Par Inc. Case Study

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Contents

The Assignment

Case Study: Par Inc.

Par Inc., is a major manufacturer of golf equipment. Management believes that Par's market share could be increased with the introduction of a cut-resistant, longer-lasting golf ball. Therefore, the research group at Par has been investigating a new golf ball coating designed to resist cuts and provide a more durable ball. The tests with the coating have been promising. One of the researchers voiced concern about the effect of the new coating on driving distances. Par would like the new cut-resistant ball to offer driving distances comparable to those of the current-model golf ball. To compare the driving distances for the two balls, 40 balls of both the new and current models were subjected to distance tests. The testing was performed with a mechanical hitting machine so that any difference between the mean distances for the two models could be attributed to a difference in the design.

The results of the tests, with distances measured to the nearest yard, are contained in the data set "Golf". Prepare a Managerial Report

Questions

1. Formulate and present the rationale for a hypothesis test that par could use to compare the driving distances of the current and new golf balls

2. Analyse the data to provide the hypothesis testing conclusion. What is the p-value for your test? What is your recommendation for Par Inc.?

3. Provide descriptive statistical summaries of the data for each model

4. What is the 95% confidence interval for the population mean of each model, and what is the 95% confidence interval for the difference between the means of the two population?

5. Do you see a need for larger sample sizes and more testing with the golf balls? Discuss

Golf Dataset:-

CURRENT	NEW
264	277
261	269
267	263
272	266
258	262
283	251
258	262
266	289
259	286
270	264
263	274
264	266
284	262
263	271
260	260
283	281
255	250
272	263
266	278
268	264
270	272
287	259
289	264
280	280
272	274
275	281
265	276
260	269
278	268
275	262
281	283
274	250
273	253
263	260
275	270
267	263
279	261
274	255
276	263
262	279

Summary

Preliminary Analysis

- Sample Size: 40, Number of Samples = 2
- Measurement repeated on Current Golf Balls and New Cut-Resistant Golf Balls
- Observations:
  - Both the samples seems to be normally distributed
  - Mean and Median values are not that much different
  - The Current Golf balls data are seems to be left skewed whereas sample of the New Golf balls are normally distributed

Question 1

Formulate and present the rationale for a hypothesis test that par could use to compare the driving distances of the current and new golf balls

- Number of samples = 2
- Both of the samples are Independent samples
- Sample Size, N = 40
- Level of Significance (Alpha) = 0.05
- Since Both the Population Standard Deviation (Sigma) is unknown, but the populations are normally distributed we have to use a 2 Sample t-test
- Mean distance of current-model balls: $\mu_{current}$.

  Mean distance of new cut-resistant balls: μ_{new}
- Hypothesis Formulation

NULL HYPOTHESIS

$H_0: \mu_{current} = \mu_{new}$

(Mean distance of current balls equals mean distance of new balls).

ALTERNATIVE HYPOTHESIS

$H_1: \mu_{current} \neq \mu_{new}$

(Mean distance of current balls is not equal mean distance of new balls)

- The ≠ sign in the alternative hypothesis indicates that the test is two-tailed

Question 2

Analyse the data to provide the hypothesis testing conclusion. What is the p-value for your test? What is your recommendation for Par Inc.?

To further test our hypothesis, we have set α at 0.05 and our rejection criteria is to Reject the Null Hypothesis and accept the Alternative Hypothesis i.e. to prove that there is actually a change in the mean distances for the two models could be attributed to a difference in the design.

```
> t.test(Current, New, alternative = "two.sided", var.equal = FALSE)

        Welch Two Sample t-test

data:  Current and New
t = 1.3284, df = 76.852, p-value = 0.188
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.384937  6.934937
sample estimates:
mean of x mean of y
  270.275   267.500
```

```
> Diff.means=((mean(Current))-(mean(New)))
> Diff.means
[1] 2.775
```

```
> IQR(Current)
[1] 12.25
> IQR(New)
[1] 12.5
```

- Degrees of freedom = 76.852
- t = 1.3284
- p-value = 0.188

Looking at the descriptive statistics for each samples, we can say that Current Golf balls has a longer range of distance based on the 40 samples with a mean of 270.3 compared to 267.5 for the New Golf balls. The standard deviation of the Current Golf balls is 8.75 and as for the New Golf balls it is 9.89. The mean differences between distances in Current and New golf balls is 2.775, not showing a significant difference to prove that there is a relevant change between the Current and the New Golf balls. Inter Quartile Ranges (IQR) of both the samples are hardly any different from each other to suggest that there is any significant change.

