

Survey of Online Graduate Industrial & Systems Engineering and Supply Chain Management Programs

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Abstract

Online programs are becoming more appealing for engineering departments and related fields in the last few years. Industrial and systems engineering (ISE) and supply chain management (SCM) online programs are among the fastest growing online programs. This paper includes a survey of some current teaching trends and study plans from top ISE and SCM online graduate programs. There is a common ground between ISE and SCM. In general, there are some similar courses in the two fields and an overlap in the study plans; this is more obvious in the undergraduate level. This paper introduces a comparison between the ISE and SCM online programs at the master's degree level. The survey of this study can be used to develop a graduate online curriculum for an up-to-date program that combines ISE and SCM.

Keywords

Engineering Education, Graduate Online Programs, Industrial & Systems Engineering, Supply Chain Management.

Introduction and Background

The increased importance of ISE is coming from the need to improve the efficiency in industries and businesses, reduce wastes, optimize operations, and effectively integrate the components of any system. Supply chain has an impact on every production sector. Reducing supply chain vulnerability due to unexpected or extreme factors while optimizing the performance indicators is not covered only in SCM or operations management programs, but also in some ISE programs.

Industrial & systems engineering is a broad discipline. A thorough ISE curriculum includes topics in production and manufacturing, management, ergonomics, operations management, statistics and data analysis, and optimization in addition to the basic knowledge of math, science, and engineering. The analytical skills with the broad knowledge of industrial engineers can benefit supply chains. As considering supply chain management minor for industrial & systems engineering undergraduate students can prepare fresh graduates to different roles in many industries, combining the basic and advance knowledge of ISE and SCM at the graduate level helps in addressing some current challenges in industries and supply chains.

It is common for many engineers to consider graduate studies in ISE. Improving the managerial and analytical skills or getting into a leadership role in management are some of the reasons that make ISE appealing for many engineers when they look for a post graduate degree or a professional development opportunity. An engineering program that combines the ISE basics and techniques to solve SCM problems can help some professionals in different industries in their day-to-day duties.

The flexibility of online graduate programs and the new communication technologies and solutions have increased the number of professionals who seek a graduate degree. There is a growing number of graduate engineering departments who offer a 100% synchronous and/or asynchronous online graduate programs, and hybrid graduate programs that combine online and conventional face-to-face learning delivery methods. Due to the nature of ISE and its relatively simple lab requirements, ISE is one of the easiest engineering disciplines to be offered online for either undergraduate and graduate levels.

The survey results of 20 top ISE and SCM online master's programs are presented in this paper. The possibility of combining some elements of ISE and SCM in one graduate curriculum is one of the objectives of this paper. Improving the ISE and SCM curricula at the master's level by adding topics related to recent trends and issues is another objective of this paper.

Literature Review

Relatively a few universities currently have online undergraduate engineering programs. Online degree option can help some students overcome the barriers between them and higher education. The Industrial and Systems Engineering department, at Lamar University (LU) has begun in the fall of 2014 offering a bachelor's degree in industrial engineering (BSIE) in a 2+2 online format. As of 2021, LU has the only BS industrial engineering program with an online pathway. The first 2 years of the 2+2 online degree are to be taken in a community college (or a different school), and the last 2 years are online (without relocating) at a 4-year college/university. The online courses offered online in the last 2 years include Probability & Statistics, Operations Research, Quality Improvement, Simulation, Industrial Engineering Systems Design. The manufacturing lab is the only course to be taken on campus in the last two years of the program; it is offered for one week in a machine shop. The Work Design, CAD/CAM, Simulation, Senior Design, and Automation have been adapted to online learning. The increase of faculty load to support traditional and international students, offering the 3rd and 4th year classes in the face-to-face and online modes, and teaching advanced tech electives in both modes are the main 2+2 online program challenges¹.

A mixture of foundational modeling and simulation courses were used to establish an online Modeling & Simulation Master of Engineering Program within the Fulton School of Engineering at Arizona State University (ASU) to satisfy the increasing demand for a program that contains the simulation-based system development. The program is offered online for traditional students and professionals in different sectors. The program is designed to attract students with strong engineering or science undergraduate records preferably from industrial engineering and computer science programs. One of the program's objectives is to prepare the graduates to engineer solutions for complex decision-making systems. The Center Professional Development (CPD) was created in 2001 at ASU and offers technical capabilities and management resources to provide near seamless in-class learning and teaching experiences. Students can customize capabilities of the Blackboard to match their needs and can experience in-class use of simulation and software tools. The CPD staff offer students professional service to have in-class experience through online media².

