MANAGEMENT SCIENCE AND ENGINEERING

Courses offered by the Department of Management Science and Engineering are listed under the subject code MS&E on the (https://explorecourses.stanford.edu/search?view=catalog&academicYear=&page=0&q=MS%26E&filter-departmentcode-MS%26E=on&filter-coursestatus-Active=on&filter-term-Autumn=on)*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 4, 2018, and the deadline for application to the master's program is January 15, 2019.

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://exploredegrees.stanford.edu/schoolofhumanitiesandsciences/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]		23
CME 100	Vector Calculus for Engineers	
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CME 103	Introduction to Matrix Methods	
MS&E 120	Probabilistic Analysis	
MS&E 121	Introduction to Stochastic Modeling	
MS&E 125	Introduction to Applied Statistics	
Select two of the following options:		8-10
CHEM 31B	Chemical Principles II	
or CHEM 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	
PHYSICS 41	Mechanics	
or PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 43	Electricity and Magnetism	
or PHYSICS 23	Electricity, Magnetism, and Optics	
BIO 81	Introduction to Ecology	
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 85	Evolution	
BIO 86	Cell Biology	
Math, Science, or Statistics Elective from SoE approved lists. [1]		3
Up to ten units of AP/IB Calculus, MATH 19, 20, 21, 41, or 42.		10
Technology in Society		
Select one of the following; see SoE Basic Requirement 4		3-5

AA 252	Techniques of Failure Analysis
COMM 120W	Digital Media in Society
BIOE 131	Ethics in Bioengineering
CS 181	Computers, Ethics, and Public Policy
ENGR 117	Expanding Engineering Limits: Culture, Diversity, and Equity
ENGR 131	Ethical Issues in Engineering [4]
ME 267	Ethics and Equity in Transportation Systems
MS&E 193	Technology and National Security [4]
POLISCI 114S	International Security in a Changing World
STS 1	The Public Life of Science and Technology

Engineering Fundamentals [2]

Two courses; see SoE Basic Requirement 3		8-10
CS 106A	Programming Methodology [3]	
Select one of the following:		
ENGR 10	Introduction to Engineering Analysis	
ENGR 14	Intro to Solid Mechanics	
ENGR 15	Dynamics	
ENGR 20	Introduction to Chemical Engineering	
ENGR 21	Engineering of Systems	
ENGR 25B	Biotechnology	
ENGR 25E	Energy: Chemical Transformations for Production, Storage, and Use	
ENGR 40A	Introductory Electronics	
ENGR 40M	An Intro to Making: What is EE	
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
ENGR 50E	Introduction to Materials Science, Energy Emphasis	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
ENGR 80	Introduction to Bioengineering (Engineering Living Matter)	
ENGR 90	Environmental Science and Technology	

Engineering Depth [2]

Core Courses (all six required)		25-27
CS 106B	Programming Abstractions [4]	
or CS 106X	Programming Abstractions (Accelerated)	
ECON 50	Economic Analysis I	
MS&E 108	Senior Project (WIM)	
MS&E 111	Introduction to Optimization [4]	
or MS&E 111X	Introduction to Optimization (Accelerated)	
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

