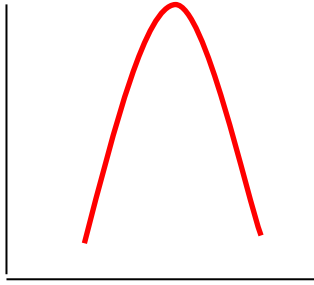


Level 5 – Continuous Improvement with Industry 4.0

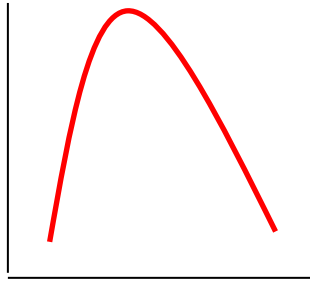
Analyse 3 – Paired Test / ANOVA



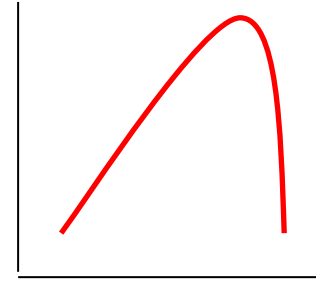
Analyse – distribution shapes



Normal
Distribution



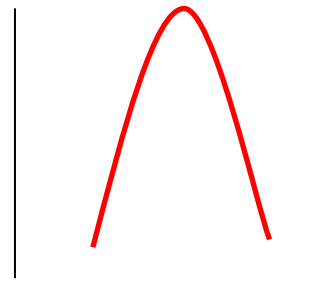
Skewed to
the right



Skewed to
the left

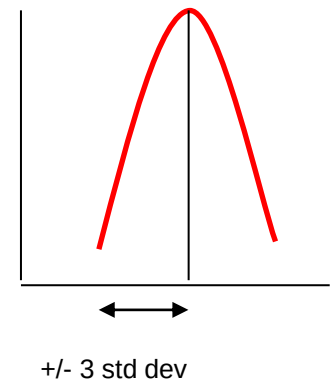
Not all continuous random variables are normally distributed

We need to evaluate how near the set of data is to the normal distribution



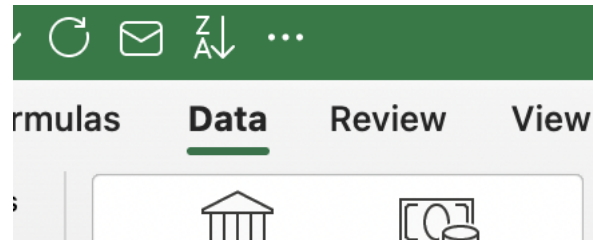
How can we tell?

- Construct a histogram and see if the data has a normal distribution
- Do the mean, median and mode have similar values?
- Is the range approximately 6 standard deviations (± 3 from mean)
- Evaluate mathematically (Excel, Minitab)

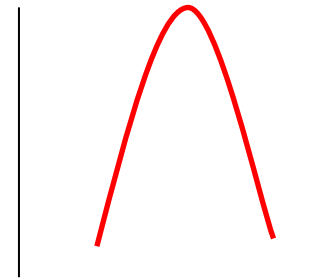
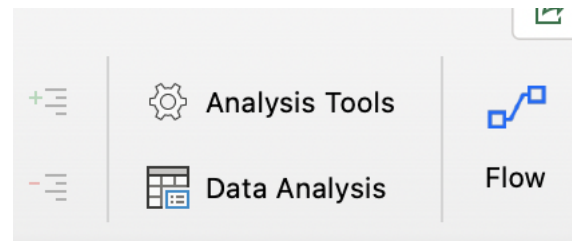


Analyse – Testing for Normality in Excel

- Open new excel spreadsheet and key in the following numbers into a column and click on 'Data' tab

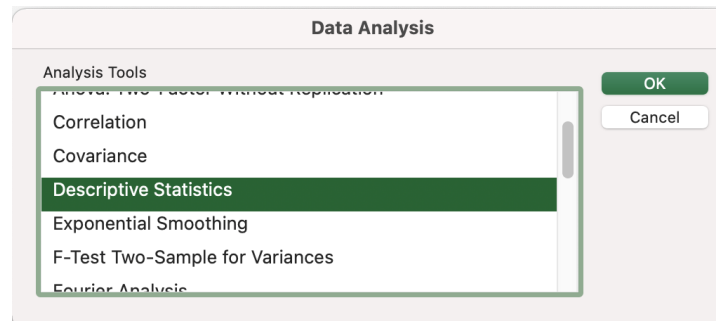


- Click on the 'Data Analysis' icon

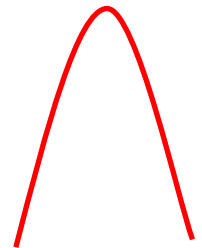
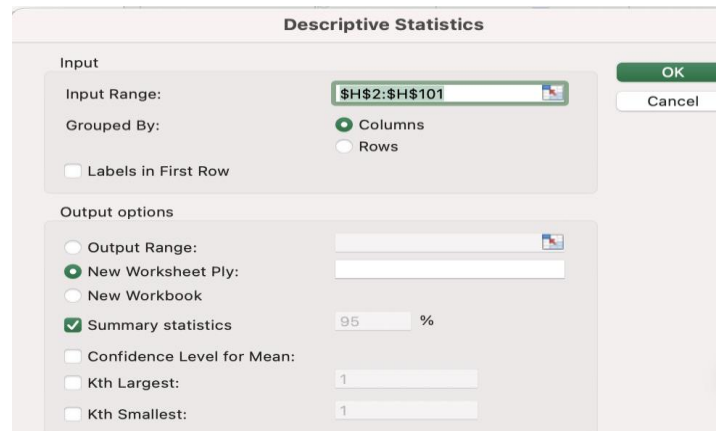


Analyse – Testing for Normality in Excel

- Scroll down and highlight 'Descriptive Statistics' from menu and click 'OK'



- Click on input range and paint column of numbers, highlight summary statistics and click 'OK'



Analyse – Testing for Normality in Excel

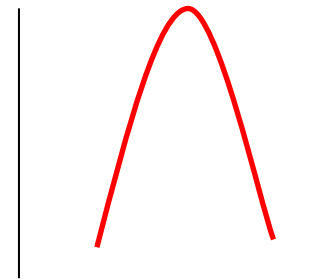
73
70
72
70
73
66
74
74
69
72
70
71
74
72
72
72
71
70
68
70
71
70
73
72
72
73

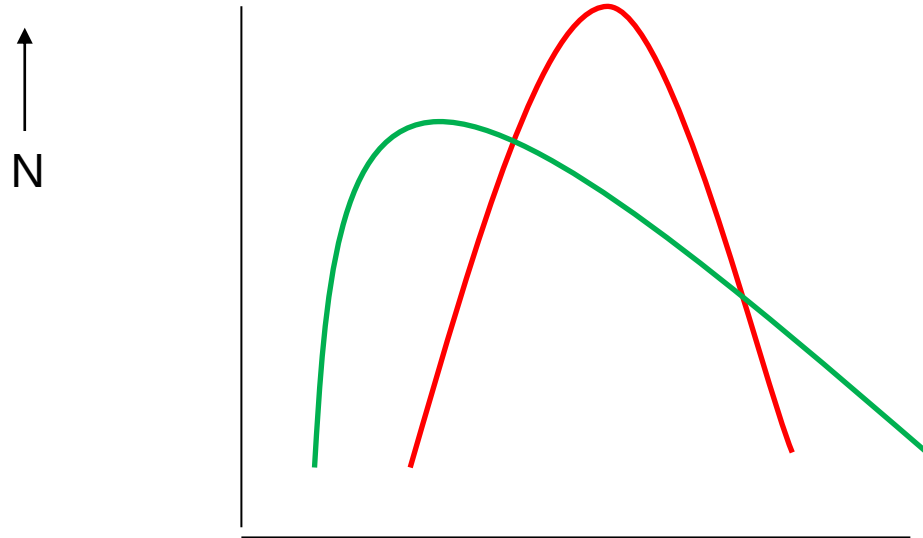
Master Final Round 2021

Mean	71.28
Standard Error	0.38952963
Median	72
Mode	70
Standard Deviation	1.94764815
Sample Variance	3.79333333
Kurtosis	0.8140209
Skewness	-0.760273
Range	8
Minimum	66
Maximum	74
Sum	1782
Count	25

