Engineering Education in Service Systems

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Abstract: The world's first industrial engineering academic program was established at Penn State by General Beaver, then Governor of Pennsylvania, in 1908. Since that time, the Department has graduated more than 7000 students. In 2005 the department faculty made major changes in the curriculum with the vision of educating the World Class Industrial Engineer. The major innovation in the new curriculum is specialization tracks in manufacturing systems, service systems, and information systems. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession which can be applied to these tracks. The revised curriculum builds a strong foundation for the development of a professionally competent and versatile industrial engineer, able to function in a traditional manufacturing environment as well as in a much broader economy, including financial services, communication, information technology, transportation, health care, and consulting. Given the increasingly dominant role of services in the world economy, it is imperative that engineering curricula be systematically adapted to this significant shift. The aim of this paper is to present new courses developed to support the engineering services systems track along with some of the challenges faced in this effort. We will discuss in detail courses at the undergraduate and graduate level including Retail Services Engineering, Competitive and Sustainable Industrial Enterprises, Financial Engineering, Financial Services Engineering, and Information Technology for Industrial Engineering. We will conclude with a discussion on how these courses serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering into the curriculum.

Keywords: Industrial Engineering, Service Systems, Service Enterprises, Curriculum Innovation

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1. INTRODUCTION

Modern economy can be broadly divided into three major sectors: agriculture, industry and services. Examples of services include advertising, broadcasting & news, call centres, consulting, education, entertainment, financial services (stock brokering, banking), government services, healthcare, hospitality, information technology, insurance, marketing, real estate, retail, transportation, and travel & tourism. Services has become a significant part of the world economy, employing about 40% of the work force and contributing about 63% to the world economic output. In the United States services employs about 77% of the work force and contributes about 77% of the GDP (CIA 2009). This has made services larger than the agriculture and industry sectors worldwide, and in the U.S., as shown in Figures 1(a) and 1(b). It is therefore imperative that engineering curricula be systematically adapted to this significant shift in the economy, which is consistent with the findings of the U.S. National Academy of Engineering (NAE) Committee on Engineering Education (CEE) (NAE, 2010).