Active learning methods were used in the online data management course for industrial engineering students at Frankfurt University of Applied Sciences to increase student retention

and to improve the students' motivation. The active learning methods include 1-Minute Paper, Fishbowl, Snowball, Quescussion, Think-Pair-Share, Buzz Groups, Think Aloud, Peer Review, Complete Turn Taking, Pro-Con Grid. Quescussion is easy to explain and an effective interactive method. In this method, the instructor starts each web conference with a short questions session to get the students involved from the beginning. Snowball is another effective active method used in the last 10 minutes of the web session where a student shall generate three reactions to an issue presented during the web session. Then, two students join and their task is to find three things about the topic that they agree on³. The online students studied by Stanley et al. are in favor of either active experimentation or reflective exercises. They would probably adapt to both linear and novel approaches on course topics. Online instructors may want to incorporate factual, practical applications and examples for students, and evaluate the visual content in their courses⁴.

The integrated systems and software engineering degree program at Texas Tech University was resulted from the collaboration between the Department of Industrial Engineering and the Department of Computer Science after revising the existing Master of Science in Software Engineering (MSSE). The revised MSSE program is a classroom/online degree program to address the poor communication between systems and software engineers in some sectors as in the defense sector. The MSSE is a classroom/online degree program focusing on developing graduates capable of defining, developing, testing, and maintaining complex software systems by using engineering techniques that integrate hardware, software, human factors, economic, and application considerations. Proficiency in probability and statistics is an admission requirement for applicants with a bachelor's degree in computer science or engineering⁵.

Undergraduate and graduate students (approximately 360 students) at Corvinus University of Budapest were asked about their feedback regarding the courses of the Operations Management Program (BSc) and the Supply Chain Management-focused Program (MSc). In addition to the questionnaire, the student results achieved in the previous years were compared to determine whether there is a significant difference between the results of the past semesters and those from students converted to distance learning recently. According to the considered hypothesis, distance learning students were challenged to independently understand and master the theoretical curriculum. Still, they were more forced to apply a practical perspective in case studies and problem-solving⁶.

Survey & Observations

Two groups of the top master's programs were selected from the ISE field and the SCM field for the survey of this paper. Each group includes 10 master's programs out of the top 15 in the field as in September 2022 of the U.S. News & World Report. The programs in this survey are offered by the universities listed in Table 1. The survey was conducted only for 100% online master's level programs (synchronous and asynchronous). 20% of the surveyed ISE programs emphasized on industrial and systems engineering as appeared in their names – Industrial & Systems Engineering, 50% emphasized on industrial engineering, and 30% emphasized on systems engineering only. 20% of the surveyed SCM programs emphasized on the global aspect of supply chain as in their names - Global Supply Chain Management.

Table 1: The hosting universities of the surveyed ISE and SCM master's programs in this study.

ISE	SCM
Purdue University-West Lafayette	University of Southern California
Arizona State University	Boston University
Johns Hopkins University	University of Texas-Dallas
University of Illinois--Urbana-Champaign	Rutgers University
North Carolina State University	University of San Diego
Texas A&M University	Pennsylvania State University-World Campus
Drexel University	Embry-Riddle Aeronautical University-Worldwide
University of California - LA	Portland State University
University of Southern California	Syracuse University
Clemson University	Florida Institute of Technology

30 credit hours of course work is required for graduation by 80% of the surveyed ISE programs; one program requires 36 credit hours, and another one requires 32 credit hours for the thesis track and 36 credit hours for the non-thesis track. One of the programs is organized into four 10-week quarters per year where one semester credit is equivalent to 1.5 quarter credits. 30% of the surveyed ISE programs require a thesis or a project course for graduation, while one of them offers the option between 3-credit project and 6-credit thesis. Another 30% of these programs have the thesis/project course as an optional requirement. 40% of the remaining surveyed ISE programs don't have a thesis or a project requirement for graduation; final oral defense exam is required in of the nonthesis programs. 8 surveyed SCM programs require 30 credit hours for graduation and 2 programs require 40 or more credit hours; one program requires 40 credit hours and the other one requires 45 credit hours. Thesis track option is less common among the top online master's SCM programs in comparison to their counterparts in ISE programs as in this survey. 60% of the surveyed SCM programs don't offer a thesis option.