The amount in the tails of distribution

Measure of symmetry





As the sample size increases the means of the data becomes normal

Analyse – Central Limit Theorem - example



Analyse – Central Limit Theorum - example

I rolled 5 dice and noted their individual numbers and worked out the average

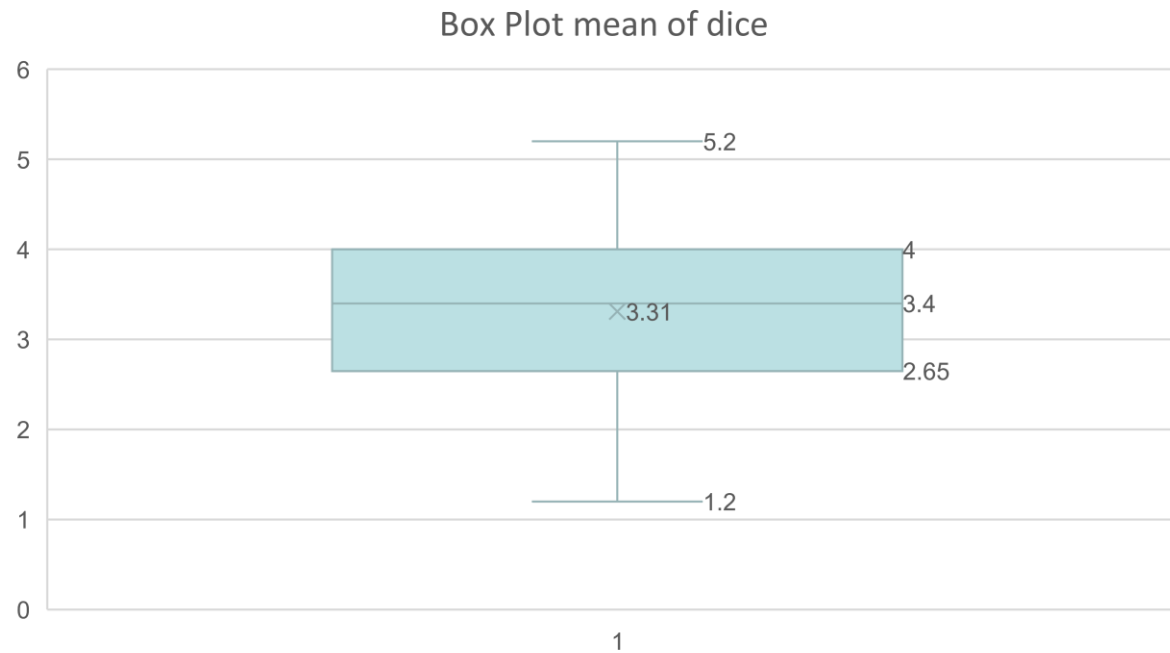
Then rolled them a further 99 times

Noted the individual rolls and worked out all the averages

Entered them into a spreadsheet and generated a histogram



Analyse – Central Limit Theorem - example



Analyse – Types of Errors

	Do not reject H_0	Reject H_0
H_0 is true	Correct	Type I Error You think there is a difference when there isn't Alpha risk
H_0 is false	Type II Error You think there is no difference when there is Beta risk	Correct



Fire alarm goes off when there is no fire – false positive – type I error

Fire alarm fails to go off when there is a fire - false negative type II error

A confidence interval is a type of estimate computed from the statistics of the observed data. This gives a range of values for an unknown parameter.

The interval has an associated confidence level that gives the probability with which an estimated interval will contain the true value of the parameter.

Its use – “we can be 95% confident that a given value falls between x and y ”

Generally, in industry it is acceptable to have 95% confidence or we are willing to accept 5% error

$$CI = \bar{x} \pm z \frac{s}{\sqrt{n}}$$

CI = confidence interval

$\bar{x}$ = sample mean

z = confidence level value

s = sample standard deviation

n = sample size

Example:-

We measured 40 men's height and had a mean of 175cms

The Standard Deviation was 20cms

We need 95% confidence so we use a Z value of 1.96

$$CI = 175 \pm 1.96 \frac{20}{\sqrt{40}}$$

$$CI = 175 \pm 6.20 \text{ cms}$$

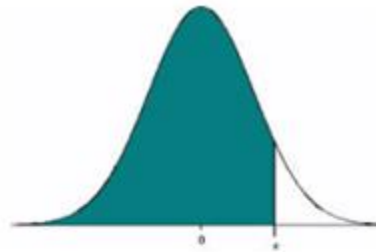
This is known as the margin of error

Therefore, we can be 95% confident that our measurement will fall between 168.8 and 181.2cms

Warning :- but 5% could be outside these limits!

Confidence Interval	z
80%	1.282
85%	1.440
90%	1.645
95%	1.960
99%	2.576
99.5%	2.807
99.9%	3.291

Analyse – Confidence Intervals – Z values



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964

$$CI = 71.28 \pm 1.96 \frac{1.94}{\sqrt{25}}$$

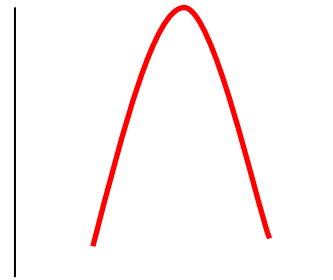
$$CI = 71.28 \pm 0.76$$

Therefore, we can be 95% confident that the final round shots were between 70.52 and 72.04

Analyse – Confidence Intervals another example



Hideki Matsuyama winner by 1 shot, -10

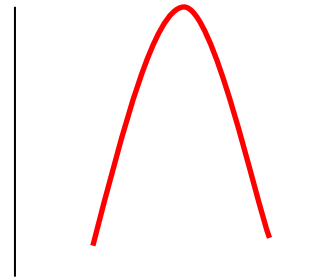


If we reject the null hypothesis, the P value is the probability of being incorrect

Or it's the probability of making a type I error

Put more simply if P value is less than 0.05 we reject the null hypothesis

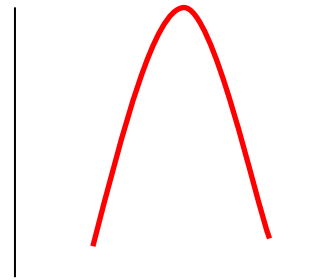
Analyse – T Test



Analyse – Practice – Call Centre Response Times



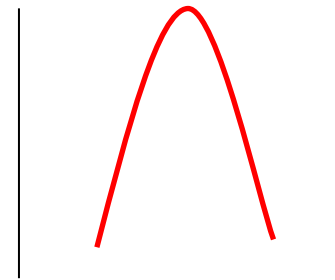
[This Photo](#) by Unknown Author is licensed under [CC BY-SA-NC](#)



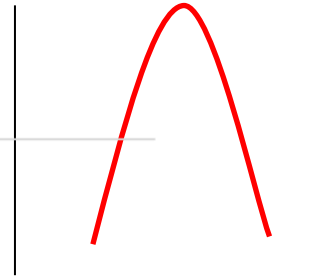
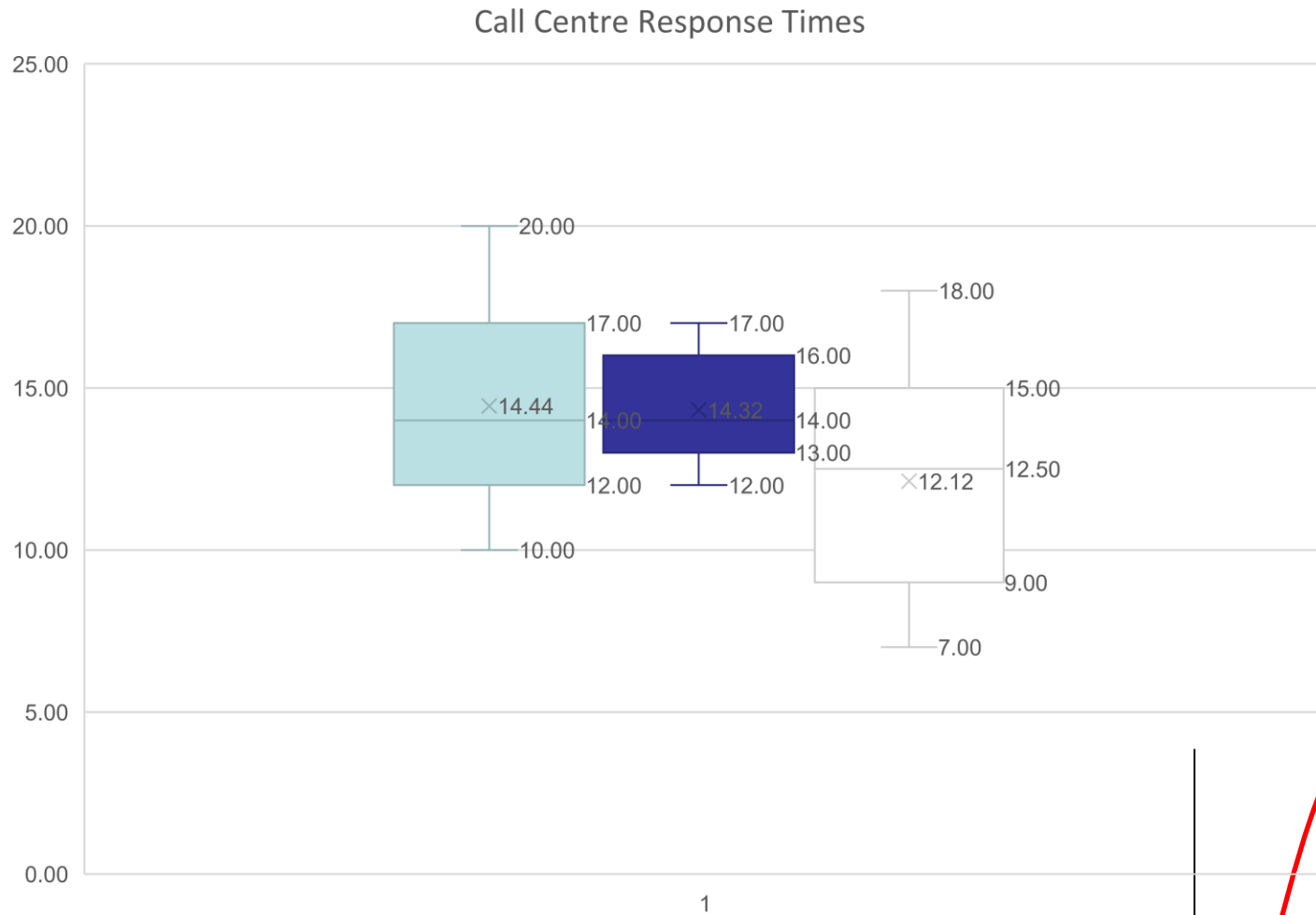
Analyse – Practice – Call Centre Response Times