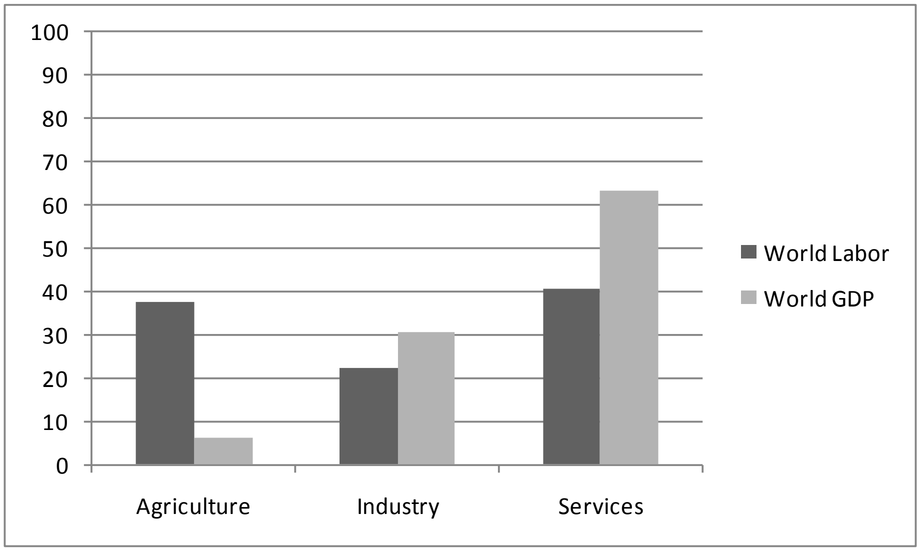

Figure 1 (a) Economy and labour by sector for the world

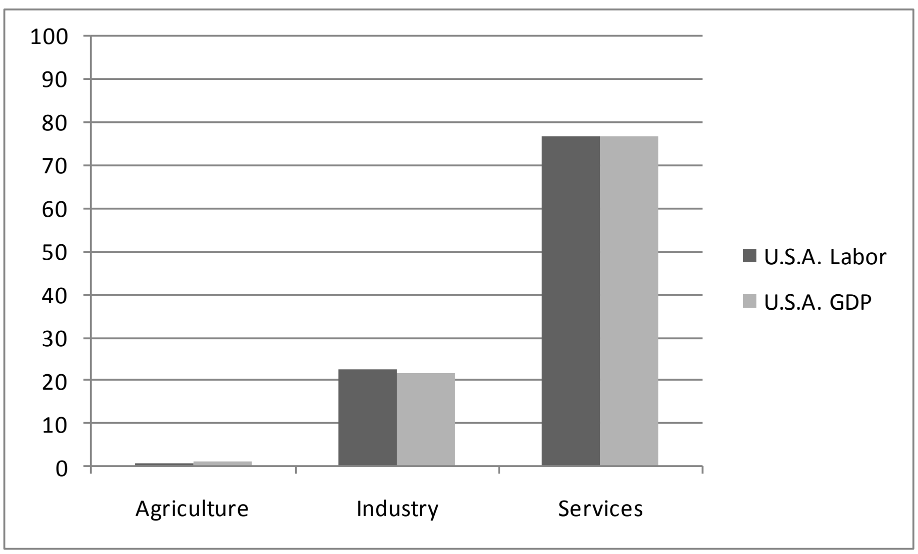

Figure 2 (b) Economy and labour by sector for U.S.A.

With this in mind, in 2005 the industrial engineering faculty at Penn State made major changes in the curriculum with a vision to educate the World Class Industrial Engineer. The major innovation in the new curriculum is specialization tracks in manufacturing systems, service systems, and information systems to equip engineers for new opportunities. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession which can be applied to these tracks. The revised undergraduate curriculum built on a strong foundation for the development of a professionally competent and versatile industrial engineer, able to function in a traditional manufacturing environment as well as in a much broader economy, including services. After the undergraduate curriculum revision, the Center for Service Enterprise Engineering was established in 2007, and several new graduate courses in services have also been developed and taught.

The rest of this paper presents new courses developed to support the engineering services systems track along with some of the challenges faced in this effort. We will discuss in detail courses at the undergraduate and graduate level including Retail Services Engineering, Financial Engineering, Financial Services Engineering, and Information Technology for Industrial Engineering. We will conclude with a discussion on how these courses serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering into the curriculum.

2. UNDERGRADUATE CURRICULUM

The Institute of Industrial Engineers defines its members as "engineers concerned with the design, improvement and installation of integrated systems of people, materials, equipment, and energy. They draw upon specialized knowledge 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." Many industrial engineers play important leadership roles in various organizations. Therefore the design of a curriculum for industrial engineering students needs to balance depth and breadth to prepare graduates for diverse roles in the overall economy. To further the vision of educating the World Class Industrial Engineer, the department has also developed exchange programs with universities in Japan, Dominican Republic, and Spain. These exchange programs are implemented through a 1-credit course in which students learn about the country, and visit the host university's country for a week. During the visit the students tour local manufacturing and service industries, sit in on classes to see how engineers are taught in other countries, and also visit cultural sites to get a better understanding of the people and history.

2.1 Curriculum

As in other engineering majors, IE students take courses in basic sciences and engineering, and general education during the first two years. After this IE students take courses required for the major, which are designed to introduce the student to basic Industrial Engineering. The overall curriculum requires 129 credits, and is summarized in Figure 2 (PSUIME 2010).

2.2 Specialization Track: Engineering Service Systems

Along with the required courses, students chose one of the three tracks of specialization: Manufacturing Systems Engineering, Engineering Service Systems or Engineering Information Systems. Since the studies regarding service industry is an interdisciplinary area, recommended course work in the engineering service systems track also includes courses from other departments as shown in Table 1.

