COURSE OUTLINE: MH4702

Course Title	**Probabilistic Methods in Operations Research**		
Course Code	**MH4702**		
Offered	Study Year 4, Semester 1		
Course Coordinator	Yan Zhenzhen (Asst Prof)	yanzz@ntu.edu.sg	6513 7466
Pre-requisites	(MH2500 and MH3512) OR (MH2500 and MH3701)		
AU	4		
Contact hours	Lectures: 39, Tutorials: 12		
Approved for delivery from	AY 2021/22 semester 1		
Last revised	17 Feb 2021, 17:32		

Course Aims

Operations Research (OR) is about assessing the best utilization of resources based on scientific principles, it aims to improve efficiency and productivity in complex decision-making situations. You will acquire knowledge in modelling and finding solutions to practical problems under an uncertain circumstance. Students who wish to acquire some mathematical models to solve industrial problems will benefit from this course.

Intended Learning Outcomes

Upon successfully completing this course, you should be able to:

1. Recognise a queueing system and determine its expected queue length and average waiting time.
2. Evaluate a stochastic system, e.g. queueing system using the simulation method
3. Model an operational problem under an uncertain circumstance in a mathematical form
4. Solve the optimization problem under uncertainties
5. Formulate a Markov decision model to solve for a sequential decision making under uncertainty
6. Use one of the algorithms discussed in the lecture to determine the optimal policy for a Markov decision process.

Course Content

General Introduction to Operations Research: Revision of Basic Probability Theory

Basic Queueing System, Birth-death Process, Little’s Formula, The M/M/s, M/M/s/K models, Queue Length and Waiting Time,

Sampling continuous and discrete distribution, Monto Carlo methods, Variance Reduction Techniques

Sensitivity Analysis in a Linear Program, Sample Average Approximation Method, Robust Optimization with Box Uncertainty Set

Formulating Markov Decision Model, Linear Programming Approach, Policy Improvement Algorithm

Assessment

Component	Course ILOs tested	SPMS-MAS Graduate Attributes tested	Weighting	Team / Individual	Assessment Rubrics
Continuous Assessment					
Tutorials					
Assignment	1, 2, 3, 4, 5, 6	**1.** a, b, c, d **2.** a, b, c **3.** a, b **5.** a	20	team	See Appendix for rubric
Mid-semester Quiz					
Short Answer Questions	1, 2	**1.** a, b, c **2.** a, b	20	individual	See Appendix for rubric
Examination (2 hours)					
Short Answer Questions	1, 2, 3, 4, 5, 6	**1.** a, b, c **2.** a, b	60	individual	See Appendix for rubric
		Total	**100%**		

These are the relevant SPMS-MAS Graduate Attributes.

1. Competence

a. Independently process and interpret mathematical theories and methodologies, and apply them to solve problems

b. Formulate mathematical statements precisely using rigorous mathematical language

c. Discover patterns by abstraction from examples

d. Use computer technology to solve problems, and to communicate mathematical ideas

2. Creativity

a. Critically assess the applicability of mathematical tools in the workplace

b. Build on the connection between subfields of mathematics to tackle new problems

c. Develop new applications of existing techniques

3. Communication

a. Present mathematics ideas logically and coherently at the appropriate level for the intended audience

b. Work in teams on complicated projects that require applications of mathematics, and communicate the results verbally and in written form

5. Character

a. Act in socially responsible and ethical ways in line with the societal expectations of a mathematics professional, particularly in relation to analysis of data, computer security, numerical computations and algorithms

Formative Feedback

Midterm Test: Feedback on common mistakes and the level of difficulty of the problems will be given.

Assignments: Students will receive individual written and/or verbal feedback about their assignments, as the lecturer will return each assignment individually.

Learning and Teaching Approach

Lectures (39 hours)	Helps you to understand the motivation and definitions of the concepts and notions, approaches to solving problems in pursuant to the learning outcomes
Tutorials (12 hours)	Assignment: Develops your writing and presentation skills, strengthens your understanding of the concepts and notions, and offers you the opportunity to apply the techniques in problem solving Tutorial: Develops your problem solving skills, reinforces your understanding of the concepts and notions

Reading and References

1. Introduction to Operations Research. Hillier & Lieberman, 10th Ed, McGraw Hill (ISBN 10: 0073376299 ISBN 13: 978-0072535105)
2. Introduction to Probability Models, by Sheldon M. Ross. 10th Edition. (ISBN: 9780128143469)
3. Stochastic Models in Operations Research by D. Heyman and M. Sobel (2 volumes) (ISBN 10: 0486432602 ISBN 13: 9780486432601)

Course Policies and Student Responsibilities

(1) General

You are expected to complete all assignments and take the midterm test. You are expected to take responsibility to follow up with course notes, assignments and course related announcements if they are absent.

