

MANAGEMENT SCIENCE AND ENGINEERING

Courses offered by the Department of Management Science and Engineering are listed under the subject code MS&E on the *Stanford Bulletin's* ExploreCourses web site.

The Department of Management Science and Engineering leads at the interface of engineering, business, and public policy. The department's mission is, through education and research, to advance the design, management, operation, and interaction of technological, economic, and social systems. The department's engineering research strength is integrated with its educational program at the undergraduate, master's, and doctoral levels: graduates of the program are trained as engineers and future leaders in technology, policy, and industry. Research and teaching activities are complemented by an outreach program that encourages the transfer of ideas to the environment of Silicon Valley and beyond.

Management Science and Engineering (MS&E) provides programs of education and research by integrating three basic strengths:

1. depth in conceptual and analytical foundations
2. comprehensive coverage of functional areas of application
3. interaction with other Stanford departments, Silicon Valley industry, and organizations throughout the world.

The analytical and conceptual foundations include decision and risk analysis, dynamic systems, economics, optimization, organizational science, and stochastic systems. The functional areas of application include entrepreneurship, finance, information, marketing, organizational behavior, policy, production, and strategy. Close associations with other engineering departments and with industry enrich the programs by providing opportunities to apply MS&E methods to important problems and by motivating new theoretical developments from practical experience. MS&E's programs also provide a basis for contributing to other areas such as biotechnology, defense policy, environmental policy, information systems, and telecommunications.

Mission of the Undergraduate Program in Management Science and Engineering

The mission of the undergraduate program in Management Science and Engineering is to provide students with the fundamentals of engineering systems analysis so that they are able to plan, design, and implement complex economic and technical management systems. The program builds on the foundational courses for engineering including calculus, engineering fundamentals, and physics or chemistry as well as management science. Students complete core courses in accounting, computer science, economics, ethics, organizational theory, mathematical modeling, optimization, probability, and statistics. To personalize their exploration, students select additional courses from different areas of the department, with greater emphasis in one of them. The major prepares students for a variety of career paths, including investment banking, management consulting, facilities and process management, or for graduate school in industrial engineering, operations research, business, economics, law, medicine, or public policy.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to be able:

1. to apply the knowledge of mathematics, science, and engineering;

2. to design and conduct experiments;
3. to design a system or components to meet desired needs;
4. to identify, formulate, and solve engineering problems;
5. to use techniques, skills, and modern engineering tools necessary for engineering practice;
6. to function on multidisciplinary teams;
7. to communicate effectively;
8. to recognize the need for and demonstrate an ability to engage in life-long learning;
9. to obtain the background necessary for admission to top professional graduate engineering or business programs;
10. to understand professional and ethical responsibility;
11. to obtain the broad education necessary to understand the impact of engineering solutions in a global and societal context; and
12. to obtain a knowledge of contemporary issues pertinent to the field of management science and engineering.

Graduate Programs in Management Science and Engineering

MS&E offers programs leading to the degrees of Master of Science and Doctor of Philosophy. The department also offers a coterminal B.S./M.S. degree, a dual master's degree in cooperation with each of the other departments in the School of Engineering, and joint master's degrees with the School of Law and the Public Policy Program.

For University coterminal degree program rules and University application forms, see the Registrar's coterminal degrees web site (<http://studentaffairs.stanford.edu/registrar/publications/#Coterm>).

Applicants for admission as graduate students in MS&E must submit the results of the verbal, quantitative, and analytical parts of the Graduate Record Examination. The deadline for application to the doctoral program is December 6, 2016, and the deadline for application to the master's program is January 17, 2017.

Except in unusual circumstances, admission is limited to the Autumn Quarter because courses are arranged sequentially with basic courses and prerequisites offered early in the academic year.

Assistantships and Fellowships

A limited number of fellowships and assistantships are awarded each year. Applicants admitted to the doctoral program, who have indicated on their application that they would like to be considered for financial aid, are automatically considered for these assistantships and fellowships. New and returning master's students may apply for course assistantships each quarter, but priority is given to MS&E doctoral students.

Information about loan programs and need-based aid for U.S. citizens and permanent residents can be obtained from the Financial Aid Office.

Learning Outcomes (Graduate)

The M.S. prepares engineers for a lifelong career addressing the critical technical and managerial needs of private and public organizations. The program emphasizes developing analytic abilities, making better decisions, developing and executing strategies while also leading people who innovate. Unlike an MBA, our master's program addresses the technical as well as the behavioral challenges of running organizations and complex systems. We emphasize quantitative analytic skills and an entrepreneurial spirit.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares

students to make original contributions in Management Science and Engineering and related fields.

Careers in MS&E

MS&E students are candidates for careers in consulting, product and project management, financial analysis, and work in policy arenas. A significant number join or found start-ups. Many have become leaders in technology-based businesses which have an increasing need for analytically oriented people who understand both business and technology. Other graduates make careers tackling the problems faced by local, national, and international governments by developing new healthcare systems, new energy systems and a more sustainable environment. The major problems of the day demand an ability to integrate the technical, social and economic ways of thinking. This is precisely what the department educates its students to do.

Bachelor of Science in Management Science and Engineering

The program leading to the B.S. degree in Management Science and Engineering (MS&E) is outlined in the School of Engineering section of this bulletin; more information is contained in the School of Engineering's *Handbook for Undergraduate Engineering Programs*. Students are encouraged to plan their academic programs as early as possible, ideally in the freshman or sophomore year. Students should not wait until they are declaring a major to consult with the department's student services staff. This is particularly important for students who would like to study overseas or pursue another major or minor.

The undergraduate curriculum in Management Science and Engineering provides students training in the fundamentals of engineering systems analysis to prepare them to plan, design, and implement complex economic and technological management systems where a scientific or engineering background is necessary or desirable. The major prepares students for a variety of career paths, including investment banking, management consulting, facilities and process management, or for graduate school in industrial engineering, operations research, business, economics, law, medicine, or public policy.

The educational objectives of the undergraduate degree program are:

- *Principles and Skills*—provide students with a basic understanding of management science and engineering principles, including analytical problem solving and communications skills.
- *Preparation for Practice*—prepare students for practice in a field that sees rapid changes in tools, problems, and opportunities.
- *Preparation for Continued Growth*—prepare students for graduate study and self development over an entire career.
- *Preparation for Service*—develop in students the awareness, background, and skills necessary to become responsible citizens, employees, and leaders.

See also the department's undergraduate Learning Outcomes (p.) for additional learning objectives.

The program builds on the foundational courses for engineering, including calculus, mathematical modeling, probability, statistics, engineering fundamentals, and physics or chemistry.

Students interested in a minor should see the Minor tab in this section.

MS&E also participates with the departments of Computer Science, Mathematics, and Statistics in a program leading to a B.S. in Mathematical and Computational Science. See the "Mathematical and Computational Science (<http://exploreddegrees.stanford.edu/schoolofhumanitiesandsciences/>)" section of this bulletin.

mathematicalandcomputationalscience/#bachelorstext)" section of this bulletin.

Core

The department core, taken for all areas, includes courses in accounting, computer science, deterministic optimization, economics, organization theory, and a capstone senior project. Through the core, students in the program are exposed to the breadth of faculty interests, and are in a good position to choose an area during the junior year.

Areas

The major is designed to allow a student to explore all three areas of the department in greater depth.

1. *Finance and Decision*: focuses on the design and analysis of financial and strategic plans.
2. *Operations and Analytics*: focuses on algorithms, theory, and the design and analysis of manufacturing, production, and service systems.
3. *Organizations, Technology, and Policy*: focuses on understanding, design, and analysis of organizations and public policy, particularly technology-based issues.

Management Science and Engineering (MS&E)

Completion of the undergraduate program in Management Science and Engineering leads to the conferral of the Bachelor of Science in Management Science and Engineering.

Requirements

		Units
Mathematics and Science		
All required; see SoE Basic Requirements 1 and 2 ¹		
CME 100 or MATH 51	Vector Calculus for Engineers Linear Algebra and Differential Calculus of Several Variables	5
CME 103	Introduction to Matrix Methods	5
MS&E 120	Probabilistic Analysis	5
MS&E 121	Introduction to Stochastic Modeling	4
MS&E 125	Introduction to Applied Statistics	4
Select one of the following sequences:		8
CHEM 31B & CHEM 33	Chemical Principles II and Structure and Reactivity	
CHEM 31X & CHEM 33	Chemical Principles Accelerated and Structure and Reactivity	
PHYSICS 21 & PHYSICS 22 & PHYSICS 23 & PHYSICS 24	Mechanics, Fluids, and Heat and Mechanics, Fluids, and Heat Laboratory and Electricity, Magnetism, and Optics and Electricity, Magnetism, and Optics Laboratory	
PHYSICS 41 & PHYSICS 43	Mechanics and Electricity and Magnetism	
Electives from SoE approved list or AP/IB credit ¹		13
Technology in Society		
Select one of the following; see SoE Basic Requirement 4		3
COMM 120W	Digital Media in Society	
CS 181	Computers, Ethics, and Public Policy	
ENGR 131	Ethical Issues in Engineering	
MS&E 193	Technology and National Security (WIM)	
STS 1	The Public Life of Science and Technology	
Engineering Fundamentals ²		
Three courses; see SoE Basic Requirement 3		

CS 106A	Programming Methodology ³	5
Select one of the following:		3
ENGR 25B	Biotechnology	
or ENGR 25E	Energy: Chemical Transformations for Production, Storage, and Use	
ENGR 40	Introductory Electronics	
or ENGR 40A	Introductory Electronics	
or ENGR 40M	An Intro to Making: What is EE	
or ENGR 40P	Physics of Electrical Engineering	
ENGR 80	Introduction to Bioengineering (Engineering Living Matter)	

Select one of the following (or ENGR 25, ENGR 40, or ENGR 80 if not used above): 3

ENGR 10	Introduction to Engineering Analysis	
ENGR 14	Intro to Solid Mechanics	
ENGR 15	Dynamics	
ENGR 20	Introduction to Chemical Engineering	
ENGR 30	Engineering Thermodynamics	
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
or ENGR 50E	Introduction to Materials Science, Energy Emphasis	
or ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
ENGR 90	Environmental Science and Technology	

Engineering Depth²

Core Courses (all six required) 25

CS 103	Mathematical Foundations of Computing ⁴	
or CS 106B	Programming Abstractions	
or CS 106X	Programming Abstractions (Accelerated)	
ECON 50	Economic Analysis I	
MS&E 108	Senior Project	
MS&E 111	Introduction to Optimization ⁴	
MS&E 140	Accounting for Managers and Entrepreneurs	
or MS&E 140X	Financial Accounting Concepts and Analysis	
MS&E 180	Organizations: Theory and Management	

Area Courses (see below) 27

Choose four or five courses (minimum 15 units) from a primary area and two courses (minimum 6 units) from each of the other two areas.

Depth Areas

Finance and Decision Area

Units
6-15

Students choosing F&D as their primary area must take at least two of ECON 51, MS&E 145, and MS&E 152

Introductory (appropriate for freshmen and sophomores)

MS&E 147	Finance and Society for non-MBAs	
MS&E 152	Introduction to Decision Analysis (WIM)	
Intermediate (appropriate for juniors and seniors)		
MS&E 145	Introduction to Investment Science	
MS&E 146	Corporate Financial Management	
MS&E 245G	Finance for Non-MBAs	
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	

Advanced (intended primarily for graduate students)

MS&E 245A	Investment Science	
MS&E 246	Financial Risk Analytics	
MS&E 250A	Engineering Risk Analysis	
MS&E 250B	Project Course in Engineering Risk Analysis	

MS&E 245B	Advanced Investment Science	
Operations and Analytics Area		6-15

Students choosing O&A as their primary area may also include CS 161, CS 229, and STATS 202 in their selections⁴

Introductory (no prerequisites)

MS&E 107	Interactive Management Science Methods	
MS&E 112	Mathematical Programming and Combinatorial Optimization	
MS&E 135	Networks	
MS&E 213	Introduction to Optimization Theory	
MS&E 223	Simulation	
MS&E 226	"Small" Data	
MS&E 231	Introduction to Computational Social Science	
MS&E 237	Networks, Markets, and Crowds	
MS&E 251	Stochastic Control	

Applications

MS&E 130	Information Networks and Services	
MS&E 233	Networked Markets	
MS&E 235	Analytics in Action	
MS&E 260	Introduction to Operations Management	
MS&E 262	Supply Chain Management	
MS&E 263	Healthcare Operations Management	
MS&E 267	Service Operations and the Design of Marketplaces	

Organizations, Technology, and Policy Area 6-15

Students choosing OT&P as their primary area must take at least two of ENGR 145, MS&E 175, MS&E 181, MS&E 184, MS&E 185, PSYCH 70, and SOC 114 (but not both PSYCH 70 and SOC 114)⁴

Introductory (no prerequisites)

ENGR 131	Ethical Issues in Engineering ⁴	
MS&E 178	The Spirit of Entrepreneurship	
MS&E 190	Methods and Models for Policy and Strategy Analysis	
MS&E 193	Technology and National Security (WIM) ⁴	
MS&E 197	Ethics, Technology, and Public Policy (WIM) ⁴	

Advanced (has prerequisites and/or appropriate for juniors and seniors)

ENGR 145	Technology Entrepreneurship	
MS&E 175	Innovation, Creativity, and Change	
MS&E 177	Creativity Rules	
MS&E 181	Issues in Technology and Work ⁴	
MS&E 183	Leadership in Action	
MS&E 184	New Directions in the Psychology of Technology and Work	
MS&E 185	Global Work	
MS&E 243	Energy and Environmental Policy Analysis	
MS&E 292	Health Policy Modeling	
MS&E 294	Climate Policy Analysis	
MS&E 295	Energy Policy Analysis	

¹ Math and Science must total a minimum of 44 units. Electives must come from the School of Engineering approved list, or, PSYCH 50 Introduction to Cognitive Neuroscience, or PSYCH 70 Self and Society: Introduction to Social Psychology, and may not repeat material from any other requirement. AP/IB credit for Chemistry, Mathematics, and Physics may be used.

² Engineering fundamentals plus engineering depth must total a minimum of 60 units.

³ Students may petition to place out of CS 106A Programming Methodology.

⁴ Courses used to satisfy the Math, Science, Technology in Society, or Engineering Fundamental requirement may not also be used to satisfy an engineering depth requirement.

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (<http://ughb.stanford.edu>).

Management Science and Engineering (MS&E) Minor

The following courses are required to fulfill the minor requirements:

Background requirements (two courses)

CME 100	Vector Calculus for Engineers	5
or MATH 51	Linear Algebra and Differential Calculus of Several Variables	
CS 106A	Programming Methodology	5

Minor requirements (seven courses, letter-graded)

MS&E 111	Introduction to Optimization	4
MS&E 120	Probabilistic Analysis	5
MS&E 121	Introduction to Stochastic Modeling	4
MS&E 125	Introduction to Applied Statistics	4
MS&E 180	Organizations: Theory and Management	4
Electives (select any two 100- or 200-level MS&E courses)		6

Recommended courses

In addition to the required background and minor courses, it is recommended that students also take the following courses.

ECON 50	Economic Analysis I	5
MS&E 140	Accounting for Managers and Entrepreneurs (may be used as one of the required electives above)	2-4
or MS&E 140X	Financial Accounting Concepts and Analysis	

Coterminal Program in Management Science and Engineering

This program allows Stanford undergraduates an opportunity to work simultaneously toward a B.S. in Management Science and Engineering or another quantitative major, and an M.S. in Management Science and Engineering.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (<http://exploreddegrees.stanford.edu/cotermdegrees>)" section. University requirements for the master's degree are described in the "Graduate Degrees (<http://exploreddegrees.stanford.edu/graduatedegrees/#masterstext>)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Master of Science in Management Science and Engineering

Units The M.S. degree programs require a minimum of 45 units beyond the equivalent of a B.S. degree at Stanford. All programs represent substantial progress in the major field beyond the bachelor's degree.

University requirements for the master's degree are described in the "Graduate Degrees (<http://exploreddegrees.stanford.edu/graduatedegrees>)" section of this bulletin.

The master's in Management Science and Engineer prepares engineers for a lifelong career addressing the technical and managerial needs of private and public organizations. The program emphasizes developing analytic abilities, making better decisions, and developing and executing strategies while also leading people who innovate. Unlike an M.B.A., the department's master's program addresses the technical as well as the behavioral challenges of running organizations and complex systems, emphasizing quantitative analytic skills and an entrepreneurial spirit.

MS&E students know math, engineering, as well as behavioral science. They can conduct experiments to design better systems, organizations and work processes. They understand how to analyze data to solve real world problems. They can develop mathematical and computational models to inform action. They know how to surface and examine unarticulated assumptions and root causes. These students can communicate effectively in the team environments found in so many contemporary organizations.

MS&E master's students have breadth as well as depth. All are required to develop competence in optimization and analytics, organizations and decisions, and probability. In addition every student pursues a specialty in one of six areas:

1. *Financial Analytics*: Students who concentrate in Financial Analytics are prepared for careers requiring analytical rigor and the ability to innovate around market challenges. Example career paths include financial services, risk management, investment management, financial technology and data processing, financial regulation and policy, exchanges and clearing houses, and auditing and compliance. The concentration combines the in-depth study of quantitative techniques with practical, hands-on business problem solving. Students learn to use mathematical models and quantitative tools to solve complex problems in finance practice. The concentration exploits the intellectual ties between finance, operations research, computer science, and engineering. It offers a high level of flexibility and a range of elective courses that allow students to tailor the program to their specific career goals. Required courses immerse students in quantitative methods and deepen their understanding of finance fundamentals. Projects courses feature practical, data-driven team projects and case studies, fostering group learning and interaction with peers.
2. *Operations and Analytics*: Students following the Operations and Analytics track become prepared in the fundamentals and applications that are critical to careers in a fields ranging from operations management in the service, health care, production, manufacturing, computer, telecommunications, banking, industries to modern Silicon Valley information technology and data analytics. The program emphasizes a balance between the technical rigor of

methodologies with lasting value and insightful modern applications and design challenges in a variety of established and emerging industries and operations environments. It offers a portfolio of courses in probabilistic modeling, optimization, simulation, algorithms, data science, networks, markets, and corresponding applications.

