Personal Ethics Statement Individual Assignment:

By signing this Statement, I am attesting to the fact that I have reviewed the entirety of my attached work and that I have applied all the appropriate rules of quotation and referencing in use at the Telfer School of Management at the University of Ottawa, as well as adhered to the fraud policies outlined in the Academic Regulations in the University's Undergraduate Studies Calendar. I further attest that I have knowledge of and have respected the "Beware of Plagiarism" brochure found on the Telfer School of Management's doc-depot site.

Nitish Kumar

Signature

March 21st, 2012 ,

Date

. Kumar, Nitish .
Last Name (print), First Name (print)

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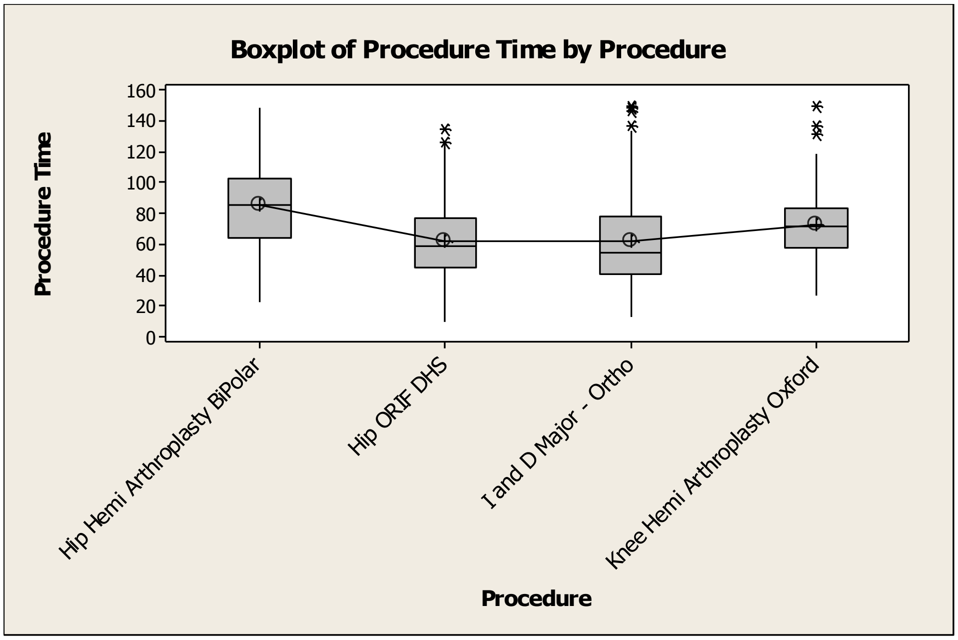
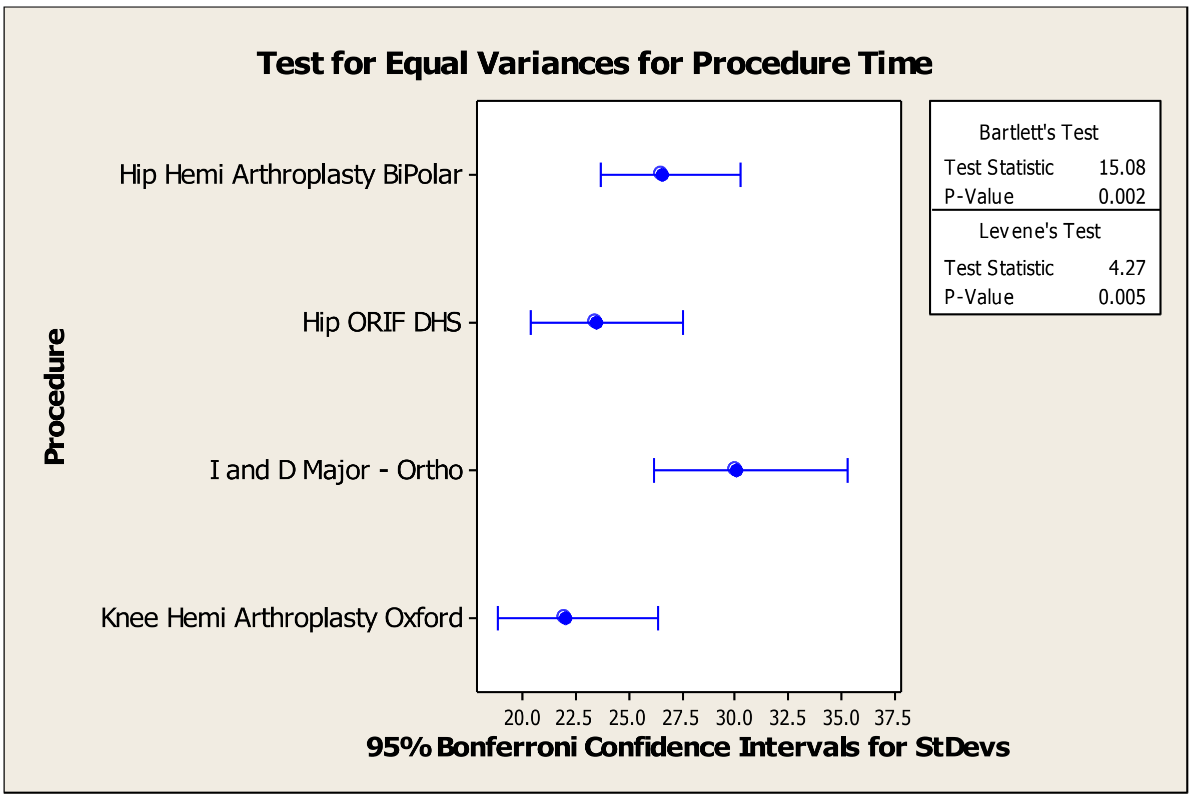
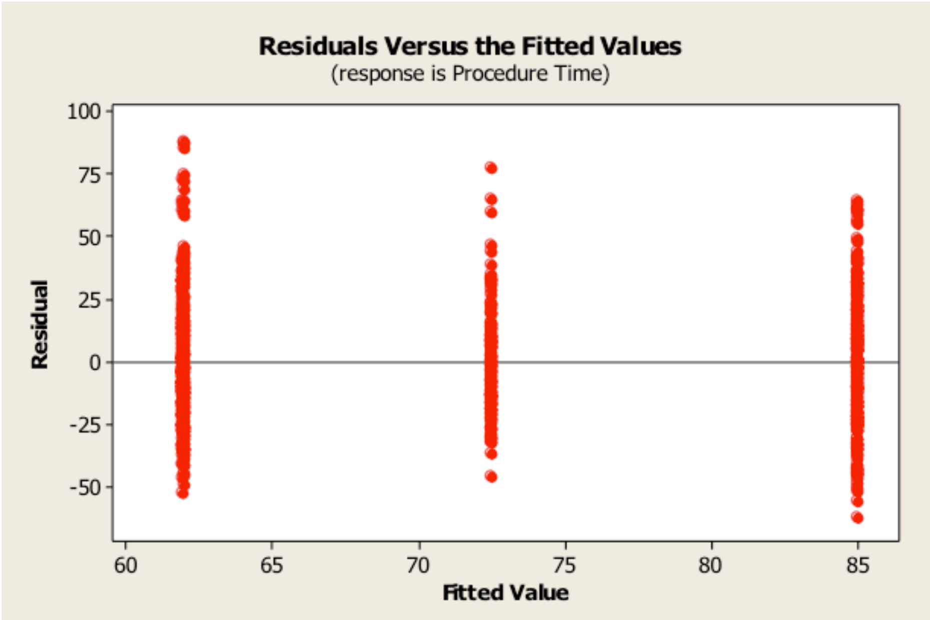
Student Number