A	B	C
13.00	13.00	14.00
12.00	13.00	8.00
16.00	12.00	11.00
20.00	16.00	18.00
20.00	14.00	7.00
11.00	17.00	13.00
16.00	14.00	8.00
11.000	17.00	13.00
15.000	15.00	15.00
11.000	14.00	18.00
10.000	12.00	8.00
14.000	12.00	7.00
14.000	13.00	7.00
15.000	12.00	11.00
19.000	14.00	17.00
10.000	17.00	13.00
19.000	15.00	18.00
12.000	15.00	15.00
20.000	12.00	10.00
11.000	16.00	8.00
15.000	16.00	13.00
16.000	16.00	9.00
13.000	17.00	17.00
20.000	12.00	13.00
14.000	12.00	8.00
18.000	13.00	17.00
15.000	17.00	16.00
12.000	14.00	13.00
14.000	13.00	13.00
18.000	13.00	11.00
15.000	13.00	9.00
17.000	12.00	15.00
16.000	13.00	15.00
17.000	17.00	14.00
13.000	16.00	8.00
11.000	17.00	12.00
20.000	13.00	10.00
12.000	12.00	12.00
12.000	17.00	9.00
16.000	15.00	7.00
12.000	17.00	11.00
17.000	15.00	11.00
10.000	13.00	15.00
10.000	12.00	15.00
12.000	17.00	14.00
13.000	14.00	15.00
20.000	15.00	10.00
10.000	15.00	15.00
12.000	13.00	10.00
13.000	14.00	10.00

Call Centre Inc. has 3 call centres
find out which are statistically
different if any

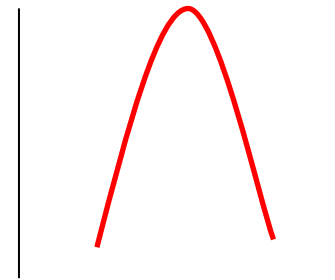


Analyse – Practice – Call Centre Response Times



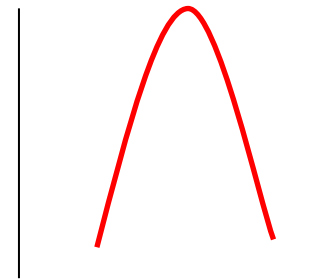
Analyse – Practice – Call Centre Response Times

t-Test: Two-Sample Assuming Unequal Variances		
	A	B
Mean	14.44	14.32
Variance	10.25142857	3.324082
Observations	50	50
Hypothesized Mean Difference	0	
df	78	
t Stat	0.23029694	
P(T<=t) one-tail	0.409231983	
t Critical one-tail	1.664624645	
P(T<=t) two-tail	0.818463966	
t Critical two-tail	1.990847069	



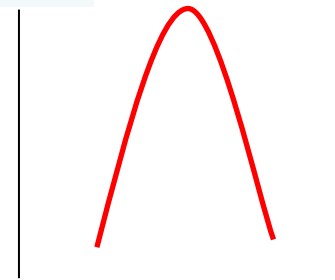
Analyse – Practice – Call Centre Response Times

t-Test: Two-Sample Assuming Unequal Variances		
	A	C
Mean	14.44	12.12
Variance	10.25142857	10.96489796
Observations	50	50
Hypothesized Mean Difference	0	
df	98	
t Stat	3.561540536	
P(T<=t) one-tail	0.000285506	
t Critical one-tail	1.660551217	
P(T<=t) two-tail	0.000571012	
t Critical two-tail	1.984467455	



Analyse – Practice – Call Centre Response Times

t-Test: Two-Sample Assuming Unequal Variances		
	B	C
Mean	14.32	12.12
Variance	3.32	10.96
Observations	50.00	50.00
Hypothesized Mean Difference	0.00	
df	76.00	
t Stat	4.12	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.00	
t Critical two-tail	1.99	



All the data looks normal but how do we test to see if they are different?

2 sample T test – tests the means of two populations to see if they are the same – independent samples

Paired T test – tests the means of two populations to see if they are the same but considers that the samples are dependent on each other (paired)

Paired T test – examples

Before and after a manufacturing operation:-

Flattening operation

Heat treatment operation

Measurement operation with two pieces of equipment

Analyse – T Test / Paired Test

2 sample T test

thermometer 1	thermometer 2
37.10	36.9
37.10	36.8
35.80	36.3
36.10	36.4
37.20	36.8
37.10	36.9
37.10	37
35.90	35.8
36.30	36.4
36.90	36.7
37.20	37.1
36.20	36.3
37.20	36.8
36.40	36.7
35.90	35.8
37.30	37.1
37.80	37.4
36.30	36.5
35.90	35.8
37.90	37.7
36.20	35.9
36.30	36.2
37.10	36.8
36.90	36.6
36.50	36.7



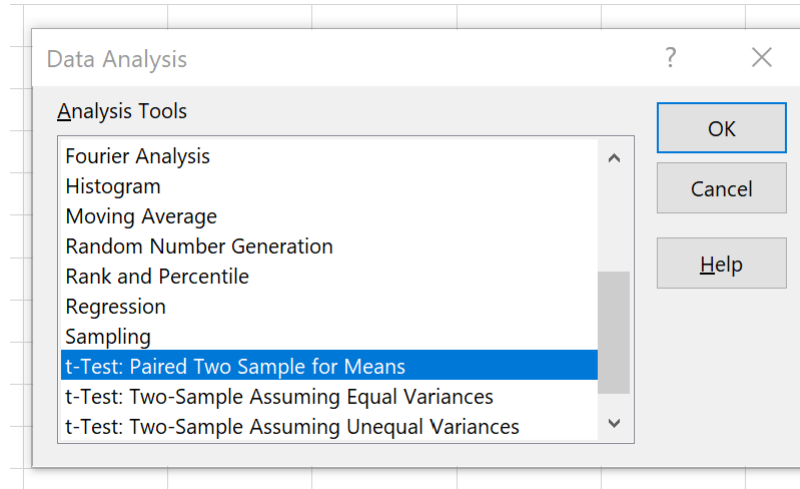
Analyse – T Test / Paired Test

Paired test

thermometer 1		thermometer 2
37.10	→	36.9
37.10	→	36.8
35.80	→	36.3
36.10	→	36.4
37.20	→	36.8
37.10	→	36.9
37.10	→	37
35.90	→	35.8
36.30	→	36.4
36.90	→	36.7
37.20	→	37.1
36.20	→	36.3
37.20	→	36.8
36.40	→	36.7
35.90	→	35.8
37.30	→	37.1
37.80	→	37.4
36.30	→	36.5
35.90	→	35.8
37.90	→	37.7
36.20	→	35.9
36.30	→	36.2
37.10	→	36.8
36.90	→	36.6
36.50	→	36.7



Analyse – T Test / Paired Test



Analyse – T Test / Paired Test

t-Test: Two-Sample Assuming Unequal Variances			
	thermometer	thermometer	
	1	2	
Mean	36.708	36.616	
Variance	0.368267	0.238067	
Observations	25	25	
Hypothesized Mean Difference	0		
df	46		
t Stat	0.590748		
P(T<=t) one-tail	0.27879		
t Critical one-tail	1.67866		
P(T<=t) two-tail	0.557581		
t Critical two-tail	2.012896		

t-Test: Paired Two Sample for Means			
	thermometer	thermometer	
	1	2	
Mean	36.708	36.616	
Variance	0.368267	0.238067	
Observations	25	25	
Pearson Correlation	0.924085		
Hypothesized Mean Difference	0		
df	24		
t Stat	1.892187		
P(T<=t) one-tail	0.035295		
t Critical one-tail	1.710882		
P(T<=t) two-tail	0.070591		
t Critical two-tail	2.063899		

Analyse – T Test / Paired Test – chemical treatment

after	before
1.19	1.35
1.17	1.35
1.28	1.35
1.01	1.05
1.21	1.3
1.1	1.25
1.06	1.276
1.13	1.2
1.1	1.25
1.27	1.31
1.255	1.45
1.1	1.35
0.97	1.2
1.21	1.318
1.17	1.34
1.01	1.29
1.02	1.05
1.24	1.35
1.01	1.05
0.97	1.4
1.25	1.35
1.02	1.35
1.21	1.3
1.03	1.2
1.26	1.3

t-Test: Two-Sample Assuming Unequal Variances

	before	after
Mean	1.28	1.13
Variance	0.01	0.01
Observations	25.00	25.00
Hypothesized Mean Difference	0.00	
df	48.00	
t Stat	5.04	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.01	

t-Test: Paired Two Sample for Means

	before	after
Mean	1.28	1.13
Variance	0.01	0.01
Observations	25.00	25.00
Pearson Correlation	0.54	
Hypothesized Mean Difference	0.00	
df	24.00	
t Stat	7.46	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.71	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.06	

All the data looks normal but how do we test to see if they are different?