3. *Technology and Engineering Management*: Students who concentrate in Technology and Engineering Management are prepared for careers including product and project management, management consulting, and entrepreneurship. They acquire skills to manage technical organizations, foster innovation, and deal with rapidly evolving technologies and dynamic markets. Specialized coursework is flexible, allowing students to explore and gain depth, understanding technical organizations to develop a culture of successful innovation and entrepreneurship, along with methods for decision making under uncertainty, financial analysis, and strategic planning.
4. *Computational Social Science*: The Computational Social Science track teaches students how to apply rigorous statistical and computational methods to address problems in economics, sociology, political science, and beyond. The program prepares students for a diverse set of career paths in data science, information technology, and policy analysis. The core coursework covers fundamental statistical concepts, large-scale computation, and network analysis. Through electives, students can explore topics such as experimental design, algorithmic economics, and machine learning.
5. *Decision and Risk Analysis*: Students who specialize in Decision and Risk Analysis are prepared for careers including management consulting, policy analysis, and risk management, applying engineering systems analysis to tackle complex economic and technical management problems in the private and public sectors. They acquire the skills to identify and develop opportunities in uncertain situations while recognizing and hedging the downside risks. Specialized course work includes the mathematical foundations for modeling in dynamic uncertain environments to value and manage uncertain opportunities and risks, applications to public policy, and an opportunity to work on a client project under faculty guidance.
6. *Energy and Environment*: The Energy and Environment track is designed for students interested in energy and environmental issues from the perspectives of public policy, nongovernmental organizations, or corporations. This track includes core courses; courses in economic analysis, energy resources, and energy/environmental policy analysis; and an individually designed concentration, typically emphasizing policy, strategy, or technology. Seminars provide insights into current corporate strategy, public policy, and research community developments. Energy/environmental project courses give practice in applying methodologies and concepts.
7. *Health Systems Modeling*: The Health Systems Modeling track is designed for students interested in healthcare operations and policy. The courses in this track emphasize the application of mathematical and economic analysis to problems in public health policy and the design and operation of healthcare services.

The master's degree is designed to be a terminal degree program with a professional focus. The M.S. degree can be earned in one academic year (three academic quarters) of full-time work, although most students choose to complete the program in five academic quarters, or eighteen months, and work as an intern in the Summer Quarter.

Background Requirements

Students are expected to have completed both MATH 51 Linear Algebra and Differential Calculus of Several Variables, or an equivalent multivariable differential calculus course, and CS 106A Programming Methodology, or an equivalent general programming course, before

beginning graduate study. These courses do not count toward degree requirements.

Degree Requirements

Students must take a minimum of 45 course units as follows:

- Three core courses (9-12 units)
- A primary or specialized concentration (12-24 units)
- One project course or two integrated project courses (0-8 units)
- Elective courses (1-24 units; see restrictions below)

Core Courses (three courses required)

Optimization and Analytics (select one)

		Units
MS&E 211	Linear and Nonlinear Optimization	3-4
MS&E 226	"Small" Data	3
Relevant 200 or 300 level MS&E course in optimization or analytics if a comparable introductory course in optimization or analytics has already been completed.		3-4

Organizations and Decisions (select one)

		Units
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	3-4
MS&E 280	Organizational Behavior: Evidence in Action	3-4
Relevant 200 or 300 level MS&E course in organizations or decisions if a comparable introductory course in organizations or decisions has already been completed.		3-4

Probability (select one)

		Units
MS&E 220	Probabilistic Analysis	3-4
MS&E 221	Stochastic Modeling	3
Relevant 200 or 300 level MS&E course in probability or stochastics if a comparable introductory course in probability or stochastics has already been completed.		3-4

Primary Concentrations

Financial Analytics Concentration (five courses required)

		Units
Financial Theory and Modeling (select one):		
MS&E 245A	Investment Science	3
MS&E 245B	Advanced Investment Science	3
MS&E 246	Financial Risk Analytics	3
Quantitative Methods (two required):		
Select one (whichever wasn't taken for core):		
MS&E 211	Linear and Nonlinear Optimization	3-4
MS&E 226	"Small" Data	3
Select one:		
MS&E 322	Stochastic Calculus and Control	3
MS&E 349	Financial Statistics	3
STATS 207	Introduction to Time Series Analysis	3
STATS 240	Statistical Methods in Finance	3-4
STATS 241	Data-driven Financial and Risk Econometrics	3-4
Financial Applications (select two):		
CME 243	Risk Analytics and Management in Finance and Insurance	2-4
MS&E 347	Credit Risk: Modeling and Management	3
MS&E 348	Optimization of Uncertainty and Applications in Finance	3
MS&E 445	Projects in Wealth Management	3-4
MS&E 446	Artificial Intelligence in Financial Technology	3

MS&E 447	Systemic and Market Risk : Notes on Recent History, Practice, and Policy	3
MS&E 448	Big Financial Data and Algorithmic Trading	3

Operations and Analytics Concentration (four courses required)

Units

Required Courses

MS&E 211	Linear and Nonlinear Optimization (whichever course wasn't taken for core)	3-4
or MS&E 226	"Small" Data	
MS&E 221	Stochastic Modeling (or a more advanced course in probability (i.e. MS&E 223 Simulation) if a student has taken an equivalent class in stochastic modeling)	3
MS&E 235	Analytics in Action	3
or MS&E 251	Stochastic Control	
MS&E 260	Introduction to Operations Management	3
or MS&E 261	Inventory Control and Production Systems	
or MS&E 263	Healthcare Operations Management	

Recommended Elective Courses:

MS&E 212	Mathematical Programming and Combinatorial Optimization	3
MS&E 213	Introduction to Optimization Theory	3
MS&E 223	Simulation	3
MS&E 231	Introduction to Computational Social Science	3
MS&E 233	Networked Markets	3
MS&E 235	Analytics in Action	3
MS&E 237	Networks, Markets, and Crowds	3
MS&E 243	Energy and Environmental Policy Analysis	3
MS&E 245A	Investment Science	3
MS&E 250A	Engineering Risk Analysis	3
MS&E 251	Stochastic Control	3
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	3-4
MS&E 260	Introduction to Operations Management	3
MS&E 261	Inventory Control and Production Systems	3
MS&E 262	Supply Chain Management	3
MS&E 263	Healthcare Operations Management	3
MS&E 267	Service Operations and the Design of Marketplaces	3
MS&E 270	Strategy in Technology-Based Companies	3-4
MS&E 292	Health Policy Modeling	3

Technology and Engineering Management Concentration (five courses required)

The course used to satisfy the Organizations and Decisions Core may also be counted here.

Organizations and Strategy (select at least one):

MS&E 270	Strategy in Technology-Based Companies	3-4
MS&E 274	Dynamic Entrepreneurial Strategy	3
MS&E 278	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
MS&E 280	Organizational Behavior: Evidence in Action	3-4
MS&E 282	Transformational Leadership	3
MS&E 284	Designing Modern Work Organizations	3
Entrepreneurship and Innovation (select at least one):		
MS&E 270	Strategy in Technology-Based Companies	3-4
MS&E 271	Global Entrepreneurial Marketing	3-4

MS&E 273	Technology Venture Formation	3-4
MS&E 275	Foundations for Large-Scale Entrepreneurship	3
MS&E 276	Entrepreneurial Management and Finance	3
MS&E 277	Creativity and Innovation	3-4
ENGR 245	The Lean LaunchPad: Getting Your Lean Startup Off the Ground	3-4

Finance and Decisions (select at least one):

MS&E 240	Accounting for Managers and Entrepreneurs	3-4
MS&E 245A	Investment Science	3
MS&E 245G	Finance for Non-MBAs	3
MS&E 250A	Engineering Risk Analysis	3
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	3-4
MS&E 352	Decision Analysis II: Professional Decision Analysis	3-4

Specialized Concentrations (must have approval of the academic advisor)

Computational Social Science (four courses required)

Statistics (select at least one)

MS&E 226	"Small" Data (may not be duplicated in core)	3
STATS 203	Introduction to Regression Models and Analysis of Variance	3
STATS 305A	Introduction to Statistical Modeling	3

Computation (select at least one)

MS&E 231	Introduction to Computational Social Science	3
MS&E 235	Analytics in Action	3
CS 246	Mining Massive Data Sets	3-4

Networks (select at least one)

MS&E 233	Networked Markets	3
CS 224W	Social and Information Network Analysis	3-4
ECON 291	Social and Economic Networks	2-5
MS&E 334	The Structure of Social Data	3

Social Science (select at least one)

MS&E 270	Strategy in Technology-Based Companies	3-4
MS&E 280	Organizational Behavior: Evidence in Action	3-4
MS&E 284	Designing Modern Work Organizations	3
ECON 202N	Microeconomics I For Non-Economics PhDs	2-5
ECON 203N	Microeconomics II For Non-Economics PhDs	2-5
PSYCH 212	Classic and contemporary social psychology research	1-3
PSYCH 265	Social Psychology and Social Change	2-3
SOC 220	Interpersonal Relations	4
SOC 224B	Relational Sociology	4

Recommended Elective Courses

Causal Inference

COMM 382	Big Data and Causal Inference	1-5
POLISCI 355C	Causal Inference for Social Science	5

Computation

CS 147	Introduction to Human-Computer Interaction Design	3-5
CS 229	Machine Learning	3-4
CS 448B	Data Visualization	3

Economics

MS&E 241	Economic Analysis	3-4
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Natural Language Processing

CS 124	From Languages to Information	3-4
CS 224N	Natural Language Processing with Deep Learning	3-4

CS 224S	Spoken Language Processing	2-4
POLISCI 452	Text as Data	3-5
LINGUIST 278	Programming for Linguists	1-4
LINGUIST 281	Computational Models of Linguistic Formalism	1-4
Networks		
OB 622	Topics in Social Network Analysis: Structure and Dynamics	2
SOC 369	Social Network Methods	4-5
Psychology		
PSYCH 216	Public Policy and Social Psychology: Implications and Applications	4
PSYCH 238	Wise Interventions	4
Sociology		
OB 637	Modeling Culture	3
SOC 214	Economic Sociology	4
SOC 218	Social Movements and Collective Action	4
SOC 262	Markets and Governance	4
SOC 270	Classics of Modern Social Theory	4
SOC 271	Organizational Analysis	4
Statistics		
STATS 209	Statistical Methods for Group Comparisons and Causal Inference	3
STATS 263	Design of Experiments	3
STATS 315A	Modern Applied Statistics: Learning	2-3
STATS 315B	Modern Applied Statistics: Data Mining	2-3

Decision and Risk Analysis Concentration (four courses required)

Units

Core Courses are restricted as follows:

MS&E 211	Linear and Nonlinear Optimization	3-4
MS&E 221	Stochastic Modeling	3
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	3-4

Required Courses (select two):

MS&E 241	Economic Analysis	3-4
MS&E 250A	Engineering Risk Analysis	3
MS&E 352	Decision Analysis II: Professional Decision Analysis	3-4

Policy Course (select one):

MS&E 243	Energy and Environmental Policy Analysis	3
MS&E 292	Health Policy Modeling	3
MS&E 293	Technology and National Security	3
MS&E 294	Climate Policy Analysis	3
MS&E 295	Energy Policy Analysis	3
MS&E 297	"Hacking for Defense": Solving National Security issues with the Lean Launchpad	3-4

Project Course:

MS&E 250B	Project Course in Engineering Risk Analysis	3
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Energy and Environment Concentration (six courses required)

Units

Required Courses:

CEE 207A	Understanding Energy	3-5
MS&E 241	Economic Analysis	3-4
MS&E 243	Energy and Environmental Policy Analysis	3

Three additional courses from energy, policy, or strategy areas below.

Policy:

ECON 251	Natural Resource and Energy Economics	2-5
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ENERGY 158	Bringing New Energy Technologies to Market: Optimizing Technology Push and Market Pull	3
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GSBGEN 336	Energy Markets and Policy	3
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MS&E 293	Technology and National Security	3
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MS&E 294	Climate Policy Analysis	3
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MS&E 295	Energy Policy Analysis	3
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Strategy:

ECON 203N	Microeconomics II For Non-Economics PhDs	2-5
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ENERGY 158	Bringing New Energy Technologies to Market: Optimizing Technology Push and Market Pull	3
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GSBGEN 538	Energy Policy, Markets, and Climate Change	2
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MS&E 270	Strategy in Technology-Based Companies	3-4
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MS&E 271	Global Entrepreneurial Marketing	3-4
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MS&E 273	Technology Venture Formation	3-4
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MS&E 274	Dynamic Entrepreneurial Strategy	3
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MS&E 275	Foundations for Large-Scale Entrepreneurship	3
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MS&E 276	Entrepreneurial Management and Finance	3
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MS&E 277	Creativity and Innovation	3-4
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MS&E 278	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
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Energy:

ENERGY 102	Fundamentals of Renewable Power	3
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ENERGY 104	Sustainable Energy for 9 Billion	3
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ENERGY 158	Bringing New Energy Technologies to Market: Optimizing Technology Push and Market Pull	3
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ME 370A	Energy Systems I: Thermodynamics	3
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ME 370B	Energy Systems II: Modeling and Advanced Concepts	4
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PHYSICS 240	Introduction to the Physics of Energy	3
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PHYSICS 241	Introduction to Nuclear Energy	3
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Recommended Seminars:

ECON 341	Public Economics and Environmental Economics Seminar	1-10
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ENERGY 301	The Energy Seminar	1
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MS&E 441	Policy and Economics Research Roundtable	1
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MS&E 472	Entrepreneurial Thought Leaders' Seminar	1
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Recommended Elective Courses:

ECON 250	Environmental Economics	2-5
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ECON 270	Intermediate Econometrics I	2-5
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ECON 278	Behavioral and Experimental Economics I	2-5
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MGTECON 603	Econometric Methods I	4
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MS&E 201	Dynamic Systems	3-4
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MS&E 211	Linear and Nonlinear Optimization	3-4
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MS&E 244	Economic Growth and Development	3
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MS&E 251	Stochastic Control	3
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Health Systems Modeling Concentration (four courses required)

Units

Required Courses (select four)

HRP 263	Advanced Decision Science Methods and Modeling in Health	3
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HRP 392	Analysis of Costs, Risks, and Benefits of Health Care	4
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MS&E 263	Healthcare Operations Management	3
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MS&E 292	Health Policy Modeling	3
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MS&E 463	Healthcare Systems Design	3
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Recommended Elective Courses:

HRP 256	Economics of Health and Medical Care	5
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HRP 391	Health Law: Finance and Insurance	3
MS&E 256	Technology Assessment and Regulation of Medical Devices	3
MS&E 257	Healthcare Reforms and Value-Based Biomedical Technology Innovation	3

Projects

Select one project course or two integrated project courses; may double-count as part of the core or concentration.

Project Courses

MS&E 250B	Project Course in Engineering Risk Analysis	3
MS&E 348	Optimization of Uncertainty and Applications in Finance	3
MS&E 403	Integrative Modeling	3
MS&E 445	Projects in Wealth Management	3-4
MS&E 447	Systemic and Market Risk : Notes on Recent History, Practice, and Policy	3
MS&E 448	Big Financial Data and Algorithmic Trading	3
MS&E 463	Healthcare Systems Design	3-4
Integrated Project Courses		
MS&E 201	Dynamic Systems	3-4
MS&E 226	"Small" Data	3
MS&E 233	Networked Markets	3
MS&E 243	Energy and Environmental Policy Analysis	3
MS&E 245A	Investment Science	3
MS&E 245B	Advanced Investment Science	3
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	3-4
MS&E 256	Technology Assessment and Regulation of Medical Devices	3
MS&E 260	Introduction to Operations Management	3
MS&E 262	Supply Chain Management	3
MS&E 265	Product Management Fundamentals	3
MS&E 270	Strategy in Technology-Based Companies	3-4
MS&E 271	Global Entrepreneurial Marketing	3-4
MS&E 273	Technology Venture Formation	3-4
MS&E 274	Dynamic Entrepreneurial Strategy	3
MS&E 275	Foundations for Large-Scale Entrepreneurship	3
MS&E 277	Creativity and Innovation	3-4
MS&E 280	Organizational Behavior: Evidence in Action	3-4
MS&E 282	Transformational Leadership	3
MS&E 284	Designing Modern Work Organizations	3
MS&E 294	Climate Policy Analysis	3
MS&E 295	Energy Policy Analysis	3
MS&E 311	Optimization	3
MS&E 338	Advanced Topics in Information Science and Technology	3
MS&E 347	Credit Risk: Modeling and Management	3
MS&E 355	Influence Diagrams and Probabilistics Networks	3

Additional Requirements

- At least 45 units must be in courses numbered 100 and above.
- The degree program must be completed with a grade point average (GPA) of 3.0 or higher.
- At least 27 units must be in courses numbered 200 and above in MS&E, taken for a letter grade and a minimum of two units each.
- At least 36 letter-graded units must be in MS&E or closely related fields. Closely related fields include any department in the School

of Engineering, mathematics, statistics, economics, sociology, psychology, or business.

- All courses used to satisfy core, concentration, or project requirements must be taken for a letter grade.
- A maximum of three units of 1-unit courses such as seminars, colloquia, workshops, in any department, including MS&E 208A, B, and C, Curricular Practical Training.
- A maximum of 18 non-degree option (NDO) units through the Stanford Center for Professional Development (SCPD).
- Courses in athletics, physical education, and recreation may not be applied toward the degree.

Units

Professional Education

The Stanford Center for Professional Development (SCPD) provides opportunities for employees of some local and remote companies to take courses at Stanford.