Some departments, ISE and SCM, offer the conventional in-person master's programs along with the online programs with almost the same requirements and course load. Usually the diplomas don't specify whether the graduates earn their degrees online or in person. The main areas, tracks, and grouping of the surveyed programs are shown in Table 2. In this survey, one of the ISE programs has a concentration option in advanced analytics. An ISE program is supply chain and logistics focus with 50% or more of the courses are supply chain and logistics related courses. Two of the surveyed SCM programs are global supply chain management programs; at least one of them approved by the Institute for Supply Management (ISM). Some of the SCM programs have partnered with industries and global companies such as Boeing, Nike, and Daimler Trucks North America. A SCM program has two courses that are not required, unless requested by the student's employer.

Three of the survived ISE programs are master's in systems engineering; however, they vary in defining systems engineering and the required courses. One of the three programs is more software engineering oriented and one is more industrial engineering oriented, but the three programs include courses that can be required for industrial engineering degree or industrial & systems engineering degree. The software engineering oriented program has different tracks for the elective courses (systems, cybersecurity, human systems, modeling and simulation, project

management, and software systems), and the student has to select 2-3 courses from these tracks; the cybersecurity and software tracks are software engineering tracks. One of the three systems engineering programs in this survey offer a wide range of technical domains from different engineering disciplines ranging from composite technology and thin film technology to computer networking, radar systems, and cyber security.

Table 2: Areas, tracks, and groups of the surveyed ISE and SCM programs.

Programs	Area/Track/Group
ISE	<p><i>Areas:</i></p> <ul style="list-style-type: none"> - Human Factors Engineering - Manufacturing Systems Engineering - Operational Research - Production Systems Engineering - Information Systems Engineering - Management Systems Engineering - Operations Research and Production Systems - Quality and Reliability Engineering
	<p><i>Groups of Elective Courses:</i></p> <ul style="list-style-type: none"> - Systems - Cybersecurity - Human Systems - Modeling and Simulation - Project Management - Software Systems
	<p><i>Breadth Requirement Groups:</i></p> <ul style="list-style-type: none"> - Economic & Decision Analysis - Human Factors & Ergonomics - Manufacturing Systems - Supply Chain and Logistics - Systems Analytics and Optimization - Computer Science, Mathematics, and Statistics
SCM	<p><i>Areas of Global Supply Chain Management:</i></p> <ul style="list-style-type: none"> - Global Sourcing - Global Trade & Logistics - Supply Chain Analysis, Strategy, Simulation & Modeling - Closed Loop Supply Chain/Sustainability/Circular Economy - Advanced Leadership

Trends

The curricula and study plans of the total 20 surveyed programs were studied and analyzed as published in their websites. Eight common knowledge areas between ISE and SCM were identified as in Figure 1. These knowledge areas are recognized by main ISE and SCM professional organizations or required to be covered in the ISE and SCM undergraduate curricula. The coverage breadth and depth of each area may vary between the two fields, ISE &

SCM, and between the programs within the field. Any of the 8 knowledge areas was considered covered in a program if there is at least one course in the program’s study plan covers the main elements or topics of the area.



Figure 1: The eight common knowledge areas between ISE and SCM as identified in this paper.

The published study plans of the 20 ISE and SCM programs show that all of the surveyed online ISE master’s programs include a course or more in Modeling and Analytics and most of these programs (more than 70%) include a course or more in Operations Research & Optimization and Statistics & Regression Analysis as in Table 3. Operations Management and Lean Six Sigma are the least common knowledge areas among the surveyed ISE programs. Evidently, Supply Chain Management area is covered by one course or more for all of the surveyed SCM programs followed by Modeling & Analytics and Operations Management areas. One Surveyed SCM program covers Operations Research & Optimization and two SCM programs cover Quality Control. 40% of the surveyed ISE programs cover 6 or more of the 8 common knowledge areas, 10% cover 5, and 50% of the surveyed ISE programs cover 3 of the common knowledge areas. While 20% of the surveyed SCM programs cover 7 of the common knowledge areas or more, 5 and 6 knowledge areas are covered each by 20% of these programs, and 40% of the surveyed SCM programs cover 3 common knowledge areas.

Table 3: % of the surveyed programs that cover the ISE & SCM common knowledge areas.