		Units
Finance and Decision Area		6-15
Students choosing F&D as their primary area must take at least two of ECON 51, MS&E 145 (or 245A), and MS&E 152 (or 252), as part of their 15 units		
Introductory (no prerequisites)		
MS&E 147	Finance and Society for non-MBAs	
MS&E 152	Introduction to Decision Analysis	
Intermediate (has prerequisites and/or appropriate for juniors and seniors)		
MS&E 145	Introduction to Investment Science	
MS&E 146	Corporate Financial Management	
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	
Advanced (intended primarily for graduate students, but may be taken by advanced undergraduates)		
MS&E 245A	Investment Science	
MS&E 245B	Advanced Investment Science	
MS&E 246	Financial Risk Analytics	
MS&E 250A	Engineering Risk Analysis	
MS&E 250B	Project Course in Engineering Risk Analysis	
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 selections [4]		
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: Prediction, Inference, Causality	
MS&E 231	Introduction to Computational Social Science	
MS&E 251	Introduction to Stochastic Control with Applications	
Applications		
MS&E 130	Information Networks and Services	
MS&E 234	Data Privacy and Ethics	
MS&E 235	Network Analytics	
MS&E 260	Introduction to Operations Management	
MS&E 263	Healthcare Operations Management	
MS&E 267	Service Operations and the Design of Marketplaces	
MS&E 330	Law, Bias, & Algorithms	
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 182, MS&E 184, and MS&E 185 as part of their 15 units		
Introductory (no prerequisites)		
ENGR 131	Ethical Issues in Engineering [4]	
MS&E 190	Methods and Models for Policy and Strategy Analysis	
MS&E 193	Technology and National Security [4]	
Advanced (has prerequisites and/or appropriate for juniors and seniors)		
ENGR 145	Technology Entrepreneurship	
MS&E 175	Innovation, Creativity, and Change	
or MS&E 177	Creativity Rules	
MS&E 182	Leading Organizational Change	
MS&E 183		
MS&E 184	Future of Work: Issues in Organizational Learning and Design	
MS&E 185	Global Work	
MS&E 188	Organizing for Good	

	MS&E 243	Energy and Environmental Policy Analysis
	MS&E 292	Health Policy Modeling
	MS&E 294	
	MS&E 295	

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, and may not repeat material from any other requirement. AP/IB credit for Chemistry and Physics may be used.

2 Engineering fundamentals plus engineering depth must total a minimum of 60 units. Recommended engineering fundamentals are E25B, E25E, E40A, E40M, and E80.

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

4 A course may only be counted towards one requirement; it may not be double-counted. For example, MS&E 193 may not count towards both TiS and towards the OTP depth area, and MS&E 111/ENGR 62 may not count towards both an engineering fundamental and towards the MS&E core depth.

5 All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

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:

		Units
Background requirements (two courses; letter-graded or CR/NC)		
CME 100	Vector Calculus for Engineers	5
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CS 106A	Programming Methodology	5
Minor requirements (seven courses; all letter-graded)		
MS&E 111	Introduction to Optimization	3-4
or MS&E 111X	Introduction to Optimization (Accelerated)	
MS&E 120	Probabilistic Analysis [1]	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	

1 Students completing a calculus-based probability course such as CS 109 or STATS 116 for their major, may substitute another MS&E course for MS&E 120.

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://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.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

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://exploredegrees.stanford.edu/graduatedegrees)" section of this bulletin.

The master's in Management Science and Engineering 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 seven 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. 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:* The Operations and Analytics track prepares students in the fundamentals and applications that are critical to careers in fields ranging from operations management in the service, healthcare, production, manufacturing, computer, telecommunications, and 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 and understanding of 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, non-governmental organizations, or corporations. This track includes core 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, Multivariable Calculus, and Modern Applications , 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	Introduction to Optimization	
or MS&E 211X	Introduction to Optimization (Accelerated)	
or MS&E 213	Introduction to Optimization Theory	
MS&E 226	"Small" Data: Prediction, Inference, Causality	
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.		

Organizations and Decisions (select one)

		Units
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	
MS&E 270	Strategy in Technology-Based Companies	
MS&E 280	Organizational Behavior: Evidence in Action	
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.		

Probability (select one)

		Units
MS&E 220	Probabilistic Analysis	
MS&E 221	Stochastic Modeling	
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.		

Primary Concentrations

Financial Analytics Concentration (five courses required)

		Units
Financial Theory and Modeling (select one):		
MS&E 245A	Investment Science	
MS&E 245B	Advanced Investment Science	
MS&E 246	Financial Risk Analytics	
Quantitative Methods (two required):		
Select one (whichever of optimization or analytics wasn't taken for core):		
MS&E 211	Introduction to Optimization	
or MS&E 211X	Introduction to Optimization (Accelerated)	
or MS&E 213	Introduction to Optimization Theory	
MS&E 226	"Small" Data: Prediction, Inference, Causality	
Select one:		
MS&E 223	Simulation	
MS&E 245B	Advanced Investment Science (if not used above)	
MS&E 246	Financial Risk Analytics (if not used above)	
MS&E 322	Stochastic Calculus and Control	
MS&E 349	Financial Statistics	
STATS 207	Introduction to Time Series Analysis	
STATS 240	Statistical Methods in Finance	
Financial Applications (select two):		
MS&E 249	Corporate Financial Management	
MS&E 346	Reinforcement Learning for Stochastic Control Problems in Finance	
MS&E 347	Credit Risk: Modeling and Management	
MS&E 348	Optimization of Uncertainty and Applications in Finance	
MS&E 445	Statistical and Machine Learning Approaches to Problems in Investment Management	
MS&E 448	Big Financial Data and Algorithmic Trading	
STATS 241	Data-driven Financial Econometrics	