The Honors Cooperative Program (HCP) provides opportunities for employees of SCPD member companies to earn an M.S. degree, over a longer period, by taking one or two courses per academic quarter. Some courses are only offered on campus; HCP students may attend those courses at Stanford to meet the degree requirements. It is possible to complete this program as a remote HCP student although the remote offerings are limited. Students must apply for a degree program through the standard application process, and must meet the standard application deadlines.

The non-degree option (NDO) allows employees of some local companies to take courses for credit from their company sites before being admitted to a degree program. Students apply to take NDO courses each quarter through the Stanford Center for Professional Development. Up to 18 units taken as an NDO student may be applied toward a degree program. For additional information about the NDO application process and deadlines, see the SCPD web site (<http://scpd.stanford.edu>), or contact SCPD at (650) 725-3000.

Certificate

The department offers a certificate program within the framework of the NDO program. A certificate can be obtained by completing three MS&E core courses, plus one MS&E elective course for a total of four courses. For further information, see <http://scpd.stanford.edu/scpd/programs/certs/managementSci.htm>.

Dual Master's Degree Program

The dual degree program enables a small group of graduate students to obtain two master's degrees simultaneously. Students complete the course requirements for each department. A total of 90 units is required to complete the dual master's degree.

Admission

For the dual degree, admission to two departments is required, but is coordinated by designated members of both admissions committees who make recommendations to the committees of their respective departments. Students may apply to only one department initially. After the first quarter at Stanford, students may apply to be admitted to the second department.

Advising

Every student in the dual degree program has one adviser in each department.

Joint MS&E and Law Degrees

The School of Law and the Department of Management Science and Engineering offer joint degree programs leading to a J.D. degree and an

M.S. degree in MS&E, or to a J.D. and Ph.D. in MS&E. These programs are designed for students who wish to prepare themselves for careers in areas relating to both law and to the decision making, policy making, and problem solving knowledge and skills developed in the MS&E program. Students interested in either joint degree program must apply and gain admission separately to the School of Law and the Department of Management Science and Engineering and, as an additional step, must secure consent from both academic units to pursue degrees in those units as part of a joint degree program. Interest in either joint degree program should be noted on the student's admission applications and may be considered by the admission committee of each program. Alternatively, an enrolled student in either the Law School or MS&E may apply for admission to the other program and for joint degree status in both academic units after commencing study in either program.

Joint degree students may elect to begin their course of study in either the School of Law or MS&E. Students are assigned to a joint program committee composed of at least one faculty member from Law and one from MS&E. This committee plans the student's program jointly with the student. Students must be enrolled full time in the Law School for the first year of law studies, and it is recommended that students devote exclusively one Autumn Quarter to the MS&E M.S. program to initiate their MS&E work. After that time, enrollment may be in MS&E or Law, and students may choose courses from either program regardless of where enrolled. A candidate in the joint J.D./Ph.D. program should spend a substantial amount of full time residency in MS&E. Students must satisfy the requirements for both the J.D. and the M.S. or Ph.D. degrees as specified in this bulletin or by the School of Law. The Law School may approve courses from MS&E or courses in the student's MS&E program from outside of the Department of Management Science and Engineering that may count toward the J.D. degree, and MS&E may approve courses from the Law School that may count toward the M.S. or Ph.D. degree in MS&E. In either case, approval may consist of a list applicable to all joint degree students or may be tailored to each individual student's program. The lists may differ depending on whether the student is pursuing an M.S. or a Ph.D. in MS&E.

In the case of a J.D./M.S. program, no more than 45 units of approved courses may be counted toward both degrees. In the case of a J.D./Ph.D. program, no more than 54 units of approved courses may be counted toward both degrees. In either case, no more than 36 units of courses that originate outside the Law School may count toward the law degree. To the extent that courses under this joint degree program originate outside the Law School but count toward the law degree, the law credits permitted under Section 17(1) of the Law School Regulations are reduced on a unit-per-unit basis, but not below zero. The maximum number of law school credits that may be counted toward the M.S. in MS&E is the greater of: (a) 18 units in the case of the M.S., or (b) the maximum number of hours from courses outside the department that an M.S. candidate in MS&E is permitted to count toward the applicable degree under general departmental guidelines or under departmental rules that apply in the case of a particular student.

Tuition and financial aid arrangements are normally through the school in which the student is then enrolled.

Joint MS&E and Master of Public Policy Degree

MS MS&E students who wish to apply their analytical and management skills to the field of public policy can simultaneously pursue a master degree in MS&E and a master degree in Public Policy. The MPP is a two-year degree program, but MS MS&E students who pursue the joint program can earn both degrees in a minimum of two years, depending on prior preparation and elective choices, by counting up to 45 quarter units of course work toward both degrees. After admission to the Department of Management Science and Engineering, incoming or current MS

students request that their application file be forwarded to the MPP program director for review.

Students in the joint program normally will spend most of their first year taking MS&E core courses. The second year is typically devoted to the MPP core, concentration, and practicum. The joint degree requires 90 quarter units. Tuition for the first year of study is paid at the Graduate Engineering rate, the remaining time at the graduate rate.

Doctor of Philosophy in Management Science and Engineering

University requirements for the Ph.D. degree are described in the "Graduate Degrees" section of this bulletin.

The Ph.D. degree in MS&E is intended for students primarily interested in a career of research and teaching, or high-level technical work in universities, industry, or government. The program requires three years of full-time graduate study, at least two years of which must be at Stanford. Typically, however, students take four to five years after entering the program to complete all Ph.D. requirements. The Ph.D. is organized around the expectation that the students acquire a certain breadth across all areas of the department, and depth in one of them. The current areas are:

- Computational Social Science
- Decision and Risk Analysis
- Energy and Environmental Policy
- Finance
- Health Policy
- National Security Policy
- Operations Management
- Optimization and Stochastics
- Organizations
- Strategy, Innovation, and Entrepreneurship

Doctoral students are required to take a number of courses, both to pass a qualifying exam in one of these areas, and to complete a dissertation based on research which must make an original contribution to knowledge.

Each student admitted to the Ph.D. program must satisfy a breadth requirement and pass a qualification procedure. The purpose of the qualification procedure is to assess the student's command of the field and to evaluate his or her potential to complete a high-quality dissertation in a timely manner. The student must complete specified course work in one of the areas of the department.

The qualification decision is based on the student's course work and grade point average (GPA), on the one or two preliminary papers prepared by the student with close guidance from two faculty members, at least one of whom must be an MS&E faculty member, the student's performance in an area examination or defense of the written paper(s), and an overall assessment by the faculty of the student's ability to conduct high-quality Ph.D. research. Considering this evidence, the department faculty vote on advancing the student to candidacy in the department at large. The Ph.D. requires a minimum of 135 units, up to 45 units of which may be transferred from another graduate program.

All courses used to satisfy breadth and depth requirements must be taken for a letter grade, if the letter graded option is available. Prior to candidacy, at least 3 units of work must be taken with each of four Stanford faculty members. Finally, the student must pass a University oral examination and complete a Ph.D. dissertation. During the course of the Ph.D. program, students who do not have a master's degree are

strongly encouraged to complete one, either in MS&E or in another Stanford department.

Breadth Requirement

All first year students are required to attend and participate in MS&E 302 Fundamental Concepts in Management Science and Engineering, which meets in the Autumn Quarter.

Each course session is devoted to a specific MS&E Ph.D. research area. At a given session several advanced P.h.D students in that area make carefully prepared presentations designed for first-year doctoral students regardless of area. The presentations are devoted to: (a) illuminating how people in the area being explored that day think about and approach problems, and (b) illustrating what can and cannot be done when addressing problems by deploying the knowledge, perspectives, and skills acquired by those who specialize in the area in question.

Faculty in the focal area of the week comment on the student presentations. The rest of the session is devoted to questions posed and comments made by the first year Ph.D. students.

During the last two weeks of the quarter, groups of first year students make presentations on how they would approach a problem drawing on two or more of the perspectives to which they have been exposed earlier in the class.

Attendance is mandatory and performance is assessed on the basis of the quality of the students' presentations and class participation

Qualification Procedure Requirements

The qualification procedure is based on depth in an area of the student's choice and preparation for dissertation research. The qualification process must be completed by the end of the month of May of the student's second year of graduate study in the department. The performance of all doctoral students is reviewed every year at a department faculty meeting at the end of May or beginning of June. Ph.D. qualification decisions are made at that time and individual feedback is provided.

The Ph.D. qualification requirements comprise these elements:

1. *Courses and GPA*: Students must complete the depth requirements of one of the areas of the MS&E department. (The Ph.D. area course requirements are below).
All courses used to satisfy depth requirements must be taken for a letter grade, if the letter graded option is available. Course substitutions may be approved by the doctoral program adviser or the MS&E dissertation adviser on the candidacy form or on a request for graduate course waiver/substitution form. A student must maintain a GPA of at least 3.4 in the set of all courses taken by the student within the department. The GPA is computed on the basis of the nominal number of units for which each course is offered.
2. *Paper(s)*: A student may choose between two options. The first option involves one paper supervised by a primary faculty adviser and a second faculty reader. This paper should be written in two quarters. The second option involves two shorter sequential tutorials, with two different faculty advisers. Each tutorial should be completed in one quarter. In both options, the student chooses the faculty adviser(s)/reader with the faculty members' consent. There must be two faculty members, at least one of whom must be an MS&E faculty member, supervising and evaluating this requirement for advancement to candidacy. The paper/tutorials must be completed before the Spring Quarter of the student's second year of graduate study in the department if the student's qualifying exam is during the Spring Quarter, and before the end of May of that year otherwise. A student may register for up to 3 units per tutorial and up to 6 units for a paper.
3. *Area Qualification*: In addition, during the second year, a student must pass an examination in one of the areas of the MS&E department,

or defense of the written paper(s). The student chooses the area/program in which to take the examination. This area examination is written, oral, or both, at the discretion of the area faculty administering the exam. Most areas offer the qualifying exam only once per year, which may be early in the second year.

Degree Progress and Student Responsibility

Each student's progress is reviewed annually by the MS&E faculty. Typically, this occurs at a faculty meeting at the end of Spring Quarter, and email notifications are sent over the summer.

1. First-year students should complete 30 units of breadth and depth courses, including MS&E 302, and develop relationships with faculty members who might serve as dissertation adviser and reading committee.
2. Second-year students should complete most, if not all, of the required depth courses, work with two faculty members, at least one of whom must be an MS&E faculty member, on tutorials/research paper, and pass an area qualifying exam. Most areas offer the qualifying exam only once per year, which may be early in the second year. Students should continue to develop relationships with faculty members who might serve as dissertation advisers and reading committee, and select a dissertation adviser before the beginning of the third year.
3. Third-year students should complete any remaining depth courses, select a dissertation topic, and make progress on the dissertation.
4. Fourth-year students should select a reading committee, and complete, or nearly complete, the oral exam and dissertation.

It is the responsibility of the student to initiate each step in completing the Ph.D. program.

It is strongly recommended that each student, in the first year of graduate study at Stanford, make it a special point to become well acquainted with MS&E faculty members and to seek advice and counsel regarding possible Ph.D. candidacy. A faculty member is more likely to accept the responsibility of supervising the research of a student whom he or she knows fairly well than a student whose abilities, initiative, and originality the faculty member knows less.

It is expected that advanced students regularly report to their full reading committee on the progress of their dissertation. It is also expected that the student avail him/herself of the different expertise represented on the committee continually. Each member of this committee must certify approval of both the scope and quality of the dissertation.

The doctoral dissertation reading committee consists of the principal dissertation adviser and two other readers. At least one member must be from the student's major department.

As administered in this department, the University oral examination is a defense of the dissertation; however, the candidate should be prepared to answer any question raised by any members of the Academic Council who choose to be present. Students should schedule three hours for the oral examination, which usually consists of a 45-minute public presentation, followed by closed-session questioning of the examinee by the committee, and committee deliberation. The University oral examination may be scheduled after the dissertation reading committee has given tentative approval to the dissertation. The student must be enrolled in the quarter of their oral examination.

The examining committee usually consists of the three members of the reading committee as well as a fourth faculty member and an orals chair.

It is the responsibility of the student's adviser to find an appropriate orals chair. The chair must be an Academic Council member and may not be affiliated with either the Department of Management Science and Engineering nor any department in which the student's adviser has a regular appointment. Emeriti professors are eligible to serve as an orals chair. The student needs to reserve a room, and meet with the student services manager to complete the oral examination schedule

and pick up other paper work. This paperwork, along with an abstract, needs to be delivered to the orals chair at least one week prior to the oral examination.

Course Requirements

Computational Social Science

The Computational Social Science track teaches students how to apply rigorous statistical and computational methods to address problems in economics, sociology, political science and beyond. The core course work covers fundamental statistical concepts, large-scale computation, and network analysis. Through electives, students can explore topics such as experimental design, algorithmic economics, and machine learning.

Select at least one class from each of four different core areas.

Statistics core:

MS&E 226 "Small" Data 3

STATS 203 Introduction to Regression Models and Analysis of Variance 3

STATS 305A Introduction to Statistical Modeling 3

Computation core:

MS&E 231 Introduction to Computational Social Science 3

MS&E 235 Analytics in Action 3

CS 246 Mining Massive Data Sets 3-4

Networks core:

MS&E 233 Networked Markets 3

MS&E 334 The Structure of Social Data 3

CS 224W Social and Information Network Analysis 3-4

ECON 291 Social and Economic Networks 2-5

Social Science core:

MS&E 270 Strategy in Technology-Based Companies 3-4

MS&E 280 Organizational Behavior: Evidence in Action 3-4

MS&E 274 Dynamic Entrepreneurial Strategy 3

ECON 202N Microeconomics I For Non-Economics PhDs 2-5

ECON 203N Microeconomics II For Non-Economics PhDs 2-5

PSYCH 212 Classic and contemporary social psychology research 1-3

PSYCH 265 Social Psychology and Social Change 2-3

SOC 220 Interpersonal Relations 4

SOC 224B Relational Sociology 4

Recommended:

Causal Inference

COMM 382 Big Data and Causal Inference 1-5

POLISCI 355C Causal Inference for Social Science 5

Computation

CS 147 Introduction to Human-Computer Interaction Design 3-5

CS 229 Machine Learning 3-4

CS 448B Data Visualization 3

Economics

MS&E 241 Economic Analysis 3-4

Natural Language Processing

CS 124 From Languages to Information 3-4

CS 224N Natural Language Processing with Deep Learning 3-4

CS 224S Spoken Language Processing 2-4

LINGUIST 278 Programming for Linguists 1-4

LINGUIST 281 Computational Models of Linguistic Formalism 1-4

POLISCI 452 Text as Data 3-5

Networks

OB 622 Topics in Social Network Analysis: Structure and Dynamics 3,2

SOC 369 Social Network Methods 4-5

Psychology

PSYCH 216 Public Policy and Social Psychology: Implications and Applications 4

PSYCH 238 Wise Interventions 4

Sociology

OB 637 Modeling Culture 3

SOC 214 Economic Sociology 4

SOC 218 Social Movements and Collective Action 4

SOC 262 Markets and Governance 4

SOC 270 Classics of Modern Social Theory 4

SOC 271 Organizational Analysis 4

Statistics

STATS 209 Statistical Methods for Group Comparisons and Causal Inference 3

STATS 263 Design of Experiments 3

STATS 315A Modern Applied Statistics: Learning 2-3

STATS 315B Modern Applied Statistics: Data Mining 2-3

Students can substitute other classes (including those from other departments) from the same general area on a case-by-case basis, subject to approval by the student's program/dissertation adviser. The students must obtain a GPA of 3.50 or better in the core courses to qualify. The core courses must be completed in or before the Spring Quarter of the student's second year.

Computational Social Science Qualifying Procedure

The student does two quarter-length tutorials with CSS faculty. At the end of these tutorials, the student must make a 45-minute presentation of one of their tutorials to a committee of three CSS faculty members. The student can do both tutorials with the same faculty member, in which case the presentation can be of the two tutorials together, and another committee member must be kept informed of the student's progress on a regular basis during the two quarters. The presentation should take place in the Spring Quarter of the student's second year, or earlier. The presentation must include original research or promising directions towards original research. During this presentation, the student must also provide the name of their chosen focus area, and the list of courses that the student has completed and intends to complete in the core as well as in the chosen focus area. The committee then makes a recommendation to the CSS area and the MS&E department regarding qualification of the student for the Ph.D. program in CSS.

Decision Analysis and Risk Analysis

Prerequisites:

CS 106A Programming Methodology

CME 100 Vector Calculus for Engineers

CME 103 Introduction to Matrix Methods

Required:

MS&E 201 Dynamic Systems

or EE 263 Introduction to Linear Dynamical Systems

MS&E 211 Linear and Nonlinear Optimization

or MS&E 311 Optimization

MS&E 220 Probabilistic Analysis

MS&E 221 Stochastic Modeling

or STATS 217 Introduction to Stochastic Processes I

MS&E 223 Simulation

MS&E 241 Economic Analysis

MS&E 250A Engineering Risk Analysis

MS&E 250B Project Course in Engineering Risk Analysis

MS&E 251	Stochastic Control
or MS&E 351	Dynamic Programming and Stochastic Control
MS&E 252	Decision Analysis I: Foundations of Decision Analysis
MS&E 352	Decision Analysis II: Professional Decision Analysis
MS&E 353	Decision Analysis III: Frontiers of Decision Analysis
MS&E 355	Influence Diagrams and Probabilistic Networks
Recommended:	
MS&E 207	Interactive Management Science
MS&E 245A	Investment Science
MS&E 254	The Ethical Analyst
MS&E 270	Strategy in Technology-Based Companies
MS&E 280	Organizational Behavior: Evidence in Action
MS&E 299	Voluntary Social Systems
MS&E 321	Stochastic Systems
or STATS 218	Introduction to Stochastic Processes II
MS&E 450	Lessons in Decision Making
or MS&E 453	Decision Analysis Applications
CS 228	Probabilistic Graphical Models: Principles and Techniques
CS 270	Modeling Biomedical Systems: Ontology, Terminology, Problem Solving
ECON 286	Game Theory and Economic Applications
ECON 290	Multiperson Decision Theory
MGTECON 332	Analysis of Costs, Risks, and Benefits of Health Care
STATS 200	Introduction to Statistical Inference
or STATS 201	Design and Analysis of Experiments
or STATS 202	Data Mining and Analysis
or ECON 271	Intermediate Econometrics II

Economics and Finance

The economics and finance area emphasizes the use of economic and financial concepts, methods, and practice for problem solving, in areas including individual choice, financial engineering, economic policy analysis, and financial market analysis. A strong mathematical and systems analysis background is essential to the area. Students in this area are expected to develop a strong background in economics and finance and closely related disciplines and to obtain experience in addressing significant problem areas.