2 sample T test – tests the means of two populations to see if they are the same

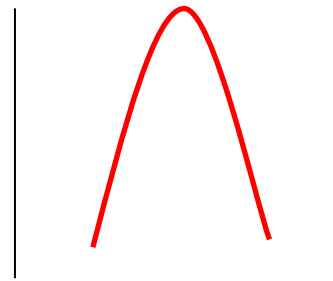
ANOVA – analysis of variance tests the means of two or more populations to see if they are the same

Analysis of variance - ANOVA

analysis of variance tests the means of two or more populations to see if they are the same

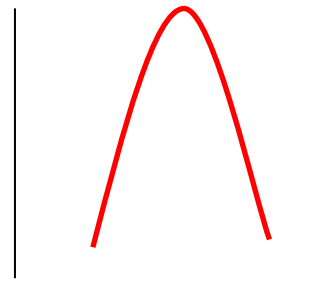
Our Hypothesis is

$$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$$

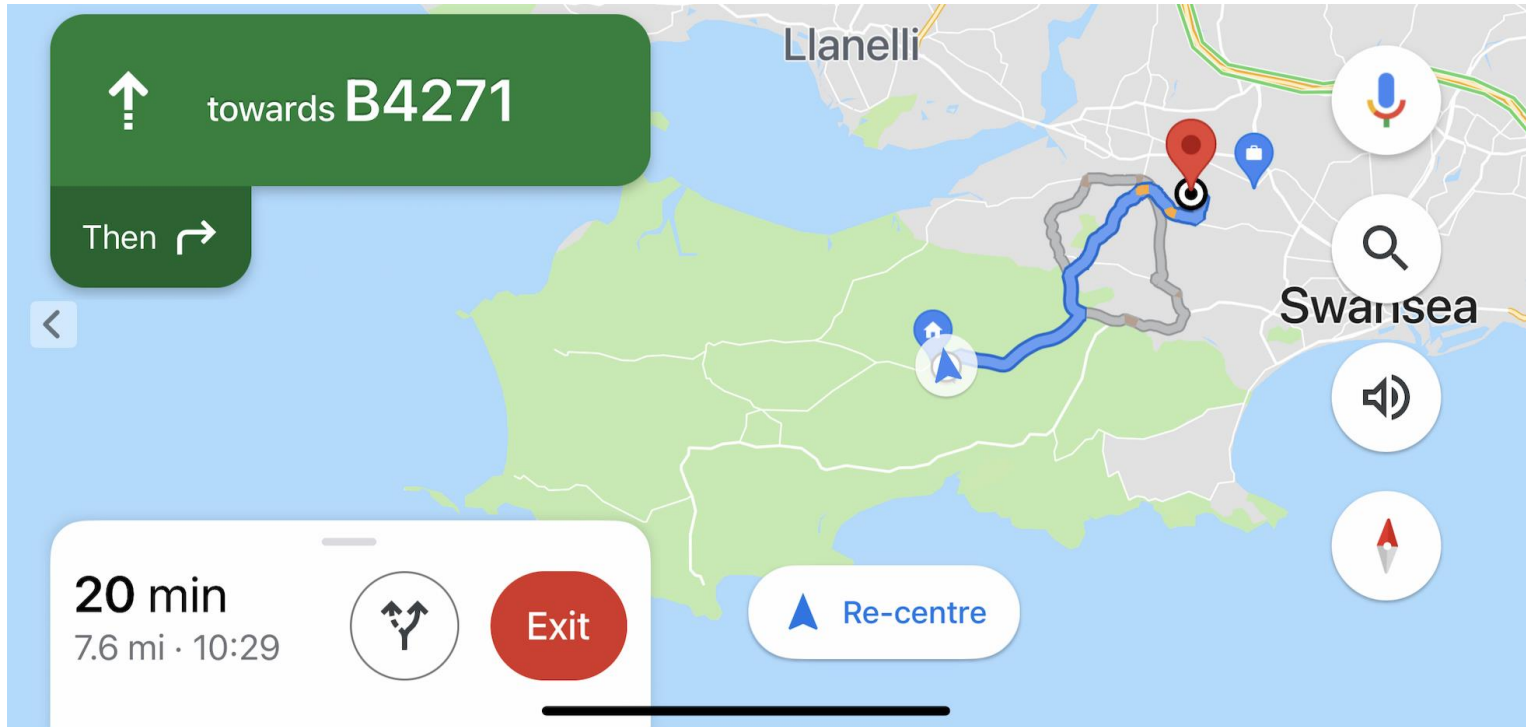


One way ANOVA tests involves one factor it tests the means of sets of results to see if they are the same - it does not tell us which one is different

Two way ANOVA involves many factors



My Journey to Work



Analyse – T Test / Analysis of Variance (ANOVA)

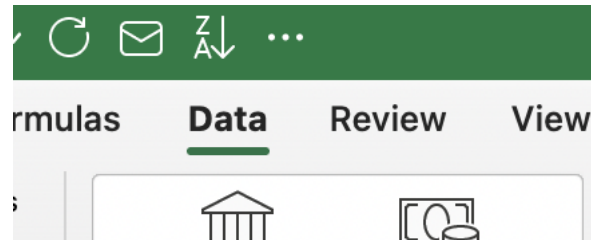
Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

- 4 different routes
- Same time of day
- Same car

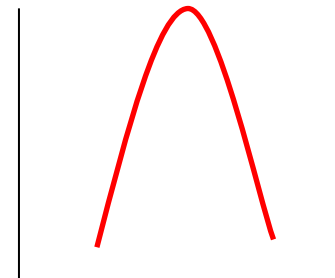
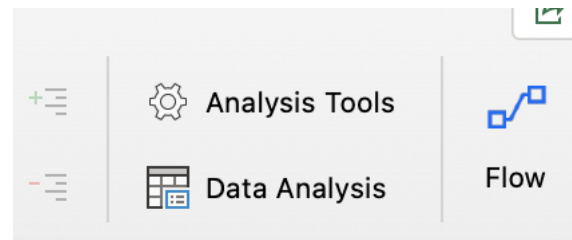
Analyse – ANOVA

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

Open new excel spreadsheet and key in the following numbers into a column and click on 'Data' tab



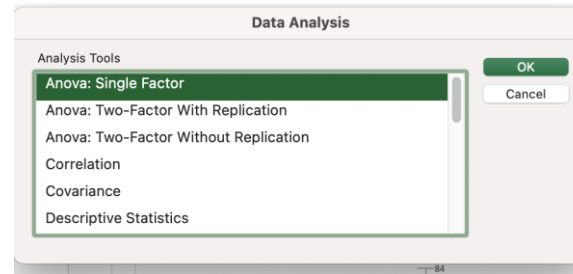
Click on the 'Data Analysis' icon



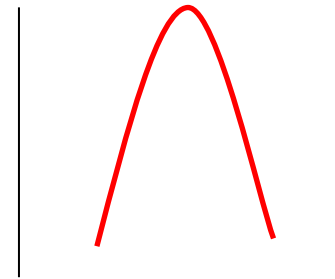
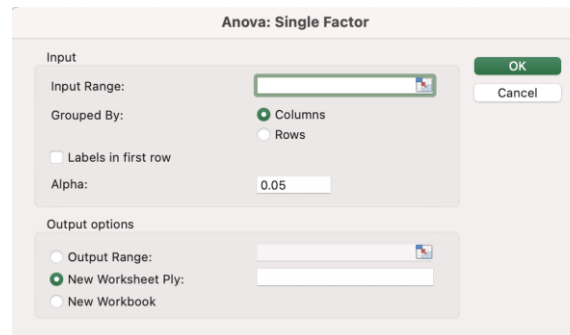
Analyse – ANOVA

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

- Click on ANOVA Single Factor



- Paint in the 4 ranges of data and ensure Alpha is 0.05 (confidence of 95%) and press 'OK'



Analyse – ANOVA

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

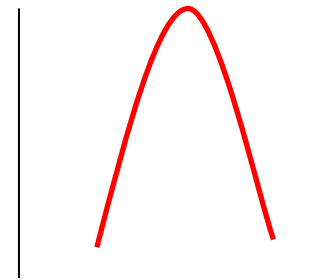
Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Route A	30	780	26	2.827586
Route B	30	978	32.6	9.627586
Route C	30	953	31.76667	6.598851
Route D	30	1123	37.43333	18.39195

ANOVA

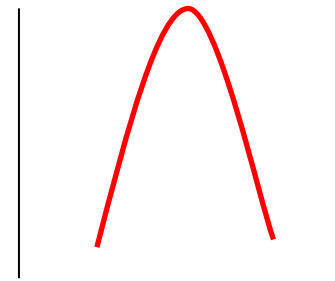
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1977.767	3	659.2556	70.42204	0.00	2.682809
Within Groups	1085.933	116	9.361494			
Total	3063.7	119				



