**Business Analytics - ADM 2302 Fall 2022**

## Final Exam December 9, 2022

**Time:** **3 hours or 180 minutes**

**Last Name:** \_\_\_\_\_\_\_\_\_\_ **First Name:** \_\_\_\_\_\_\_\_\_\_

**Student Identification Number:** \_\_\_\_\_\_\_ **Section:** \_\_\_\_\_\_\_\_\_

**Instructions:**

1. A grace period of 10 minutes at the beginning of the exam is provided to allow you to read the instructions below, type in your last and first name, your Student ID number, your section on the first page, and sign the Statement of Academic Integrity (by typing your name or inserting your electronic signature). Also, a grace period of 15 minutes after the exam is available to accommodate you with the upload of your PDF document.
2. Write in your last and first name, your Student ID number, and your section in the spaces above, and sign the Statement of Academic Integrity on page 2.
3. The Final exam is an open book exam. However, make sure to prepare as if it is a closed book exam and have a sheet of summary notes ready for quick reference, in order to finish this exam within 3 hours. You may also use software (MS Excel) for help with your calculations. **These Excel worksheets must be created by YOU. Make sure NOT to share them with someone else otherwise it will lead to cases of plagiarism.**
4. DO NOT use someone else’s templates unless they are provided by the professor.
5. The Final exam is to be submitted electronically as a **PDF document via** Brightspace. However, it is acceptable to plot Decision Tree and Project Network by hand and to SCAN/INCLUDE them within the PDF document file as long as they are placed well within the PDF document (proper rotation, readable quality, and well organized). **Note that there is a 1GB limit on submissions. Therefore, upload the image photos of the graphs with a medium/small resolution**
6. Read each question very carefully: only provide what is asked. The table of areas under the standardized Normal curve is provided on the last page.
7. You must NOT reproduce or communicate the contents of the Final exam in any way. The **Final exam is an individual effort.** You must complete it individually (i.e. alone). **Failing to do so is considered *academic fraud*.**
8. I trust that you will act according to the above instructions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Questions** | **1** | **2** | **3** | **4** | **Total** |
| **Points** |  |  |  |  |  |
| **Total Value** | **22** | **24** | **30** | **24** | **100** |

|  |
| --- |
| **Statement of Academic Integrity**  The Telfer School of Management does not condone academic fraud, an act by a student that may result in a false academic evaluation of that student or of another student. Without limiting the generality of this definition, academic fraud occurs when a student commits any of the following offences: plagiarism or cheating of any kind, use of books, notes, mathematical tables, dictionaries or other study aid unless previously authorized in writing.  By submitting my answers electronically, I declare that I have read the text on academic integrity and I pledge not to have committed or attempted to commit academic fraud in this examination. I also declare that I took this Midterm Exam by myself without the assistance of another individual and that I was not aware of the content of this Midterm Exam and I have never discussed it previously with other students or colleagues.  **Statement to be signed by the student**  I have read the text on academic integrity and I pledge not to have committed or attempted to commit academic fraud in this examination.  Signed: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (type your name or insert your electronic signature).  Note: An examination without this signed statement will not be graded and will receive a final exam grade of zero. |

**QUESTION 1: Linear Programming and Sensitivity Analysis (22 points)**

Hanna Joy LTD. produces four products: W, X, Y and Z, using three resources, namely wood, metal and labour. The first three constraints in the algebraic formulation and SOLVER output below are resource availability constraints. Hanna Joy LTD. must produce a total of at least 205 units of the first two products and proper use of his machinery requires that the amount of Y produced be at exactly 1/3 of the amount of Z produced. The tables below give the revenue per unit for the products, and the cost per unit for the resources.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Product | Revenue per unit |  | Resources | Cost per unit |
| W | $82 |  | Wood (meters) | $3 |
| X | $65 |  | Metal (meters) | $5 |
| Y | $131 |  | Labour (hours) | $4 |
| Z | $63 |  |  |  |

Here is a correct algebraic formulation of the problem.

Let W, X, Y and Z denote the number units of products W, X, Y and Z to produce.

