NANYANG TECHNOLOGICAL UNIVERSITY
NANYANG BUSINESS SCHOOL
BC2410
PRESCRIPTIVE ANALYTICS: FROM DATA TO DECISIONS

Academic Year	:	2023/2024	**Semester**	:	2
Course Coordinator	:	Tang Qinshen			
Pre-requisites	:	BC0401 or AB0403 or MH1201 or MH1403 or CE1103 or SC1003or CZ1103 or CE2002, or CZ2002, SC2002			
No. of AUs	:	4			
Contact Hours	:	52 hours			

A) Course Aims

In the recent era, numerous corporations and public entities are directing substantial resources towards a diverse array of analytical methodologies. Prescriptive Analytics emerges as a critical frontier that transcends the scope of deciphering past occurrences (Descriptive Analytics) and forecasting future events (Predictive Analytics). It delves into the realm of actionable insights, elucidating the optimal sequence of actions for companies and public organizations to bolster their decision-making process. This course will help students to comprehensively approach prescriptive analytics, bridging the gap between raw data and informed decision-making strategies. The curriculum seamlessly integrates the two below pivotal facets.

1. Data-driven Optimization Theories and Techniques:
Central to this module is an exploration of a spectrum of optimization theories and techniques that are underpinned by data-driven methodologies. Students will have exposure to optimization paradigms, including linear optimization, discrete optimization, network optimization, quadratic optimization, stochastic optimization, and robust optimization. Students are equipped with the analytical prowess to harness these optimization techniques in diverse scenarios.

2. Important Business Applications in Finance, Investments and Operations Management:
This course segment will unfurl the tangible impact of prescriptive analytics across domains such as finance, investment, and operations management. The materials will indicate how the methodologies are applied in real industry, including but not limited to portfolio selection, asset allocation, revenue optimization, pricing strategies, appointment scheduling, retail operations, and project management. The examples will be diversified from close to student life such as course selection, study loan to more complex such as portfolio management or monetized arbitrage.

By enrolling in this course, students embark on a transformative journey where they traverse the intersection of cutting-edge analytics and pragmatic decision-making. Through a blend of comprehensive theoretical exposition and real-world case studies, learners emerge as adept navigators of the intricate landscape of data-driven optimization and its tangible applications, poised to drive innovation and foster informed choices in an increasingly data-driven world. The group project will also act as an additional important part to give you hands-on experience and problem-solving skills on a realistic problem.

We will also place a specific focus on analyzing real data and solving optimization models using Python with commercial solver Gurobi*.
* Academic version is free.

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B) Intended Learning Outcomes (ILO)/Objectives

By the end of this course, you (as a student) would be able to:

(1) Explain the principles of prescriptive analytics, and identify real-world business problems that can be addressed by prescriptive analytics techniques.
(2) Apply analytical tools to analyse varying kinds of data and find underlying patterns.
(3) Identify problems for business cases based on the analysed data.
(4) Model the problems with data-driven optimization tools.
(5) Solve optimization problems using programming, e.g., Python, with commercial solver Gurobi.
(6) Formulate a strategy to apply analytical tools to make real-world decisions.
(7) Make a case for the role and importance of prescriptive analytics.

See Annex F for learning objective taxonomy.

C) Course Content

This course unfolds over five engaging modules, each accompanied by real-world examples and/or datasets for hands-on experience. We'll kick off with an introduction to prescriptive analytics and a refresher on elementary linear algebra. Weeks two to four delve into linear optimization, highlighting its role in areas like asset cash flow matching and production planning. Module two introduces integer programming, optimizing dilemmas like project and course selection. In the third module, we'll navigate network optimization, applying it to practical challenges such as Hawker centre inspections and project management. Module four centers on quadratic optimization, guiding you through savvy portfolio decisions. We'll conclude with the fifth module, venturing into decision-making amidst uncertainty. Here, we'll explore the realms of stochastic and robust optimization, elucidating their roles in scenarios like stochastic portfolio optimization and inventory management.