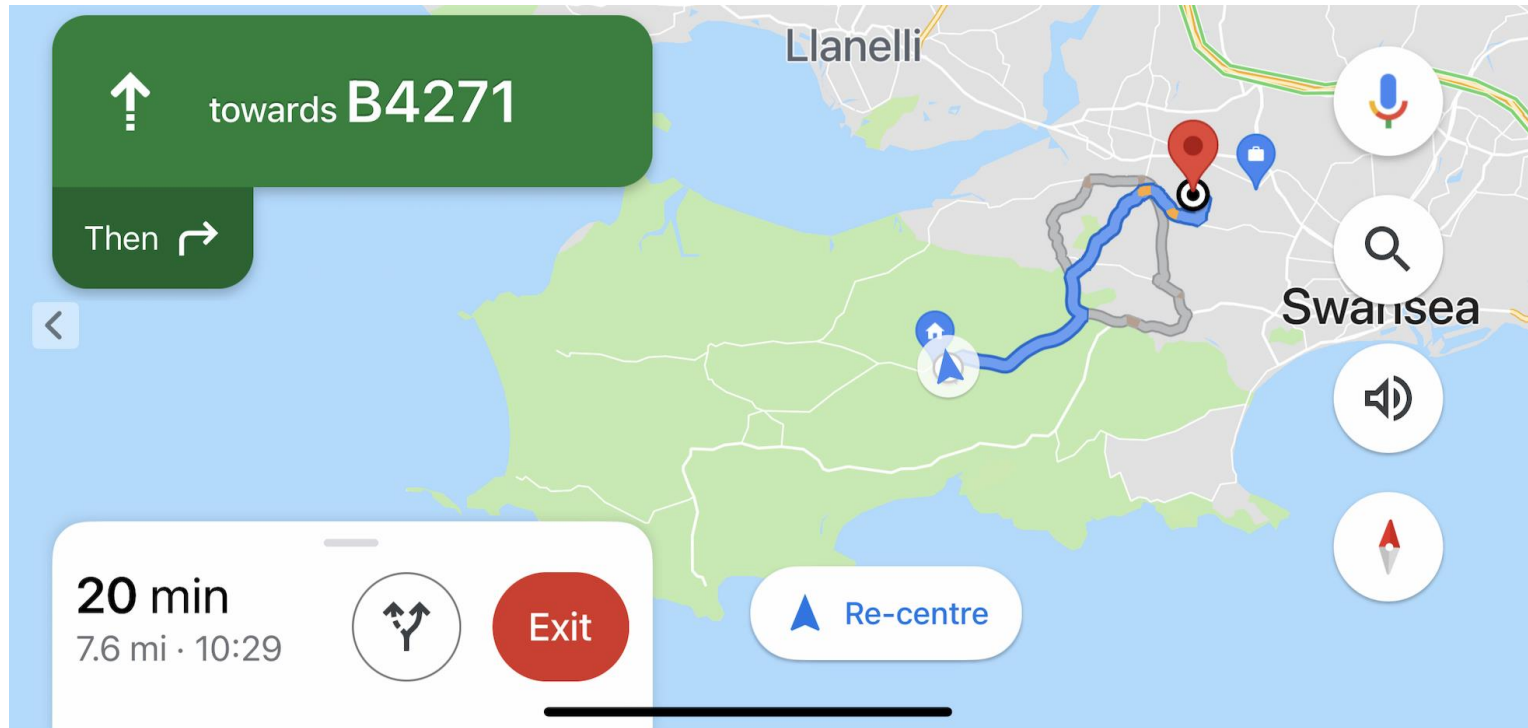
Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

One way ANOVA tests involves one factor it tests the means of sets of results to see if they are the same - it does not tell us which one is different - me driving

Two-way ANOVA involves many factors – two drivers



My Journey to Work



Analyse – T Test / Analysis of Variance (ANOVA)

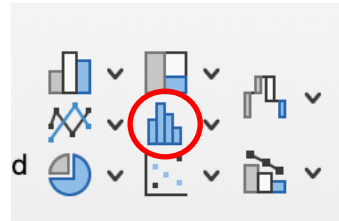
Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

Route A		Route B	
Mean	26	Mean	32.6
Standard Error	0.31	Standard Error	0.57
Median	26	Median	32.5
Mode	26	Mode	29
Standard Deviation	1.68	Standard Deviation	3.10
Sample Variance	2.83	Sample Variance	9.63
Kurtosis	-0.23	Kurtosis	-1.09
Skewness	0.37	Skewness	0.20
Range	7	Range	10
Minimum	23	Minimum	28
Maximum	30	Maximum	38
Sum	780	Sum	978
Count	30	Count	30
Route C		Route D	
Mean	31.77	Mean	37.43
Standard Error	0.47	Standard Error	0.78
Median	32	Median	37.5
Mode	34	Mode	34
Standard Deviation	2.57	Standard Deviation	4.29
Sample Variance	6.60	Sample Variance	18.39
Kurtosis	-0.33	Kurtosis	-1.35
Skewness	-0.76	Skewness	0.07
Range	9	Range	14
Minimum	26	Minimum	31
Maximum	35	Maximum	45
Sum	953	Sum	1123
Count	30	Count	30

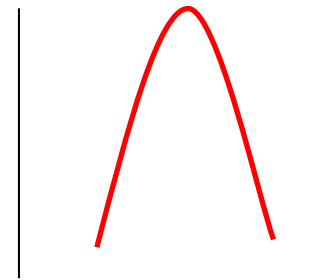
Analyse – T Test / Analysis of Variance (ANOVA)

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

- Paint in ALL numbers choose 'Insert' tab click on histogram icon



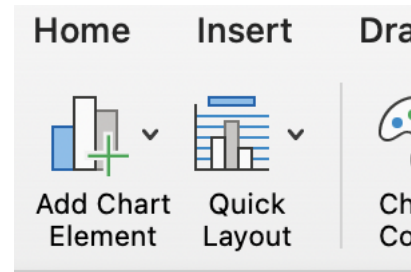
- Choose 'Box and Whisker'



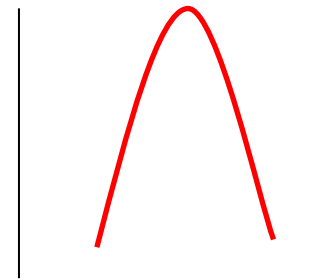
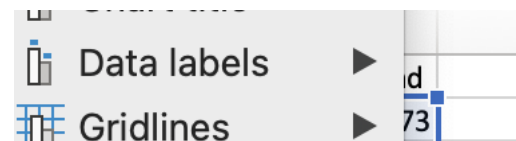
Analyse – T Test / Analysis of Variance (ANOVA)

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

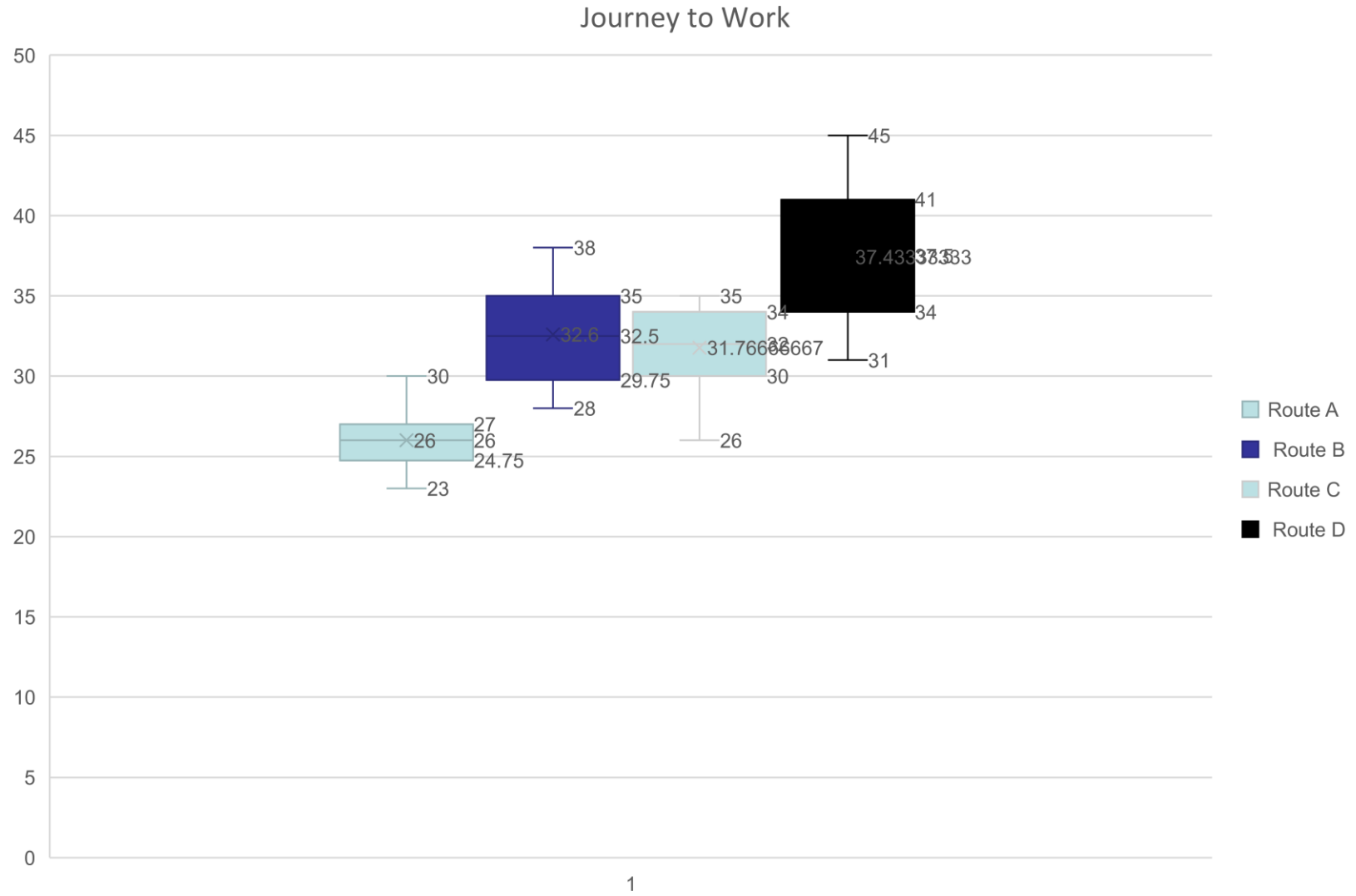
Choose 'add chart element'



Choose 'Data Labels' to display values on chart



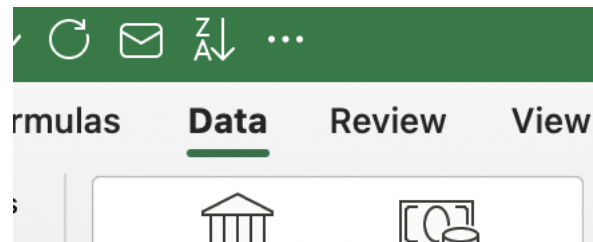
Analyse – T Test / Analysis of Variance (ANOVA)



