Lingnan University
Course Syllabus

Course Title	:	Operations Simulation with Decision Analysis
Course Code	:	CDS3002
Recommended Study Year	:	3
No. of Credits/Term	:	3
Mode of Tuition	:	Sectional Approach
Class Contact Hours	:	3 hours per week
Category in Major Prog.	:	Required
Prerequisite(s)	:	(a) CDS1003 Probability and Statistics 1, or (b) BUS1102 Statistics for Business
Co-requisite	:	Nil
Exclusion	:	Nil
Exemption Requirement	:	Nil

Brief Course Description:

This course is designed for Data Science students. They are required to have previous knowledge of probability and statistics. Simulation is a commonly used and practical technique for modelling and analysing real operating systems to make more effective decisions. Examples of such systems include transportation, supply chain networks, job flow, airports, banks, ocean terminals, information systems, emergency response systems and human behaviour in a social network. Due to the considerable complexity of real systems, many people and organisations find it difficult to investigate human activities, manufacturing and service designs and processes without a computer simulation model. More than 89% of Fortune 500 firms have used simulation for system improvement and have experienced the benefits for a long time. This course is designed to introduce basic concepts of system modelling and computer simulation. The process and methodology of using simulation for problem solving and decision making are emphasised.

Moreover, the course would utilize interactive Colab notebooks and the Python programming language to help students better understand simulation system modeling. Some assignments may require students to write simple Python programs to build a simulation pipeline.

Aims:

This course deals with the data collection, simulation, analysis, and decisions related to human activities, operations, and optimization of system performance. Students are expected to gain a comprehensive understanding of

1. identification, collection, and probability fitting and estimates of data;
2. realistic and feasible construction of simulation systems;
3. understanding and applications of the simulation results.

Learning Outcomes (LOs):

On completion of this course, students are expected to be able to:

1. apply critical thinking skills to analyze problems and support decision making.

2. collect, manage, store, process, analyze, and visualize data from different data sources with various characteristics.
3. formulate real-world problems as simulation models.
4. develop computer programs to simulate systems of any size.
5. understand the implications of simulation results and apply them to solve real problems.

Indicative Contents:

Module 1: Fundamental Simulation Concepts
Introduction to simulation systems
System modeling fundamentals
Review of probability theory and statistics essentials
Introduction to Colab notebooks

Module 2: Monte Carlo Simulation
Overview of Monte Carlo methods
Random number generation
Monte Carlo estimation and decision making
Hands-on implementation in Colab

Module 3: Queuing Model
Queuing basics: compoenents of queues model and notations
Key performance metrics
Simulation of queuing systems

Case studes: single/multiple server, bottleneck analysis

Module 4: Markov Decision Process
MDP fundamentals: states, actions, rewards, etc.
Connection to reinforcement learning
Solution appraoches: value iterations, policy iterations, Q-learning
Applications: inventory control, navigation and simple games

Module 5: Genetic Algorithm
Simluation-based optimization and evolutionary strategies
Genetic algorithm foundation: representation and fitness function
Genetic operations: selection, crossover, mutation, replacement, elitism, etc.
Algorithm implementation and parameter tuning
Application: scheduling, allocation, etc.

Module 6: Other Simluation Based Optimizations
Connection to artificial intelligence
Simulated annealing
Tabu search
Particle swarm optimization

Teaching Method:

The course will adopt a lecture-based sectional format with a focus on the software applications in simulation. All classes will take place in a computer lab, where we lecture practical concepts, skills, and techniques, and develop simple programs to the management of real systems and processes. In order to improve the students' skills of solving real problems, we will provide the students with an opportunity to work on real projects.

We encourage the students to actively participate in all classes. We will deliver to students our teaching materials and other materials (e.g., complementary notes, assignments, solutions and cases) through email or other feasible ways. The students are responsible to organize and read the materials.

In classes, we use the teaching notes in .pdf or .ppt format, as well as Colab interactive notebooks. In addition, we also use the whiteboard to solve some numerical examples. We will post all of our announcements by email, and also show these announcements in class. All students can feel free to meet with the instructor for any question. However, if a student hopes to see the instructor, the student should make an appointment by e-mail and/or phone.