Question 2:

a.


Boxplot of Procedure Time by Procedure
Procedure Time
160
140
120
100
80
60
40
20
0
Hip Hemi Arthroplasty BiPolar
Hip ORIF DHS
I and D Major - Ortho
Knee Hemi Arthroplasty Oxford
Procedure


Test for Equal Variances for Procedure Time
Procedure
Hip Hemi Arthroplasty BiPolar
Hip ORIF DHS
I and D Major - Ortho
Knee Hemi Arthroplasty Oxford
20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
95% Bonferroni Confidence Intervals for StDevs
Bartlett's Test
Test Statistic 15.08
P-Value 0.002
Levene's Test
Test Statistic 4.27
P-Value 0.005



After analyzing the residual plot, one can see there appears to be a significant level of outliers more than 2 standard deviations away from zero. As a result of these outliers, we cannot assume equal variance.

After conducting a test of equal variances, both the Bartlett's and Levene's test should have a significant p-value, as a result, we cannot assume equal variance.

However, the normality assumption applies. Our sample size is large enough (N>30).

We may also assume that the data are random and independent of one another since the data were collected on different surgeries.

b.

One-way ANOVA: Procedure Time versus Procedure

```
Source       DF      SS     MS      F      P
Procedure     3   63875  21292  31.48  0.000
Error       599  405151    676
Total       602  469026

S = 26.01   R-Sq = 13.62%   R-Sq(adj) = 13.19%


                                        Individual 95% CIs For Mean Based on
                                        Pooled StDev
Level               N   Mean  StDev  --------+---------+---------+---------+-
Hip Hemi Arthrop  211  85.02  26.60                              (---*----)
Hip ORIF DHS      138  61.96  23.45  (----*-----)
I and D Major -   141  61.99  30.11  (----*-----)
Knee Hemi Arthro  113  72.48  22.03               (-----*-----)
                                     --------+---------+---------+---------+-
                                          64.0      72.0      80.0      88.0

Pooled StDev = 26.01
```

$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$
$H_a: The\ means\ are\ not\ all\ the\ same$

The one-way ANOVA test shows, with an F-statistic of 31.48, and degrees of freedom of 3 & 599, it relates to a p-value of less than 0.0001.

**We must reject the null hypothesis when [p-value < alpha].
(P-value<0.0001) < (alpha = 0.05)
Therefore, we reject the null hypothesis. We conclude, there is sufficient evidence to show that the means are not all the same.

c.

$$\frac{\alpha}{2J} = \frac{0.05}{2(6)} \cong 0.00416$$

$This\ is\ the\ probability\ (alpha) we\ will\ use\ to\ calculate\ Z_{crit}$

$Z_{crit} \cong 2.638258$
$\mu_1 = Hip\ Hemi\ Athroplasty\ BiPolar$
$\mu_2 = Hip\ ORIF\ DHS$
$\mu_3 = I\ and\ D\ Major - Ortho$
$\mu_4 = Knee\ Hemi\ Arthroplasty\ Ortho$

Confidence Intervals:

$$\mu_1 vs\ \mu_2: \left(\mu_1 - \mu_2 \pm Z_{crit} \times S_p \times \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}\right)$$

$$\mu_1 vs\ \mu_2: \left(85.02 - 61.96 \pm 2.638 \times 26.01 \times \sqrt{\frac{1}{211} + \frac{1}{138}}\right)$$

$$= (15.55, 30.57)$$

$$\mu_1 vs\ \mu_3: \left(85.02 - 61.99 \pm 2.638 \times 26.01 \times \sqrt{\frac{1}{211} + \frac{1}{141}}\right)$$

$$= (15.57, 30.49)$$

$$\mu_1 vs\ \mu_4: \left(85.02 - 72.48 \pm 2.638 \times 26.01 \times \sqrt{\frac{1}{211} + \frac{1}{113}}\right)$$

$$= (4.54, 20.54)$$

$$\mu_2 vs\ \mu_3: \left(61.96 - 61.99 \pm 2.638 \times 26.01 \times \sqrt{\frac{1}{138} + \frac{1}{141}}\right)$$

$$= (-8.24, 8.18)$$

$$\mu_2 vs\ \mu_4: \left(61.96 - 72.48 \pm 2.638 \times 26.01 \times \sqrt{\frac{1}{138} + \frac{1}{113}}\right)$$

$$= (-19.23, -1.81)$$

$$\mu_3 vs\ \mu_4: \left(61.99 - 72.48 \pm 2.638 \times 26.01 \times \sqrt{\frac{1}{141} + \frac{1}{113}}\right)$$
$$= (-19.15, -1.82)$$

The only confidence interval containing 0 is the one comparing $\mu_2 and\ \mu_3$, therefore, we can conclude:

$\mu_1 differs\ from\ \mu_2,$
$\mu_1 differs\ from\ \mu_3,$
$\mu_1 differs\ from\ \mu_4,$
$\mu_2 differs\ from\ \mu_4,$
$\mu_3 differs\ from\ \mu_4$

**However,

$$We\ have\ insufficient\ evidence\ to\ say\ that\ \mu_2\ and\ \mu_3\ differ\ from\ each\ other$$

As a result, we can say, with a total (family) confidence of 95%, that only one of our means does not differ from the other ($\mu_2 and\ \mu_3$). $\mu_2 and\ \mu_3$ do not differ.

d.