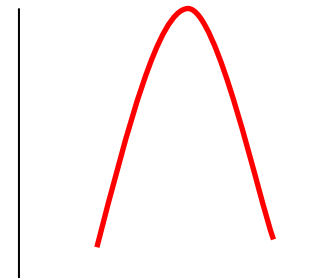
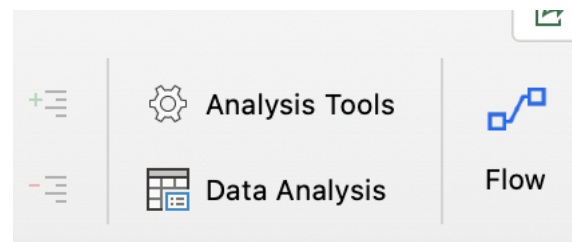
Analyse – T Test in Excel

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

Open new excel spreadsheet and key in the following numbers into a column and click on 'Data' tab



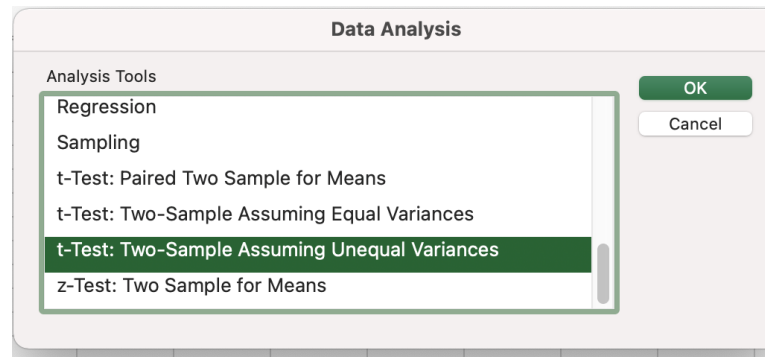
Click on the 'Data Analysis' icon



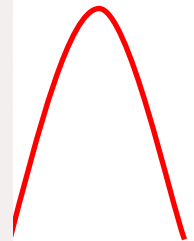
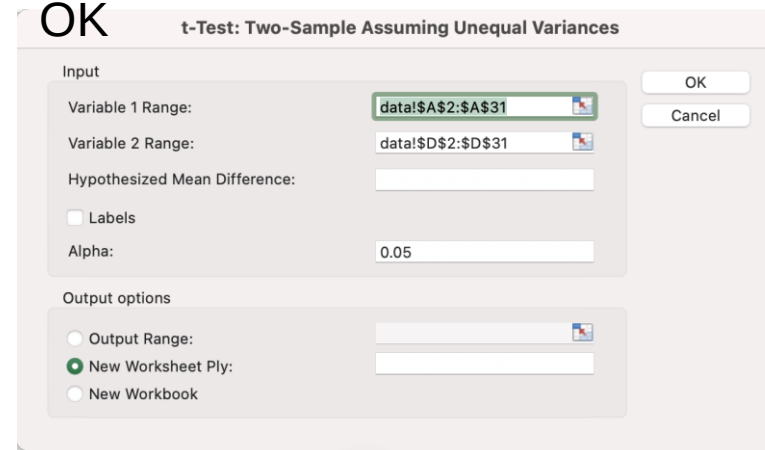
Analyse – T Test in Excel

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

- Click on T- test: two sample assuming unequal variances



- Click on input range and paint columns of A and D, check alpha 0.05 and click OK



Analyse – T Test in Excel

route A	Route B	Route C	route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

t-Test: Two-Sample Assuming Unequal Variances

Mean

Variance

Observations

Hypothesized Mean Difference

df

t Stat

P(T<=t) one-tail

t Critical one-tail

P(T<=t) two-tail

t Critical two-tail

route A

route D

26.0

37.4

2.8

18.4

30.0

30.0

0.0

38.0

-13.6

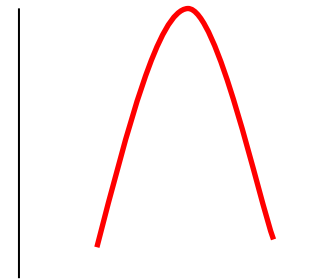
0.0

1.7

0.0

2.0

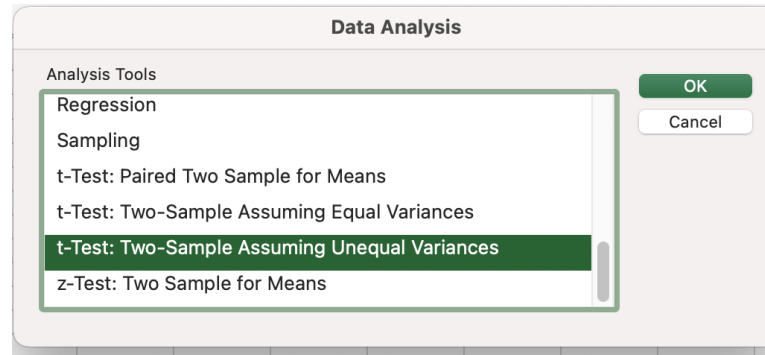
***P less than 0.05
therefore difference is
significant***



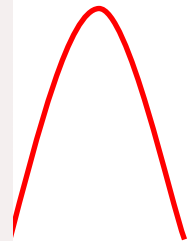
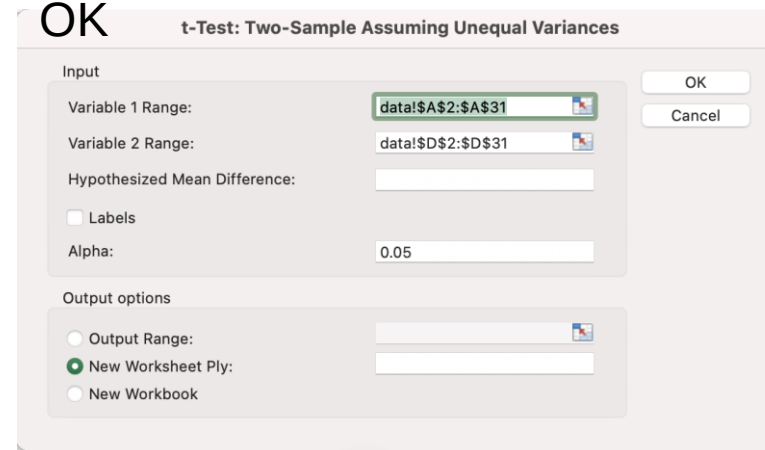
Analyse – T Test in Excel

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

- Click on T- test: two sample assuming unequal variances



- Click on input range and paint columns of B and C, check alpha 0.05 and click OK



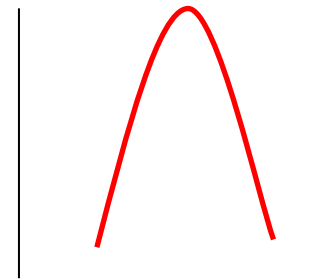
Analyse – T Test in Excel

Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35	31	34
24	31	27	34
28	33	35	38
24	37	30	43
26	32	30	33
24	29	27	32
26	32	34	32
25	34	33	42

t-Test: Two-Sample Assuming Unequal Variances

	Route B	Route C
Mean	32.60	31.77
Variance	9.63	6.60
Observations	30.00	30.00
Hypothesized Mean Difference	0.00	
df	56.00	
t Stat	1.13	
P(T<=t) one-tail	0.13	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.26	
t Critical two-tail	2.00	

***P greater than 0.05
therefore difference is
not significant***

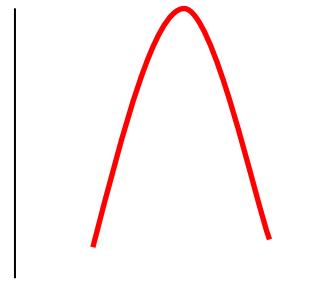


Our Hypothesis is

$$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$$

And $P = 0.000$ therefore we reject the null hypothesis

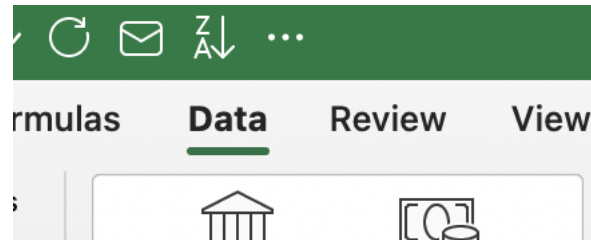
H_a : At Least One Inequality



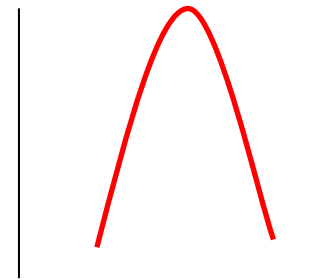
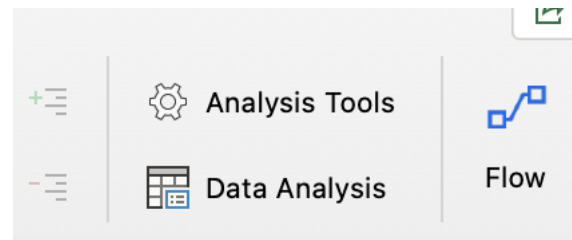
Analyse – ANOVA – Open exercise

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

- Open new excel spreadsheet and key in the following numbers into a column and click on 'Data' tab