Measurement of Learning Outcomes:

1. Starting from Module 2, students will critically think about how to construct models to simulate real systems/operations. All students are required to *independently* identify and collect data, estimate best-fitting probability distributions, develop simple simultation programs, and learn implications from simulation results. Every student's individual performance will be evaluated in his or her assignments and final exam for **learning outcomes 1, 4, and 5**.
2. At the end of this course, students are required to work on real-life simulation projects and gain experience on applying modern simulation technology for problem solving in a variety of real systems and operations. Specifically, each student will participate in a group which will be formed by the students themselves. It is students' responsibility to find a real world problem for system modeling and simulation. The project should be carefully selected to demonstrate the meaningful use of simulation and to be completed in a reasonable amount of time.

   Each group will identify a real simulation system, conduct data collection and simulation, and write a project report including at least the following sections: (i) **Introduction**: background of the organization involved, decision problems under study, and justification of using simulation for solving the problem; (**ii**) **Problem formulation**: variables and constraints, system performance measures and objective functions, and interrelationship between variables; (**iii**) **Data collection and analysis**: methods of data collection, and data analysis; (**iv**) **model construction and validation**: simulation model written using Arena, model verification and validation; (**v**) **model experimentation and output analysis**; (**vi**) **conclusion and recommendation**: the interpretation of simulation results, and recommendations to solve the problem; and (**vii**) **limitations and further improvement**: the limitation of current study, and suggested improvement in the future.

   Every student's performance in project study will be evaluated for **learning outcomes 1, 2, 3, 4, and 5**.

Assessment:

In-class performance	20%
Group based project analysis and presentation	20%*
Individual assignments	20%
End-of-term Examination	40%
Total	100%

* For group-based case study, the whole group will be given a common grade depending on the group's performance.

Required/Essential Readings:

1. There is no single official textbook for this course. Students should focus on lecture notes and notebook examples. Topics are selected based on popularity and real-world application usuage. Students could find relavent contents from supplementary readings.

Recommended/Supplementary Readings:

1. Law, Averill M. *Simulation Modeling and Analysis*. 6th ed., McGraw-Hill Education, 2024.
2. Ross, Sheldon M. *Simulation*. 6th ed., Academic Press, 2022.
3. Hillier, Frederick S., and Gerald J. Lieberman. *Introduction to Operations Research*. 11th ed., McGraw Hill Education, 2021.
4. Ciaburro, Giuseppe. *Hands-On Simulation Modeling with Python*. 2nd ed. Packt Publishing, 2022.

Important Notes:

(1) Students are expected to spend a total of 9 hours (i.e. 3 hours of class contact and 6 hours of personal study) per week to achieve the course learning outcomes.

(2) Students shall be aware of the University regulations about dishonest practice in course work, tests and examinations, and the possible consequences as stipulated in the Regulations Governing University Examinations and Coursework. In particular, plagiarism, being a kind of dishonest practice, is "the presentation of another person's work without proper acknowledgement of the source, including exact phrases, or summarised ideas, or even footnotes/citations, whether protected by copyright or not, as the student's own work". Students are required to strictly follow university regulations governing academic integrity and honesty.

(3) Students are required to submit writing assignment(s) using Turnitin.

(4) To enhance students' understanding of plagiarism, a mini-course "Online Tutorial on Plagiarism Awareness" is available on https://pla.ln.edu.hk/.

(5) Students must adhere to the University's guidelines and practices when using Generative Artificial Intelligence (GAI) tools. The official documents *"Guidelines for Using GAI Tools at Lingnan University" and "Best Practices for Ethical and Responsible Use of GAI Tools in Course Assessments" can be found here: https://www.ln.edu.hk/tlc/generative-artificial-intelligence/gai-guidelines-best-practices* .

