Exam information	
Course code and title	MATH3202 *Operations Research and Mathematical Planning*
Semester	Semester 1, 2021
Exam type	Online, non-invigilated, final examination
Exam technology	File upload to Blackboard Assignment
Exam date and time	Your examination will begin at the time specified in your personal examination timetable. If you commence your examination after this time, the end for your examination does NOT change. The total time for your examination from the scheduled starting time will be: 2 hours 10 minutes (including 10 minutes reading time during which you should read the exam paper and plan your responses to the questions). A 15-minute submission period is available for submitting your examination after the allowed time shown above. If your examination is submitted after this period, late penalties will be applied unless you can demonstrate that there were problems with the system and/or process that were beyond your control.
Exam window	You must commence your exam at the time listed in your personalised timetable. You have from the start date/time to the end date/time listed in which you must complete your exam.
Permitted materials	This is an open book exam.
Recommended materials	Ensure the following materials are available during the exam: Computer with Python and Gurobi installed; phone/camera/scanner
Instructions	You will need to download the question paper included within the Blackboard Test. Once you have completed the exam, upload the completed exam answers file to the Blackboard assignment submission link. You may submit multiple times, but only the last uploaded file will be graded. You can print the question paper and write on that paper or write your answers on blank paper (clearly label your solutions so that it is clear which problem it is a solution to) or annotate an electronic file on a suitable device. You will also upload your separate Python files for each question.
Who to contact	Given the nature of this examination, responding to student queries and/or relaying corrections to exam content during the exam may not be feasible. If you have any concerns or queries about a particular question or need to make any assumptions to answer the question, state these at the start of your solution to that question. You may also include queries you may have made with respect to a particular question, should you have been able to 'raise your hand' in an examination-type setting. If you experience any interruptions to your examination, please collect evidence of the interruption (e.g. photographs, screenshots or emails).

	If you experience any issues during the examination, contact ONLY the Library AskUs service for advice as soon as practicable: **Chat:** support.my.uq.edu.au/app/chat/chat_launch_lib **Phone:** +61 7 3506 2615 **Email:** examsupport@library.uq.edu.au You should also ask for an email documenting the advice provided so you can provide this as evidence for a late submission.
Late or incomplete submissions	In the event of a **late submission**, you will be required to submit evidence that you completed the assessment in the time allowed. This will also apply if there is an **error in your submission** (e.g. corrupt file, missing pages, poor quality scan). We **strongly recommend** you use a phone camera to take time-stamped photos (or a video) of every page of your paper during the time allowed (even if you submit on time). If you submit your paper after the due time, then you should send details to SMP Exams (exams.smp@uq.edu.au) as soon as possible after the end of the time allowed. Include an explanation of why you submitted late (with any evidence of technical issues) AND time-stamped images of every page of your paper (eg screen shot from your phone showing both the image and the time at which it was taken).
Important exam condition information	Academic integrity is a core value of the UQ community and as such the highest standards of academic integrity apply to all examinations, whether undertaken in-person or online. This means: • You are permitted to refer to the allowed resources for this exam, but you cannot cut-and-paste material other than your own work as answers. • You are not permitted to consult any other person – whether directly, online, or through any other means – about any aspect of this examination during the period that it is available. • If it is found that you have given or sought outside assistance with this examination, then that will be deemed to be cheating. If you submit your online exam after the end of your specified reading time, duration, and 15 minutes submission time, the following penalties will be applied to your final examination score for late submission: • Less than 5 minutes – 5% penalty • From 5 minutes to less than 15 minutes – 20% penalty • More than 15 minutes – 100% penalty These penalties will be applied to all online exams unless there is sufficient evidence of problems with the system and/or process that were beyond your control. Undertaking this online exam deems your commitment to UQ's academic integrity pledge as summarised in the following declaration: *"I certify that I have completed this examination in an honest, fair and trustworthy manner, that my submitted answers are entirely my own work, and that I have neither given nor received any unauthorised assistance on this examination".*

Question 1

32 marks total

Part A

16 marks

Major Retailing Company (MRC) has a logistic network consisting of suppliers, distribution centres and retail outlets.

Each supplier sends products to distribution centres. Distribution centres consolidate products from different suppliers and send them onwards to retail outlets. Units of these different products are similar in size.

MRC knows the following information:

- The demand for each product type at each retail outlet (in units)
- The maximum supply of each product type from each supplier (in units)
- The cost per unit of each product type from each supplier
- The maximum total throughput of each distribution centre, in units
- The cost per unit of handling at each distribution centre
- The cost per unit for transport between suppliers and distribution centres and between distribution centres and retail outlets.

a) Formulate a linear programming model that will work out the optimal movement of products between suppliers, distribution centres and retail outlets, minimising the total cost of products, handling and transport. Clearly define all sets, data, variables, objective function and constraints.

b) Using the data provided in the stub, implement your solution in Python. What is the optimal objective value and solution?

c) Use Gurobi's sensitivity analysis features to determine the reduction in cost for each unit increase in the throughput capacity of distribution centre A.

Part B

16 marks

MRC realise that their model of distribution needs to be modified as follows.

- Each customer needs to be supplied from exactly one distribution centre.
- Transportation costs should be calculated per truckload, not per unit. To allow you to do this they have specified the capacity of a truck, in units, and the cost per truckload for all transportation options.
- Distribution centres can operate above their specified capacity. There is a fixed cost for any distribution centre which does this, which increases the capacity of the distribution centre to a higher level. The fixed cost of expansion and the higher capacity vary by distribution centre.
- Distribution centres need to operate at a minimum level. They can alternatively be closed for a fixed cost. The minimum level and fixed cost of closing vary by distribution centre.

Formulate a mixed integer programming model that will work out the optimal movement of products between suppliers, distribution centres and retail outlets, minimising all costs. You should define any new sets, data and variables from those used in Part A. You should fully specify the objective function and all constraints.

Question 2

18 marks total

Part A

9 marks

Each month a mathematician tries to prove new theorems. She always manages to prove one new theorem per month but in month $j \in \{0, \dots, 11\}$ she has probability p_j of proving a second theorem.

At the start of each month, she can decide to write up all her current theorems for publication. If her publication includes n theorems, then she receives $f(n) = n^{1.6}$ career points. However, spending time publishing reduces the theorems she writes that month by 1.

Alternatively, each month she does not publish, there is a probability q that someone else will discover and publish all her current theorems, so she will lose them. She will still have any new theorems she proved that month.

Any unpublished theorems at the end of the year earn her 1 career point each.

The mathematician wants to maximise her total career points for the year. Provide a dynamic programming formulation to solve this problem. You should use Bellman's equation and identify the stages, states, actions and the value function.

Part B

9 marks

Implement your formulation in Python and use it to describe the publication strategy for the values in the stub.

END OF EXAMINATION