P-value=0.188>0.05=α. This suggests the following:

- Failed to reject the null hypothesis i.e. H_0
- Mean distance of the New cut-resistant Golf balls **equals** mean distance of Current model Golf balls
- The new cut-resistant balls have **no significant difference** in distance compared to the Current model Golf balls

Thus, it can be **recommended** for Par Inc. to launch the New cut-resistant Golf balls as it is not impacting the distance aspect as suggested.

Question 3

Provide descriptive statistical summaries of the data for each model

The sample contains 40 observations. There are no outliers.

```
> summary(Golf)
    Current           New
 Min.   :255.0   Min.   :250.0
 1st Qu.:263.0   1st Qu.:262.0
 Median :270.0   Median :265.0
 Mean   :270.3   Mean   :267.5
 3rd Qu.:275.2   3rd Qu.:274.5
 Max.   :289.0   Max.   :289.0
> sd(Current)
[1] 8.752985
> sd(New)
[1] 9.896904
> var(Current)
[1] 76.61474
> var(New)
[1] 97.94872
> IQR(Current)
[1] 12.25
> IQR(New)
[1] 12.5
> range(Golf)
[1] 250 289
> range(Current)
[1] 255 289
> range(New)
[1] 250 289
> CurrentStandardError=(sd(Current)/sqrt(n))
> CurrentStandardError
[1] 1.383968
> NewStandardError=(sd(New)/sqrt(n))
> NewStandardError
[1] 1.564838
```

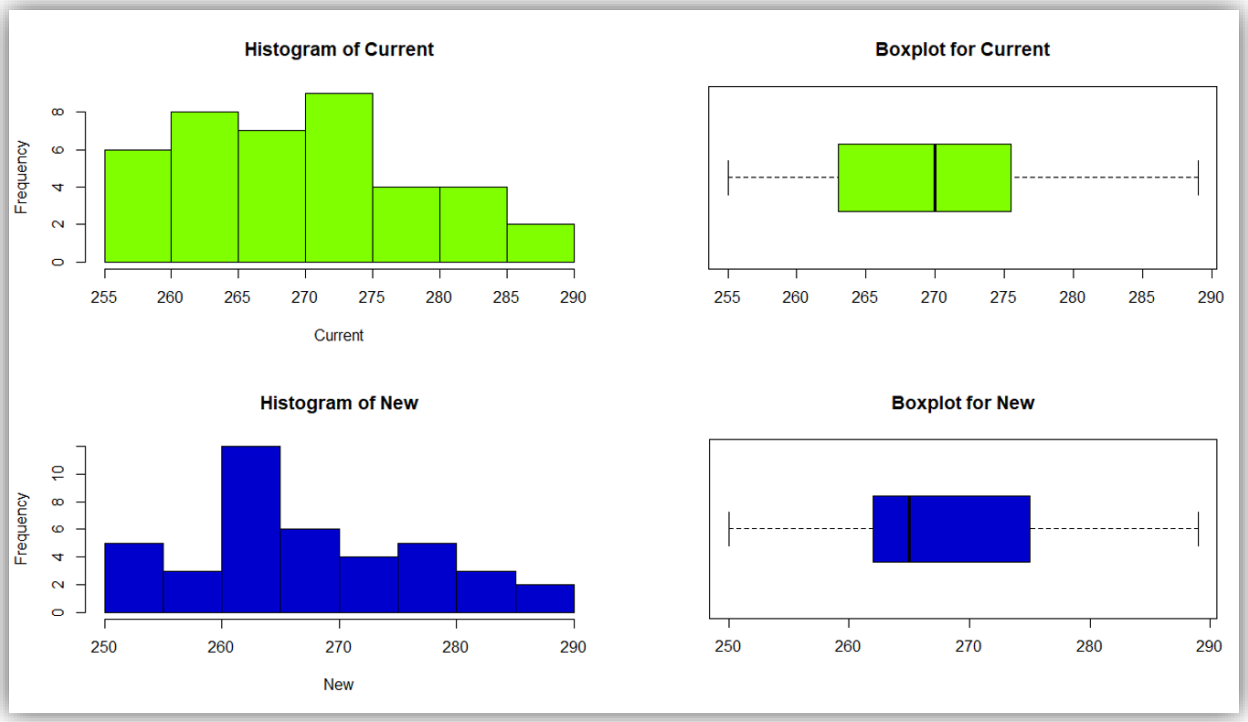
The mean distance of Current Golf ball is a bit higher than that of New cut-resistant Golf ball (i.e. 2.775). On the other hand, the standard deviation of the Current ball is lower than that of

the New Ball (8.75 as compared to 9.90). The variance of the Current ball is thus obviously lower than that of the New cut-resistant Golf balls (76.61 compared to 97.95).