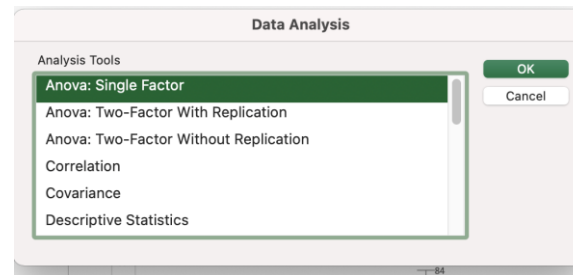
- Click on the 'Data Analysis' icon



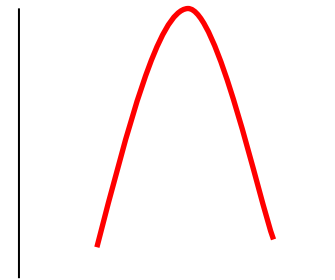
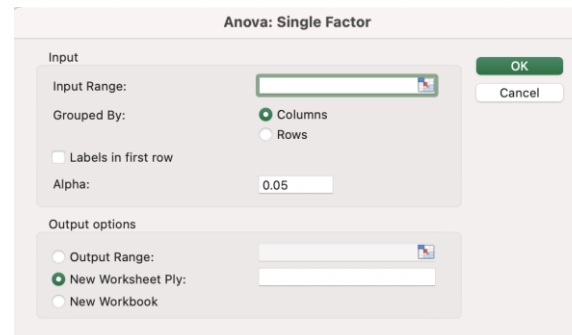
Analyse – ANOVA

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

- Click on ANOVA Single Factor



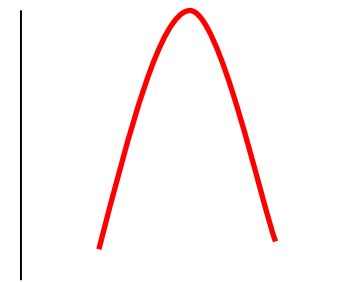
- Paint in the 4 ranges of data and ensure Alpha is 0.05 (confidence of 95%) and press 'OK'

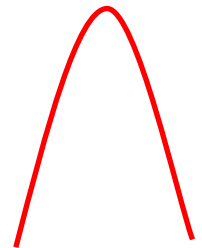
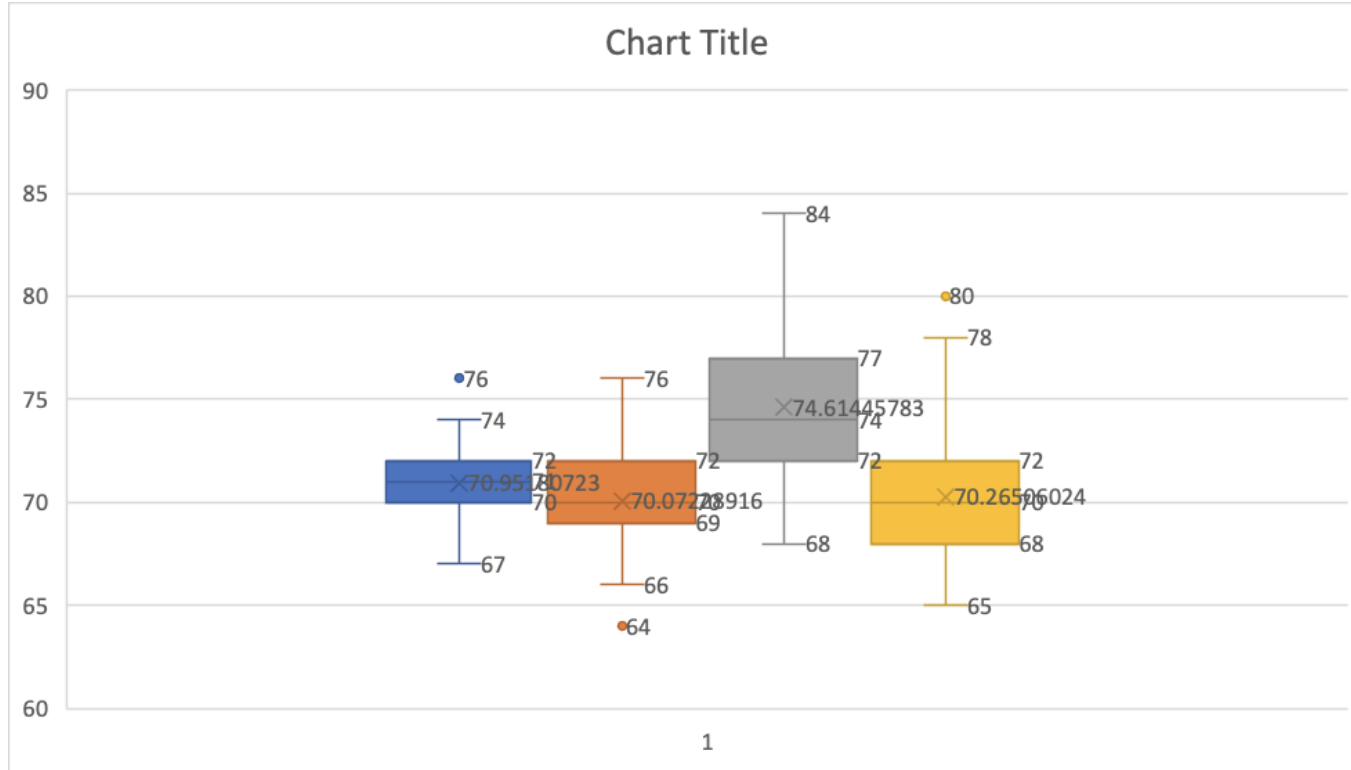


Analyse – ANOVA

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	83	5889	70.95	4.00		
Column 2	83	5816	70.07	5.46		
Column 3	83	6193	74.61	13.07		
Column 4	83	5832	70.27	10.08		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1125.602410	3.000000	375.200803	46.036825	0.000000	2.632142
Within Groups	2673.204819	328.000000	8.150015			
Total	3798.807229	331.000000				

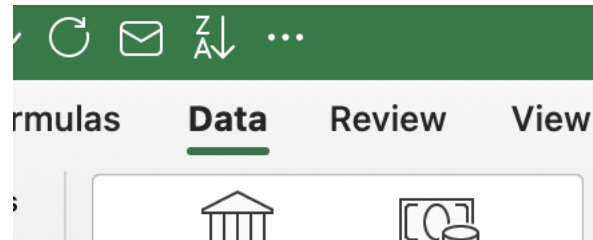




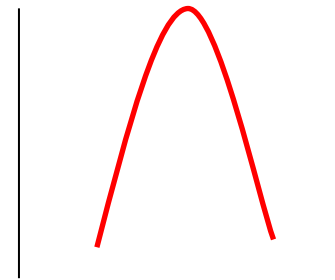
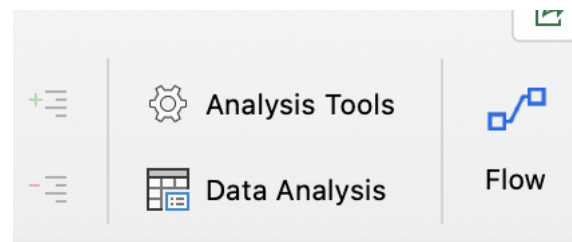
Analyse – T Test in Excel

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

- Open new excel spreadsheet and key in the following numbers into a column and click on 'Data' tab



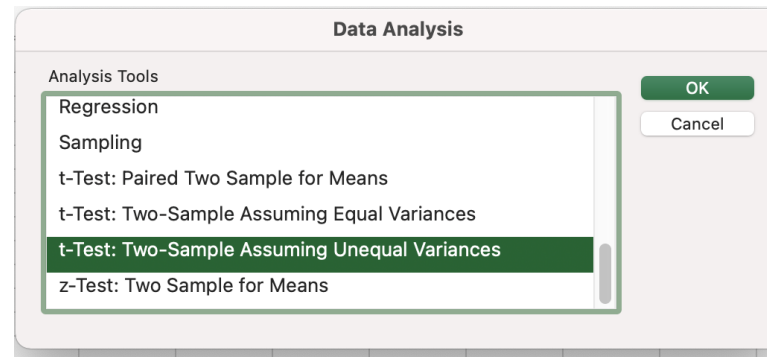
- Click on the 'Data Analysis' icon



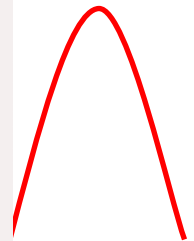
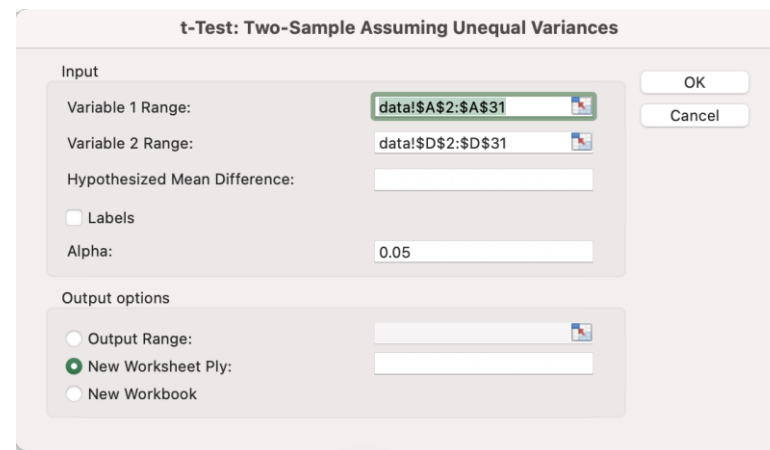
Analyse – T Test in Excel

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

- Click on T- test: two sample assuming unequal variances



- Click on input range and paint columns of R2 and R3, check alpha 0.05 and click OK