Kruskal-Wallis Test: Procedure Time versus Procedure

```
Kruskal-Wallis Test on Procedure Time

Procedure                         N  Median  Ave Rank      Z
Hip Hemi Arthroplasty BiPolar   211   85.00     385.5   8.63
Hip ORIF DHS                    138   58.50     239.2  -4.82
I and D Major - Ortho           141   54.00     233.0  -5.38
Knee Hemi Arthroplasty Oxford   113   71.00     308.9   0.47
Overall                         603             302.0

H = 88.67  DF = 3  P = 0.000
H = 88.69  DF = 3  P = 0.000  (adjusted for ties)
```

$H_0: median\ 1 = median\ 2 = median\ 3 = median\ 4$
$H_a: Not\ all\ medians\ are\ the\ same$

**Reject the null hypothesis when [P-value < Alpha]

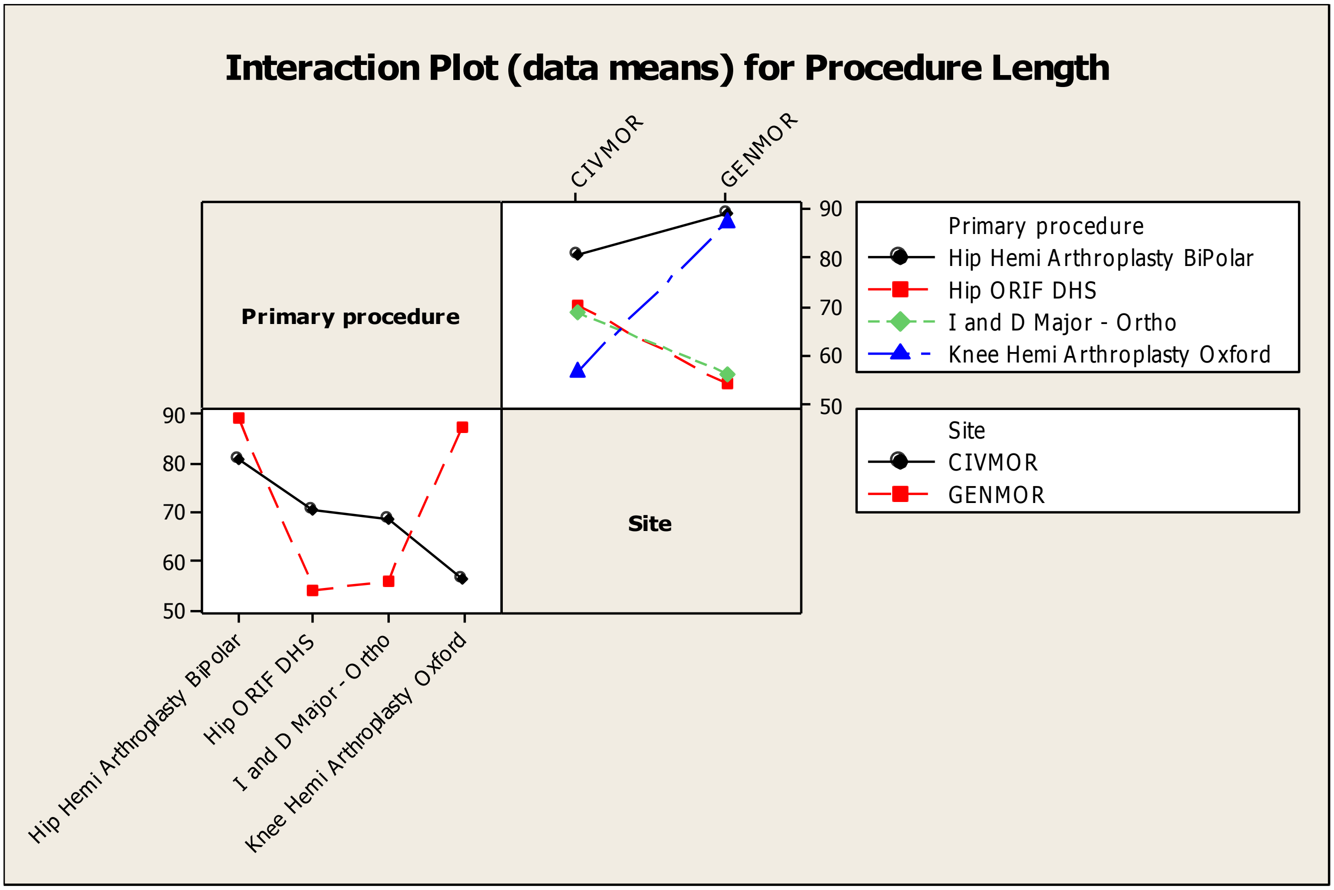
P-value = (p-value < 0.0001)
Alpha = 0.05

From the Minitab output of the Kruskall-Whalis test, there is sufficient evidence to reject the null. We can see that the p-value (p-value < 0.0001) is lower than our significance level (alpha = 0.05). We can conclude that not all medians are the same.

e. It is evident that all the surgeries do not take the same amount of time (save for Hip ORIF DHS and I&D Major – Ortho). Therefore, I recommend that the hospital be more proactive in allocating the time per surgery in order to meet historical means. The hospital should evaluate the surgical process and determine if they can reduce times.