D) Assessment (includes both continuous and summative assessment)

Assessment for face-to-face or hybrid teaching

Component	ILO Tested	NBS Learning Goal (Refer to Appendix 1 for list)	Weightage	Team/Individual	Assessment Rubrics (attach rubrics in appendix)
1. Class Participation	ILO1 - 7	Oral Communication; Critical Thinking	15%	Individual	Annex B1
2. Group Assignments+	ILO2 - 5	Teamwork & Interpersonal Skills; Problem Solving and Decision Making; Acquisition of Knowledge	25%	Team	Annex B2 and B4
3. Group Project (written report 25% + in-class presentation 15%*+)	ILO2-7	Teamwork & Interpersonal Skills; Oral Communication; Problem-solving & Decision making	40%	Team (25%) + Individual (15%)	Annex B2, B3, and B4
4. Mid-Term Quiz^	ILO2, ILO4, ILO5, ILO6	Problem-solving and Decision Making; Acquisition of Knowledge	20%	Individual	N.A

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Total	100%		

*Students to do group project presentation during week 13. Every team member is required to present.

+Peer evaluation will be incorporated. Peer evaluation will adopt the use of Annex B4 to assess individual team member's contribution to be submitted through NTULearn. It will be a mandatory submission for all students. Each student is required to fill in the contribution of all team members in the same group. Should the contribution be significantly unequal, assignment/project marks of individual student will be weighted accordingly to peer evaluation input from group members according to the instruction in page 13 in this document.

^The mid-term quiz could be purely open-ended questions or a combination of MCQs and open-ended questions.

Description of Assessment Components:

Group Assignments: There will be 3 group assignments for this class. You are required to solve 2-5 problems as a team for each assignment. The group assignments are designed to prepare you well for analyzing data and modeling real world problems.

Group Project: The project for this class is to do careful modeling and optimization of a real application. Choose a problem to address that is of particular interest to your group. Your project should include a clearly defined business problem, assumptions, model setting, optimization formulation, and computational results. Each group would have to present and submit the report, including the code after the presentation but within same week.

All parts of the project will be primarily evaluated in the following aspects:
a. Innovation: is the problem interesting and new?
b. Relevance: are the problem and model practical?
c. Rigor: is the model formulation correct?

E) Formative feedback

You are required to participate in classroom discussions and will be accessed based on your participation and the quality of your inputs. You will receive verbal feedback during and after the in-class discussion. Assignments will be graded, answer keys will not be provided, but common mistakes and weaknesses will be reviewed in class. You will receive feedback on your group project in one week after the in-class presentation. Group peer evaluation is mandatory at the end of the semester.

F) Learning and Teaching approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures and classroom discussions	Most of the classes will be conducted via the "Lectures and Classroom Discussions" approach. Lectures will facilitate me to articulate the key concepts and methodologies in prescriptive analytics; Classroom discussions will demonstrate your learning progress, allowing you to share your intuitions, to express your difficulties in understanding the content, and it also provides me opportunities to assess your ability to think critically and articulate clearly.
Case Studies	Case studies will focus on the applications of the analytics tools and methodologies of mathematical formulation. The roles of the instructors are to facilitate discussion and to guide you to apply the concepts and theories. You are expected to adopt, adapt and synthesize the acquired concepts and theories into real business problems.

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Group Project	Each group has approximately four students. You are required to choose a business problem to address that is of particular interest to you. The project should be careful modeling and optimization of a real application. This project will comprehensively demonstrate your ability to identify and define business problems, make assumptions clearly, and formulate optimization models properly. Through the group project, you will have a deep understanding of the role and importance of prescriptive analytics.
Exercises	Exercises, both in-class and off-class, not only help build the fundamental technical knowledge required for this course, but also help develop your individual learning abilities and attitudes toward active learning. Answers for in-class exercises will be provided after the discussion, but answers for off-class exercises will not be offered.

G) Reading and References

Recommended books:

- [CR] Gerard Cornuejols and Reha Tütüncü. *Optimization Methods in Finance*. Vol. 5. Cambridge University Press.
- [H] Frederick S. Hillier. *Introduction to Operations Research*. Tata McGraw-Hill Education, 2012.
- [AW] Christian Albright and Wayne L. Winston. *Business Analytics: Data Analysis and Decision Making*. Cangage Learning, 2015.
- [BOP] Dimitris Bertsimas, Allison O'Hair and Bill Pulleyblank. *The Analytics Edge*, Dynamic Ideas, 2016. ISBN: 978-0989910897.
- [G] Gilbert Strang. *Introduction to Linear Algebra*. 5th ed. Wellesley, MA: Wellesley-Cambridge Press, February 2016. ISBN: 9780980232776

Other Materials:

Lecture slides, exercises, assignments, and other course materials will be made available on the course website (**NTULearn)** in due time. You shall be notified via university email whenever new materials are available. The course website will also be used for announcements and other course communication purposes. You are therefore encouraged to regularly check the course website and your university email account for any updates.