(2) Absenteeism

Absence from test and examination without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.

(3) Absence Due to Medical or Other Reasons

If you are sick and not able to attend the midterm, you have to submit the original Medical Certificate (or another relevant document) to the administration to obtain official leave. In this case, the missed assessment component will not be counted towards the final grade. There are no make-up midterm.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the Academic Integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Yan Zhenzhen (Asst Prof)	SPMS-MAS-05-19	6513 7466	yanzz@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	General Introduction to Operations Research: methods and applications, Revision of Basic Probability Theory	1	Read several papers as auxiliary materials to understand what is operations research.
2	Basic Queueing System, Birth-death Process, Little's Formula, The M/M/s, M/M/s/K models, Queue Length and Waiting Time,	1	Chapter 17 of Hillier & Lieberman, 10th Ed
3	Basic Queueing System, Birth-death Process, Little's Formula, The M/M/s, M/M/s/K models, Queue Length and Waiting Time,	1	Chapter 17 of Hillier & Lieberman, 10th Ed
4	Basic Queueing System, Birth-death Process, Little's Formula, The M/M/s, M/M/s/K models, Queue Length and Waiting Time,	1	Chapter 17 of Hillier & Lieberman, 10th Ed
5	Basic Queueing System, Birth-death Process, Little's Formula, The M/M/s, M/M/s/K models, Queue Length and Waiting Time,	1	Chapter 17 of Hillier & Lieberman, 10th Ed
6	Sampling continuous and discrete distribution, Monto Carlo methods, Variance Reduction Techniques	2	Chapter 20 of Hillier & Lieberman, 10th Ed
7	Sampling continuous and discrete distribution, Monto Carlo methods, Variance Reduction Techniques	2	Chapter 20 of Hillier & Lieberman, 10th Ed
8	Introduction to optimization under uncertainty. Introduce Stochastic Optimization and Robust optimization and Sample Average Approximation Method	3, 4	Chapter 3,6,7 of Hillier & Lieberman, 10th Ed
9	Introduction to optimization under uncertainty. Introduce Stochastic Optimization and Robust optimization and Sample Average Approximation Method	3, 4	Chapter 3,6,7 of Hillier & Lieberman, 10th Ed
10	Introduction to optimization under uncertainty. Introduce Stochastic Optimization and Robust optimization and Sample Average Approximation Method	3, 4	Chapter 3,6,7 of Hillier & Lieberman, 10th Ed
11	Introduction to optimization under uncertainty. Introduce Stochastic Optimization and Robust optimization and Sample Average Approximation Method	3, 4	Chapter 3,6,7 of Hillier & Lieberman, 10th Ed
12	Formulating Markov Decision Model, Linear Programming Approach, Policy Improvement Algorithm	5, 6	Chapter 19 of Hillier & Lieberman, 10th Ed
13	Formulating Markov Decision Model, Linear Programming Approach, Policy Improvement Algorithm	5, 6	Chapter 19 of Hillier & Lieberman, 10th Ed

Appendix 1: Assessment Rubrics

Rubric for Tutorials: Assignment (20%)

Criteria	Standards		
	Fail standard	**Pass standard**	**High standard**
Methods of approach	· Using methods that are irrelevant or do not apply to the given problem. · Invoking theorems whose conditions are not satisfied.	· Using relevant methods that help solve the problem. · Invoking theorems whose conditions are satisfied.	Finding methods and utilizing theorems that are both relevant and effective
Validity of reasoning	Reasoning is logically invalid.	Reasoning is logically valid.	Reasoning is logically valid and effective.
Clarity of argument	Reasoning is poorly explained or not explained at all.	Reasoning is clear but may contain some gaps.	Reasoning is clear, precise with no or insignificant gaps.

Rubric for Mid-semester Quiz: Short Answer Questions (20%)
Point-based

Rubric for Examination: Short Answer Questions (60%)
Point-based