Operations and Analytics Concentration (four courses required)

		Units
Required Courses		
MS&E 211X	Introduction to Optimization (Accelerated) (whichever of optimization or analytics wasn't taken for core)	
or MS&E 213	Introduction to Optimization Theory	
or MS&E 226	"Small" Data: Prediction, Inference, Causality	
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)	
MS&E 212	Mathematical Programming and Combinatorial Optimization	
or MS&E 235	Network Analytics	
or MS&E 251	Introduction to Stochastic Control with Applications	
MS&E 260	Introduction to Operations Management	
or MS&E 263	Healthcare Operations Management	
or MS&E 267	Service Operations and the Design of Marketplaces	
Recommended Elective Courses:		
MS&E 212	Mathematical Programming and Combinatorial Optimization	
MS&E 213	Introduction to Optimization Theory	
MS&E 223	Simulation	
MS&E 231	Introduction to Computational Social Science	
MS&E 232	Introduction to Game Theory and Market Design	
MS&E 234	Data Privacy and Ethics	
MS&E 235	Network Analytics	
MS&E 241	Economic Analysis	
MS&E 243	Energy and Environmental Policy Analysis	
MS&E 245A	Investment Science	
MS&E 250A	Engineering Risk Analysis	
MS&E 251	Introduction to Stochastic Control with Applications	
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	
MS&E 260	Introduction to Operations Management	
MS&E 263	Healthcare Operations Management	
MS&E 267	Service Operations and the Design of Marketplaces	
MS&E 292	Health Policy Modeling	

Technology and Engineering Management Concentration (four courses beyond core required)

The course used to satisfy the Organizations and Decisions Core satisfies one of the areas below, but the course units do not double-count.

		Units
Organizations and Strategy (select at least one):		
MS&E 265	Product Management Fundamentals	
MS&E 270	Strategy in Technology-Based Companies	
MS&E 274	Dynamic Entrepreneurial Strategy	
MS&E 278	Patent Law and Strategy for Innovators and Entrepreneurs	
MS&E 280	Organizational Behavior: Evidence in Action	
MS&E 282		
MS&E 284	Designing Modern Work Organizations	
Entrepreneurship and Innovation (select at least one):		
MS&E 270	Strategy in Technology-Based Companies	
MS&E 271	Global Entrepreneurial Marketing	
MS&E 272	Entrepreneurship without Borders	
MS&E 273	Technology Venture Formation	
or CEE 246	Venture Creation for the Real Economy	
MS&E 275	Intelligent Growth in Startups	
MS&E 276	Entrepreneurial Management and Finance	
MS&E 277	Creativity and Innovation	
ENGR 245	The Lean LaunchPad: Getting Your Lean Startup Off the Ground	
Finance and Decisions (select at least one):		
MS&E 240	Accounting for Managers and Entrepreneurs	

MS&E 245A	Investment Science
MS&E 245B	Advanced Investment Science
MS&E 246	Financial Risk Analytics
MS&E 249	Corporate Financial Management
MS&E 250A	Engineering Risk Analysis
MS&E 250B	Project Course in Engineering Risk Analysis
MS&E 252	Decision Analysis I: Foundations of Decision Analysis
MS&E 352	Decision Analysis II: Professional Decision Analysis

Specialized Concentrations (must have approval of the academic adviser)

Computational Social Science (four courses required)