Required

MS&E 201	Dynamic Systems
MS&E 220	Probabilistic Analysis
MS&E 241	Economic Analysis
MS&E 245A	Investment Science
MS&E 245B	Advanced Investment Science
MS&E 311	Optimization
MATH 115	Functions of a Real Variable
or MATH 171	Fundamental Concepts of Analysis

Select five of the following options:

General

MS&E 314	Linear and Conic Optimization with Applications
EE 263	Introduction to Linear Dynamical Systems
STATS 310A	Theory of Probability I
or MATH 205A	Real Analysis

Economics (two of Econ 280-290 may be used)

ECON 370	Econometrics Workshop
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or ECON 271	Intermediate Econometrics II
or ECON 272	Intermediate Econometrics III
or ECON 273	Advanced Econometrics I
or ECON 274	Advanced Econometrics II
or ECON 275	Time Series Econometrics
or ECON 276	Computational Econometrics
ECON 282	Contracts, Information, and Incentives
or ECON 283	Theory and Practice of Auction Market Design
or ECON 285	Matching and Market Design
or ECON 286	Game Theory and Economic Applications
or ECON 288	Computational Economics
or ECON 289	Advanced Topics in Game Theory and Information Economics
or ECON 290	Multiperson Decision Theory

Finance

MS&E 347	Credit Risk: Modeling and Management
MS&E 348	Optimization of Uncertainty and Applications in Finance
MATH 136	Stochastic Processes

Students should consult with their dissertation advisers to select additional courses from any department to complete a Ph.D. in their area.

Students should plan to complete most if not all required courses by the end of the first year of graduate study. The choice courses should be chosen to form a coherent program either in economics, finance or both. Ph.D. students must also meet the department's requirements for both an M.S. degree and a Ph.D. degree.

Economics and Finance Qualifying Procedure

In addition to beginning an appropriate course program, students must pass two quarters of tutorial and an oral examination to obtain qualification. The tutorials emphasize basic research skills. The oral examination emphasizes command of basic concepts as represented in the required courses as well as the modeling of practical situations.

Energy and Environment Policy (see Policy and Strategy)

Health Policy (see Policy and Strategy)

National Security Policy (see Decision and Risk Analysis)

Operations Management

Foundation courses (may be waived based on prior coursework):

MS&E 211	Linear and Nonlinear Optimization
MS&E 241	Economic Analysis
or ECON 202N	Microeconomics I For Non-Economics PhDs
MS&E 260	Introduction to Operations Management
or MS&E 261	Inventory Control and Production Systems

Methodology courses (all):

MS&E 221	Stochastic Modeling
or STATS 217	Introduction to Stochastic Processes I
MS&E 223	Simulation
or STATS 362	Topic: Monte Carlo
MS&E 251	Stochastic Control
or MS&E 351	Dynamic Programming and Stochastic Control
MS&E 311	Optimization
or EE 364A	Convex Optimization I
MS&E 321	Stochastic Systems
MS&E 335	Queueing and Scheduling in Processing Networks
ECON 203N	Microeconomics II For Non-Economics PhDs

OM research courses (any four):

MS&E 336	Platform and Marketplace Design
MS&E 365	Advanced Topics in Market Design

Faculty-approved GSB OIT Ph.D. courses (about six are offered every two years).

Optimization and Stochastics

Prerequisites:

MS&E 220 or STATS 116	Probabilistic Analysis Theory of Probability
MS&E 221 or STATS 217	Stochastic Modeling Introduction to Stochastic Processes I
MS&E 241 or ECON 50	Economic Analysis Economic Analysis I
CS 106A or CS 106X	Programming Methodology Programming Abstractions (Accelerated)
MATH 113	Linear Algebra and Matrix Theory
MATH 115 or MATH 171	Functions of a Real Variable Fundamental Concepts of Analysis

Strongly Recommended:

CME 108	Introduction to Scientific Computing
STATS 200	Introduction to Statistical Inference
STATS 203	Introduction to Regression Models and Analysis of Variance

Core (four courses):

MS&E 310	Linear Programming
MS&E 321	Stochastic Systems
Two of the following three courses:	
MS&E 311	Optimization
MS&E 316	Discrete Mathematics and Algorithms
STATS 310A	Theory of Probability I

Three to four courses in some coherent area of specialization.

In addition to the four core courses, students should take at least four 3-4 unit courses in some coherent area of specialization. The area of specialization may be methodological; examples include (but are not limited to) optimization, stochastic systems, stochastic control, algorithms, economic analysis, statistical inference, scientific computing, etc. The area of specialization could also have a significant modeling and application component, such as (but not limited to) information services, telecommunications, financial engineering, supply chains, health care, energy, etc. Independent of the choice of specialization, students are encouraged to take a range of courses covering methodology, modeling, and applications. Any MS&E courses satisfying this requirement must be at the 300-level, while courses outside MS&E must be at a comparable level. Students are expected to earn a letter grade of A- or better in all courses counted for the requirements. A student's plan for completing these requirements must be discussed with and approved by their faculty adviser by the beginning of Autumn Quarter of their second year.

Optimization and Stochastics Qualifying Procedure

Students take the area qualifying exam at the beginning of their second year of study. The qualifying exam consists of two written exams: one in Optimization and one in Stochastic Systems. The first exam covers the material in MS&E 310 and related prerequisites. The second exam covers the material in MS&E 321 and related prerequisites.

The student does two quarter-length tutorials with Optimization and Stochastics faculty (or affiliated faculty). A written report approved by the supervising faculty member is required on each tutorial. In addition, at the end of the second year, students are expected to make a 30-minute presentation to the broader Optimization and Stochastics faculty. The presentation must include original research or promising directions towards original research. The student can do both tutorials with the

same faculty member; in this case a single written report is sufficient, and the presentation can be of the two tutorials together.

Organizations, Strategy, Innovation, and Entrepreneurship

Foundation in Organizational Behavior (five courses):

PSYCH 212	Classic and contemporary social psychology research
SOC 363A	Seminar on Organizational Theory
Plus three of the following:	
MS&E 371	Innovation and Strategic Change
MS&E 372	Entrepreneurship Doctoral Research Seminar
MS&E 374	Cross Border Regional Innovation
MS&E 375	Research on Entrepreneurship
MS&E 376	Strategy Doctoral Research Seminar
MS&E 380	Doctoral Research Seminar in Organizations
MS&E 381	Doctoral Research Seminar in Work, Technology, and Organization
MS&E 383	Doctoral Seminar on Ethnographic Research
MS&E 384	Groups and Teams
MS&E 387	Design of Field Research Methods
MS&E 388	Contemporary Themes in Work and Organization Studies
MS&E 389	Seminar on Organizational Theory
Statistics and Research Methods (examples; three courses required)	
MS&E 231	Introduction to Computational Social Science
PSYCH 252	Statistical Methods for Behavioral and Social Sciences
SOC 381	Sociological Methodology I: Introduction
SOC 382	Sociological Methodology II: Principles of Regression Analysis
SOC 383	Sociological Methodology III: Models for Discrete Outcomes
SOC 384	New Models and Methods in the Social Sciences

In their first two years in the Ph.D. program, all students are expected to work with faculty on research. To ensure an early start, all students must work at least 25% of their time in their first year as a research assistant with a faculty member. Students on fellowships can earn course credit for the work. With approval from the students' adviser, one quarter of the requirement may be fulfilled by working as a Course Assistant (CA).

Ph.D. students in organizational behavior must take 3 courses in statistics and research methods. Two of these courses must be statistics courses.

Ph.D. students are required to take a minimum of 2 advanced-content courses chosen with input from their adviser.

Students are expected to complete a yearly plan, of no more than two typed pages in length, detailing the student's plans for the next year in terms of education (e.g., courses and seminars), research (e.g., RAships), and teaching (e.g., TAships). This plan should be provided to the students' academic adviser for review no later than May 15 each calendar year.

Policy and Strategy

The Policy and Strategy (P&S) Area addresses policy and strategy questions in a variety of organizational and societal settings. In order to approach interdisciplinary research questions in application domains as diverse as energy, environment, health, information technology, innovation, and government regulation, P&S faculty members rely on a broad range of analytical and empirical tools, such as decision analysis, optimization and operations research methods, formal economic modeling, econometrics, case studies, and simulation. After having been exposed to foundational knowledge of economics, strategy, and

organizational theory, doctoral students in the P&S Area can select from a variety of courses to deepen their understanding of the specific application domains. The P&S Area's mission is to provide a first-class learning and research environment preparing doctoral students for careers at research universities, government institutions, and in the private sector.

Foundation in Policy and Strategy (three):

MS&E 241	Economic Analysis
MS&E 375	Research on Entrepreneurship
or MS&E 376	Strategy Doctoral Research Seminar
or MS&E 390	Doctoral Research Seminar in Health Systems Modeling
or MS&E 391	Doctoral Research Seminar in Energy-Environmental Systems Modeling and Analysis

Statistics and Research Methods (three):

MS&E 201	Dynamic Systems
MS&E 211	Linear and Nonlinear Optimization
MS&E 212	Mathematical Programming and Combinatorial Optimization
MS&E 221	Stochastic Modeling
MS&E 223	Simulation
MS&E 352	Decision Analysis II: Professional Decision Analysis
PSYCH 252	Statistical Methods for Behavioral and Social Sciences
SOC 383	Sociological Methodology III: Models for Discrete Outcomes
SOC 384	New Models and Methods in the Social Sciences

The student must select a program of four or more electives including disciplinary depth courses that reflects his or her interests and this approved by the Policy and Strategy faculty. The following are a number of sample programs:

Sample Program: Modeling Emphasis

Research Methods	
MS&E 201	Dynamic Systems
MS&E 252	Decision Analysis I: Foundations of Decision Analysis
MS&E 311	Optimization
MS&E 321	Stochastic Systems
Domain Depth	
MS&E 292	Health Policy Modeling
HRP 392	Analysis of Costs, Risks, and Benefits of Health Care

Two of the following:

MS&E 263	Healthcare Operations Management
MS&E 463	Healthcare Systems Design
HRP 256	Economics of Health and Medical Care
HRP 263	Advanced Decision Science Methods and Modeling in Health

Sample Program: Economics Emphasis

Research Methods	
ECON 282	Contracts, Information, and Incentives
ECON 286	Game Theory and Economic Applications
Domain Depth	
ECON 257	Industrial Organization 1
ECON 285	Matching and Market Design

Sample Program: Strategy Emphasis

Research Methods	
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MS&E 408	Directed Reading and Research ((Methods Apprenticeship))
SOC 369	Social Network Methods
Domain Depth	
MS&E 371	Innovation and Strategic Change
MS&E 376	Strategy Doctoral Research Seminar
SOC 314	Economic Sociology
Sample Program: Risk Analysis Emphasis	
Research Methods	
MS&E 250A	Engineering Risk Analysis
MS&E 251	Stochastic Control
MS&E 252	Decision Analysis I: Foundations of Decision Analysis
MS&E 355	Influence Diagrams and Probabilistics Networks
Domain Depth	
MS&E 250B	Project Course in Engineering Risk Analysis
or MS&E 452	
MS&E 353	Decision Analysis III: Frontiers of Decision Analysis

Students are expected to complete a yearly plan, of no more than two typed pages in length, detailing the student's plans for the next year in terms of education (e.g., courses and seminars), research (e.g., RAships), and teaching (e.g., TAships). This plan should be provided to the students' academic adviser for review no later than May 15 each calendar year.

Policy and Strategy Qualifying Procedure

Advancement to Ph.D. candidacy is determined at the end of the student's second year of studies, based on the following three components:

1. the student's overall grade point average in the program (a GPA of 3.5 or higher is required);
2. a second-year research paper that is written by the student under the supervision of a faculty member, and that is presented to examining faculty members in the second year;
3. a written and an oral qualifying examination taken by the student in the spring quarter of the second year.

Ph.D. Minor in Management Science and Engineering

Students pursuing a Ph.D. in another department who wish to receive a Ph.D. minor in Management Science and Engineering should consult the MS&E student services office. A minor in MS&E may be obtained by completing 20 units of approved graduate-level MS&E courses, of which at least 6 units must be at the 300-level. Courses approved for the minor must form a coherent program, and include a breadth of courses from across the department. The program must include a minimum of 16 letter-graded units, and a minimum grade point average of 3.3 must be achieved in these courses.

Emeriti: (Professors) James L. Adams, Kenneth J. Arrow, Stephen R. Barley, Richard W. Cottle, B. Curtis Eaves, Frederick S. Hillier, Donald L. Iglehart, David G. Luenberger, Michael M. May, William J. Perry, David A. Thompson; *(Professor, Research)* Walter Murray

Chair: Nicholas Bambos

Professors: Nicholas Bambos, Margaret L. Brandeau, Kathleen M. Eisenhardt, Peter W. Glynn, Ashish Goel, Warren H. Hausman, Pamela J. Hinds, Ronald A. Howard, Riitta Katila, M. Elisabeth Paté-Cornell, Robert I. Sutton, James L. Sweeney, Benjamin Van Roy, Yinyu Ye

Associate Professors: Samuel S. Chiu, Kay Giesecke, Ramesh Johari, Amin Saberi, Ross D. Shachter, Edison T. S. Tse

Assistant Professors: Itai Ashlagi, Charles E. Eesley, Sharad Goel, Markus Pelger, Aaron Sidford, Johan Ugander, Melissa A. Valentine

Professors (Research): Siegfried S. Hecker, Michael A. Saunders, John P. Weyant

Professors (Teaching): Thomas H. Byers, Robert E. McGinn

Professor of the Practice: Tina L. Seelig

Courtesy Professors: Stephen P. Boyd, Douglas K. Owens, Sylvia Plevritis, Walter Powell, Balaji Prabhakar, Alvin Roth, Tim Roughgarden

Courses

MS&E 20. Discrete Probability Concepts And Models. 4 Units.

Fundamental concepts and tools for the analysis of problems under uncertainty, focusing on structuring, model building, and analysis. Examples from legal, social, medical, and physical problems. Topics include axioms of probability, probability trees, belief networks, random variables, conditioning, and expectation. The course is fast-paced, but it has no prerequisites.

MS&E 52. Introduction to Decision Making. 3 Units.

How to ensure focus, discipline, and passion when making important decisions. Comprehensive examples illustrate Decision Analysis fundamentals. Consulting case studies highlight practical solutions for real decisions. Student teams present insights from their analyses of decisions for current organizations. Topics: declaring when and how to make a decision, framing and structuring the decision basis, defining values and preferences, creating alternative strategies, assessing unbiased probabilistic judgments, developing appropriate risk/reward and portfolio models, evaluating doable strategies across the range of uncertain future scenarios, analyzing relevant sensitivities, determining the value of additional information, and addressing the qualitative aspects of communication and commitment to implementation. Not intended for MS&E majors.

MS&E 92Q. International Environmental Policy. 3 Units.

Preference to sophomores. Science, economics, and politics of international environmental policy. Current negotiations on global climate change, including actors and potential solutions. Sources include briefing materials used in international negotiations and the U.S. Congress.

MS&E 93Q. Nuclear Weapons, Energy, Proliferation, and Terrorism. 3 Units.

Preference to sophomores. At least 20 countries have built or considered building nuclear weapons. However, the paths these countries took in realizing their nuclear ambitions vary immensely. Why is this the case? How do the histories, cultures, national identities, and leadership of these countries affect the trajectory and success of their nuclear programs? This seminar will address these and other questions about nuclear weapons and their proliferation. Students will learn the fundamentals of nuclear technology, including nuclear weapons and nuclear energy, and be expected to use this knowledge in individual research projects on the nuclear weapons programs of individual countries. Case studies will include France, UK, China, India, Israel, Pakistan, North Korea, South Africa, Libya, Iraq, and Iran, among others. Please note any language skills in your application. Recommended: 193 or 293.

MS&E 101. Undergraduate Directed Study. 1-15 Unit.

Subject of mutual interest to student and faculty member. Prerequisite: faculty sponsor.

MS&E 101A. Undergraduate Directed Study. 1-4 Unit.

Subject of mutual interest to student and mentor.

MS&E 107. Interactive Management Science. 3 Units.

Analytical techniques such as linear and integer programming, Monte Carlo simulation, forecasting, decision analysis, and Markov chains in the environment of the spreadsheet. Probability management. Materials include spreadsheet add-ins for implementing these and other techniques. Emphasis is on building intuition through interactive modeling, and extending the applicability of this type of analysis through integration with existing business data structures.

Same as: MS&E 207

MS&E 108. Senior Project. 5 Units.

Restricted to MS&E majors in their senior year. Students carry out a major project in groups of four, applying techniques and concepts learned in the major. Project work includes problem identification and definition, data collection and synthesis, modeling, development of feasible solutions, and presentation of results. Service Learning Course (certified by Haas Center).

MS&E 111. Introduction to Optimization. 4 Units.

Formulation and analysis of linear optimization problems. Solution using Excel solver. Polyhedral geometry and duality theory. Applications to contingent claims analysis, production scheduling, pattern recognition, two-player zero-sum games, and network flows. Prerequisite: CME 100 or MATH 51.