Maximize 45W + 26X + 53Y + 34Z

subject to: 3W + 10X + 2Y + 5Z ≤ 2900

4W + X + 12Y + 2Z ≤ 400

2W + X + 3Y + Z ≤ 300

W + X ≥ 205

Y - 0.33Z = 0

W, X, Y and Z ≥ 0

The SOLVER solution is shown below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | W | X | Y | Z |  |  |  |
|  | 0.00 | 286.05 | 2.33 | 6.98 |  |  |  |
|  | 45 | 26 | 53 | 34 | 7797.67 |  |  |
| Wood (meters) | 3 | 10 | 2 | 5 | 2900.00 | <= | 2900 |
| Metal (meters) | 4 | 1 | 12 | 2 | 327.91 | <= | 400 |
| Labour (hours) | 2 | 1 | 3 | 1 | 300.00 | <= | 300 |
| First two products | 1 | 1 | 0 | 0 | 286.05 | >= | 205 |
| Y and Z requirement | 0 | 0 | 1 | -0.33 | 0.00 | = | 0 |

**Instructions for parts (a) to (c) below**: In these three parts, the problem above is altered by adding additional features to the problem description. In each part, you are to provide a correct linear programming formulation of the new problem. You do not necessarily have to rewrite the whole formulation, as long as you can clearly and unambiguously indicate what should be done. The three parts are independent of each other (i.e. when doing one of the parts, ignore all of the others).

1. The price per meter of metal has risen to $6. (Hint: rewrite the objective function equation). (3 points)
2. A total of at most $10,000 is available for acquisition of the wood material. (Hint: add an additional constraint). (3 points)
3. Hanna Joy LTD. decided that the amount produced of product Y must constitute at least 30% of the total number of units produced. (Hint: add an additional constraint). (2 points)

The following correct output for this problem in its original form is provided below as an Excel Solver output. You will need this output to answer **questions (d) through (g)** **each part of which is to be considered independently of all others.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Cells | | |  |  |  |  |  |
|  |  |  | **Final** | **Reduced** | **Objective** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Cost** | **Coefficient** | **Increase** | **Decrease** |
|  | $C$8 | W | 0.00 | -6.60 | 45 | 6.60 | 1E+30 |
|  | $D$8 | X | 286.05 | 0.00 | 26 | 17.75 | 0.17 |
|  | $E$8 | Y | 2.33 | 0.00 | 53 | 1.00 | 16.71 |
|  | $F$8 | Z | 6.98 | 0.00 | 34 | 0.33 | 5.57 |
|  |  |  |  |  |  |  |  |
| Constraints | | |  |  |  |  |  |
|  |  |  | **Final** | **Shadow** | **Constraint** | **Allowable** | **Allowable** |
|  | **Cell** | **Name** | **Value** | **Price** | **R.H. Side** | **Increase** | **Decrease** |
|  | $G$10 | Wood | 2900.00 | 0.02 | 2900 | 100.00 | 258.33 |
|  | $G$11 | Metal | 327.91 | 0.00 | 400 | **A** | **B** |
|  | $G$12 | Labour | 300.00 | 25.77 | 300 | 19.02 | 10.00 |
|  | $G$13 | Demand | 286.05 | 0.00 | 205 | 81.05 | 1E+30 |
|  | $G$14 | Balance | 0.00 | -24.35 | 0 | 3.57 | 6.67 |

1. Two numbers have been removed from the resource sensitivity table by your professor (the letters A and B appear instead of the numbers). What are the correct values of A and B? Justify. (4 points)
2. In order to start producing product W (e.g. W > 0), what would need to happen to the revenue per unit of W? Justify. (2 points)
3. Up to 15 additional hours (beyond the original 300 hours) of labour are available, at the same cost of $4/hour. What is the new optimal value of the objective function? Justify. (4 points)
4. If the revenue for product Y has changed from $131 to $121, do the optimal values of the decision variables change? Justify. What about the objective function? If you can determine what the new optimal value of the objective function is, then do so. (4 points)

**QUESTION 2: BIP Formulation (24 points):**

A basketball team is about to be chosen and now must put together the ideal staffing of five. The players’ statistics are shown in the table below. The defense rating and teamwork rating are subjective evaluations from 1 to 5, with 5 being the best. The players who have two positions listed can play at either position.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Player | Position | Scoring average | Turnovers per game | Fouls per game | Defense rating | Teamwork |
| Agnew | Center/Forward | 30.2 | 4 | 4.1 | 4 | 3 |
| Bellinger | Guard/Center | 14.5 | 0.5 | 1.3 | 5 | 5 |
| Jackson | Forward | 22.7 | 2.1 | 2.5 | 2 | 3 |
| Ezell | Center | 19.6 | 3.6 | 3.8 | 4 | 4 |
| Fossner | Guard/Forward | 23.9 | 4.4 | 4.1 | 5 | 5 |
| Hecht | Center | 25.7 | 1.8 | 2.3 | 5 | 4 |
| Ingalls | Guard | 32.1 | 4.1 | 3.3 | 3 | 2 |