		Units
Statistics (select at least one)		
MS&E 226	"Small" Data: Prediction, Inference, Causality (may not be duplicated in core)	
STATS 203	Introduction to Regression Models and Analysis of Variance	
STATS 305A	Applied Statistics I	
Computation (select at least one)		
MS&E 231	Introduction to Computational Social Science	
CS 246	Mining Massive Data Sets	
Networks (select at least one)		
MS&E 235	Network Analytics	
MS&E 334	Topics in Social Data	
CS 224W	Analysis of Networks	
Social Science (select at least one)		
MS&E 232	Introduction to Game Theory and Market Design	
MS&E 241	Economic Analysis	
MS&E 270	Strategy in Technology-Based Companies	
MS&E 280	Organizational Behavior: Evidence in Action	
MS&E 284	Designing Modern Work Organizations	
ECON 202N	Microeconomics I For Non-Economics PhDs	
PSYCH 212	Classic and contemporary social psychology research	
PSYCH 265	Social Psychology and Social Change	
SOC 220	Interpersonal Relations	
SOC 224B	Relational Sociology	
Recommended Elective Courses		
Causal Inference		
COMM 382	Big Data and Causal Inference	
POLISCI 355C	Causal Inference for Social Science	
Computation		
MS&E 234	Data Privacy and Ethics	
CS 147	Introduction to Human-Computer Interaction Design	
CS 229	Machine Learning	
CS 448B	Data Visualization	
Economics		
MS&E 241	Economic Analysis	
Natural Language Processing		
CS 124	From Languages to Information	
CS 224N	Natural Language Processing with Deep Learning	
CS 224S	Spoken Language Processing	
POLISCI 452	Machine Learning with Application to Text as Data	
LINGUIST 278	Programming for Linguists	
Networks		
SOC 369	Social Network Methods	
Psychology		
PSYCH 216	Public Policy and Social Psychology: Implications and Applications	
PSYCH 238	Wise Interventions	
Sociology		
SOC 214	Economic Sociology	
SOC 218	Social Movements and Collective Action	
SOC 262	The Social Regulation of Markets	
SOC 270	Classics of Modern Social Theory	
SOC 271	Organizational Analysis	
Statistics		
STATS 209	Statistical Methods for Group Comparisons and Causal Inference	
STATS 263	Design of Experiments	
STATS 315A	Modern Applied Statistics: Learning	
STATS 315B	Modern Applied Statistics: Data Mining	

Decision and Risk Analysis Concentration (four courses required)

		Units
Core Courses are restricted as follows:		
MS&E 211	Introduction to Optimization	
or MS&E 211X	Introduction to Optimization (Accelerated)	
or MS&E 213	Introduction to Optimization Theory	
MS&E 221	Stochastic Modeling	
MS&E 252	Decision Analysis I: Foundations of Decision Analysis	
Required Courses (select two):		
MS&E 241	Economic Analysis	
MS&E 250A	Engineering Risk Analysis	
MS&E 251	Introduction to Stochastic Control with Applications	
or EE 263	Introduction to Linear Dynamical Systems	
MS&E 355	Influence Diagrams and Probabilistics Networks	
Policy Course (select one):		
MS&E 243	Energy and Environmental Policy Analysis	
MS&E 292	Health Policy Modeling	
MS&E 293	Technology and National Security	
Project Course:		
MS&E 250B	Project Course in Engineering Risk Analysis	
MS&E 297	"Hacking for Defense": Solving National Security issues with the Lean Launchpad	

Energy and Environment Concentration (six courses required)

		Units
Required Courses:		
MS&E 241	Economic Analysis	
MS&E 243	Energy and Environmental Policy Analysis	
CEE 207A	Understanding Energy	
Three additional courses from energy, policy, or strategy areas below.		
Policy:		
MS&E 292	Health Policy Modeling	