Same as: ENGR 62

MS&E 112. Mathematical Programming and Combinatorial Optimization. 3 Units.

Combinatorial and mathematical programming (integer and non-linear) techniques for optimization. Topics: linear program duality and LP solvers; integer programming; combinatorial optimization problems on networks including minimum spanning trees, shortest paths, and network flows; matching and assignment problems; dynamic programming; linear approximations to convex programs; NP-completeness. Hands-on exercises. Prerequisites: 111 or MATH 103, CS 106A or X.

Same as: MS&E 212

MS&E 120. Probabilistic Analysis. 5 Units.

Concepts and tools for the analysis of problems under uncertainty, focusing on structuring, model building, and analysis. Examples from legal, social, medical, and physical problems. Topics include axioms of probability, probability trees, random variables, distributions, conditioning, expectation, change of variables, and limit theorems. Prerequisite: CME 100 or MATH 51.

MS&E 121. Introduction to Stochastic Modeling. 4 Units.

Stochastic processes and models in operations research. Discrete and continuous time parameter Markov chains. Queuing theory, inventory theory, simulation. Prerequisite: 120, 125, or equivalents.

MS&E 125. Introduction to Applied Statistics. 4 Units.

An increasing amount of data is now generated in a variety of disciplines, ranging from finance and economics, to the natural and social sciences. Making use of this information, however, requires both statistical tools and an understanding of how the substantive scientific questions should drive the analysis. In this hands-on course, we learn to explore and analyze real-world datasets. We cover techniques for summarizing and describing data, methods for statistical inference, and principles for effectively communicating results. Prerequisite: 120, CS 106A, or equivalents.

MS&E 130. Information Networks and Services. 3 Units.

Architecture of the Internet and performance engineering of computer systems and networks. Switching, routing and shortest path algorithms. Congestion management and queueing networks. Peer-to-peer networking. Wireless and mobile networking. Information service engineering and management. Search engines and recommendation systems. Reputation systems and social networking technologies. Security and trust. Information markets. Select special topics and case studies. Prerequisites: 111, 120, and CS 106A.

MS&E 135. Networks. 3 Units.

This course provides an introduction to how networks underly our social, technological, and natural worlds, with an emphasis on developing intuitions for broadly applicable concepts in network analysis. The course will include: an introduction to graph theory and graph concepts; social networks; information networks; the aggregate behavior of markets and crowds; network dynamics; information diffusion; the implications of popular concepts such as "six degrees of separation", the "friendship paradox", and the "wisdom of crowds".

MS&E 140. Accounting for Managers and Entrepreneurs. 3-4 Units.

Non-majors and minors who have taken or are taking elementary accounting should not enroll. Introduction to accounting concepts and the operating characteristics of accounting systems. The principles of financial and cost accounting, design of accounting systems, techniques of analysis, and cost control. Interpretation and use of accounting information for decision making. Designed for the user of accounting information and not as an introduction to a professional accounting career. Enrollment limited. Admission by order of enrollment.

Same as: MS&E 240

MS&E 140X. Financial Accounting Concepts and Analysis. 2 Units.

Introductory course in financial accounting. Accounting is referred to as the language of business. Developing students ability to read, understand, and use business financial statements. Understanding the mapping between the underlying economic events and financial statements, and how this mapping can affect inferences about future firm profitability. Introduction to measuring and reporting of the operating cycle; the process of preparing and presenting primary financial statements; the judgment involved and discretion allowed in making accounting choices; the effects of accounting discretion on the quality of the (reported) financial information; and the fundamentals of financial statement analysis. Class time will be allocated to a combination of lectures, cases and discussions of cases. Capstone project analyzing a company's financials at the end of the quarter. Enrollment limited. Admission by order of enrollment.

MS&E 145. Introduction to Investment Science. 3 Units.

Introduction to the financial concepts and empirical evidence that are useful for investment decisions. Time-value of money: understanding basic interest rates, evaluating investments with present value and internal rates of return, fixed-income securities. Risk-return tradeoff and pricing models: mean variance optimization and portfolio choice, capital asset pricing theory and extensions. No prior knowledge of finance is required. Concepts are applied in a stock market simulation with real data. Prerequisites: basic preparation in probability, statistics, and optimization as covered e.g. in 111 and 120.

MS&E 146. Corporate Financial Management. 4 Units.

Key functions of finance in both large and small companies, and the core concepts and key analytic tools that provide their foundation. Making financing decisions, evaluating investments, and managing cashflow, profitability and risk. Designing performance metrics to effectively measure and align the activities of functional groups and individuals within the firm. Structuring relationships with key customers, partners and suppliers. Prerequisite: 145, 245A, 245G or equivalent.

MS&E 147. Finance and Society for non-MBAs. 4 Units.

The financial system is meant to help people, businesses, and governments fund, invest, and manage risks, but it is rife with conflicts of interests and may allow people with more information and control to harm those with less of both. In this interdisciplinary course we explore the forces that shape the financial system and how individuals and society can benefit most from this system without being unnecessarily harmed and endangered. Topics include the basic principles of investment, the role and "dark side" of debt, corporations and their governance, banks and other financial institutions, why effective financial regulations are essential yet often fail, and political and ethical issues in finance. The approach will be rigorous and analytical but not overly technical mathematically. Prerequisite: Econ 1.

Same as: ECON 143, POLISCI 127A, PUBLPOL 143

MS&E 148. Ethics of Finance. 2 Units.

Explores the ethical reasoning needed to make banking, insurance and financial services safer, fairer and more positively impactful. Weighs tradeoffs in how money is created, privileging some, under-privileging others, using market mechanisms for transforming and trading financial risk, return, maturity and asset types. Technology is changing banks, financial markets, insurance and money. Like technology for medicine, finance is being rebuilt as machine learned code, algorithmic investment rules and regulatory monitoring. Risk models can be built to detect fraud and ethical lapses, or to open doors for them. Investment valuation models can optimize short term or long term returns, by optimizing or ignoring environmental and social impacts. Transparency or opacity can be the norm. Transforming finance through engineering requires finding, applying and evolving codes of professional conduct to make sure that engineers use their skills within legal and ethical norms. Daily, financial engineers focus on two horizons: on the floor, we stand on the bare minimum standards of conduct, and on the ceiling, we aim for higher ethical goals that generate discoveries celebrated though individual fulfillment and TED Talks. Stanford engineers, computer scientists, data scientists, mathematicians and other professionals are building systems for lending, investment and portfolio management decisions that determine future economic and social growth. This course uses the case method to preview intersecting codes of conduct, legal hurdles and ethical impact opportunities, and creates as a safe academic setting for seeing career-limiting ethical stop signs (red lights) and previewing "what's my life all about" events, as unexpected threats or surprising ah-ha moments. Guest speakers will highlight real life situations, lawsuits and other events where ethics of financial engineering was a predominant theme, stumbling block or humanitarian opportunity.

MS&E 149. Hedge Fund Management. 1-3 Unit.

Introduction to hedge fund management. Students actively manage the \$1MM Stanford Kudla Fund employing Equity Long/Short, Macro and Quantitative Investment Strategies. Modeled after a hedge fund partnership culture, participation involves significant time commitment, passion for investing, and uncommon teamwork and communication skills. Open to advanced undergraduate and graduate students with continuing participation expectation. Limited to 12 students. Enrollment by application and permission of Instructor.

MS&E 152. Introduction to Decision Analysis. 3-4 Units.

How to make good decisions in a complex, dynamic, and uncertain world. People often make decisions that on close examination they regard as wrong. Decision analysis uses a structured conversation based on actional thought to obtain clarity of action in a wide variety of domains. Topics: distinctions, possibilities and probabilities, relevance, value of information and experimentation, relevance and decision diagrams, risk attitude. Students seeking to fulfill the Writing in the Major requirement should register for MS&E 152W.

Same as: MS&E 152W

MS&E 152W. Introduction to Decision Analysis. 3-4 Units.

How to make good decisions in a complex, dynamic, and uncertain world. People often make decisions that on close examination they regard as wrong. Decision analysis uses a structured conversation based on actional thought to obtain clarity of action in a wide variety of domains. Topics: distinctions, possibilities and probabilities, relevance, value of information and experimentation, relevance and decision diagrams, risk attitude. Students seeking to fulfill the Writing in the Major requirement should register for MS&E 152W.

Same as: MS&E 152

MS&E 175. Innovation, Creativity, and Change. 3-4 Units.

Problem solving in organizations; creativity and innovation skills; thinking tools; creative organizations, teams, individuals, and communities. Limited enrollment. (Katila).

MS&E 177. Creativity Rules. 4 Units.

This experiential course explores a wide array of tools that are used to enhance innovation and how those tools are applied across engineering disciplines. Using workshops, demonstrations, and field trips, students will learn how creative problem solving is deployed across engineering fields and, in partnership with the Stanford Virtual Human Interaction Lab, expand their own creative problem solving skills with virtual reality experiences that stretch their imagination. Limited enrollment. Admission by application.

MS&E 178. The Spirit of Entrepreneurship. 3 Units.

Is there more to entrepreneurship than inventing the better mouse trap? This course uses the speakers from the Entrepreneurial Thought Leader seminar (MS&E472) to drive research and discussion about what makes an entrepreneur successful. Topics include venture financing, business models, and interpersonal dynamics in the startup environment. Students meet before and after MS&E 472 to prepare for and debrief after the sessions. Enrollment limited to 60 students. Admission by application.

MS&E 180. Organizations: Theory and Management. 4 Units.

For undergraduates only; preference to MS&E majors. Classical and contemporary organization theory; the behavior of individuals, groups, and organizations. Limited enrollment. Students must attend and complete an application at the first class session.

MS&E 181. Issues in Technology and Work. 3 Units.

How changes in technology and organization are altering work and lives, and how understanding work and work practices can help design better technologies and organizations. Topics include job and organization design; collaboration and networking tools; distributed and virtual organizations; project work, taskification, and the platform economy; the blurring of boundaries between work and private life; monitoring and surveillance in the workplace; trends in skill requirements and occupational structures; downsizing and its effects on work systems; the growth of contingent employment, telecommuting, and the changing nature of labor relations. Limited enrollment.

MS&E 183. Leadership in Action. 3 Units.

Leadership in action is designed with a significant lab component in which students will be working on leadership projects throughout the quarter. The projects will provide students with hands on experience trying out new leadership behaviors in a variety of situations, along with the opportunity to reflect on these experience and, in turn, expand their leadership skills. Limited enrollment. Students must attend first class session.

MS&E 184. New Directions in the Psychology of Technology and Work. 3 Units.

The nature of work is changing, with consequences for how we structure jobs, careers, teams, organizations, and labor markets. This class teaches analytical tools from organizational behavior, social psychology, and socially distributed cognition to empower students to analyze and understand the changes and their consequences. Enrollment Limited. Prerequisite: 180.

MS&E 185. Global Work. 4 Units.

Issues, challenges, and opportunities facing workers, teams, and organizations working across national boundaries. Topics include geographic distance, time zones, language and cultural differences, technologies to support distant collaboration, team dynamics, and corporate strategy. Limited enrollment. Recommended: 180.

MS&E 190. Methods and Models for Policy and Strategy Analysis. 3 Units.

Guest lectures by departmental practitioners. Emphasis is on links among theory, application, and observation. Environmental, national security, and health policy; marketing, new technology, and new business strategy analyses. Comparisons between domains and methods.

MS&E 193. Technology and National Security. 3 Units.

The interaction of technology and national security policy from the perspective of history to implications for the new security imperative, homeland defense. Key technologies in nuclear and biological weapons, military platforms, and intelligence gathering. Policy issues from the point of view of U.S. and other nations. The impact of terrorist threat. Guest lecturers include key participants in the development of technology and/or policy.

Same as: MS&E 293

MS&E 197. Ethics, Technology, and Public Policy. 5 Units.

Ethical issues in science- and technology-related public policy conflicts. Focus is on complex, value-laden policy disputes. Topics: the nature of ethics and morality; rationales for liberty, justice, and human rights; and the use and abuse of these concepts in policy disputes. Case studies from biomedicine, environmental affairs, technical professions, communications, and international relations.

MS&E 201. Dynamic Systems. 3-4 Units.

Goal is to think dynamically in decision making, and recognize and analyze dynamic phenomena in diverse situations. Concepts: formulation and analysis; state-space formulation; solutions of linear dynamic systems, equilibria, dynamic diagrams; eigenvalues and eigenvectors of linear systems, the concept of feedback; nonlinear dynamics, phase plane analysis, linearized analysis, Liapunov functions, catastrophe theory. Examples: grabber-holder dynamics, technology innovation dynamics, creation of new game dynamics in business competition, ecosystem dynamics, social dynamics, and stochastic exchange dynamics. Prerequisite: CME 100 or MATH 51 or equivalent.

MS&E 207. Interactive Management Science. 3 Units.

Analytical techniques such as linear and integer programming, Monte Carlo simulation, forecasting, decision analysis, and Markov chains in the environment of the spreadsheet. Probability management. Materials include spreadsheet add-ins for implementing these and other techniques. Emphasis is on building intuition through interactive modeling, and extending the applicability of this type of analysis through integration with existing business data structures.

Same as: MS&E 107

MS&E 208A. Practical Training. 1 Unit.

MS&E students obtain employment in a relevant industrial or research activity to enhance professional experience, consistent with the degree program they are pursuing. Students submit a statement showing relevance to degree program along with offer letter to the Student Services Office before the start of the quarter, and a 2-3 page final report documenting the work done and relevance to degree program at the conclusion of the quarter. Students may take each of A, B, and C once.

MS&E 208B. Practical Training. 1 Unit.

MS&E students obtain employment in a relevant industrial or research activity to enhance professional experience, consistent with the degree program they are pursuing. Students submit a statement showing relevance to degree program along with offer letter to the Student Services office before the start of the quarter, and a 2-3 page final report documenting the work done and relevance to degree program at the conclusion of the quarter. Students may take each of A, B, and C once.

MS&E 208C. Practical Training. 1 Unit.

MS&E students obtain employment in a relevant industrial or research activity to enhance professional experience, consistent with the degree program they are pursuing. Students submit a statement showing relevance to degree program along with offer letter to the Student Services office before the start of the quarter, and a 2-3 page final report documenting the work done and relevance to degree program at the conclusion of the quarter. Students may take each of A, B, and C once.

MS&E 208D. Practical Training. 1 Unit.

MS&E students obtain employment in a relevant industrial or research activity to enhance professional experience, consistent with the degree program they are pursuing. Students submit a one-page statement showing relevance to degree program along with offer letter before the start of the quarter, and a 2-3 page final report documenting the work done and relevance to degree program at the conclusion of the quarter. Students may take each of A, B, and C once, and may petition to take D.

MS&E 211. Linear and Nonlinear Optimization. 3-4 Units.

Optimization theory and modeling. The role of prices, duality, optimality conditions, and algorithms in finding and recognizing solutions. Perspectives: problem formulation, analytical theory, computational methods, and recent applications in engineering, finance, and economics. Theories: finite dimensional derivatives, convexity, optimality, duality, and sensitivity. Methods: simplex and interior-point, gradient, Newton, and barrier. Prerequisite: CME 100 or MATH 51.

MS&E 212. Mathematical Programming and Combinatorial Optimization. 3 Units.

Combinatorial and mathematical programming (integer and non-linear) techniques for optimization. Topics: linear program duality and LP solvers; integer programming; combinatorial optimization problems on networks including minimum spanning trees, shortest paths, and network flows; matching and assignment problems; dynamic programming; linear approximations to convex programs; NP-completeness. Hands-on exercises. Prerequisites: 111 or MATH 103, CS 106A or X. Same as: MS&E 112

MS&E 213. Introduction to Optimization Theory. 3 Units.

Introduction of core algorithmic techniques and proof strategies that underlie the best known provable guarantees for minimizing high dimensional convex functions. Focus on broad canonical optimization problems and survey results for efficiently solving them, ultimately providing the theoretical foundation for further study in optimization. In particular, focus will be on first-order methods for both smooth and non-smooth convex function minimization as well as methods for structured convex function minimization, discussing algorithms such as gradient descent, accelerated gradient descent, mirror descent, Newton's method, interior point methods, and more. Prerequisite: multivariable calculus and linear algebra.

Same as: CS 2690

MS&E 220. Probabilistic Analysis. 3-4 Units.

Concepts and tools for the analysis of problems under uncertainty, focusing on model building and communication: the structuring, processing, and presentation of probabilistic information. Examples from legal, social, medical, and physical problems. Spreadsheets illustrate and solve problems as a complement to analytical closed-form solutions. Topics: axioms of probability, probability trees, random variables, distributions, conditioning, expectation, change of variables, and limit theorems. Prerequisite: CME 100 or MATH 51. Recommended: knowledge of spreadsheets.

MS&E 221. Stochastic Modeling. 3 Units.

Focus is on time-dependent random phenomena. Topics: discrete and continuous time Markov chains, renewal processes, queueing theory, and applications. Emphasis is on building a framework to formulate and analyze probabilistic systems. Prerequisite: 220 or consent of instructor.

MS&E 223. Simulation. 3 Units.

Discrete-event systems, generation of uniform and non-uniform random numbers, Monte Carlo methods, programming techniques for simulation, statistical analysis of simulation output, efficiency-improvement techniques, decision making using simulation, applications to systems in computer science, engineering, finance, and operations research. Prerequisites: working knowledge of a programming language such as C, C++, Java, Python, or FORTRAN; calculus-base probability; and basic statistical methods.

MS&E 226. "Small" Data. 3 Units.