1st Semester

MATH 140	***Calculus I***	***4***
EDSGN 100	Engr. Design & Graphics	3
ENGL 15 or 30	Rhetoric & Composition	3
CHEM 110	***Chemical Principles***	***3***
Arts, Humanities, Social Sciences		3
		16

2nd Semester

MATH 141	***Calculus II***	***4***
PHYS 211	***Mechanics***	***4***
CHEM 111	Experimental Chemistry	1
ECON 2 or 4	(Social Science)	3
Arts, Humanities, Social Sciences		3
First-Year Seminar		1
		16

3rd Semester

MATH 231	Calculus of Several Variables	2
PHYS 212	Electricity & Magnetism	4
CAS 100A/B	Effective Speech	3
+E MCH 210[A]	**Statics & Strength of Materials**	**5**
Arts, Humanities, Social Sciences		3
		17

4th Semester

MATH 220	Matrices	2
CMPSC 200, 201, or 202	Matlab C or Fortran Programming	3
MATH 250	Differential Equations	3
Science Elective [B]		3
~ Choose 6 credits from approved list		6
		17

5th Semester

+I E 302	**Engineering Economy**	**3**
+I E 305	**Product Design, Specification & Measurement**	**3**
+I E 322	**Probabilistic Models in IE**	**3**
+I E 327	**Introduction to Work Design**	**3**
MATSE 259	Materials, Properties & Processing	3
Health & Physical Activity*		1.5
		16.5

6th Semester

+I E 323	**Statistical Methods in IE**	**3**
+I E 405	**Linear Programming**	**3**
+I E 330	**Information Technology for IE**	**3**
Choose a manufacturing processing course[C]		3
Engl 202C	Technical Writing	3
Health & Physical Activity*		1.5
		16.5

7th Semester

I E 425	Intro to Operations Research	3
I E 408 or 419	Cognitive Work Design or Work Design-Productivity and Safety	3
I E 470	Manufacturing System Design & Analysis	3
Specialization Course[D]		3
Arts, Humanities, Social Sciences		3
		15

8th Semester

I E 453	Simulation Modeling for Decision Support	3
I E 480 W	Capstone Design Course	3
Specialization Courses[D]		6
Arts, Humanities, Social Sciences		3
		15

Courses listed in ***boldface italic type*** require a grade of C or better for entrance into this major.
+Courses listed in **boldface type** require a grade of C or better for graduation in this major.
[A] Students may substitute E MCH 211 and 213 or 213D for E MCH 210.
[B] Science Elective: Select from BIOL 141, CHEM 112, 202, MATH 310, 311W, 401, 405, 411, PHYS 214. (NOTE: Students taking the 2-credit PHYS 214 will need to take an additional credit to meet the 129 credit degree requirement).
[C] Select from IE 306, IE 307, IE 311, IE 464
[D] All undergraduates must take 9-credits (3 courses) of specialization track electives chosen from the Department's list. Of these 9-credits, a minimum of 6 credits must be IE courses.
~ Choose 6 credits: CMPEN 271 or EE 211, ME 201 or 300, E Mch 212, 3 credits from a minor upon completion of the minor as approved by the IE department, 3 credits any combination of Co-op or Internship, 3 credits of ROTC upon completion of the ROTC program.
*Students may satisfy this requirement with one, 3 credit GHA course or 3 credits of ROTC upon completion of the ROTC program.

Figure 3 Overall undergraduate curriculum in Industrial Engineering

I E 408 Cognitive Work Design	I E 478 Retail Services Engineering
I E 418 Human/Computer Interface Design	IE 497x Service Enterprise Engineering
I E 419 Work Design - Productivity and Safety	IE 497x Healthcare Systems Engineering
I E 433 Regression and Design of Experiments	BIOE 402 Biomedical Instrumentation and Measurement
I E 434 Statistical Quality Control	
I E 436 Six Sigma Methodology	BIOE 406 Medical Imaging
I E 454 Applied Decision Analysis	C E 422 Transportation Planning
I E 466 Concurrent Engineering	C E 424 Optimization in Civil Engineering Systems
I E 467 Facility Layout and Material Handling	Math/Stat 416 Stochastic Modeling
I E 468 Optimization Modeling and Methods	M E 446 Reliability and Risk Concepts in Design
IE 497x Data Envelopment Analysis	STAT 462 Applied Regression Analysis

TABLE 1 List of courses for the Enginering Service Systems Track

3. COURSES

This section introduces some courses which are newly developed for the engineering service systems track.

