

Example 1: One Way ANOVA in MINITAB

A consumer group wants to compare a new brand of wax (Brand-X) to two leading brands (Sureglow and Mirrorsheen) in terms of Effectiveness of wax. Following data is collected for this purpose:

| Brand | Effectiveness | Brand | Effectiveness | Brand | Effectiveness |
|----------|---------------|-------------|---------------|---------|---------------|
| Sureglow | 93 | Mirrorsheen | 90 | Brand_X | 105 |
| Sureglow | 96 | Mirrorsheen | 97 | Brand_X | 91 |
| Sureglow | 87 | Mirrorsheen | 91 | Brand_X | 95 |
| Sureglow | 91 | Mirrorsheen | 94 | Brand_X | 107 |
| Sureglow | 88 | Mirrorsheen | 100 | Brand_X | 90 |
| Sureglow | 85 | Mirrorsheen | 95 | Brand_X | 96 |
| Sureglow | 88 | Mirrorsheen | 88 | Brand_X | 92 |
| Sureglow | 91 | Mirrorsheen | 92 | Brand_X | 94 |
| Sureglow | 82 | Mirrorsheen | 94 | Brand_X | 84 |
| Sureglow | 91 | Mirrorsheen | 89 | Brand_X | 86 |
| Sureglow | 86 | Mirrorsheen | 96 | Brand_X | 82 |
| Sureglow | 93 | Mirrorsheen | 91 | Brand_X | 91 |
| Sureglow | 91 | Mirrorsheen | 97 | Brand_X | 106 |
| Sureglow | 87 | Mirrorsheen | 92 | Brand_X | 90 |
| Sureglow | 88 | Mirrorsheen | 92 | Brand_X | 91 |
| | | | | Brand_X | 92 |
| | | | | Brand_X | 91 |
| | | | | Brand_X | 106 |
| | | | | Brand_X | 98 |
| | | | | Brand_X | 97 |
| | | | | Brand_X | 80 |
| | | | | Brand_X | 97 |
| | | | | Brand_X | 91 |
| | | | | Brand_X | 99 |
| | | | | Brand_X | 86 |

To test the null hypothesis of equal mean effectiveness for the three brands of wax, the data is first converted to Group Format which will have 2 columns, Brand and Effectiveness.

ANOVA in R

```
d1<-read.csv("g:/Stats24x7/R/WaxEffectiveness.csv",header=TRUE)
```

```
attach(d1)
```

```
> names(d1)
[1] "Brand"      "Effectiveness"
```

```
> a1 <- aov(Effectiveness ~ Brand, data=d1)
```

```
> a1
Call:
aov(formula = Effectiveness ~ Brand, data = d1)
```

Terms:

```
      Brand Residuals
Sum of Squares 197.0085 1626.3733
Deg. of Freedom    2     52
```

```
Residual standard error: 5.592532
Estimated effects may be unbalanced
```

```
> summary(a1)
      Df Sum Sq Mean Sq F value Pr(>F)
Brand   2 197.01  98.504  3.1495 0.05116 .
Residuals 52 1626.37 31.276
```

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Read the datafile
WaxEffectiveness.csv in R.

Attach the dataframe d1.

Look at the variable names.

Run 1-way ANOVA in R.

Output of 1-way ANOVA in R.

Example 2: Two Way ANOVA in MINITAB

Following table shows drying time of concrete obtained from a set of 12 experiments conducted at 3 levels of CONCRETE amounts, and 2 levels of WATER amounts.

| CONCRETE(CUPS) | WATER(CUPS) | TIME(MINUTES) |
|----------------|-------------|---------------|
| 1.5 | 0.25 | 23 |
| 1.5 | 0.25 | 21 |
| 1.5 | 0.5 | 153 |
| 1.5 | 0.5 | 161 |
| 1.75 | 0.25 | 25 |
| 1.75 | 0.25 | 27 |
| 1.75 | 0.5 | 159 |
| 1.75 | 0.5 | 171 |
| 2 | 0.25 | 29 |
| 2 | 0.25 | 31 |
| 2 | 0.5 | 183 |
| 2 | 0.5 | 187 |

Test if the factors CONCRETE and WATER have an effect on mean drying time.

Open the data file Concrete.csv in R:

```
d2<-read.csv("g:/Stats24x7/R/Concrete.csv",header=TRUE)
attach(d2)
```

```
> names(d2)
[1] "CONCRETE" "WATER" "TIME"
```

Read the datafile
Concrete.csv in R.

Attach the dataframe d2.

Look at the variable names.

```
> a2 <- aov(TIME ~ CONCRETE + WATER, data=d2)
> a2
```

Run 2-way ANOVA in R, the
model here is ADDITIVE.