1. Define the **seven binary decision variables** you would use to select the team. (3 points)
2. If your objective is to select a team that will play well together, write an objective function to maximize teamwork. (2 points)
3. The team **must** consist of one center, two guards, and two forwards. Five people must be chosen. Write the corresponding constraints. (6 points)
4. The team should have a total defensive rating of at least 16. Write the corresponding constraint. (2 points)
5. The team should produce a **scoring average** of at least 23 points **per player.** Please note that the team is five players/people. Write the corresponding constraint. (2 points)
6. Ezell and Hetch should **not** both be selected. Write the corresponding constraint.   
   (3 points)
7. If Fossner is selected, then Ingalls must be selected and **vice versa**. Write the corresponding constraint. (3 points)
8. **Must** select Agnew if Jackson **and** Bellinger are selected. Write the corresponding constraint. (3 points)

**QUESTION 3: Decision Analysis (30 points)**

**Part I: Decision Table (13 points)**

Your professor has two major routes to take to work. One alternative is to take several roads to work, and the other alternative is to use the highway. Her goal is to **minimize her travel time**. Over the past two months, your professor has tried each route several times under different traffic conditions. This information is summarized in minutes of travel time to work in the following table:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **No Traffic Congestion (Minutes)** | **Mild Traffic Congestion (Minutes)** | **Severe Traffic Congestion (Minutes)** |  |
| Several roads  Highway | 15  25 | 30  25 | 45  35 |  |

1. Which route would you recommend your professor to select to minimize her regret. (Hint: construct a regret table). Show your work. (5 points)

In the past 60 days, your professor encountered severe traffic congestion 15 days and mild traffic congestion 24 days. Assume that the past 60 days are typical of traffic conditions. (**This information applies to parts (b) and (c) below).**

1. Using the Expected Payoff (EP) criterion, what road should your professor take? Show your work. (5 points)
2. Your professor has learned that a radio station in Ottawa would tell her the exact traffic conditions before she heads to work. How much time in minutes on the average would your professor save by listening to the radio station? (Hint: calculate the EVPI) Show your work. (3 points)

**Part II: Decision Tree (17 points)**

The Hope Development Firm (HGF) needs a permit from the city of Ottawa, Ontario, in order to build a shopping center on a piece of land. The price of buying the land is $800,000. HGF estimates that it can construct the shopping center for an additional $700,000 and sell the completed center for approximately $2,000,000. A permit application costs $30,000 in fees and expenses, and there is only a 30% chance that the permit will be approved by the city of Ottawa. Regardless of the outcomes, the permit process takes two months. If HGF purchases the property and the permit is denied, the company will sell the property for $750,000.

HGF has also another alternative: purchase a three-month option on the property for $40,000, which would allow it to apply for a permit, and then buy the land if the permit is granted at the same price as before ($800,000) in order to construct the shopping center.

HGF can also decide on not to proceed with this project (do nothing).

For $5000 an urban planning consultant can be hired to study the situation and render an opinion as to whether the permit will be approved or denied.