H) Course Policies and Student Responsibilities

(1) General

You are expected to complete all assigned pre-class readings and activities, attend all seminar classes punctually, and take all scheduled assignments and tests by due dates. You are expected to take responsibility to follow up with course notes, assignments, and course-related announcements for seminar sessions they have missed. You are expected to participate in all seminar discussions and activities.

(2) Absenteeism

Absence from class 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.

If you miss a lecture, you must inform the course instructor via email prior to the start of the class.

I) 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.

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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.

J) Course Instructors

Instructor	Office Location	Phone	Email	Consultation Hours
Dr. Tang Qinshen	ABS-06-042	(65) 6592 3265	qinshen.tang@ntu.edu.sg	TBD

K) Planned Weekly Schedule

Week	Topic	Applications	ILO	Readings/ Activities
1	Introduction to prescriptive analytics	N.A.	1,5,7	Lecture slides BOP, Chapter 1. G, Chapter 1 & 2
2	Linear optimization	Manufacturing problem, production scheduling problem, transportation problem, scheduling problem, revenue management problem	1,2,3,4,6	Lecture slides CR, Chapter 3
3	Hands-on session 1	Investment under taxation, investment on bonds	2,5	Lecture slides
4	Geometry of linear optimization	Pottery company's problem	2,3,4,5,6	Lecture slides H, Chapter 3
5	Sensitive analysis and duality	Pottery company's problem	2,3,4,5,6	Lecture slides CR, Chapter 4 H, Chapter 6
6	Discrete optimization	Project selection problem, course selection, Sudoku	1,2,3,4,6	Lecture slides H, Chapter 12 CR, Chapter 12
7	Tutorial	Short-term financing problem, facility location problem	2,5	Lecture slides
8	Network optimization	Transportation problem, assignment problem, shortest/longest path problem, project management	1,2,3,4,6	Lecture slides H, Chapter 10
9	Hands-on session 2	Arbitrage, travelling salesman problem		
10	Stochastic optimization	Fund investment, demand modelling and prediction	1,2,3,4,6	Lecture slides CR, Chapter 16
11	Quadratic optimization	Portfolio optimization problem	1,2,3,4,6	Lecture slides CR, Chapter 7 & 8
12	Stochastic and robust optimization	Newsvendor problem	1,2,3,4,6	Lecture slides CR, Chapter 16
13	Group project presentations	N.A.	2,3,4,5,6,7	

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ANNEX B1: ASSESSMENT CRITERIA FOR CLASS PARTICIPATION

Traits	Performance		
	Lacking (0-4)	**Good (5-7)**	**Excellent (8-10)**
Participation frequency	Does not contribute in lesson	Occasionally contributes in lesson	Contributes in all lessons
Participation quality	No contributions/Contributions lack substance	Contributions demonstrate knowledge of subject matter	Contributions demonstrate understanding and insightful

ANNEX B2: ASSESSMENT CRITERIA FOR Assignments and Group Project

Traits	Performance	
Define the Problem	**Not Yet** Does not identify the problem clearly; demonstrates limited understanding of the problem or related contextual factors.	**Substantially Developed** Identifies the problem clearly and thoroughly; demonstrates the ability to construct a clear and insightful problem statement with evidence of all relevant contextual factors.
	Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
Devise Strategies to Solve the Problem	**Not Yet** Selects a strategy without regard to fit; does not demonstrate the ability to consider new strategies even if his/her approach is clearly not appropriate; identifies alternatives that reflect limited understanding of the situation.	**Substantially Developed** Identifies multiple strategies for solving the problem that apply within a specific context; demonstrates the ability to invert a process to form a plan and clearly articulates his/her decision-making process; identifies alternatives that reflect an in depth understanding of the situation.
	Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
Assess implementation feasibility	**Not Yet** Does not examine how well the stakeholders/ beneficiaries are involved and not able to identify areas of risk and possible side-effects. Does not specify how the implementation will be monitored and controlled. No indicators or instruments to review or analyze the success of the action.	**Substantially Developed** Clearly assess how well the stakeholders/ beneficiaries are involved; considers areas of risk and provides insights in addressing possible side-effects. Able to state how the implementation will be monitored effectively; identifies the stages at which progress should be measured and specify what results are expected to have been achieved at these stages.