Question 3.

a.



One can see that from the interaction plot there seems to be an interaction between the two factors (site and procedure performed), because in both the graphs, the lines are not parallel. This means that when we change the type of surgery given, or the sites, the two factors interact. By interact we mean, one factor causes the other to either increase or decrease.

E.g., Knee Hemi Arthroplasty Oxford increases in surgery time when comparing GENMOR and CIVMOR, however, both the Hip ORIF DHS and I and D Major – Ortho decrease when comparing CIVMOR to GENMOR, showing that there is an interaction between these types of surgeries and the site in which they are performed.

**Note: We cannot determine the amount of interaction that exists between the two factor, we must use the two-way ANOVA test to determine how much interaction exists as well as the how much each factor impacts the response.

b.

Two-way ANOVA: Procedure Length versus Primary procedure, Site

Source	DF	SS	MS	F	P
Primary procedur	3	6180.5	2060.17	9.29	0.000
Site	1	117.6	117.56	0.53	0.469
Interaction	3	6392.3	2130.78	9.61	0.000
Error	64	14192.2	221.75		
Total	71	26882.6			

S = 14.89   R-Sq = 47.21%   R-Sq(adj) = 41.43%

Two-way ANOVA: Procedure Length versus Primary procedure, Site [Additive model]

Source	DF	SS	MS	F	P
Primary procedur	3	6180.5	2060.17	6.71	0.001
Site	1	117.6	117.56	0.38	0.538
Error	67	20584.6	307.23		
Total	71	26882.6			

S = 17.53   R-Sq = 23.43%   R-Sq(adj) = 18.86%

H_0: *There is no interaction between the site and the procedure performed*
H_a: *Site and procedure type do interact*

**Reject the null hypothesis when [P-value < Alpha]

P-value = (p-value < 0.0001)
Alpha = 0.05

Therefore, we reject the null hypothesis due to the fact that we have a p-value of less than 0.0001, which is lower than our significant level of 0.05.

We can see that the p-value (p-value < 0.0001) is lower than our significance level (alpha = 0.05).As a result we can conclude that there is sufficient evidence to state that there is an interaction between the factors, site and procedure performed. This conclusion is drawn according to the Minitab output of the Two-Way ANOVA test for the data, which contains the factors, site and procedure type.

H_0: *Site does not have an impact on the surgical time*
H_a: *Site does have an impact on the surgical time*

The p-value (0.469) is greater than our significance level (alpha = 0.05). Therefore there is insufficient evidence to conclude that the site has an impact on the surgical time. The data was collected from the output of the Two-Way ANOVA test for the data.

H_0: *Procedure performed does not have an impact on the surgical length*
H_a: *Procedure performed does have an impact on the surgical length*

The p-value (0.0000) is less than our significance level (alpha = 0.05). Therefore there is sufficient evidence to conclude that the procedure performed does indeed have an impact on the surgical time. The data was collected from the output of the Two-Way ANOVA test for the data.

OR:

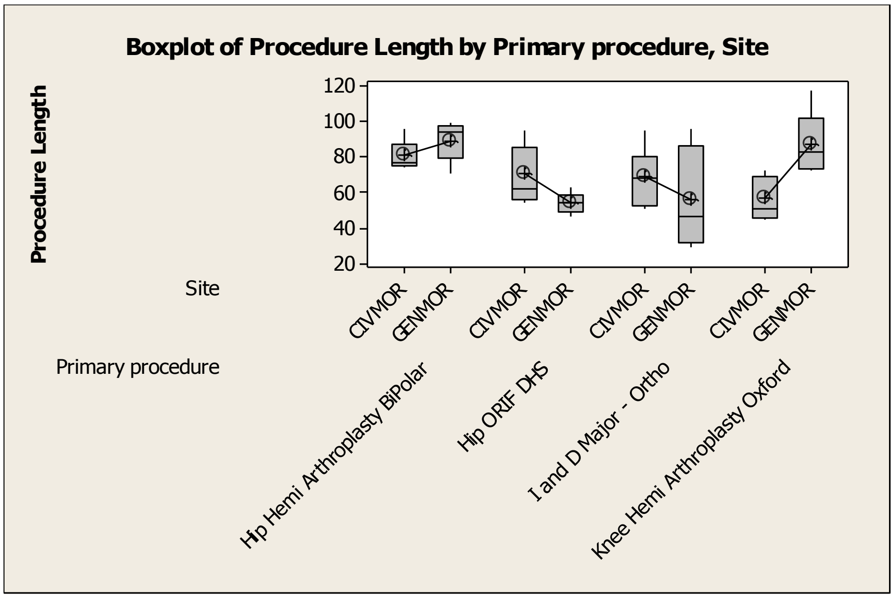
S1: H_o: Interaction with ω_{jk} are NOT present
H_a: Interaction with ω_{jk} are present.