3.1 Information Technology for Industrial Engineering

This is a required course for all undergraduate students in the major. Objective of this course is the study and application of computing and information technology to industrial engineering. It covers an overview of Enterprise Information Modeling, Analysis of Data Bases, Data Mining, Internet technologies, and Object Oriented Programming. Specific application examples from industrial engineering, manufacturing and service areas are discussed. Hands-on lab exercises complement the lectures, and provide a source of practical examples.

3.2 Retail Services Engineering

Objective of this course is to understand modern retail industry with focus on their operations and information technologies. The course starts with an overview of the basics of types of retailing, their channels, and economics of their operations. Much of the emphasis in the course is on processes and information technologies used in retail industry such as point of sale systems, barcode, RFID/EPC, data warehouse and analytics for decision support. An important part of the course is the group project. This course is also allowed for graduate credit in the Department.

3.3 Service Enterprise Engineering

This course covers the use of tools from industrial engineering and operations research to build mathematical models and to develop methodologies for optimal design and control of service systems. Topics covered include overview of service systems, quality and evaluation of service, financial engineering, supply chain engineering, and revenue management.

3.4 Competitive and Sustainable Industrial Enterprises

Energy and emissions are becoming increasingly important in manufacturing and service enterprises in the U.S and around the world. Engineering decisions in product design, manufacturing, distribution, usage, and disposal all impact energy consumption and emissions. Manufacturing and service enterprises are initiating sustainability in their operation as a part of their corporate social responsibility mission. This course, which is being developed, will focus on understanding the fundamentals sustainability. Technical focus will be on engineering models to characterize energy consumption and emissions in manufacturing and service processes.

Tentative topics include, industry megatrend in sustainability; various forms of energy used in industry such as renewable, hydrocarbon fuels, electricity, steam, and compressed air; emissions and natural resource consumption in various processes; energy efficiency improvements through lighting and HVAC; Life Cycle Assessment (LCA) and impact during design, manufacturing, packaging, transportation, usage and disposal; LCA of CFL bulbs, wind turbines, solar PV panels, storage batteries, and data centers; energy and emission impact in tourism and entertainment services.

3.5 Financial Engineering

This course is an introductory graduate level course in financial engineering. It consists of cash flow analysis, options pricing, real options, and applications. The lectures include theories from a portfolio selection using a nonlinear programming method to American option pricing using a stochastic dynamic programming method. Based on the lectures, the students are encouraged to develop their ideas as a term project and apply the state of the art methodologies to real world problems.

3.6 Financial Services for Enterprise and Supply Chain Engineering

Objective of this course is to study current and emerging electronic financial services used in enterprise and supply chain operations. Emphasis will be on technologies used in these services and how they can be used for improving operations of individual enterprises and across global supply chains. Topics covered include electronic finance, electronic payments, electronic trading, service oriented architectures, treasury technology, and enterprise and supply chain decisions based on financial services. This is an entry-level graduate level course suitable for students in engineering that is scheduled to be taught for the first time during Fall 2010.

3.7 Distributed Systems and Control

The objective of this course is to study current research and engineering challenges in distributed systems and control in the context of manufacturing and service enterprises, and supply chains. Emphasis will be placed on understanding the dynamics and computational aspects of decision making and control algorithms in integrated enterprises. Recently several new open architecture standards have emerged for control and information systems in industrial enterprises. These standards have been largely driven by industry to reduce the cost of integrating and configuring a new breed of distributed enterprises to be engineered. This course deals with the multidisciplinary aspects of controls, computing, and communication in this rapidly evolving area. Term project topics in the course have included hospital emergency room scheduling, call center management, distribution logistics, and hospitality services.

These courses have been developed by individual faculty members with expertise and interest in the corresponding subject matter. Availability of the faculty to teach these courses has been quite good essentially because of the relatively large number of faculty (≈ 25) in the department. Another encouraging factor is that these courses have been well subscribed by the students. Some of the common challenges in developing these courses include lack of good text books, and occasional perception that some of the topics may be better covered in other majors. However, these courses have been well received by industry which sees the need for engineering graduates trained in these topics.