MS&E 293	Technology and National Security
MS&E 294	
MS&E 295	
ECON 251	Natural Resource and Energy Economics
Strategy:	
MS&E 270	Strategy in Technology-Based Companies
MS&E 271	Global Entrepreneurial Marketing
MS&E 272	Entrepreneurship without Borders
MS&E 273	Technology Venture Formation
MS&E 274	Dynamic Entrepreneurial Strategy
MS&E 275	Intelligent Growth in Startups
MS&E 276	Entrepreneurial Management and Finance
MS&E 277	Creativity and Innovation
MS&E 278	Patent Law and Strategy for Innovators and Entrepreneurs
Energy:	
ENERGY 102	Fundamentals of Renewable Power
ENERGY 104	Sustainable Energy for 9 Billion
ME 370A	Energy Systems I: Thermodynamics
ME 370B	Energy Systems II: Modeling and Advanced Concepts
PHYSICS 240	Introduction to the Physics of Energy
PHYSICS 241	Introduction to Nuclear Energy
Recommended Seminars:	
MS&E 441	Policy and Economics Research Roundtable
MS&E 472	Entrepreneurial Thought Leaders' Seminar
ECON 341	Public Economics and Environmental Economics Seminar
ENERGY 301	The Energy Seminar
Recommended Elective Courses:	
MS&E 201	Dynamic Systems
MS&E 211	Introduction to Optimization
or MS&E 211X	Introduction to Optimization (Accelerated)
or MS&E 213	Introduction to Optimization Theory
MS&E 251	Introduction to Stochastic Control with Applications
ECON 250	Environmental Economics
ECON 270	Intermediate Econometrics I
ECON 278	Behavioral and Experimental Economics I
MGTECON 603	Econometric Methods I

Health Systems Modeling Concentration (four courses required)

		Units
Required Courses (select four)		
MS&E 263	Healthcare Operations Management	
MS&E 292	Health Policy Modeling	
MS&E 463	Healthcare Systems Design	
HRP 263	Advanced Decision Science Methods and Modeling in Health	
HRP 392	Analysis of Costs, Risks, and Benefits of Health Care	
Recommended Elective Courses:		
MS&E 256	Technology Assessment and Regulation of Medical Devices	
HRP 256	Economics of Health and Medical Care	
HRP 391	Health Law: Finance and Insurance	

Projects

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

		Units
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 448	Big Financial Data and Algorithmic Trading	3
MS&E 463	Healthcare Systems Design	3-4
Integrated Project Courses		
ENGR 248	Principled Entrepreneurial Decisions	3
MS&E 201	Dynamic Systems	3-4
MS&E 226	"Small" Data: Prediction, Inference, Causality	3
MS&E 243	Energy and Environmental Policy Analysis	3
MS&E 245A	Investment Science	3-4
MS&E 245B	Advanced Investment Science	3
MS&E 246	Financial Risk Analytics	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 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 272	Entrepreneurship without Borders	3-4
MS&E 273	Technology Venture Formation	3-4
MS&E 274	Dynamic Entrepreneurial Strategy	3
MS&E 275	Intelligent Growth in Startups	3
MS&E 277	Creativity and Innovation	3-4
MS&E 280	Organizational Behavior: Evidence in Action	3-4
MS&E 284	Designing Modern Work Organizations	3
MS&E 311	Optimization	3
MS&E 338	Reinforcement Learning	3
MS&E 347	Credit Risk: Modeling and Management	3
MS&E 349	Financial Statistics	3
MS&E 355	Influence Diagrams and Probabilistics Networks	3

Additional Requirements

1. At least 45 units must be in courses numbered 100 and above.
2. The degree program must be completed with a grade point average (GPA) of 3.0 or higher.
3. 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.
4. 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.
5. A maximum of 4 units of directed or individual study units may count toward the letter-grade requirement.
6. All courses used to satisfy core, concentration, or project requirements must be taken for a letter grade.
7. A maximum of three units of 1-unit courses such as seminars, colloquia, workshops, in any department, including MS&E 208A, B, C, and D Practical Training, and MS&E 208E Part-Time Practical Training.

8. A maximum of 18 non-degree option (NDO) units through the Stanford Center for Professional Development (SCPD).
9. Courses taken in Health and Human Performance (e.g. Athletics, Club Sports, Kinesiology, Leadership Innovations, Lifeworks, Outdoor Education, Physical Education, and Wellness Education) may not be applied toward the degree.

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 fully employed working professionals 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 who have completed an undergraduate degree with a minimum of a 3.0 grade point average, may apply to take NDO courses each quarter through the Stanford Center for Professional Development. Completion of multivariable calculus and linear algebra is required for most courses and certificates. 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/programs/graduate-certificates.