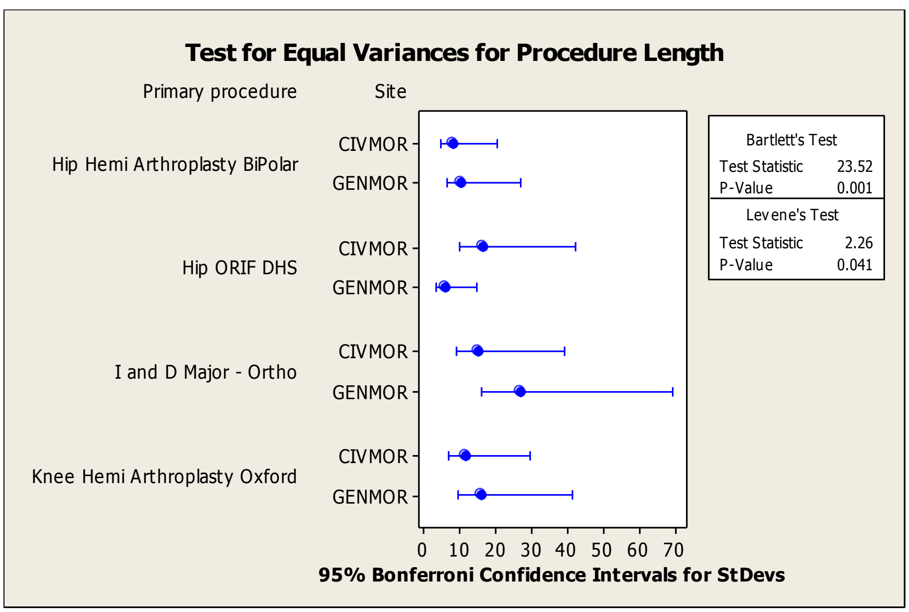
S2: $F_{calc}\,(df_1,df_2) = MS_{interaction}/MS_{error}$
$= 2130.78/221.75$
$=9.61$

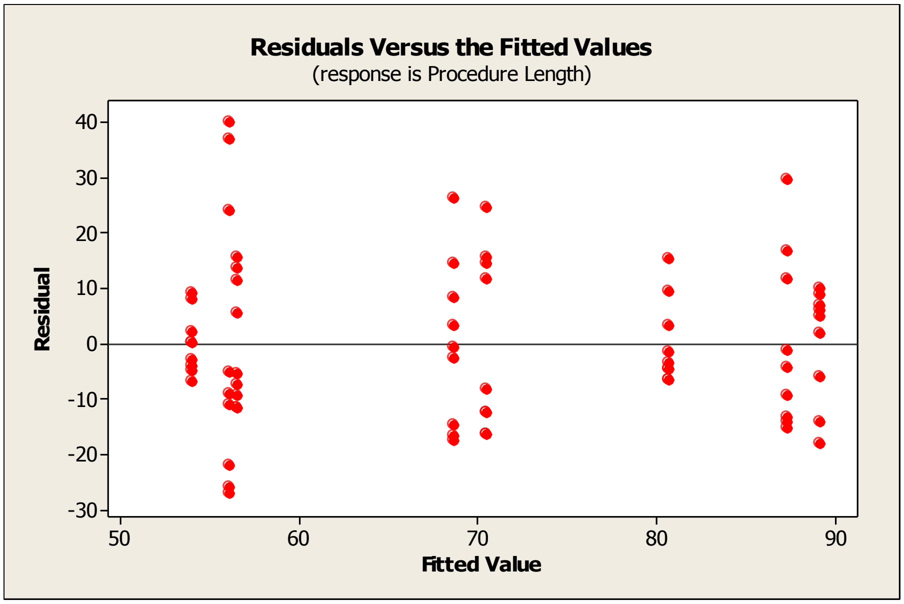
S3: $F_{crit} = F_{0.05}(df_1=3,df_2=64) = 2.745$

S4: Since $\{F_{calc}=9.61\} > \{F_{crit}=2.745\}$ We Reject the null, therefore we can conclude that an interaction between location and job type effect is present.

c.







