# Annexe A: New/Revised Course Content in OBTL+ Format

## Course Overview

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|---|---|
| Expected Implementation in Academic Year | AY2021-2022 |
| Semester/Trimester/Others (specify approx. Start/End date) | Semester 1 |
| Course Author<br>* Faculty proposing/revising the course | Yan Zhenzhen |
| Course Author Email | yanzz@ntu.edu.sg |
| Course Title | Probabilistic Methods in Operations Research |
| Course Code | MH4702 |
| Academic Units | 4 |
| Contact Hours | 51 |
| Research Experience Components | Not Applicable |

## Course Requisites (if applicable)

| | |
|---|---|
| Pre-requisites | (MH2500 and MH3512) OR (MH2500 and MH3701) |
| Co-requisites | |
| Pre-requisite to | |
| Mutually exclusive to | |
| Replacement course to | |
| Remarks (if any) | |

## 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.

## Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

| | |
|---|---|
| ILO 1 | Recognise a queueing system and determine its expected queue length and average waiting time. |
| ILO 2 | Evaluate a stochastic system, e.g. queueing system using the simulation method |
| ILO 3 | Model an operational problem under an uncertain circumstance in a mathematical form |
| ILO 4 | Solve the optimization problem under uncertainties |
| ILO 5 | Formulate a Markov decision model to solve for a sequential decision making under uncertainty |
| ILO 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

## Reading and References (if applicable)

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) (ISBN10: 0486432602 ISBN 13: 9780486432601)

## Planned Schedule

| Week or Session | Topics or Themes | ILO | Readings | Delivery Mode | 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 | | |

| Week or Session | Topics or Themes | ILO | Readings | Delivery Mode | Activities |
|---|---|---|---|---|---|
| 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 | | |

| Week or Session | Topics or Themes | ILO | Readings | Delivery Mode | Activities |
|---|---|---|---|---|---|
| 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 | | |

| Week or Session | Topics or Themes | ILO | Readings | Delivery Mode | Activities |
|---|---|---|---|---|---|
| 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 | | |

## Learning and Teaching Approach

| Approach | How does this approach support you in achieving the learning outcomes? |
|---|---|
| Lectures | Helps you to understand the motivation and definitions of the concepts and notions, approaches to solving problems in pursuant to the learning outcomes |
| Tutorials | Assignment:<br>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<br>Tutorial:<br>Develops your problem solving skills, reinforces your understanding of the concepts and notions |

## Assessment Structure

Assessment Components (includes both continuous and summative assessment)

| No. | Component | ILO | Related PLO or Accreditation | Weightage | Description of Assessment Component | Team/Individual | Rubrics | Level of Understanding |
|---|---|---|---|---|---|---|---|---|
| 1 | Continuous Assessment (CA): Assignment(Assignment ) | 1, 2, 3, 4, 5, 6 | 1. a, b, c, d 2. a, b, c 3. a, b 5. a | 20 | | Team | Analytic | Extended Abstract |
| 2 | Continuous Assessment (CA): Test/Quiz(Mid-semester Quiz - Short Answer Questions) | 1, 2 | 1. a, b, c 2. a, b | 20 | | Individual | Analytic | Extended Abstract |
| 3 | Summative Assessment (EXAM): Final exam(Short Answer Questions ) | 1,2, 3, 4, 5, 6 | 1. a, b, c 2. a, b | 60 | | Individual | Analytic | Extended Abstract |

Description of Assessment Components (if applicable)

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.

## NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

| Attributes/Competency | Level |
|---|---|
| Collaboration | Advanced |
| Communication | Intermediate |
| Creative Thinking | Intermediate |
| Decision Making | Advanced |
| Problem Solving | Advanced |

# Course Policy

Policy (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. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (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.

Policy (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.

Policy (Others, if applicable)

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.