Knowledge Area	ISE	SCM
Modeling & Analytics	100%	90%
Operations Research & Optimization	80%	10%
Statistics & Regression Analysis	70%	40%
Lean Six Sigma	10%	40%
Project Management	50%	60%
Supply Chain Management	40%	100%
Quality Control	60%	20%
Operations Management	30%	80%

Advanced mathematical analysis techniques are not covered in the surveyed SCM programs as in the ISE programs since Operations Research & Optimization, Statistics & Regression Analysis, and Quality Control are not included in most of the SCM programs. Robust analytical tools along with the ability to draw conclusions from the available data sets are some of the basic requirements needed in several today's engineering-oriented jobs to handle the huge flux of information and the fierce competition in the market⁷. Many of the online master's programs in ISE or related fields include data analysis and decision making in their curriculum, which can't be effectively covered without a sufficient previous knowledge in statistics (descriptive and inferential) for all students⁷.

One of the surveyed ISE programs is supply chain oriented and designed for working professionals who want advanced degree in supply chain and logistics, and want to improve and optimize the supply chain wherever they work – manufacturing, distribution, banking, healthcare, and tourism, as well as in capital projects and construction. Another ISE program gives the students the option to select courses in supply chain and data analytics such as Supply Chain Modeling and Analysis, Introduction to International Logistics Systems, Enterprise Modeling, Statistical Learning for Data Mining, Network Optimization and Algorithms, and Data Science for Systems Decision Analytics. One ISE program offers Advanced Analytics concentration that consists of 12 credit hours of IE/SE courses which count toward the 32 or 36 credit hours required to complete the master's in ISE degree. This concentration includes courses such as Deep Learning, Stochastic Calculus & Numerical Models in Finance, Stats of Big Data & Clustering, Algorithms for Data Analytics, Analysis of Network Data, Big Graphs and Social Networks, Optimization of Large Systems, Financial Computing, and Data-Based Systems Modeling.

Several surveyed SCM programs focus on SAP (Systems Applications and Products in Data Processing) which is an ERP (Enterprise Resource Planning) software. A surveyed SCM program offers a three-course sequence of SAP courses to be eligible for SAP student recognition award. The study plan for one of the SCM programs includes advanced analytics courses such as Multiple Regression with Business Applications, Special Topics in Data Science, Technology for Business, Special Topics in Data Science, Machine Learning Applications for Managers, Blockchain in Business, in addition to advanced courses in supply chain as Reverse Logistics and Closed Loop Supply Chain. Two of the surveyed SCM programs ask students to meet face-to-face through a few interactive on-campus sessions during the semester or a residency weekend orientation program when the student joins the degree.

Insights

Half of the 20 surveyed programs (4 ISE and 6 SCM) don't have a thesis or a capstone project requirement for graduation and some of the other 10 programs have the thesis/capstone project requirement optional. For full time professionals who prefer online programs for their graduate studies, waiving the thesis/project requirement toward the end of the program is convenient. However, this may cause missing an important hand-on learning experience where the student can practice using the knowledge gained through the program to solve a real-world problem.

The proposed 30-credit hour plan for a new online master's in industrial and systems engineering in this section includes a 3-credit thesis over two semesters (1 credit in the first semester and 2

credit in the second semester). The proposed plan in Table 4 is supply chain oriented and includes courses cover the common knowledge areas between ISE and SCM as identified in this paper. The courses in this plan were selected mainly from the study plans of the 20 surveyed ISE and SCM programs in this paper.

Table 4: Proposed study plan for a new online master’s in industrial engineering that covers the common knowledge areas between ISE & SCM.

Course	Cr. hr.	ISE & SCM Common Areas
Linear Programming	3	Operations Research & Optimization
Applied Stochastic Operations Research Models	3	Operations Research & Optimization / Modeling & Analytics
Supply Chain Modeling and Analysis	3	Modeling & Analytics / Supply Chain Management
Enterprise Resource Planning (ERP)/SAP	3	Supply Chain Management / Operations Management
Applied Lean Six Sigma	3	Lean Six Sigma
Advanced Statistics for Data Science	3	Statistics & Regression Analysis
Advanced Quality Control	3	Quality Control
Engineering Project Management	3	Project Management
Advanced Production Planning and Scheduling	3	Operations Management
Thesis	3	

Inputs from experts and professional will be sought to evaluate the proposed study plan in this section. A next step is to extend the proposed study plan in Table 4 to include concentrations such as applied industrial engineering and data analysis. The future work includes offering an online master’s in industrial engineering with emphasis on supply chain analytics (without considering the common knowledge areas between ISE and SCM), which includes topics related to blockchain, deep learning, industrial internet of things (IIoT), and machine learning.

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