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	Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
Evaluate Outcomes	**Not Yet** Reviews results superficially in terms of the problem defined with no consideration of need for further work.	**Substantially Developed** Reviews results relative to the problem defined with thorough, specific considerations of need for further work.
	Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	

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ANNEX B3: ASSESSMENT CRITERIA FOR PRESENTATION

Traits		Performance	
Communication Outcome	• Has a clear message for audience • Maximizes likelihood of audience accepting the message	**Not Yet** Central message is not explicitly stated in the presentation. Main points are not clearly identified, audience unsure of the direction of the message.	**Substantially Developed** Central message is precisely stated; main points are clearly identified.
		Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
Situational Factors	• Addresses audience needs • Builds rapport with audience	**Not Yet** Topic is irrelevant to audience needs and interest. No attempt made to connect topic to audience.	**Substantially Developed** Connection of topic to audience needs and interest is stated with sophistication. Identifies and expresses a deep understanding of the target audience.
		Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
Design Factors	**Content** • Presents relevant information • Supports main points with strong evidence	**Not Yet** Content is erroneous or irrelevant; references and supporting materials are absent. Lacks of depth in content and little insights are exhibited. Presentation falls outside set time parameters.	**Substantially Developed** Content is accurate, thorough, and directly on point; strong support and references are provided. Exhibits depth and insight in content. Effective use of time and stays within time parameters.
		Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
	Structure • Organises content coherently • Signals transitions between points	**Not Yet** Organizational pattern (specific introduction and conclusion, sequenced materials within the body, and transitions) is not observable.	**Substantially Developed** Organizational pattern is clearly and consistently observable and makes the content of the presentation cohesive.
		Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	
	Verbal • Speaks at appropriate speed and volume • Uses correct grammar and pronunciation	**Not Yet** Grammar, pronunciation and word choice are deficient. Vocal delivery is too soft or too fast to understand; gap-fillers interfere with expression.	**Substantially Developed** Free of errors in grammar and pronunciation; good choices of word enhance clarity of expression. Vocal delivery is varied and dynamic. Speech rate, volume, and tone facilitate audience comprehension. Minimal gap fillers.
		Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	

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	Non-Verbal • Establishes eye contact • Uses gestures and movement to convey energy and confidence	**Not Yet** Eye contact, posture, gestures, movement and facial expressions are inappropriate and significantly distracting.	**Substantially Developed** Eye contact, posture, gestures, movement and facial expressions make the presentation compelling, and speaker appears polished and confident.
		Evaluation: Not Yet 1 2 3 4 5 6 7 8 9 10 Substantially Developed	

References:

- Garnett,J.L (1992). "Applying a Strategic Model to Government Communication." *Communicating for Results in Government*. San Francisco,CA: Jossey-Bass.
- Munter,M.(2009). *Guide to Managerial Communication*. Upper Saddle River, NJ: Prentice Hall.
- Roger,P.S. & Hildebrandt, H.W. "Competing Values Instruments for Analyzing Written and Spoken Management Messages", *Human Resource Management*; 1993; 32 ,1.
- Trevino,L.K., Daft,R.L. & Lengel, R.H. (1990). "Understanding Managers' Media Choices: A Symbolic Interactionist Perspective". *Organizations and Communication Technology.* (eds. Fulk,J. & C. Steinfeld). Sage Publications.
- *Oral Communication Rubrics - Mississippi Gulf Coast Community College.* Retrieved from http://www.mgccc.edu/instruction/rubrics/MGCCC_oral_communication_rubric.pdf
- *Oral Communication Value Rubric - Association of American Colleges and Universities.* Retrieved from http://www.aacu.org/value/rubrics/pdf/OralCommunication.pdf
- *Rubric for the Assessment of Oral Communication – Valencia College.* Retrieved from http://valenciacollege.edu/learningevidence/documents/rubrics.pdf