We can assume the data was collected at random.

95% of the data is within two standard deviations of zero, and there are approximately equal numbers of points above and below the zero line, as a result we can assume normality.

Judging by the residual plot, it appears as though the equal variance assumption doesn't hold. The residual plot shows some samples with an extremely small amount of spread, while other samples with having a large variability within the spread.

**A test of equal variances proves that the equal variance assumption does not hold (according to the Bartlett's and Levene's test).

d. Because ANOVA is justified, the two-way analysis suggests that there is interaction between the impacts of the two factors. This means that both factors affect the mean of the outcome variable so that the level of one factor affects the impact of the other factor on the outcome variable.

e.
We have 3 comparisons, therefore J=3

Therefore,

$$\beta = \frac{\alpha}{2J} = \frac{0.05}{2(3)} \cong 0.0833$$

$$df = 64\ (df\ of\ MSE)$$

i)

$$H_0: \mu_1 = \mu_2\ (Mean\ GENMOR = Mean\ CIVMOR)$$

$$H_a: \mu_1 \neq \mu_2$$

$$\left(x_{.i.} - x_{.j.} \pm t_{\frac{\beta}{2},df} \times \sqrt{MSE\left(\frac{1}{ar} + \frac{1}{ar}\right)} \right)$$

$$\left(71.638 - 69.083 \pm 1.998 \times \sqrt{221.75\left(\frac{1}{36} + \frac{1}{36}\right)}\right)$$
$(-4.45, 9.57)$

0 is within the confidence interval; therefore we have insufficient evidence to prove that the means between the two sites differ.

ii)
$H_0: \mu_1 = \mu_2$ $(Mean\ Knee\ hemi = Mean\ Hip\ Hemi)$
$H_a: \mu_1 \neq \mu_2$

$$\left(x_{i..} - x_{j..} \pm t_{\frac{\beta}{2},df} \times \sqrt{MSE\left(\frac{1}{br} + \frac{1}{br}\right)}\right)$$
$$\left(71.944 - 84.889 \pm 2.723 \times \sqrt{221.75\left(\frac{1}{18} + \frac{1}{18}\right)}\right)$$
$(-26.46, 0.57)$

0 is within the confidence interval; therefore we have insufficient evidence to prove that the means between the two surgeries differ.

iii)
$H_0: \mu_1 = \mu_2$ $(Mean\ knee\ hemi\ GENMOR = Mean\ knee\ hemi\ CIVMOR)$
$H_a: \mu_1 \neq \mu_2$

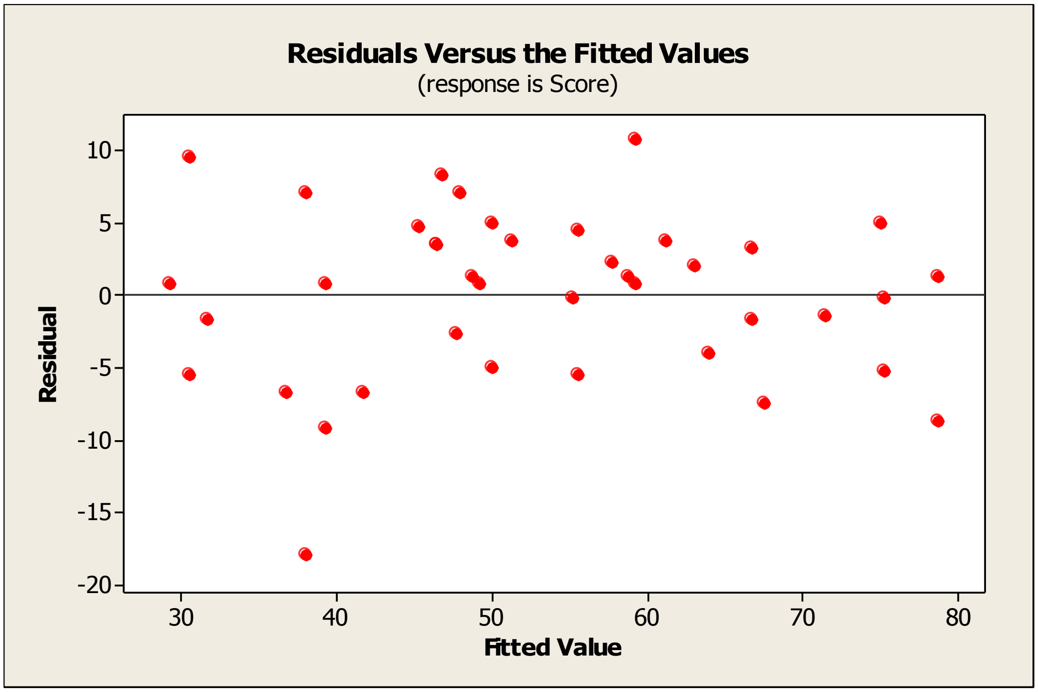
$$\left(x_{..i} - x_{..j} \pm t_{\frac{\beta}{2},df} \times \sqrt{MSE\left(\frac{1}{r} + \frac{1}{r}\right)}\right)$$
$$\left(87.333 - 56.556 \pm 3.26 \times \sqrt{221.75\left(\frac{1}{9} + \frac{1}{9}\right)}\right)$$
$= (7.89, 53.66)$