Rubrics for Assessments (CDS3002 – Operations Simulation with Decision Analysis**)**

Assessment Task 1: In-Class Performance

- **Program Learning Outcomes**:
  Learning Goal 1: Students can apply critical thinking skills to analyze problems and support decision making.
  Learning Goal 3: Formulate real-world problems as simulation models.
  Learning Goal 5: Students can understand the implications of simulation results and apply them to solve real problems.
- **Process**: Every student will be assessed according to his or her study performance on various class activities, which include questions, comments and recommendations, responses to the instructor's questions, and others.
- **QA Criterion**: In terms of the overall performance for all traits, 80% of students will reach the level of satisfactory or above.
- **Maximum Score**: 80.
- **The cutoff score for satisfactory performance**: 60

Traits	Very Unsatisfactory (0 point)	Unsatisfactory (5 points)	Fair (10 points)	Satisfactory (15 points)	Very Satisfactory (20 points)
Able to attend all the classes.	Does not attend 20% or above of the classes without providing strong evidence (e.g., medical proofs) to justify the absences.	Attends at least 20% of the classes but does not attend 40% or above of the classes without providing strong evidence to justify the absences.	Attends at least 40% of the classes but does not attend 60% or above of the classes without providing strong evidence to justify the absences.	Attends at least 60% of the classes but does not attend 80% or above of the classes without providing strong evidence to justify the absences.	Attends at least 80% of the classes.
Able to apply critical thinking skills to analyze problems and support decision making.	Does not ask any questions in classes.	Asks some questions that are not well-related to simulation.	Asks 2 or less questions that are related to simulation.	Asks more than 2 but less than 5 questions that are related to simulation.	Asks at least 5 questions related to simulation.
Able to formulate real-world problems as simulation models.	Does not formulate a simulation model or the formulation is completely incorrect .	Formulates a simulation model, but key elements of the real-world problem are missing or incorrect.	Formulates a basic simulation model, but assumptions or system relationships are incomplete.	Correctly formulates a simulation model with minor omissions.	Clearly and accurately formulates a complete simulation model representing the real-world problem.
Able to respond to the instructor's questions in classes	Does not respond to any question raised by the instructor.	Responsd to at most 2 questions given by the instructor.	Responds to 2 or more questions given by the instructor, but does not provide any details.	Responds to 2 or more questions and also provides the details, but at least one response is not correct.	Responds to 2 or more questions with the details, and all responses are correct.

Assessment Task 2: Group Case study

- **Program Learning Outcomes**:
  Learning Goal 1: Students can apply critical thinking skills to analyze problems and support decision making.
  Learning Goal 2: Students can collect, manage, store, process, analyze, and visualize data from different data sources with various characteristics.
  Learning Goal 3: Formulate real-world problems as simulation models.
  Learning Goal 4: Students are able to develop programs to simulate systems of any size.
  Learning Goal 5: Students can understand the implications of simulation results and apply them to solve real problems.
- **Process**: Every student will be assessed according to his or her performance in case study.
- **QA Criterion**: In terms of the overall performance for all traits, 80% of students will reach the level of satisfactory or above.
- **Maximum Score**: 80
- **The cutoff score for satisfactory performance**: 60

Traits	Very Unsatisfactory (0 point)	Unsatisfactory (5 points)	Fair (10 points)	Satisfactory (15 points)	Very Satisfactory (20 points)
Able to actively participate a case study group.	Do not participate in any case discussion.	Participate some case discussions but do not actively work on the case.	Actively work on all cases, but make some mistakes during the case discussions.	Actively work on the case, but make some minror mistakes in the case study.	Actively work on the case, and do not have any mistakes in the case study.
Able to collect, manage, store, process, analyze, and visualize data from different data sources with various characteristics, and deploy the results in relevant information systems.	Do not properly identify a data source.	Identify a proper data source. but cannot collect any useful data.	Identify a proper data source and also collect some useful data but the data is not sufficient.	Identify a proper data source and also collect sufficient, useful data but cannot use "Input Analyzer" to analyze the data.	Identify a proper data source, collect sufficient, useful data, and also use "Input Analyzer" to analyze the data.
Able to formulate real-world problems as simulation models.	Does not formulate a simulation model or the formulation is completely incorrect .	Formulates a simulation model, but key elements of the real-world problem are missing or incorrect.	Formulates a basic simulation model, but assumptions or system relationships are incomplete.	Correctly formulates a simulation model with minor omissions.	Clearly and accurately formulates a complete simulation model representing the real-world problem.
Able to develop programs to simulate systems of any size.	Do not understand how to develop a simulation program.	Understand the simulation process but do not understand how to use the programming language to construct the simulation model.	Understand how to construct the simulation model, but the simulation model has some problems.	Construct a correct simulation model, but, the model cannot properly run and generate simulation results.	Construct a correct simulation model that can properly run and generate simulation results.
Able to understand the implications of simulation results and apply them to solve real problems.	Do not include any implications.	Find some implications that cannot help improve the simulation system.	Find a few minor implications that can somewhat help improve the system performance.	Find a few significant implications that can help improve the system performance.	Find considerable implications that can help improve the system performance.