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

M.S. 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 M.S. 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 M.S. 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 Analysis and Risk Analysis
- Energy and Environment
- Quantitative Finance
- Health Systems Modeling and 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 Ph.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: Prediction, Inference, Causality
STATS 203	Introduction to Regression Models and Analysis of Variance
STATS 305A	Applied Statistics I
Computation core:	
MS&E 231	Introduction to Computational Social Science
MS&E 235	Network Analytics
CS 246	Mining Massive Data Sets
Networks core:	
MS&E 334	Topics in Social Data
CS 224W	Analysis of Networks
Social Science core:	
MS&E 241	Economic Analysis
MS&E 270	Strategy in Technology-Based Companies
MS&E 280	Organizational Behavior: Evidence in Action
MS&E 274	Dynamic Entrepreneurial Strategy
ECON 202N	Microeconomics I For Non-Economics PhDs
PSYCH 212	Classic and contemporary social psychology research
PSYCH 265	Social Psychology and Social Change
SOC 220	Interpersonal Relations
SOC 224B	Relational Sociology
Recommended:	
Causal Inference	
COMM 382	Big Data and Causal Inference
POLISCI 355C	Causal Inference for Social Science
Computation	
CS 147	Introduction to Human-Computer Interaction Design
CS 229	Machine Learning
CS 448B	Data Visualization
MS&E 234	Data Privacy and Ethics
Economics	
MS&E 241	Economic Analysis
Natural Language Processing	
CS 124	From Languages to Information
CS 224N	Natural Language Processing with Deep Learning
CS 224S	Spoken Language Processing
LINGUIST 278	Programming for Linguists
POLISCI 452	Machine Learning with Application to Text as Data

Networks	
SOC 369	Social Network Methods
Psychology	
PSYCH 216	Public Policy and Social Psychology: Implications and Applications
PSYCH 238	Wise Interventions
Sociology	
SOC 214	Economic Sociology
SOC 218	Social Movements and Collective Action
SOC 262	The Social Regulation of Markets
SOC 270	Classics of Modern Social Theory
SOC 271	Organizational Analysis
Statistics	
STATS 209	Statistical Methods for Group Comparisons and Causal Inference
STATS 263	Design of Experiments
STATS 315A	Modern Applied Statistics: Learning
STATS 315B	Modern Applied Statistics: Data Mining

Students may 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	Introduction to Optimization
or MS&E 211X	Introduction to Optimization (Accelerated)
or MS&E 213	Introduction to Optimization Theory
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	Introduction to Stochastic Control with Applications
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 Probabilistics Networks
Recommended:	
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	
MS&E 321	Stochastic Systems
or STATS 218	Introduction to Stochastic Processes II
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
STATS 200	Introduction to Statistical Inference
or STATS 202	Data Mining and Analysis
or ECON 271	Intermediate Econometrics II

Quantitative Finance

The finance area focuses on the quantitative and statistical study of financial risks, institutions, markets, and technology. Students take courses in probability, statistics, optimization, finance, economics, and computational mathematics as well as a variety of other courses. Recent dissertation topics include studies of machine learning methods for risk management; systemic financial risk; algorithmic trading; optimal order execution; large-scale portfolio optimization; mortgage markets; and statistical testing of financial models. Ph.D. students in the area typically are affiliated with the Center for Financial and Risk Analytics (CFRA).

Prerequisites (may be waived based on prior coursework)	
Mathematics	
MATH 113	Linear Algebra and Matrix Theory
MATH 115	Functions of a Real Variable
or MATH 171	Fundamental Concepts of Analysis
Probability	
MS&E 220	Probabilistic Analysis
or STATS 116	Theory of Probability
MS&E 221	Stochastic Modeling
Statistics	
STATS 110	Statistical Methods in Engineering and the Physical Sciences
Programming	
CS 106A	Programming Methodology
Economics	
MS&E 241	Economic Analysis
or ECON 50	Economic Analysis I
Required Core Courses	
Optimization	

