TELFER

ÉCOLE DE GESTION **TELFER** SCHOOL OF MANAGEMENT

ADM 2304 – ASSIGNMENT 3 (50 marks)

Due date: Wednesday, March 24 2021 at 11:30 pm (Brightspace).

Instructions:

- *For each numerical question,* ***you must first show your manual computations and then use Minitab, MS Excel or any other statistical software to confirm your results. You must paste your output onto your assignment*** *to show your use of software; however, this output does not replace any of the steps outlined below. This means that answers that are exclusively software output will receive only partial marks.*
- *If you are performing a hypothesis test, make sure you state the hypotheses, the level of significance, the rejection region, the test statistic (and/or p-value, if requested), your decision (whether to reject or not to reject the null hypothesis), and a conclusion in managerial terms that answers the question posed. These steps must be completed in addition to any software output.*
- *The data for this homework assignment can be found in the files* ***Assign3Data.mpx*** and ***Assign3Data.xlsx****.*
- ***Your assignment must be typed and uploaded to Brightspace in one single pdf file****. You may upload several files, but only the most recent submission prior to the deadline will be graded****. You must start each question on a different page and answer the questions in order****. Students who fail to follow these instructions will be penalized with 10% of the marks (for example, if the assignment is marked out of 50, the penalty will be 5 marks).*
- *Late submissions will be accepted according to the late submission policy discussed in class and posted on Brightspace.*
- *Remember to include your integrity statement. Assignments submitted without a signed integrity statement will not be graded.*

Question 1 – Gas Prices (24 marks)

A small study was conducted to test whether the average price of gas differed among Montreal, Toronto, and Vancouver. For each of these three cities, the researchers randomly selected five years and recorded the average gas price as follows:

Price (cents per liter)		
Montreal	Toronto	Vancouver
100.8	94.4	105.7
117.3	110.1	119.1
128.0	118.1	126.6
129.5	120.5	122.2
136.3	127.3	125.4

a) **[3 marks]** Make a side-by-side boxplot of the data and explain if the similar variance and the nearly normality conditions for conducting an ANOVA seem to be satisfied.

b) **[2 marks]** In addition to a side-by-side boxplot, what other graphs can you use to check if the assumptions/conditions for using an ANOVA are satisfied? (Note: you don't need to produce these graphs; just explain how you would produce them.)

Answer the following questions, with exception of part g), assuming that the conditions for conducting an ANOVA are satisfied.

c) **[2 marks]** Use software to calculate the sample variance for each city and then use it to calculate the pooled variance manually. Check that your pooled variance value is the same as the MSE value displayed in the partial ANOVA table in part d) below.

d) **[6 marks]** Fill in manually the missing values in the ANOVA table below. Show your computations (maximum of 2 decimal places). Check your results using software.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	**A**	2	**B**	**C**	**D**
Within Groups	**E**	**F**	140.46		
Total	1865.94	14			

e) **[5 marks]** Using the one-way ANOVA table from part d) above, test if there is a significant difference in the true mean gas price between the three cities using the critical value approach and a 5% significance level. Make sure you follow all the steps for hypothesis testing indicated in the *Instructions* section above, show your computations, and state the business significance of your conclusion.

f) **[3 marks]** Use the Bonferroni method for multiple comparisons to determine which population means differ (if any) at $\alpha = 0.05$. Show your computations and clearly state your conclusion for each pairwise comparison.

g) **[3 marks]** Perform a Kruskal-Wallis non-parametric test to determine whether there is a difference in the gas prices across the three cities. Use a 5% significance level and the critical value approach. You can use Minitab or MS Excel for your calculations but remember to show all the steps of your hypothesis test. Is your conclusion consistent with your results in part e) above?

Question 2 – Crop Production (26 marks)

A farmer would like to maximize his revenue through crop production. For this purpose, he seeks to determine which type of seed and type of fertilizer produce the greatest crop yield. He is also interested in finding out if seed type and fertilizer type have any effect on the average crop yield. To this end, he randomly assigned different plots in a field to a combination of seed type (A, B, C or D) and fertilizer type (1, 2, 3 or 4), and measured the final crop yield in bushels per acre at harvest time. The resulting crop yields in bushels per acre for the different combinations are provided in file **Assign3Data.xlsx**.

a) **[4 marks]** Identify the experimental design and determine the number of treatments, experimental units and replicates.

b) **[5 marks]** Plot the residuals against the fitted values corresponding to the two-way ANOVA model for this analysis. What two key model assumptions can be examined with this plot and do they appear to be warranted?

c) **[4 marks]** Does the data provide enough evidence to indicate a significant interaction effect between type of seed and type of fertilizer? Conduct the appropriate hypothesis test at the 5% significance level; make sure you follow all the steps for hypothesis testing indicated in the *Instructions* section. Use software to generate the corresponding two-way ANOVA table, but show any other computations.

d) **[2 marks]** Create the corresponding interaction plot and explain if it shows interaction between type of seed and type of fertilizer impacting on crop yield; is this consistent with your results for part c) above?

e) **[3 marks]** Based on your answer to part c), does it make sense to test the effect of type of seed or the effect of type of fertilizer on the mean crop yield? If so, are these effects significant? Justify your answers.

f) **[2 marks]** Which combinations of seed type and fertilizer type (treatment means) have the lowest and highest average crop yield?

g) **[4 marks]** Calculate the Bonferroni margin of error for the confidence intervals based on all pairwise differences between the treatment means. Show your manual calculations and use an overall 95% confidence level. Why is it appropriate to use the Bonferroni method for comparing treatment means?

h) **[2 marks]** Using the calculated margin of error from part g) and the pairwise confidence interval approach, test the following statements:

- For seed type A, does fertilizer type 1 vs. fertilizer type 2 make a significant difference on average crop yield?
- For fertilizer type 4, does seed type A vs. seed type B make a significant difference on average crop yield?