Evidently, 0 is not within the confidence interval. As a result, we can conclude that there is sufficient evidence to prove that the mean surgical length differs between the Knee-Hemis at GENMOR and Knee Hemis at CIVMOR.

With a family error rate of 95%, we can conclude that we are 95% certain that only one of our means differ from the other. The mean of the Knee-Hemis surgery time at GENMOR differs from the mean of the Knee-Hemis surgery time at CIVMOR.

Question 4:

a.



Evidently, less than 5% of the data are outside 2 standard deviations and the variance of each factor is apparently similar to the other, as a result, the equal variance assumption can be made.

b.

Two-way ANOVA: Score versus Professor, Student

Source	DF	SS	MS	F	P
Professor	3	2302.5	767.500	15.67	0.000
Student	9	5402.5	600.278	12.26	0.000
Error	27	1322.5	48.981		
Total	39	9027.5			

S = 6.999   R-Sq = 85.35%   R-Sq(adj) = 78.84%

H_0: *The professors do not have an impact on the score*
H_a: *The professors do have an impact on the score*

The test we will conduct is the Randomized Block Design, it is performed basically as a two-way ANOVA test without the interaction term.

**We reject the null hypothesis when p-value < alpha.
P-value = 0.0001
Alpha = 0.05
→ [P-value<0.0001] < [0.05]
Therefore, we reject the null hypothesis.
According to our Minitab Output, there is sufficient evidence to conclude that the professors do indeed have an impact on the score.

c.

One-way ANOVA: Score versus Professor

```
Source     DF    SS   MS     F      P
Professor   3  2303  768  4.11  0.013
Error      36  6725  187
Total      39  9028

S = 13.67   R-Sq = 25.51%   R-Sq(adj) = 19.30%
```

The Randomized Block Design shows us that, the R-squared value is 85.35%, while the One-Way ANOVA provides an R-squared value of 25.51%.

We can see that the R-squared value is much higher in the Randomized Block Design compared to the One-Way Anova test, as a result, less of the variation is explainable in the One-Way ANOVA test.

*Note: Approximately 85% of the outcome is explained by knowing the professor using the Randomized Block Design, whereas only 25% of the outcome is explained using the One-Way ANOVA.

The reason there is a difference, is because there is a confounding variable. Our confounding variable in this case is the students. The received by a professor depends on both the Professor and the student who is allocating the score! Some student may be harsh, while others may be lenient which would open the door for variability between students. However, by using the Randomized Block Design, we are effectively controlling the confounding variable, which makes sure that the variability is not affected by the variability between student ratings! As a result, the variability that exists is between the professors and the students do not affect the results.

d. Friedman Test: Score versus Professor blocked by Student

```
S = 18.03  DF = 3  P = 0.000
S = 21.99  DF = 3  P = 0.000 (adjusted for ties)

                            Sum
                    Est      of
Professor   N   Median   Ranks
1          10    49.06    21.0
2          10    40.94    13.0
3          10    62.19    35.5
4          10    56.56    30.5

Grand median = 52.19
```

H_0: *All the professor'sscores are equal* $(Median\ 1 = Median\ 2 = Median\ 3 = Median\ 4)$
H_a: *Scores between professors are not the same.* $(\ Medians\ all\ differ)$

The test we are using is referred to as the Friedman test. This is a non-parametric test since we are using a test of medians instead of means.

****We reject the null hypothesis when p-value < alpha.
P-value = 0.0001
Alpha = 0.05
→ [P-value<0.0001] < [0.05]
Therefore, we reject the null hypothesis.
According to our Friedman's Minitab Output, there is sufficient evidence to conclude that the medians do indeed differ between the professors and the scores between the professors are <u>not</u> the same.