Call:

```
aov(formula = TIME ~ CONCRETE + WATER, data = d2)
```

OUTPUT:

Terms:

| | CONCRETE | WATER | Residuals |
|-----------------|----------|-------|-----------|
| Sum of Squares | 648 | 61347 | 366 |
| Deg. of Freedom | 1 | 1 | 9 |

Residual standard error: 6.377042

Estimated effects may be unbalanced

ANOVA in R

```
> summary(a2)
      Df Sum Sq Mean Sq F value Pr(>F)
CONCRETE  1  648    648  15.934 0.003149 **
WATER     1 61347  61347 1508.533 2.471e-11 ***
Residuals  9   366    41
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

OUTPUT - continued:
Both terms CONCRETE and
WATER are significant.

```
> a2I <- aov(TIME ~ CONCRETE + WATER + CONCRETE * WATER , data=d2)
> a2I
Call:
aov(formula = TIME ~ CONCRETE + WATER + CONCRETE * WATER, data = d2)
```

Run 2-way
ANOVA in R, the
model here has
an INTERACTION
TERM.

```
Terms:
      CONCRETE WATER CONCRETE:WATER Residuals
Sum of Squares   648 61347         200    166
Deg. of Freedom   1    1         1     8
```

OUTPUT:
Both terms CONCRETE and
WATER are significant, and
the INTERACTION is also
significant.

Residual standard error: 4.555217
Estimated effects may be unbalanced

```
> summary(a2I)
      Df Sum Sq Mean Sq F value Pr(>F)
CONCRETE  1  648    648  31.2289 0.0005173 ***
WATER     1 61347  61347 2956.4819 1.452e-11 ***
CONCRETE:WATER 1  200    200  9.6386 0.0145640 *
Residuals  8   166    21
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