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ANNEX B4: ASSESSMENT CRITERIA FOR PEER EVALUATION

Peer Evaluation Instructions

All members are required to complete a peer evaluation for each member of the team (i.e., including a self-assessment). The completed peer evaluation form must be submitted individually to the instructor immediately after the team project has been submitted for grading (For the group-assignment, students must submit individually the completed peer evaluation form immediately after the last assignment has been submitted for grading). Identity of appraisers will be kept **confidential** and will not be revealed to other team members.

We may use a member's ratings (on a scale ranging from 1 to 7) to award marks for the team project to other members by computing the average rating that a member receives from other members (i.e., excluding each member's self-rating). A member's mark for the team project will be computed as follows:

1. If a member's average rating is ≥ 5.5, the member will receive **100%** of the overall mark awarded to the team project.

2. If a member's average rating is < 5.5 but ≥ 4, the member will receive **80%** of the overall mark awarded to the team project.

3. If a member's average rating is < 4 but ≥ 2, the member will receive **50%** of the overall mark awarded to the team project.

4. If a member's average rating is < 2, the member will receive **30%** of the overall mark awarded to the team project.

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CONFIDENTIAL PEER EVALUATION FORM FOR TEAM PROJECT (SAMPLE)

Member's name: _____

Seminar group and team number: _____

Please use the attached Peer Evaluation Rubric to evaluate yourself and your team members on each of the 5 stated attributes (on a scale of 1 to 7). State your ratings for yourself and each of your team members in the table below. For your self-assessment, insert "(Self)" after your name in the table below.

Index #	**Name of team members**	**1 - RR**	**2 - CM**	**3 - CR**	**4 - CT**	**5 - RS**	**Average Rating**
1							
2							
3							
4							
5							
6							

If any of your ratings above is **< 4**, please provide a brief explanation to justify the ratings.

Index #	Brief explanation to justify a rating of **< 4**

You may attach supporting documents (like emails and screen shots), if any, to support your explanations above.

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Teamwork & Interpersonal Skills (Peer Evaluation) Rubric

Traits	Performance	
1. Roles and Responsibility (RR) Behaves professionally by upholding responsibility and assuming accountability for self and others in progressing towards the team's goal.	**Scant** Unclear about his/her own role; refuses to take a role in the group; insists to work individually and has limited coordination or communication with others.	**Substantially Developed** Always fulfils responsibilities; performs his/her role within the group with enthusiasm and demonstrates willingness to work collaboratively.
	Evaluation: Scant 1 2 3 4 5 6 7 Substantially Developed	
2. Communication (CM) Identifies appropriate mechanisms to coordinate and correspond with team members.	**Scant** Modes of communication are not appropriate, causing confusion and miscommunication among team members.	**Substantially Developed** Modes of communication are appropriate, and maintaining timely communication and correspondence with team members.
	Evaluation: Scant 1 2 3 4 5 6 7 Substantially Developed	
3. Conflict Resolution (CR) Resolves conflicts using a variety of approaches.	**Scant** Does not recognize conflicts or is unwilling to resolve conflicts.	**Substantially Developed** Consistently resolves conflicts through facilitating open discussion and compromise.
	Evaluation: Scant 1 2 3 4 5 6 7 Substantially Developed	
4. Contributions (CT) Contributes positive input for the team; effectively utilizes one's knowledge and expertise.	**Scant** Largely disinterested in working in a group and refuses to participate; observes passively or is unwilling to share information with other team members.	**Substantially Developed** Actively attends and participates in all activities and provides meaningful contribution in articulating ideas and opinions.
	Evaluation: Scant 1 2 3 4 5 6 7 Substantially Developed	
5. Relationship (RS) Maintains cooperative interaction with other team members regardless of individual /cultural differences and respects diverse perspectives.	**Scant** Rarely listens to others and does not acknowledge the opinions that differ from his/her own.	**Substantially Developed** Engages in respectful relationships with all other members in the team. Embraces and accepts diverse points of view without prejudice.
	Evaluation: Scant 1 2 3 4 5 6 7 Substantially Developed	

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