvements initiatives.

Conclusion

The School of Systems and Enterprises at Stevens proudly offered it's first sophomore level courses in the undergraduate Industrial and Systems Engineering (ISE) program in the spring of 2018. Subsequent courses will be offered in the years following.

The ISE program has been designed to prepare students with a broad-based engineering education, a systems thinking perspective and a strong set of data analysis skills. This set of talents will enable students to design new and innovative systems and improve existing systems in response to market needs and opportunities.

The aim of the program is to teach students to think about the ways in which technology can help organizations accomplish goals. Students learn to take a systems approach to insure the right problems are addressed, and complete solutions are developed. A broad-based engineering education enables understanding how various technologies can be applied to realize solutions. Data Science knowledge helps students develop a deep understanding of problems, and provides tools useful in optimizing solution designs.

The undergraduate ISE program benefits from the faculty knowledge and expertise embodied in the well-regarded Stevens systems engineering graduate program, which has been valued by students and corporate sponsors for over 15 years.

The job outlook for industrial and systems engineers (ISEs) is expected to grow steadily over the next decade based on data from the Bureau of Labor Statistics. Typical roles Stevens ISE students will be well-positioned to pursue after graduation include industrial engineer, systems engineer, systems integration engineer, quality engineer, project engineer, sales and marketing engineer, and more.

Lastly, this undertaking provided an important understanding of the differentiation within Industrial and Systems Engineering programs across the country. Such an understanding of the differing focus areas within ISE may be useful to other ISE programs moving forward. Such categorization may help programs understand their key differentiators and thus be able to brand themselves in a way they may not have thought of prior.

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