As we know, variance is a measure of dispersal, it can be concluded that the data of the New cut-resistant balls fluctuates more than that of the Current balls.

In terms of IQR (Inter Quartile Range) both datasets are almost similar.

Histogram and Box Plot for both type of balls:



Question 4

What is the 95% confidence interval for the population mean of each model, and what is the 95% confidence interval for the difference between the means of the two population?

For Current Golf ball at 95% confidence interval

```
data:  Current
t = 195.29, df = 39, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 267.4757 273.0743
sample estimates:
mean of x
  270.275
```

For New cut-resistant Golf ball at 95% confidence interval

```
data:  New
t = 170.94, df = 39, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 264.3348 270.6652
sample estimates:
mean of x
    267.5
```

Just by understanding from the confidence intervals of the 2 samples, it can be said that there is no significant difference between the driving distances of the Current and the New Golf balls.

95% confidence interval for the difference between the means of the two population

```
data:  Current and New
t = 1.3284, df = 76.852, p-value = 0.188
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.384937  6.934937
sample estimates:
mean of x mean of y
  270.275   267.500
```

The 95% Confidence Interval for the difference between the means of the two populations is **-1.384937; 6.934937.**

Question 5

Do you see a need for larger sample sizes and more testing with the golf balls? Discuss

P-value for this two-tailed test is 0.188, which is greater than level of significance i.e. α=0.05. Hence, H_0 will not be rejected which shows that Par Inc. should take a new ball in production as the P-value indicates that there is no significant difference between estimated population mean of current golf ball as well as new golf ball.
The 95% confidence interval for the population mean of the current golf ball is 267.4757 to 273.0743 and of the model is 264.3348 to 270.6652. It means that the estimated population mean for Par, Inc. should lie within this range for consistent result. However, the 95% confidence interval for the difference between the means of the two populations is 2.775.

Concern regarding current Sample Size:

```
> diff1=Current-New
> diff1
 [1] -13  -8   4   6  -4  32  -4 -23 -27   6 -11  -2  22  -8   0   2   5   9 -12
[20]   4  -2  28  25   0  -2  -6 -11  -9  10  13  -2  24  20   3   5   4  18  19
[39]  13 -17
> detect=mean(diff1)
> sddiff=sd(diff1)
> detect
[1] 2.775
> sddiff
[1] 13.74397
> cohen.d=detect/sddiff
> cohen.d
[1] 0.2019067
```

```
> powertest=power.t.test(n=40,d=cohen.d,sig.level = 0.05,power = NULL,alternative =
"two.sided")
> powertest

     Two-sample t test power calculation

              n = 40
          delta = 0.2019067
             sd = 1
      sig.level = 0.05
          power = 0.14274
    alternative = two.sided

NOTE: n is number in *each* group
```

Power of test for the sample is 0.14274, which is significantly low for the sample size (n) of 40. Ideally, the Power should be around 0.90 to 0.95 for the sample size.
The low power value suggests that the sample size of 40 is too small for this hypothesis testing. Thus, a bigger number sample size is required.

Sample size at 0.95 power level:

```
> powertestA=power.t.test(n=NULL,d=cohen.d,sig.level = 0.05,power=0.95,alternative =
 "two.sided")
> powertestA

     Two-sample t test power calculation

              n = 638.484
          delta = 0.2019067
             sd = 1
      sig.level = 0.05
          power = 0.95
    alternative = two.sided

NOTE: n is number in *each* group
```

If we consider a power level of 0.95 the ideal sample size for the test should be 638.

Sample size at 0.90 power level:

```
> powertestB=power.t.test(n=NULL,d=cohen.d,sig.level = 0.05,power=0.90,alternative =
 "two.sided")
> powertestB

     Two-sample t test power calculation

              n = 516.4577
          delta = 0.2019067
             sd = 1
      sig.level = 0.05
          power = 0.9
    alternative = two.sided

NOTE: n is number in *each* group
```

If we consider a power of 0.90 the ideal sample size for the test should be 516.

By, the above two data we can say that the present sample size not at all appropriate to prove the hypothesis.

Conclusion

From the given data, it may be concluded that, statistically there is no significant increase/decrease in distance because of the new cut-resistant golf ball. However, our recommendation is that the test be carried out with a larger sample size to improve the accuracy of test result. Other than testing only the driving distance, Par Inc. should also consider other factors like costing, availability of suppliers and the like before finalizing and launching the product if they are looking to test a larger sample size.