4. SERVICE ENTERPRISE ENGINEERING CENTER

The Center for Service Enterprise Engineering (CSEE) was established within the Department in January 2007. It is the first such academic center in the U.S., devoted solely to the study and practice of service engineering. CSEE has been initiated with a $1 million gift from Harold and Inge Marcus, and to-date has received additional research funds of over $1.4 million from a variety of sources including NSF, NIST, USDA, USDE, and the Ben Franklin's Center of Excellence Award. The center constitutes of 8 faculty members and 17 graduate students actively engaged in research in various aspects of service enterprise engineering. The remainder of this section will describe the main areas of research currently being pursued in CSEE along with related courses that enable integration of research and teaching.

4.1 Revenue Management

At CSEE, revenue management (RM) research includes pricing, resource allocation, and demand management. The aim of RM is to enable companies to sell the right resources to the right customers at the right time and the right price. The goal of RM is to extract all willingness to pay. We analyze and forecast demand, competitor behaviour and customer behaviour in order to optimize resource allocation and cost structure. RM can be applied to a variety of industries including security services, health care, and golfing.

Related coursework

IE 468: Optimization Modeling and Methods	IE 478: Retail Engineering
IE 497x: Service Enterprise Engineering	IE 505: Linear Programming
IE 516: Applied Stochastic Processes	IE 519: Dynamic Programming
IE 520: Multiple Criteria Optimization	IE 554: Production, Planning and Control
IE 562: Expert Systems Design in Industrial Engineering	IE 570: (SC&IS) Operations Research in Supply Chain
IE 589: Dynamic Optimization and Differential Games	IE 597x: Financial Services for Enterprise and Supply Chain Engineering
IE 597x: Introduction to Financial Engineering	

4.2. Customer Service Center Test-bed

The research aim here is to develop a customer center test bed (CCTB) as a reconfigurable, customized offline software package that simulates the realistic call center environment based on preset scenarios. The setup of the software can be changed easily by editing the scripts and processes that model various scenarios that need to be evaluated based on customer's requirements. CCTB example applications include trucking, health care, and public emergency call centers.

Related coursework:

IE 408: Cognitive Work Design	IE 418: Human/Computer Interface Design
IE 462: Expert Systems Design	IE 553: Engineering of Human Work
IE 557: Human-in-the-Loop Simulation	IE 558: Engineering of Cognitive Work
IE 567: Distributed Systems and Control	IE 578: Using Simulation Models for Design

4.3. Service Process Modeling

CSEE is researching new techniques for service process modelling for (1) better understanding of user satisfaction (2) re-engineering customers' IT systems that better support process requirements (4) cultivating innovation-rich culture throughout customer's service enterprise, and (5) helping incubate more innovative services to meet the changing needs of customers. Some of the modelling techniques have been used for analyzing enterprise transformation projects where complexity of existing and transformed processes were quantified using metrics based on information theory. Such techniques have been used for applications in healthcare, supply-chain services, and in security operations.

Related coursework:

IE 462: Expert Systems Design	IE 424: Process Quality Engineering
IE 522: Discrete Event Systems Simulation	IE 466: Concurrent Engineering
IE 578: Using Simulation Models for Design	IE 567: Distributed Systems and Control
IE 453: Simulation Modeling for Decision Support	IE 584: Time Series Control & Process Adjustment

5. CONCLUSIONS

There is a significant increase in the role of services in the economy worldwide. In order to adapt to these changes Penn State's Industrial Engineering Department has developed a track in Engineering Service Systems at the undergraduate level. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession. The revised curriculum enables the development of a professionally competent and versatile industrial engineer capable of contributing to a broad economy, including financial services, communication, information technology, transportation, health care, and consulting. The paper described the overall curriculum and the some of the new courses developed to support the service systems track. Courses especially at the graduate level serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering in the areas of revenue management, customer satisfaction, and enterprise innovation.

6. REFERENCES

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