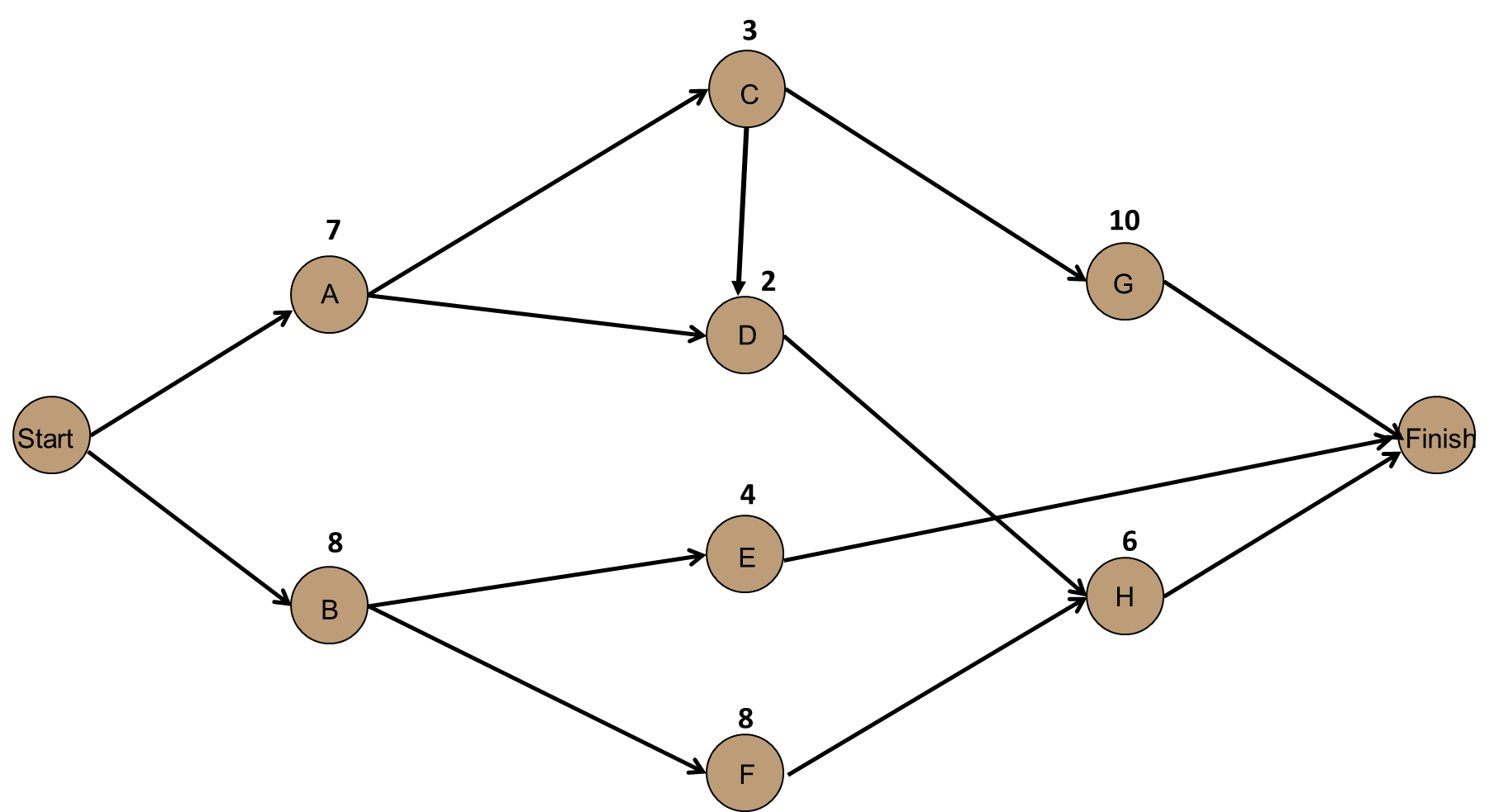
There is 0.6 probability that the consultant will predict denial of the permit, but even if the consultant predicts denial, there is a 10% chance that the permit will be granted. If the consultant predicts approval, there is still a 20% chance that the consultant prediction is wrong. **Note that these are revised/posterior probabilities.**

(d) **Draw the decision tree for this problem** that will help HGF determine the optimal strategy regarding this parcel of property. Make sure that the tree is well labeled, and that you include probabilities and cash flows/payoffs as appropriate. **Verbally communicate the decision strategy and its expected Payoff.** (Suggestion: keep track of cash/payoff flows in units of $1,000). (17 points).

**QUESTION 4: Project Management (24 points)**

**Part I (15 points)**

Consider the following PERT project network and its expected activity times.

****

1. Compute ES, EF, LS, LF, slack for each activity. (7 points)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Activity** | **Expected time (WEEKS)** | ES | EF | LS | LF | Slack |
| A | 7 |  |  |  |  |  |
| B | 8 |  |  |  |  |  |
| C | 3 |  |  |  |  |  |
| D | 2 |  |  |  |  |  |
| E | 4 |  |  |  |  |  |
| F | 8 |  |  |  |  |  |
| G | 10 |  |  |  |  |  |
| H | 6 |  |  |  |  |  |
| Finish | 0 |  |  |  |  |  |

1. What is(are) the critical path(s) and the minimum time to complete the project? (3 points)

Critical path(s): \_\_\_\_\_\_\_\_\_\_\_\_\_\_

Minimum time to complete the project: \_\_\_\_\_\_\_\_\_\_

1. Assume that variances for activity A, B, and C are 1. The variances for activity D and E are 0.75. The variances for activity F, G and H are 2. What is the project standard deviation? Show your work. Round to three decimal points. (2 points)
2. Calculate the probability of completing the project in 19 weeks. (3 points)

**Part II: Project Crashing (9 points)**

A seven-activity CPM project is described by the table and Network below.





**The critical path for this network is A-D-G and the project completion time is 13 days.**

1. If a deadline of 10 days is imposed, what activities should be crashed? What is the total minimum costthat is incurredfor crashing the project from 13 days to 10 days? *What is the total cost to complete the project in 10 days*? **Show your work** (9 points).

normal_table