This course is about understanding "small data": these are datasets that allow interaction, visualization, exploration, and analysis on a local machine. The material provides an introduction to applied data analysis, with an emphasis on providing a conceptual framework for thinking about data from both statistical and machine learning perspectives. Topics will be drawn from the following list, depending on time constraints and class interest: approaches to data analysis: statistics (frequentist, Bayesian) and machine learning; binary classification; regression; bootstrapping; causal inference and experimental design; multiple hypothesis testing. Class lectures will be supplemented by data-driven problem sets and a project. Prerequisites: CME 100 or MATH 51; 120, 220 or STATS 116; experience with R at the level of CME/STATS 195 or equivalent.

MS&E 231. Introduction to Computational Social Science. 3 Units.

With a vast amount of data now collected on our online and offline actions – from what we buy, to where we travel, to who we interact with – we have an unprecedented opportunity to study complex social systems. This opportunity, however, comes with scientific, engineering, and ethical challenges. In this hands-on course, we develop ideas from computer science and statistics to address problems in sociology, economics, political science, and beyond. We cover techniques for collecting and parsing data, methods for large-scale machine learning, and principles for effectively communicating results. To see how these techniques are applied in practice, we discuss recent research findings in a variety of areas. Prerequisites: introductory course in applied statistics, and experience coding in R, Python, or another high-level language. Same as: SOC 278

MS&E 233. Networked Markets. 3 Units.

An introduction to economic analysis for modern online services and systems. Topics include: Examples of networked markets. Online advertising. Recommendation and reputation systems. Pricing digital media. Network effects and network externalities. Social learning and herd behavior. Markets and information. Prerequisites: CME 100 or Math 51, and probability at the level of MS&E 220 or equivalent. No prior economics background will be assumed; requisite concepts will be introduced as needed.

MS&E 235. Analytics in Action. 3 Units.

Examines the role of analytics in real-world solutions across different industries. Provides a short introduction on the main concepts of analytics, and addresses common modeling approaches for both supervised (e.g., regression and classification) and unsupervised techniques (e.g., clustering, anomaly detection and pattern recognition), using platforms such as Hadoop and R. Discussion of implementations of these models in various industries, such as manufacturing, retail, banking, marketing, telecom and security. Teams of students will be required to prepare and present an analytics use case, covering aspects related to data collection, pre-processing, modeling, analyses, visualization, recommendations, implementation, business value and ROI. Students will be expected to come prepared to class, ready to discuss the case at hand, and offer their thoughts and insights. Cases will be presented in the context of leading a data science team, much as a Chief Analytics Officer (CAO) would be expected to do. Prerequisite: 226, CME 195, or equivalents.

MS&E 237. Networks, Markets, and Crowds. 3 Units.

The course explores the underlying network structure of our social, economic, and technological worlds and uses techniques from graph theory and economics to examine the structure & evolution of information networks, social contagion, the spread of social power and popularity, and information cascades. Prerequisites: basic graph and probability theory. Same as: CME 237

MS&E 238. Leading Trends in Information Technology. 3 Units.

Focuses on new trends and disruptive technologies in IT. Emphasis on the way technologies create a competitive edge and generate business value. Broad range of views presented by guest speakers, including top level executives of technology companies, and IT executives (e.g. CIOs) of Fortune 1000 companies. Special emphasis in technologies such as Cloud Computing, Artificial Intelligence, Security, Mobility, and Big Data.

MS&E 238A. Leading Trends in Information Technology. 1 Unit.

Focuses on new trends and disruptive technologies in IT. Emphasis on the way technologies create a competitive edge and generate business value. Broad range of views presented by guest speakers, including top level executives of technology companies, and IT executives (e.g. CIOs) of Fortune 1000 companies. Special emphasis in technologies such as Cloud Computing, Artificial Intelligence, Security, Mobility, and Big Data.

MS&E 240. Accounting for Managers and Entrepreneurs. 3-4 Units.

Non-majors and minors who have taken or are taking elementary accounting should not enroll. Introduction to accounting concepts and the operating characteristics of accounting systems. The principles of financial and cost accounting, design of accounting systems, techniques of analysis, and cost control. Interpretation and use of accounting information for decision making. Designed for the user of accounting information and not as an introduction to a professional accounting career. Enrollment limited. Admission by order of enrollment.

Same as: MS&E 140

MS&E 241. Economic Analysis. 3-4 Units.

Principal methods of economic analysis of the production activities of firms, including production technologies, cost and profit, and perfect and imperfect competition; individual choice, including preferences and demand; and the market-based system, including price formation, efficiency, and welfare. Practical applications of the methods presented. Recommended: 211, ECON 50.

MS&E 243. Energy and Environmental Policy Analysis. 3 Units.

Concepts, methods, and applications. Energy/environmental policy issues such as automobile fuel economy regulation, global climate change, research and development policy, and environmental benefit assessment. Group project. Prerequisite: MS&E 241 or ECON 50, 51.

MS&E 244. Economic Growth and Development. 3 Units.

Formerly 249. What generates economic growth. Emphasis is on theory accompanied by intuition, illustrated with country cases. Topics: the equation of motion of an economy; optimal growth theory; calculus of variations and optimal control approaches; deriving the Euler and Pontraguine equations from economic reasoning. Applications: former planned economies in Russia and E. Europe; the present global crisis: causes and consequences; a comparative study of India and China. The links between economic growth and civilization; the causes of the rise and decline of civilizations; lessons for the future. Intended for graduate students. Prerequisite: multivariate calculus and permission of instructor. To receive permission, submit an application at <http://web.stanford.edu/~lcottle/forms/244app.fb>.

MS&E 245A. Investment Science. 3 Units.

Basic concepts of modern quantitative finance and investments. Focus is on the financial theory and empirical evidence that are useful for investment decisions. Topics: basic interest rates; evaluating investments: present value and internal rate of return; fixed-income markets: bonds, yield, duration, portfolio immunization; term structure of interest rates; measuring risk: volatility and value at risk; designing optimal portfolios; risk-return tradeoff: capital asset pricing model and extensions. No prior knowledge of finance is required. Concepts are applied in a stock market simulation with real data. Prerequisite: basic preparation in probability, statistics, and optimization.

MS&E 245B. Advanced Investment Science. 3 Units.

Formerly MS&E 342. Topics: forwards and futures contracts, continuous and discrete time models of stock price behavior, geometric Brownian motion, Ito's lemma, basic options theory, Black-Scholes equation, advanced options techniques, models and applications of stochastic interest rate processes, and optimal portfolio growth. Computational issues and general theory. Teams work on independent projects.

Prerequisite: 245A.

MS&E 245G. Finance for Non-MBAs. 3 Units.

For graduate students and advanced undergraduates. The foundations of finance; applications in corporate finance and investment management. Financial decisions made by corporate managers and investors with focus on process valuation. Topics include criteria for investment decisions, valuation of financial assets and liabilities, relationships between risk and return, market efficiency, and the valuation of derivative securities. Corporate financial instruments including debt, equity, and convertible securities. Equivalent to core MBA finance course, FINANCE 220. Prerequisites: ECON 50, ECON 102A, or equivalents; ability to use spreadsheets, and basic probability and statistics concepts including random variables, expected value, variance, covariance, and simple estimation and regression.

Same as: ECON 135

MS&E 246. Financial Risk Analytics. 3 Units.

Practical introduction to financial risk analytics. The focus is on data-driven modeling, computation, and statistical estimation of credit and market risks. Case studies based on real data will be emphasized throughout the course. Topics include mortgage risk, asset-backed securities, commercial lending, consumer delinquencies, online lending, derivatives risk. Tools from machine learning and statistics will be developed. Data sources will be discussed. The course is intended to enable students to design and implement risk analytics tools in practice. Prerequisites: MS&E 245A or similar, some background in probability and statistics, working knowledge of R, Matlab, or similar computational/statistical package.

MS&E 250A. Engineering Risk Analysis. 3 Units.

The techniques of analysis of engineering systems for risk management decisions involving trade-offs (technical, human, environmental aspects). Elements of decision analysis; probabilistic risk analysis (fault trees, event trees, systems dynamics); economic analysis of failure consequences (human safety and long-term economic discounting); and case studies such as space systems, nuclear power plants, and medical systems. Public and private sectors. Prerequisites: probability, decision analysis, stochastic processes, and convex optimization.

MS&E 250B. Project Course in Engineering Risk Analysis. 3 Units.

Students, individually or in groups, choose, define, formulate, and resolve a real risk management problem, preferably from a local firm or institution. Oral presentation and report required. Scope of the project is adapted to the number of students involved. Three phases: risk assessment, communication, and management. Emphasis is on the use of probability for the treatment of uncertainties and sensitivity to problem boundaries. Limited enrollment. Prerequisites: MS&E 250A and consent of instructor.

MS&E 251. Stochastic Control. 3 Units.

Introduction to stochastic control, with applications taken from a variety of areas including supply-chain optimization, advertising, finance, dynamic resource allocation, caching, and traditional automatic control. Markov decision processes, optimal policy with full state information for finite-horizon case, infinite-horizon discounted, and average stage cost problems. Bellman value function, value iteration, and policy iteration. Approximate dynamic programming. Linear quadratic stochastic control. Formerly EE365. Prerequisites: EE 263, EE 178 or equivalent. Same as: EE 266

MS&E 252. Decision Analysis I: Foundations of Decision Analysis. 3-4 Units.

Coherent approach to decision making, using the metaphor of developing a structured conversation having desirable properties, and producing actionable thought that leads to clarity of action. Socratic instruction; computational problem sessions. Emphasis is on creation of distinctions, representation of uncertainty by probability, development of alternatives, specification of preference, and the role of these elements in creating a normative approach to decisions. Information gathering opportunities in terms of a value measure. Relevance and decision diagrams to represent inference and decision. Principles are applied to decisions in business, technology, law, and medicine. See 352 for continuation.

MS&E 254. The Ethical Analyst. 1-3 Unit.

The ethical responsibility for consequences of professional analysts who use technical knowledge in support of any individual, organization, or government. The means to form ethical judgments; questioning the desirability of physical coercion and deception as a means to reach any end. Human action and relations in society in the light of previous thought, and research on the desired form of social interactions. Attitudes toward ethical dilemmas through an explicit personal code.

MS&E 256. Technology Assessment and Regulation of Medical Devices. 3 Units.

Regulatory approval and reimbursement for new health technologies are critical success factors for product commercialization. This course explores the regulatory and payer environment in the U.S. and abroad, as well as common methods of health technology assessment. Students will learn frameworks to identify factors relevant to the adoption of new health technologies, and the management of those factors in the design and development phases of bringing a product to market through case studies, guest speakers from government (FDA) and industry, and a course project.

Same as: BIOE 256

MS&E 256A. Technology Assessment and Regulation of Medical Devices. 1 Unit.

Regulatory approval and reimbursement for new medical technologies as a key component of product commercialization. The regulatory and payer environment in the U.S. and abroad, and common methods of health technology assessment. Framework to identify factors relevant to adoption of new medical devices, and the management of those factors in the design and development phases. Case studies; guest speakers from government (FDA) and industry.

MS&E 257. Healthcare Reforms and Value-Based Biomedical Technology Innovation. 3 Units.

A fundamental transformation of the healthcare system is underway in which policymakers, payers and administrators are intensely focused on new policy mechanisms designed to constrain healthcare costs while promoting quality, outcomes and value. This class evaluates healthcare reforms in the U.S. and abroad with specific focus on examining their impact on the biomedical technology innovation process. Lectures and case studies, guest speakers from health plans, providers, and the medical technology industry perspectives. Students investigate real-world technology innovations in projects.

MS&E 257A. Healthcare Reforms and Value-Based Biomedical Technology Innovation. 1 Unit.

A fundamental transformation of the healthcare system is underway in which policymakers, payers and administrators are intensely focused on new policy mechanisms designed to constrain healthcare costs while promoting quality, outcomes and value. This class evaluates healthcare reforms in the U.S. and abroad with specific focus on examining their impact on the biomedical technology innovation process. Lectures and case studies, guest speakers from health plans, providers, and the medical technology industry perspectives. Students investigate real-world technology innovations in projects.

MS&E 260. Introduction to Operations Management. 3 Units.

Operations management focuses on the effective planning, scheduling, and control of manufacturing and service entities. This course introduces students to a broad range of key issues in operations management. Topics include determination of optimal facility location, production planning, optimal timing and sizing of capacity expansion, and inventory control. Prerequisites: basic knowledge of Excel spreadsheets, probability.

MS&E 261. Inventory Control and Production Systems. 3 Units.

Topics in the planning and control of manufacturing systems. The functions of inventory, determination of order quantities and safety stocks, alternative inventory replenishment systems, item forecasting, production-inventory systems, materials requirements planning (MRP), just-in-time systems, master and operations scheduling, supply chain management, and service operations. Limited enrollment. Prerequisite: 120, or STATS 116, or equivalent.

MS&E 262. Supply Chain Management. 3 Units.

Definition of a supply chain; coordination difficulties; pitfalls and opportunities in supply chain management; inventory/service tradeoffs; performance measurement and incentives. Global supply chain management; mass customization; supplier management. Design and redesign of products and processes for supply chain management; tools for analysis; industrial applications; current industry initiatives. Enrollment limited to 50. Admission determined in the first class meeting. Recommended: 260 or 261.

MS&E 263. Healthcare Operations Management. 3-4 Units.

With healthcare spending in the US exceeding 17% of GDP and growing, improvements in the quality and efficiency of healthcare services are urgently needed. This class focuses on the use of analytical tools to support efficient and effective delivery of health care. Topics include quality control and management, capacity planning, resource allocation, management of patient flows, and scheduling. Prerequisites: basic knowledge of Excel spreadsheets, probability, and optimization.

MS&E 265. Product Management Fundamentals. 3 Units.

Introduction to Product Management (PM). PM's define a product's functional requirements and lead cross functional teams responsible for development, launch, and ongoing improvement. The course uses a learning-by-doing approach covering the following topics: changing role of a PM at different stages of the product life cycle; techniques to understand customer needs and validate demand; user experience design and testing; role of detailed product specifications; waterfall and agile methods of software development. Group projects involve the specification of a software technology product though the skills taught are useful for a variety of product roles. No prior knowledge of design, engineering, or computer science required. Limited enrollment.

MS&E 267. Service Operations and the Design of Marketplaces. 3 Units.

The service sector accounts for approximately 80% of GDP and employment in the US. It is therefore imperative to develop efficient and effective operations of services. The management of service operations can require quite different constraints and objectives than manufacturing operations. The course examines both traditional and new approaches for achieving operational competitiveness in service businesses including (online) marketplaces. Topics include the service concept and operations strategy, the design of effective service delivery systems, capacity management, queuing, quality, revenue management as well as concepts from the design of marketplaces such as matching, congestion and auctions.

MS&E 270. Strategy in Technology-Based Companies. 3-4 Units.

For graduate students only. Introduction to the basic concepts of strategy, with emphasis on high technology firms. Topics: competitive positioning, resource-based perspectives, co-opetition and standards setting, and complexity/evolutionary perspectives. Limited enrollment. Students must attend and complete an application at the first class session.

MS&E 271. Global Entrepreneurial Marketing. 3-4 Units.

Skills needed to market new technology-based products to customers around the world. Case method discussions. Cases include startups and global high tech firms. Course themes: marketing toolkit, targeting markets and customers, product marketing and management, partners and distribution, sales and negotiation, and outbound marketing. Team-based take-home final exam. Limited enrollment.

MS&E 273. Technology Venture Formation. 3-4 Units.

Open to graduate students interested in technology driven start-ups. Provides the experience of an early-stage entrepreneur seeking initial investment, including: team building, opportunity assessment, customer development, go-to-market strategy, and IP. Teaching team includes serial entrepreneurs and venture capitalists. Student teams validate the business model using R&D plans and financial projections, and define milestones for raising and using venture capital. Final exam is an investment pitch delivered to a panel of top tier VC partners. In addition to lectures, teams interact with mentors and teaching team weekly. Enrollment by application: <http://www.stanford.edu/class/msande273>. Recommended: 270, 271, or equivalent.

MS&E 274. Dynamic Entrepreneurial Strategy. 3 Units.

Primarily for graduate students. How entrepreneurial strategy focuses on creating structural change or responding to change induced externally. Grabber-holder dynamics as an analytical framework for developing entrepreneurial strategy to increase success in creating and shaping the diffusion of new technology or product innovation dynamics. Topics: First mover versus follower advantage in an emerging market; latecomer advantage and strategy in a mature market; strategy to break through stagnation; and strategy to turn danger into opportunity. Modeling, case studies, and term project.

MS&E 275. Foundations for Large-Scale Entrepreneurship. 3 Units.

Explore the foundational and strategic elements needed for startups to be designed for "venture scale" at inception. Themes include controversial and disruptive insights, competitive analysis, network effects, organizational design, and capital deployment. Case studies, expert guests, and experiential learning projects will be used. Primarily for graduate students. Limited enrollment. Recommended: basic accounting.

MS&E 276. Entrepreneurial Management and Finance. 3 Units.

For graduate students only, with a preference for engineering and science majors. Emphasis on managing high-growth, early-stage enterprises, especially those with innovation-based products and services. Students work in teams to develop skills and approaches necessary to becoming effective entrepreneurial leaders and managers. Topics include assessing risk, understanding business models, analyzing key operational metrics, modeling cash flow and capital requirements, evaluating sources of financing, structuring and negotiating investments, managing organizational culture and incentives, managing the interplay between ownership and growth, and handling adversity and failure. Limited enrollment. Admission by application. Prerequisite: basic accounting.

MS&E 277. Creativity and Innovation. 3-4 Units.

Experiential course explores factors that promote and inhibit creativity and innovation in individuals, teams, and organizations. Teaches creativity tools using workshops, case studies, field trips, expert guests, and team design challenges. Enrollment limited to 40. Admission by application. See <http://dschool.stanford.edu/classes>.

MS&E 278. Patent Law and Strategy for Innovators and Entrepreneurs. 2-3 Units.