Assessment Task 3: Individual Assignments

- **Program Learning Outcomes**:
  Learning Goal 1: Students can apply critical thinking skills to analyze problems and support decision making.
  Learning Goal 3: Formulate real-world problems as simulation models.
  Learning Goal 4: Students are able to develop programs to simulate systems of any size.
  Learning Goal 5: Students can understand the implications of simulation results and apply them to solve real problems.
- **Process**: Every student will be assessed according to his or her performance in each assignment.
- **QA Criterion**: In terms of the overall performance for all traits, 80% of students will reach the level of satisfactory or above.
- **Maximum Score**: 80
- **The cutoff score for satisfactory performance**: 60

Traits	Very Unsatisfactory (0 point)	Unsatisfactory (5 points)	Fair (10 points)	Satisfactory (15 points)	Very Satisfactory (20 points)
Able to formulate real-world problems as simulation models.	Does not formulate a simulation model or the formulation is completely incorrect .	Formulates a simulation model, but key elements of the real-world problem are missing or incorrect.	Formulates a basic simulation model, but assumptions or system relationships are incomplete.	Correctly formulates a simulation model with minor omissions.	Clearly and accurately formulates a complete simulation model representing the real-world problem.
Able to develop programs to simulate systems of any size.	Do not understand how to develop a simulation program.	Understand the simulation process but do not understand how to use the programming language to construct the simulation model.	Understand how to construct the simulation model, but the simulation model has some problems.	Construct a correct simulation model, but, the model cannot properly run and generate simulation results.	Construct a correct simulation model that can properly run and generate simulation results.
Able to understand the implications of simulation results and apply them to solve real problems.	Do not include any implications.	Find some implications that cannot help improve the simulation system.	Find a few minor implications that can somewhat help improve the system performance.	Find a few significant implications that can help improve the system performance.	Find considerable implications that can help improve the system performance.

Assessment Task 4: End-of-Term (Final) Examination

- **Program Learning Outcomes**:
  Learning Goal 1: Students can apply critical thinking skills to analyze problems and support decision making.
  Learning Goal 3: Formulate real-world problems as simulation models.
  Learning Goal 5: Students can understand the implications of simulation results and apply them to solve real problems.
- **Process**: Every student will be assessed according to his or her performance in the final exam, which is an open-book exam.
- **QA Criterion**: In terms of the overall performance for all traits, 80% of students will reach the level of satisfactory or above.
- **Maximum Score**: 100
- **The cutoff score for satisfactory performance**: 60

Traits	Very Unsatisfactory (0 point)	Unsatisfactory (5 points)	Fair (12 points)	Satisfactory (18 points)	Very Satisfactory (25 points)
Ability to clearly explain the overall simulation methodology and modeling process	Cannot describe the simulation approach or key steps in the simulation process.	Provides a vague or incomplete description of the simulation approach with major conceptual errors.	Describes the main steps of the simulation process but lacks clarity, logical flow, or justification.	Clearly describes the simulation process (problem definition, data analysis, modeling, experimentation, and analysis) with minor gaps in reasoning.	Provides a clear, logical, and well-structured explanation of the simulation approach, justifying modeling choices and linking the process to decision makingm.
Able to formulate real-world problems as simulation models.	Does not formulate a simulation model or the formulation is completely incorrect .	Formulates a simulation model, but key elements of the real-world problem are missing or incorrect.	Formulates a basic simulation model, but assumptions or system relationships are incomplete.	Correctly formulates a simulation model with minor omissions.	Clearly and accurately formulates a complete simulation model representing the real-world problem.
Able to understand the implications of simulation results and apply them to solve real problems.	Do not include any implications.	Find some implications that cannot help improve the simulation system.	Find a few minor implications that can somewhat help improve the system performance.	Find a few significant implications that can help improve the system performance.	Find considerable implications that can help improve the system performance.