MS&E 211	Introduction to Optimization
or MS&E 211X	Introduction to Optimization (Accelerated)
or MS&E 213	Introduction to Optimization Theory
or MS&E 310	Linear Programming
or MS&E 311	Optimization
Stochastics	
MS&E 321	Stochastic Systems
or MS&E 322	Stochastic Calculus and Control
Statistics	
STATS 200	Introduction to Statistical Inference
or STATS 305A	Applied Statistics I
or STATS 315A	Modern Applied Statistics: Learning
Numerical Methods	
MS&E 223	Simulation
or CME 200	Linear Algebra with Application to Engineering Computations
or CME 206	Introduction to Numerical Methods for Engineering
Strongly Recommended	
STATS 300A	Theory of Statistics I
STATS 310A	Theory of Probability I
Elective Courses (select at least 4)	
MS&E 245A	Investment Science
MS&E 245B	Advanced Investment Science
MS&E 246	Financial Risk Analytics
MS&E 347	Credit Risk: Modeling and Management
MS&E 348	Optimization of Uncertainty and Applications in Finance
MS&E 349	Financial Statistics
ECON 236	Financial Economics I
ECON 237	Financial Economics II
ECON 273	Advanced Econometrics I
ECON 274	Advanced Econometrics II
ECON 276	Computational Econometrics
FINANCE 625	Empirical Asset Pricing
MATH 238	Mathematical Finance
STATS 231	Statistical Learning Theory
STATS 240	Statistical Methods in Finance
STATS 243	Risk Analytics and Management in Finance and Insurance
STATS 315B	Modern Applied Statistics: Data Mining
Students should discuss their course schedule with their dissertation advisors. Other courses in MS&E, Economics, Finance, Scientific Computing, or Statistics at the MS&E 300-level (or comparable in other departments) may be chosen after consulting with the dissertation advisor.	

Quantitative 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 Analysis and Risk Analysis)
Operations Management

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

MS&E 211	Introduction to Optimization
or MS&E 211X	Introduction to Optimization (Accelerated)
or MS&E 213	Introduction to Optimization Theory
MS&E 241	Economic Analysis
or ECON 202N	Microeconomics I For Non-Economics PhDs
MS&E 260	Introduction to Operations Management
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	Introduction to Stochastic Control with Applications
or MS&E 351	Dynamic Programming and Stochastic Control
MS&E 311	Optimization
or EE 364A	Convex Optimization I
MS&E 321	Stochastic Systems
OM research courses (any four):	
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	Probabilistic Analysis
or STATS 116	Theory of Probability
MS&E 221	Stochastic Modeling
or STATS 217	Introduction to Stochastic Processes I
MS&E 241	Economic Analysis
or ECON 50	Economic Analysis I
CS 106A	Programming Methodology
or CS 106X	Programming Abstractions (Accelerated)
MATH 113	Linear Algebra and Matrix Theory
MATH 115	Functions of a Real Variable
or MATH 171	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):	
MS&E 389	Seminar on Organizational Theory
Plus three of the following, which must include at least one 37x course and one 38x course:	
MS&E 370	Current Topics in Strategy, Innovation and Entrepreneurship
MS&E 371	Innovation and Strategic Change
MS&E 372	Entrepreneurship Doctoral Research Seminar
MS&E 376	Strategy Doctoral Research Seminar
MS&E 383	Doctoral Seminar on Ethnographic Research
MS&E 384	Groups and Teams
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 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	Introduction to Optimization
or MS&E 211X	Introduction to Optimization (Accelerated)
or MS&E 213	Introduction to Optimization Theory
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	
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	Introduction to Stochastic Control with Applications
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
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.

Graduate Advising Expectations

The Department of Management Science and Engineering is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide all students in key areas such as selecting courses, navigating policies and degree requirements, and exploring academic opportunities and professional pathways. Faculty advisors additionally guide doctoral students in designing and conducting research, and developing of teaching pedagogy.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

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

Chair: Nicholas Bambos

Professors: Nicholas Bambos, Margaret L. Brandeau, Kathleen M. Eisenhardt, Kay Giesecke, Peter W. Glynn, Ashish Goel, 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: Jose Blanchet, Samuel S. Chiu, Charles E. Eesley, Ramesh Johari, Amin Saberi, Ross D. Shachter, Edison T. S. Tse

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

Professors (Research): 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, Alvin Roth, Tim Roughgarden