This course teaches the essentials for a startup to build a valuable patent portfolio and avoid a patent infringement lawsuit. Jeffrey Schox, who is the top recommended patent attorney for Y Combinator, built the patent portfolio for Twilio (IPO), Cruise (\$1B acquisition), and 250 startups that have collectively raised over \$2B in venture capital. This course is equally applicable to EE, CS, and Bioengineering students. For those students who are interested in a career in Patent Law, please note that this course is a prerequisite for ME238 Patent Prosecution.

Same as: ME 208

MS&E 280. Organizational Behavior: Evidence in Action. 3-4 Units.

Organization theory; concepts and functions of management; behavior of the individual, work group, and organization. Emphasis is on cases and related discussion. Enrollment limited. Winter Quarter on-campus only; priority to MS&E students. Spring Quarter SCPD only; no on-campus class.

MS&E 282. Transformational Leadership. 3 Units.

The personal, team-based and organizational skills needed to become a transformative leader. Case method discussions and lectures. Themes include: personal transformation; the inside-out effect, positive intelligence, group transformation; cross-functional teams; re-engineering; rapid - non-profit and for profit - organizational transformation; and social transformation. Limited enrollment; preference to graduate students. Prerequisite: 180 or 280.

MS&E 284. Designing Modern Work Organizations. 3 Units.

This practice-based experiential lab course is geared toward MS&E masters students. Students will master the concepts of organizational design, with an emphasis on applying them to modern challenges (technology, growth, globalization, and the modern workforce). Students will also gain mastery of skills necessary for success in today's workplace (working in teams, communicating verbally, presenting project work). Guest speakers from industry will present real-world challenges related to class concepts. Students will complete a quarter-long project designing and managing an actual online organization. Limited to 25. Admission by application.

MS&E 292. Health Policy Modeling. 3 Units.

Primarily for master's students; also open to undergraduates and doctoral students. The application of mathematical, statistical, economic, and systems models to problems in health policy. Areas include: disease screening, prevention, and treatment; assessment of new technologies; bioterrorism response; and drug control policies.

MS&E 293. Technology and National Security. 3 Units.

The interaction of technology and national security policy from the perspective of history to implications for the new security imperative, homeland defense. Key technologies in nuclear and biological weapons, military platforms, and intelligence gathering. Policy issues from the point of view of U.S. and other nations. The impact of terrorist threat. Guest lecturers include key participants in the development of technology and/or policy.

Same as: MS&E 193

MS&E 294. Climate Policy Analysis. 3 Units.

Design and application of formal analytical methods in climate policy development. Issues include instrument design, technology development, resource management, multiparty negotiation, and dealing with complexity and uncertainty. Links among art, theory, and practice. Emphasis is on integrated use of modeling tools from diverse methodologies and requirements for policy making application. Prerequisites: ECON 50, MS&E 211, MS&E 252, or equivalents, or permission of instructor.

MS&E 295. Energy Policy Analysis. 3 Units.

Design and application of formal analytical methods for policy and technology assessments of energy efficiency and renewable energy options. Emphasis is on integrated use of modeling tools from diverse methodologies and requirements for policy and corporate strategy development. Prerequisites: ECON 50, MS&E 211, MS&E 252, or equivalents, or permission of instructor.

MS&E 297. "Hacking for Defense": Solving National Security issues with the Lean Launchpad. 3-4 Units.

In a crisis, national security initiatives move at the speed of a startup yet in peacetime they default to decades-long acquisition and procurement cycles. Startups operate with continual speed and urgency 24/7. Over the last few years they've learned how to be not only fast, but extremely efficient with resources and time using lean startup methodologies. In this class student teams will take actual national security problems and learn how to apply lean startup principles, ("business model canvas," "customer development," and "agile engineering") to discover and validate customer needs and to continually build iterative prototypes to test whether they understood the problem and solution. Teams take a hands-on approach requiring close engagement with actual military, Department of Defense and other government agency end-users. Team applications required in February. Limited enrollment. Course builds on concepts introduced in MS&E 477.

MS&E 298. Hacking for Diplomacy: Tackling Foreign Policy Challenges with the Lean Launchpad. 3-4 Units.

At a time of significant global uncertainty, diplomats are grappling with transnational and cross-cutting challenges that defy easy solution including: the continued pursuit of weapons of mass destruction by states and non-state groups, the outbreak of internal conflict across the Middle East and in parts of Africa, the most significant flow of refugees since World War II, and a changing climate that is beginning to have impacts on both developed and developing countries. While the traditional tools of statecraft remain relevant, policymakers are looking to harness the power of new technologies to rethink how the U.S. government approaches and responds to these and other long-standing challenges. In this class, student teams will take actual foreign policy challenges and learn how to apply lean startup principles. ("mission model canvas," "customer development," and "agile engineering") to discover and validate agency and user needs and to continually build iterative prototypes to test whether they understood the problem and solution. Teams take a hands-on approach requiring close engagement with officials in the U.S. State Department and other civilian agencies. Team applications required at the end of shopping period. Limited enrollment.

Same as: IPS 232

MS&E 299. Voluntary Social Systems. 1-3 Unit.

Ethical theory, feasibility, and desirability of a social order in which coercion by individuals and government is minimized and people pursue ends on a voluntary basis. Topics: efficacy and ethics; use rights for property; contracts and torts; spontaneous order and free markets; crime and punishment based on restitution; guardian-ward theory for dealing with incompetents; the effects of state action-hypothesis of reverse results; applications to help the needy, armed intervention, victimless crimes, and environmental protection; transition strategies to a voluntary society.

MS&E 300. Ph.D. Qualifying Tutorial or Paper. 1-3 Unit.

Restricted to Ph.D. students assigned tutorials as part of the MS&E Ph.D. qualifying process. Enrollment optional.

MS&E 301. Dissertation Research. 1-15 Unit.

Prerequisite: doctoral candidacy.

MS&E 302. Fundamental Concepts in Management Science and Engineering. 1 Unit.

Each course session will be devoted to a specific MS&E PhD research area. Advanced students will make presentations designed for first-year doctoral students regardless of area. The presentations will be devoted to: illuminating how people in the area being explored that day think about and approach problems, and illustrating what can and cannot be done when addressing problems by deploying the knowledge, perspectives, and skills acquired by those who specialize in the area in question. Area faculty will attend and participate. During the last two weeks of the quarter groups of first year students will make presentations on how they would approach a problem drawing on two or more of the perspectives to which they have been exposed earlier in the class. Attendance is mandatory and performance will be assessed on the basis of the quality of the students' presentations and class participation. Restricted to first year MS&E PhD students.

MS&E 310. Linear Programming. 3 Units.

Formulation of standard linear programming models. Theory of polyhedral convex sets, linear inequalities, alternative theorems, and duality. Variants of the simplex method and the state of art interior-point algorithms. Sensitivity analyses, economic interpretations, and primal-dual methods. Relaxations of harder optimization problems and recent convex conic linear programs. Applications include game equilibrium facility location. Prerequisite: MATH 113 or consent of instructor.

MS&E 311. Optimization. 3 Units.

Applications, theories, and algorithms for finite-dimensional linear and nonlinear optimization problems with continuous variables. Elements of convex analysis, first- and second-order optimality conditions, sensitivity and duality. Algorithms for unconstrained optimization, and linearly and nonlinearly constrained problems. Modern applications in communication, game theory, auction, and economics. Prerequisites: MATH 113, 115, or equivalent.

Same as: CME 307

MS&E 312. Advanced Methods in Numerical Optimization. 3 Units.

Topics include interior-point methods, relaxation methods for nonlinear discrete optimization, sequential quadratic programming methods, optimal control and decomposition methods. Topic chosen in first class; different topics for individuals or groups possible. Individual or team projects. May be repeated for credit.

Same as: CME 334

MS&E 313. Almost Linear Time Graph Algorithms. 3 Units.

Over the past decade there has been an explosion in activity in designing new provably efficient fast graph algorithms. Leveraging techniques from disparate areas of computer science and optimization researchers have made great strides on improving upon the best known running times for fundamental optimization problems on graphs, in many cases breaking long-standing barriers to efficient algorithm design. In this course we will survey these results and cover the key algorithmic tools they leverage to achieve these breakthroughs. Possible topics include but are not limited to, spectral graph theory, sparsification, oblivious routing, local partitioning, Laplacian system solving, and maximum flow. Prerequisites: calculus and linear algebra.

Same as: CS 269G

MS&E 314. Linear and Conic Optimization with Applications. 3 Units.

Linear, semidefinite, conic, and convex nonlinear optimization problems as generalizations of classical linear programming. Algorithms include the interior-point, barrier function, and cutting plane methods. Related convex analysis, including the separating hyperplane theorem, Farkas lemma, dual cones, optimality conditions, and conic inequalities.

Complexity and/or computation efficiency analysis. Applications to combinatorial optimization, sensor network localization, support vector machine, and graph realization. Prerequisite: MS&E 211 or equivalent.

Same as: CME 336

MS&E 316. Discrete Mathematics and Algorithms. 3 Units.

Topics: Basic Algebraic Graph Theory, Matroids and Minimum Spanning Trees, Submodularity and Maximum Flow, NP-Hardness, Approximation Algorithms, Randomized Algorithms, The Probabilistic Method, and Spectral Sparsification using Effective Resistances. Topics will be illustrated with applications from Distributed Computing, Machine Learning, and large-scale Optimization. Prerequisites: CS 261 is highly recommended, although not required.

Same as: CME 305

MS&E 317. Algorithms for Modern Data Models. 3 Units.

We traditionally think of algorithms as running on data available in a single location, typically main memory. In many modern applications including web analytics, search and data mining, computational biology, finance, and scientific computing, the data is often too large to reside in a single location, is arriving incrementally over time, is noisy/uncertain, or all of the above. Paradigms such as map-reduce, streaming, sketching, Distributed Hash Tables, Bulk Synchronous Processing, and random walks have proved useful for these applications. This course will provide an introduction to the design and analysis of algorithms for these modern data models. Prerequisite: Algorithms at the level of CS 261.

Same as: CS 263

MS&E 318. Large-Scale Numerical Optimization. 3 Units.

The main algorithms and software for constrained optimization emphasizing the sparse-matrix methods needed for their implementation. Iterative methods for linear equations and least squares. The simplex method. Basis factorization and updates. Interior methods. The reduced-gradient method, augmented Lagrangian methods, and SQP methods.

Prerequisites: Basic numerical linear algebra, including LU, QR, and SVD factorizations, and an interest in MATLAB, sparse-matrix methods, and gradient-based algorithms for constrained optimization. Recommended: MS&E 310, 311, 312, 314, or 315; CME 108, 200, 302, 304, 334, or 335.

Same as: CME 338

MS&E 319. Approximation Algorithms. 3 Units.

Combinatorial and mathematical programming techniques to derive approximation algorithms for NP-hard optimization problems. Possible topics include: greedy algorithms for vertex/set cover; rounding LP relaxations of integer programs; primal-dual algorithms; semidefinite relaxations. May be repeated for credit. Prerequisites: 112 or CS 161.

MS&E 321. Stochastic Systems. 3 Units.

Topics in stochastic processes, emphasizing applications. Markov chains in discrete and continuous time; Markov processes in general state space; Lyapunov functions; regenerative process theory; renewal theory; martingales, Brownian motion, and diffusion processes. Application to queueing theory, storage theory, reliability, and finance. Prerequisites: 221 or STATS 217; MATH 113, 115. (Glynn).

MS&E 322. Stochastic Calculus and Control. 3 Units.

Ito integral, existence and uniqueness of solutions of stochastic differential equations (SDEs), diffusion approximations, numerical solutions of SDEs, controlled diffusions and the Hamilton-Jacobi-Bellman equation, and statistical inference of SDEs. Applications to finance and queueing theory. Prerequisites: 221 or STATS 217; MATH 113, 115.

MS&E 324. Stochastic Methods in Engineering. 3 Units.

The basic limit theorems of probability theory and their application to maximum likelihood estimation. Basic Monte Carlo methods and importance sampling. Markov chains and processes, random walks, basic ergodic theory and its application to parameter estimation. Discrete time stochastic control and Bayesian filtering. Diffusion approximations, Brownian motion and an introduction to stochastic differential equations. Examples and problems from various applied areas. Prerequisites: exposure to probability and background in analysis.

Same as: CME 308, MATH 228

MS&E 325. Advanced Topics in Applied Probability. 3 Units.

Current stochastic models, motivated by a wide range of applications in engineering, business, and science, as well as the design and analysis of associated computational methods for performance analysis and control of such stochastic systems.

MS&E 330. Law, Order & Algorithms. 3 Units.

Data and algorithms are rapidly transforming law enforcement and criminal justice, including how police officers are deployed, how discrimination is detected, and how sentencing, probation, and parole terms are set. Modern computational and statistical methods offer the promise of greater efficiency, equity, and transparency, but their use also raises complex legal, social, and ethical questions. In this course, we analyze recent court decisions, discuss methods from machine learning and game theory, and examine the often subtle relationship between law, public policy, and statistics. The class is centered around several data-intensive projects in criminal justice that students work on in interdisciplinary teams. Students work closely with criminal justice agencies to carry out these projects, with the goal of producing research that impacts policy. Students with a background in statistics, computer science, law, and/or public policy are encouraged to participate. Enrollment is limited, and project teams will be selected during the first week of class.

Same as: SOC 279

MS&E 332. Topics in Social Algorithms. 3 Units.

In depth discussion of selected research topics in social algorithms, including networked markets, collective decision making, recommendation and reputation systems, prediction markets, social computing, and social choice theory. The class will include a theoretical project and a paper presentation. Prerequisites: CS 261 or equivalent; understanding of basic game theory.

MS&E 333. Social Algorithms. 1 Unit.

This seminar will introduce students to research in the field of social algorithms, including networked markets, collective decision making, recommendation and reputation systems, prediction markets, social choice theory, and models of influence and contagion.

MS&E 334. The Structure of Social Data. 3 Units.

This course provides a survey of recent research in the study of social networks and large-scale social and behavioral data. Topics will include network models based on random graphs and their properties; centrality and ranking on graphs; ranking from comparisons; heavy-tailed statistical distributions for social data; the wisdom of crowds; homophily and social influence; experimentation and causal inference on networks. Prerequisites: 221, 226, CS161.

MS&E 335. Queueing and Scheduling in Processing Networks. 3 Units.

Advanced stochastic modeling and control of systems involving queueing and scheduling operations. Stability analysis of queueing systems. Key results on single queues and queueing networks. Controlled queueing systems. Dynamic routing and scheduling in processing networks. Applications to modeling, analysis and performance engineering of computing systems, communication networks, flexible manufacturing, and service systems. Prerequisite: 221 or equivalent.

MS&E 336. Platform and Marketplace Design. 3 Units.

The last decade has witnessed a meteoric rise in the number of online markets and platforms competing with traditional mechanisms of trade. Examples of such markets include online marketplaces for goods, such as eBay; online dating markets; markets for shared resources, such as Lyft, Uber, and Airbnb; and online labor markets. We will review recent research that aims to both understand and design such markets. Emphasis on mathematical modeling and methodology, with a view towards preparing Ph.D. students for research in this area. Prerequisites: Mathematical maturity; 300-level background in optimization and probability; prior exposure to game theory.

MS&E 338. Advanced Topics in Information Science and Technology. 3 Units.

Advanced material in this area is sometimes taught for the first time as a topics course. Prerequisite: consent of instructor.

MS&E 347. Credit Risk: Modeling and Management. 3 Units.

Credit risk modeling, valuation, and hedging emphasizing underlying economic, probabilistic, and statistical concepts. Point processes and their compensators. Structural, incomplete information and reduced form approaches. Single name products: corporate bonds, equity, equity options, credit and equity default swaps, forwards and swaptions. Multiname modeling: index and tranche swaps and options, collateralized debt obligations. Implementation, calibration and testing of models. Industry and market practice. Data and implementation driven group projects that focus on problems in the financial industry.

MS&E 348. Optimization of Uncertainty and Applications in Finance. 3 Units.

How to make optimal decisions in the presence of uncertainty, solution techniques for large-scale systems resulting from decision problems under uncertainty, and applications in finance. Decision trees, utility, two-stage and multi-stage decision problems, approaches to stochastic programming, model formulation; large-scale systems, Benders and Dantzig-Wolfe decomposition, Monte Carlo sampling and variance reduction techniques, risk management, portfolio optimization, asset-liability management, mortgage finance. Projects involving the practical application of optimization under uncertainty to financial planning.

MS&E 349. Financial Statistics. 3 Units.

Topics in financial statistics with focus on current research: Time-series modeling, volatility modeling, large-dimensional factor modeling, random matrix theory with applications to finance. Prerequisites: 120, 220 or STATS 116.

MS&E 351. Dynamic Programming and Stochastic Control. 3 Units.

Markov population decision chains in discrete and continuous time. Risk posture. Present value and Cesaro overtaking optimality. Optimal stopping. Successive approximation, policy improvement, and linear programming methods. Team decisions and stochastic programs; quadratic costs and certainty equivalents. Maximum principle. Controlled diffusions. Examples from inventory, overbooking, options, investment, queues, reliability, quality, capacity, transportation. MATLAB. Prerequisites: MATH 113, 115; Markov chains; linear programming.

MS&E 352. Decision Analysis II: Professional Decision Analysis. 3-4 Units.

How to organize the decision conversation, the role of the decision analysis cycle and the model sequence, assessing the quality of decisions, framing decisions, the decision hierarchy, strategy tables for alternative development, creating spare and effective decision diagrams, biases in assessment, knowledge maps, uncertainty about probability. Sensitivity analysis, approximations, value of revelation, joint information, options, flexibility, bidding, assessing and using corporate risk attitude, risk sharing and scaling, and decisions involving health and safety. See 353 for continuation. Prerequisite: 252.

MS&E 353. Decision Analysis III: Frontiers of Decision Analysis. 3 Units.

The concept of decision composite; probabilistic insurance and other challenges to the normative approach; the relationship of decision analysis to classical inference and data analysis procedures; the likelihood and exchangeability principles; inference, decision, and experimentation using conjugate distributions; developing a risk attitude based on general properties; alternative decision aiding practices such as analytic hierarchy and fuzzy approaches. Student presentations on current research. Goal is to prepare doctoral students for research. Prerequisite: 352.