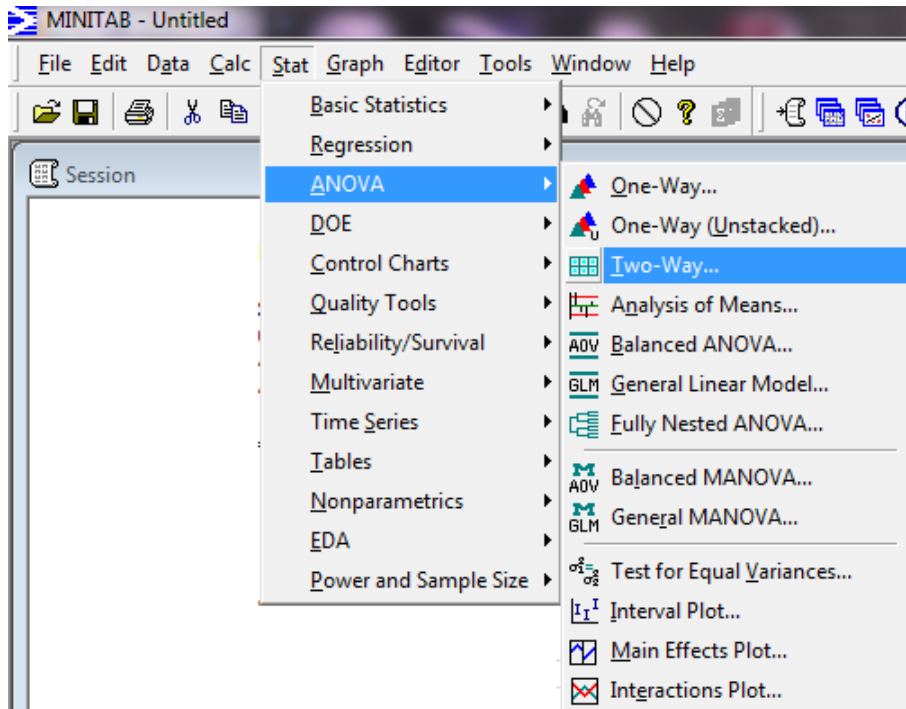


Figure 2b: Running Two-Way ANOVA in MINITAB

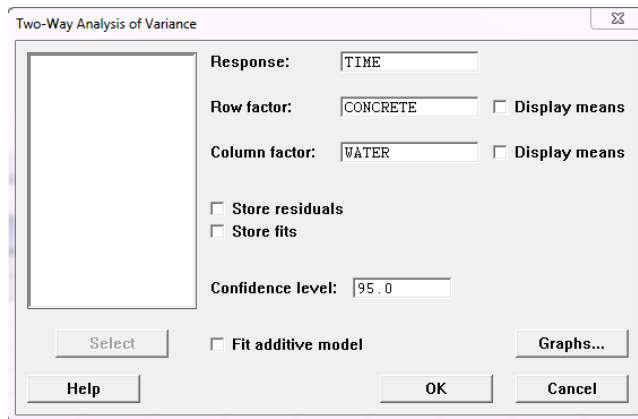


Figure 2b: Selecting Variables

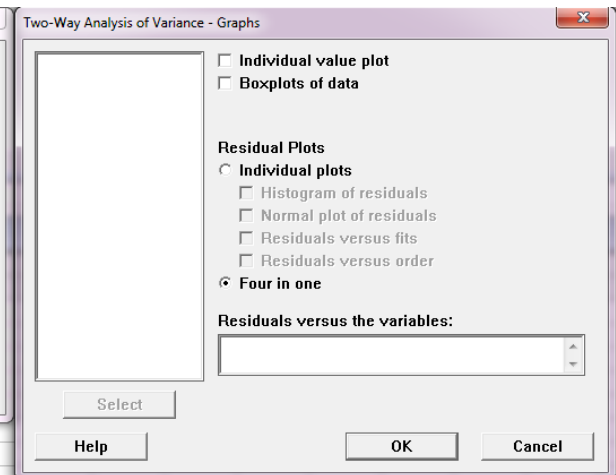


Figure 2b: Selecting Residual Plots

Output from MINITAB is shown below. The residual plots (Figure 2d) indicate that the residuals are normally distributed.

Two-way ANOVA: TIME versus CONCRETE, WATER

| Source | DF | SS | MS | F | P |
|-------------|----|-------|---------|---------|-------|
| CONCRETE | 2 | 672 | 336.0 | 17.08 | 0.003 |
| WATER | 1 | 61347 | 61347.0 | 3119.34 | 0.000 |
| Interaction | 2 | 224 | 112.0 | 5.69 | 0.041 |
| Error | 6 | 118 | 19.7 | | |

CONCRETE significant
 WATER significant
 INTERACTION significant

ANOVA in R

Total 11 62361

S = 4.435 R-Sq = 99.81% R-Sq(adj) = 99.65%

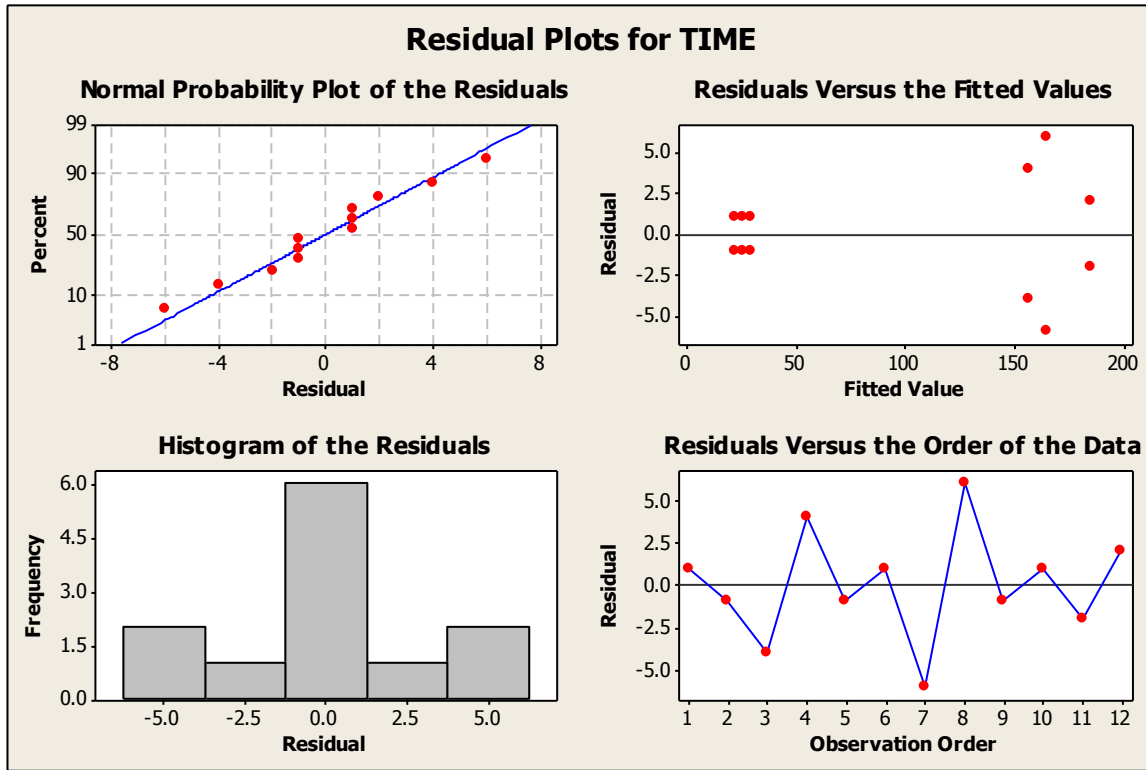


Figure 2d: Residual plots