MS&E 355. Influence Diagrams and Probabilistics Networks. 3 Units.

Network representations for reasoning under uncertainty: influence diagrams, belief networks, and Markov networks. Structuring and assessment of decision problems under uncertainty. Learning from evidence. Conditional independence and requisite information. Node reductions. Belief propagation and revision. Simulation. Linear-quadratic-Gaussian decision models and Kalman filters. Dynamic processes. Bayesian meta-analysis. Prerequisites: 220, 252, or equivalents, or consent of instructor.

MS&E 365. Advanced Topics in Market Design. 3 Units.

Primarily for doctoral students. Focus on quantitative models dealing with sustainability and related to operations management. Prerequisite: consent of instructor. May be repeated for credit.

MS&E 371. Innovation and Strategic Change. 2-3 Units.

Doctoral research seminar, limited to Ph.D. students. Current research on innovation strategy. Topics: scientific discovery, innovation search, organizational learning, evolutionary approaches, and incremental and radical change. Topics change yearly. Recommended: course in statistics or research methods.

MS&E 372. Entrepreneurship Doctoral Research Seminar. 1-3 Unit.

Classic and current research on entrepreneurship. Limited enrollment, restricted to PhD students. Prerequisites: SOC 363 or equivalent, and permission of instructor.

MS&E 374. Cross Border Regional Innovation. 3 Units.

This is an advanced research seminar class that is restricted to students that had taken MS&E 274. Disruptive innovation is the realization of new value proposition through establishment of a new ecosystem. Value proposition depends on the culture and social value in a particular region; while the ability to establish the ecosystem to realize the value proposition is highly dependent on the firm's knowledge and skills to operate effectively under the political, social, and economic structure of that particular region. Therefore cross border and regional innovations in different regions will take different path. This course will examine cases that cover innovations in developing economy, cross border e-commerce, and international business groups.

MS&E 375. Research on Entrepreneurship. 3 Units.

Restricted to Ph.D. students. Organization theory, economics, and strategy perspectives. Limited enrollment. Prerequisites: SOC 360 or equivalent, and consent of instructor.

MS&E 376. Strategy Doctoral Research Seminar. 3 Units.

Classic and current research on business and corporate strategy. Limited enrollment, restricted to PhD students. Prerequisites: SOC 363 or equivalent, and permission of instructor. Course may be repeated for credit.

MS&E 379. Social Data Analysis. 3 Units.

Applied introduction to good empirical research and causal inference for social scientists and others analyzing social data. Designed to provide an introduction to some of the most commonly used quantitative techniques for causal inference in social data including: survey design and inference, regression and propensity score matching, instrumental variables, differences-in-differences, regression discontinuity designs, standard errors, and the analysis of big data. Applications: organizations, entrepreneurship, public policy, innovation, economics, online education, visual representations, communication, critique and design of figures, graphs. Does not explicitly cover social network structure or machine learning as these topics are well-covered elsewhere. Students work in groups and individually to design and carry out a small research project based on the use of analytics, large data sets, or other digital innovations related to business or other organizations. Students become acquainted with a variety of approaches to research design, and are helped to develop their own research projects. Course prioritizes a thorough substantively grounded understanding of assumptions over mathematical proofs and derivations. Aimed at PhD students, but open by permission to Master's students and to students in other Stanford programs with relevant coursework or experience in analytics and statistics.

MS&E 380. Doctoral Research Seminar in Organizations. 3 Units.

Limited to Ph.D. students. Topics from current published literature and working papers. Content varies. Prerequisite: consent of instructor.

MS&E 381. Doctoral Research Seminar in Work, Technology, and Organization. 2-3 Units.

Enrollment limited to Ph.D. students. Topics from current published literature and working papers. Content varies. Prerequisite: consent of instructor.

MS&E 382. Social Network Perspectives on Organizing: Theories and Methods. 3 Units.

Review of theoretical, conceptual, and analytic issues associated with network perspectives on organizing. Review of scholarship on the science of networks in communication, computer science, economics, engineering, organizational science, life sciences, physical sciences, political science, psychology, and sociology, in order to take an in-depth look at theories, methods, and tools to examine the structure and dynamics of networks. Discussion of assigned readings, a series of laboratory exercises providing experience with computer-based network analysis, modeling and visualization tools, and a term paper advancing some theoretical, methodological or computational aspect of network science.

MS&E 383. Doctoral Seminar on Ethnographic Research. 3 Units.

For graduate students; upper-level undergraduates with consent of instructor. Interviewing and participant observation. Techniques for taking, managing, and analyzing field notes and other qualitative data. Methods texts and ethnographies offer examples of how to analyze and communicate ethnographic data. Prerequisite: consent of instructor.

MS&E 384. Groups and Teams. 3 Units.

Research on groups and teams in organizations from the perspective of organizational behavior and social psychology. Topics include group effectiveness, norms, group composition, diversity, conflict, group dynamics, temporal issues in groups, geographically distributed teams, and intergroup relations.

MS&E 387. Design of Field Research Methods. 3 Units.

Field research involves collecting original data (qualitative and/or quantitative) in field sites. This course combines informal lecture and discussion with practical exercises to build specific skills for conducting field research in organizations. Readings include books and papers about research methodology and articles that provide exemplars of field research. Specific topics covered include: the role of theory in field research, variance versus process models, collecting and analyzing different kinds of data (observation, interview, survey), levels of analysis, construct development and validity, blending qualitative and quantitative data (in a paper, a study, or a career), and writing up field research for publication. Students will develop intuition about the contingent relationship between the nature of the research question and the field research methods used to answer it as a foundation for conducting original field research.

MS&E 388. Contemporary Themes in Work and Organization Studies. 3 Units.

Doctoral research seminar, limited to Ph.D. students. Current meso-level field research on organizational behavior, especially work and coordination. Topics: work design, job design, roles, teams, organizational change and learning, knowledge management, performance. Focus on understanding theory development and research design in contemporary field research. Topics change yearly. Recommended: course in statistics or research methods.

MS&E 389. Seminar on Organizational Theory. 5 Units.

The social science literature on organizations assessed through consideration of the major theoretical traditions and lines of research predominant in the field.

Same as: EDUC 375A, SOC 363A

MS&E 390. Doctoral Research Seminar in Health Systems Modeling. 1-3 Unit.

Restricted to PhD students, or by consent of instructor. Doctoral research seminar covering current topics in health policy, health systems modeling, and health innovation. May be repeated for credit.

MS&E 391. Doctoral Research Seminar in Energy-Environmental Systems Modeling and Analysis. 1-3 Unit.

Restricted to PhD students, or by consent of instructor. Doctoral research seminar covering current topics in energy and environmental modeling and analysis. Current emphasis on approaches to incorporation of uncertainty and technology dynamics into complex systems models. May be repeated for credit.

MS&E 403. Integrative Modeling. 3 Units.

Modeling approaches for examining real life problems: how to get started. Critical thinking in framing and problem formulation leading to actionable solutions and communication of results to decision makers. Models to identify and evaluate multiple objectives/metrics. Models examined include both deterministic and probabilistic components. Overview of optimization and probability, decomposition principles to model large scale problems, appropriate integration of uncertainties into model formulations. Primarily team-project based assignments, with three to four group projects. Project topics drawn from applications with real data. Sample project topics include: optimizing group phone plans for large corporations, life insurance business models, making sense of the health care debate, logistic decision problems. Project teams will critically grade other teams; project reports using provided guidelines. Project presentations throughout the quarter. Prerequisites: 211, 220.

MS&E 408. Directed Reading and Research. 1-15 Unit.

Directed study and research on a subject of mutual interest to student and faculty member. Prerequisite: faculty sponsor.

MS&E 408A. Directed Reading and Research. 1-4 Unit.

Directed study and research on a subject of mutual interest to student and mentor.

MS&E 431. Projects in Computational Social Science. 3-4 Units.

Students work in interdisciplinary teams to complete a project of their choice in computational social science. Groups present their progress throughout the term, receiving regular feedback on their own projects and providing feedback on other students' projects. Students learn how to deal with the computational and statistical challenges of working with large, real-world datasets in the context of a motivating, substantive problem in the social sciences. Lectures and discussions are tailored to the specific topics that the groups pursue. Enrollment is by application only; details will be posted in the fall quarter. Prerequisite: MS&E 231 or similar.

MS&E 441. Policy and Economics Research Roundtable. 1 Unit.

Research in progress or contemplated in policy and economics areas. Emphasis depends on research interests of participants, but is likely to include energy, environment, transportation, or technology policy and analysis. May be repeated for credit.

Same as: PERR

MS&E 442. Energy Efficiency: Technology, Policy, and Investment. 1 Unit.

Provide students with a basic understanding of the technologies, policies, and investments behind energy efficiency. Explores each of these dimensions, and their interplay, through structured lectures and expert perspectives from leading professionals and practitioners. The seminar will first survey energy efficiency historically, reviewing technology and policy development, funding support, accomplishments at the state and federal levels, and key stakeholders. The second part of the seminar will focus on innovation in energy efficiency, including its role in climate change. Three areas are anticipated for study: new technologies and energy efficiency's role in the changing grid, new policies and the use of data analytics, and new entrants and investment strategies. Limited to 15 students.

Same as: PUBLPOL 342

MS&E 445. Projects in Wealth Management. 3-4 Units.

Recent theory and standard practice in portfolio design for institutions, individuals, and funds. Student projects and case studies derived from the financial industry.

MS&E 446. Artificial Intelligence in Financial Technology. 3 Units.

Survey the current Financial Technology landscape through the lens of Artificial Intelligence applications, with emphasis in 4 areas: Payments, Blockchain and Cryptocurrencies, Robo-Advisory, and Marketplace Lending. Students work in groups of 4 to develop an original financial technology project, research paper or product prototype within a chosen area. Final project posters to be presented to the class and posted online. Top posters to be selected and presented at the Stanford Financial Technology conference in January. Classes will alternate between industry speakers, lectures and scheduled group meetings with teaching team. Advanced undergraduates, graduate students, and students from other Schools are welcome to enroll. Prerequisites: Basic programming skills, knowledge of design process, introductory statistics. No formal finance experience required. Enrollment is capped at 32.

Same as: CME 238

MS&E 446A. Mathematical and Computational Finance Seminar. 1 Unit.

Same as: CME 242, STATS 239

MS&E 447. Systemic and Market Risk : Notes on Recent History, Practice, and Policy. 3 Units.

The global financial crisis of 2007-8 threw into sharp relief the ongoing challenges of understanding risk, the financial system, links with the global economy, and interactions with policy. We will explore elements of the crisis, a few other key events, and ongoing debates about systemic risk. Group projects will explore in more detail past events and current topics in systemic risk. Supplements a rigorous technical curriculum in modern finance with select aspects relevant to understanding the practice and broader context of modern financial activities such as derivatives, financial engineering, and risk management.

MS&E 448. Big Financial Data and Algorithmic Trading. 3 Units.

Project course emphasizing the connection between data, models, and reality. Vast amounts of high volume, high frequency observations of financial quotes, orders and transactions are now available, and poses a unique set of challenges. This type of data will be used as the empirical basis for modeling and testing various ideas within the umbrella of algorithmic trading and quantitative modeling related to the dynamics and micro-structure of financial markets. Due to the fact that it is near impossible to perform experiments in finance, there is a need for empirical inference and intuition, any model should also be justified in terms of plausibility that goes beyond pure econometric and data mining approaches. Introductory lectures, followed by real-world type projects to get a hands-on experience with realistic challenges and hone skills needed in the work place. Work in groups on selected projects that will entail obtaining and cleaning the raw data and becoming familiar with techniques and challenges in handling big data sets. Develop a framework for modeling and testing (in computer languages such as Python, C++ , Matlab and R) and prepare presentations to present to the class. Example projects include optimal order execution, developing a market making algorithm, design of an intra-day trading strategy, and modeling the dynamics of the bid and ask. Prerequisites: MS&E 211, 242, 342, or equivalents, some exposure to statistics and programming. Enrollment limited. Admission by application; details at first class.

MS&E 449. Buy-Side Investing. 1-2 Unit.

In-class lectures and guest speakers who work in the Buy-Side to explore the synergies amongst the various players; roles, risk appetites, and investment time and return horizons. We aim to see the forest and the different species of trees growing in the forest known as the Buy-Side, so as to develop a perspective as financial engineers for how the ecosystem functions, what risks it digests, how it generates capital at what rate and amount for the Sell-Side, and how impacts in the real economy are reflected - or should be reflected - in the culture and risk models adopted by the Buy-Side participants.

MS&E 450. Lessons in Decision Making. 1 Unit.

Entrepreneurs, senior management consultants, and executives from Fortune 500 companies share real-world stories and insights from their experience in decision making.

MS&E 453. Decision Analysis Applications. 2 Units.

How to be effective and efficient when making important personal choices as well as organizational decisions about business strategies and public policies. Applications show the use of decision analysis techniques to frame, structure, assess, evaluate, analyze, and appraise complex decisions implemented in an uncertain future world. Experienced decision professionals lead discussions of case studies about venture capital, biotech acquisition, commodity options trading, R&D portfolios, tech manufacturing strategy, litigation risk, medical diagnosis, health care delivery, pharmaceutical drug development, real estate development, energy economics, and environmental risk analysis. Discussions include lessons learned about useful processes for effective interactions, clear communications, organizational renewal, decision quality, and collaborative decision making. Prerequisite: MS&E 152 or MS&E 252.

MS&E 454. Decision Analysis Seminar. 1 Unit.

Current research and related topics presented by doctoral students and invited speakers. May be repeated for credit. Prerequisite: 252.

MS&E 463. Healthcare Systems Design. 3-4 Units.

Students work on projects to analyze and design various aspects of healthcare including hospital patient flow, physician networks, clinical outcomes, reimbursement incentives, and community health. Students work in small teams under the supervision of the course instructor and partners at the Lucille Packard Children's Hospital, the Stanford Hospital, and other regional healthcare providers. Prerequisite: 263.

MS&E 472. Entrepreneurial Thought Leaders' Seminar. 1 Unit.

Entrepreneurial leaders share lessons from real-world experiences across entrepreneurial settings. ETL speakers include entrepreneurs, leaders from global technology companies, venture capitalists, and best-selling authors. Half-hour talks followed by half hour of class interaction. Required web discussion. May be repeated for credit.

MS&E 475A. Entrepreneurial Leadership. 1 Unit.

This seminar explores a wide range of topics related to entrepreneurial leadership through class discussions, case studies, field trips, and guest speakers. It is part of the DFJ Entrepreneurial Leaders Fellowship, which requires an application during Fall quarter. Details can be found at: <http://stvp.stanford.edu/dfj/>.

MS&E 475B. Entrepreneurial Leadership. 1 Unit.

This seminar explores a wide range of topics related to entrepreneurial leadership through class discussions, case studies, field trips, and guest speakers. It is part of the DFJ Entrepreneurial Leaders Fellowship, which requires an application during Fall quarter. Details can be found at: <http://stvp.stanford.edu/dfj/>.

MS&E 476. Entrepreneurship Through the Lens of Venture Capital: Venture Capital From Past to Present. 2 Units.

Explores changes in the venture capital industry: rise of Silicon Valley and Sand Hill Road, investing in the dot-com bubble, incubators and accelerators, equity crowd funding platform, and different models of venture capital. Explores how companies are funded, grown, and scale by meeting with individuals who have been at the forefront of this change. Enrollment by application: www.lensofvc.com.

MS&E 477. Silicon Valley and the U.S. Government: Scaling Business-to-Government Technology. 2-3 Units.

Understanding how to sell and scale dual-use technologies in the business-to-government (B2G) market. Dual-use technologies are viable consumer and commercial technologies with relevance in government, or B2G, marketplaces. Government technology needs, government acquisitions channels, and how to locate and access government funding. Students gain exposure to Silicon Valley venture investors familiar with funding dual-use technologies. Topics introduced are particularly relevant to technology researchers in academia, founders of technology companies, and future employees of startups pursuing dual-use technologies.

MS&E 487. D.ORG: PROTOTYPING ORGANIZATIONAL CHANGE. 2-4 Units.

d.org will send outstanding, proven design thinkers into select organizations to architect "organizational R&D" experiments. Students will work directly with teams in those organizations to implement tools to drive change and measure results. Performance will be measured by the student's effectiveness at driving changes in the organization. Prerequisite: MS&E 489 and permission of instructor.

MS&E 488. Prototyping and Rapid Experiment Lab. 4 Units.

Gain a deeper understanding of the prototyping and user feedback parts of the design thinking process with a focus on rapid experimentation. Explore prototyping and user feedback that happens in later stages of iteration when design ideas are somewhat gelled, but designers are still uncertain about whether the design will meet the need and evoke the response intended. Introduce and generate creative ways to discover what users will do in the real world with the designs we envision. For seasoned students who thoroughly understand the design thinking process or, more broadly, human-centered design and now want to focus on one later stage aspect of it in more depth. An application process will happen in Fall Quarter. Please contact the d.school for more details.

MS&E 489. d.Leadership: Design Leadership in Context. 1-3 Unit.

d.Leadership is a course that teaches the coaching and leadership skills needed to drive good design process in groups. d.leaders will work on real projects driving design projects within organizations and gain real world skills as they experiment with their leadership style. Take this course if you are inspired by past design classes and want skills to lead design projects beyond Stanford. Preference given to students who have taken other Design Group or d.school classes. Admission by application. See dschool.stanford.edu/classes for more information. Same as: ME 368

MS&E 494. The Energy Seminar. 1 Unit.

Interdisciplinary exploration of current energy challenges and opportunities, with talks by faculty, visitors, and students. May be repeated for credit. Same as: CEE 301, ENERGY 301

MS&E 802. TGR Dissertation. 0 Units.

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