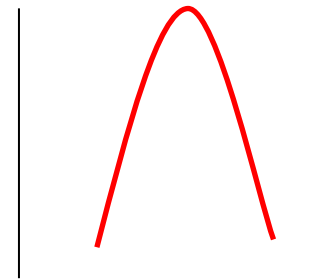


Analyse – T Test in Excel

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

t-Test: Two-Sample Assuming Unequal Variances		
	R2	R3
Mean	70.07	74.61
Variance	5.46	13.07
Observations	83.00	83.00
Hypothesized Mean Difference	0.00	
df	140.00	
t Stat	-9.61	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.66	
P(T<=t) two-tail	0.00	
t Critical two-tail	1.98	

***P less than 0.05
therefore difference is
significant***

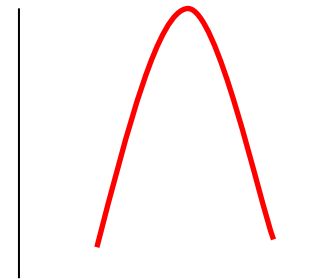


Analyse – T Test in Excel

70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

t-Test: Two-Sample Assuming Unequal Variances		
	R3	R4
Mean	74.61	70.27
Variance	13.07	10.08
Observations	83.00	83.00
Hypothesized Mean Difference	0.00	
df	161.00	
t Stat	8.24	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.65	
P(T<=t) two-tail	0.00	
t Critical two-tail	1.97	

***P less than 0.05
therefore difference is
significant***

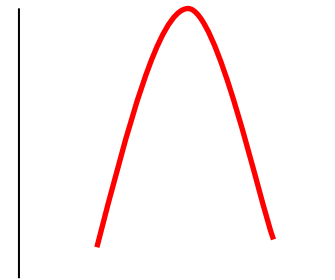


Analyse – T Test in Excel

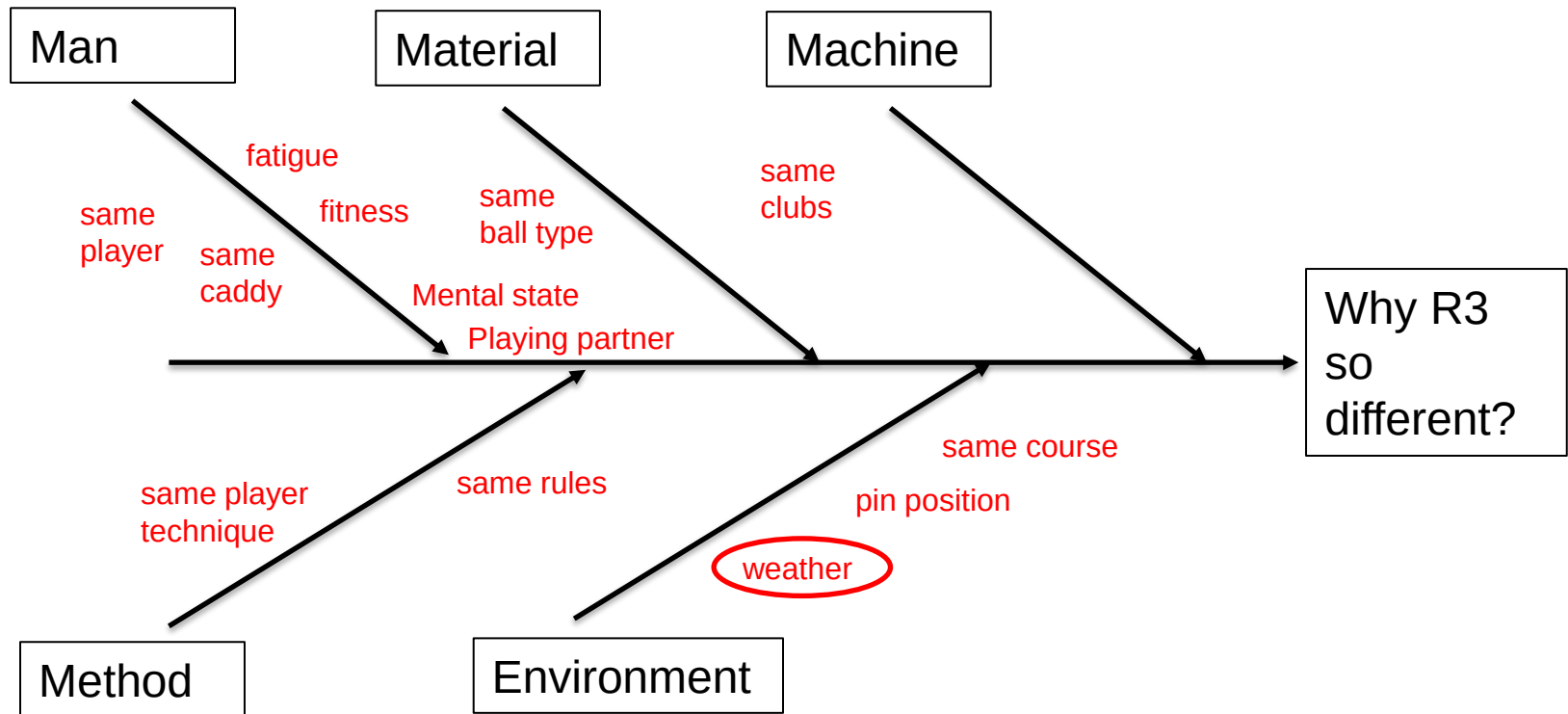
70	66	72	70
73	70	70	65
71	73	68	66
72	66	74	66
72	68	74	65
69	67	76	67
68	68	75	68
68	70	73	69
71	69	71	69
71	68	74	67
68	69	73	70
74	69	71	66
72	68	75	65
71	72	68	70
72	72	68	69
71	72	71	67
68	70	75	68
71	70	73	68
71	68	72	71
71	72	71	68

t-Test: Two-Sample Assuming Unequal Variances		
	R2	R4
Mean	70.07229	70.26506
Variance	5.458125	10.07523
Observations	83	83
Hypothesized Mean Difference	0	
df	151	
t Stat	-0.4456	
P(T<=t) one-tail	0.328261	
t Critical one-tail	1.655007	
P(T<=t) two-tail	0.656522	
t Critical two-tail	1.975799	

***P greater than 0.05
therefore difference is
not significant***



Analyse – ANOVA - fishbone



2002 Open Championship

From Wikipedia, the free encyclopedia

Coordinates:  56.043°N 2.823°W

The **2002 Open Championship** was a men's major golf championship and the 131st Open Championship, held from 18 to 21 July at Muirfield Golf Links in Gullane, East Lothian, Scotland. Ernie Els won his first Claret Jug and third major title in a playoff over Stuart Appleby, Steve Elkington, and ultimately in a sudden-death playoff over Thomas Levet.^{[2][3]}

Tiger Woods' bid for the Grand Slam came to a halt on Saturday with the worst round of his career up to that time, an 81 (+10) in cold, gusty rain.^[4] It took him and others out of contention, but he rebounded on Sunday with a six-under 65 and finished at even par, six strokes back. Woods was the first in thirty years to win the first two legs (Masters, U.S. Open), last done by Jack Nicklaus in 1972.^[5] Nicklaus' grand slam bid also ended at Muirfield, runner-up by one stroke to Lee Trevino in 1972. The only one to win the first three was Ben Hogan in 1953. Entering the championship, Woods had won seven of the previous eleven majors.^[6]

Contents [hide]

- 1 Course
- 2 Field
- 3 Round summaries
 - 3.1 First round
 - 3.2 Second round
 - 3.3 Third round
 - 3.4 Final round
 - 3.4.1 Scorecard
 - 3.5 Playoff
 - 3.5.1 Scorecard

2002 Open Championship

Tournament information

Dates	18–21 July 2002
Location	Gullane, Scotland
Course(s)	Muirfield Golf Links
Tour(s)	European Tour PGA Tour Japan Golf Tour

Statistics

Par	71 ^[1]
Length	7,034 yards (6,432 m) ^[1]
Field	156 players, 83 after cut ^[1]
Cut	144 (+2) ^[1]
Prize fund	£3,800,000 €5,947,076 \$6,004,760
Winner's share	£700,000 €1,095,514 \$1,106,140

Champion



Analyse – ANOVA



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Analyse – ANOVA



Analyse – ANOVA

W1	W2	W3	W4	
11:00	2	7	20	5
11:15	0	3	22	9
11:30	1	8	22	10
11:45	3	5	10	6
12:00	7	6	10	9
12:15	0	3	20	4
12:30	1	8	17	9
12:45	0	6	15	1
13:00	3	8	20	5
13:15	10	5	15	4
13:30	2	6	25	7
13:45	6	3	23	6
14:00	11	8	17	5
14:15	0	8	16	10
14:30	11	5	23	8
14:45	6	9	13	2
15:00	9	9	15	5
15:15	10	8	12	0
15:30	8	7	18	4
15:45	2	4	23	4
16:00	8	8	20	2
16:15	12	5	11	5
16:30	0	9	12	4
16:45	0	8	17	10
17:00	10	3	23	9
17:15	3	4	20	4
17:30	5	5	19	3
17:45	4	8	17	1
18:00	7	5	19	5
18:15	12	6	20	0
18:30	8	3	22	6
18:45	7	4	18	8
19:00	3	9	24	4
19:15	7	7	20	4
19:30	8	6	17	4
19:45	9	8	23	1
20:00	4	6	24	10
20:15	7	9	20	4
20:30	5	9	24	10
20:45	10	8	12	9
21:00	5	7	12	1
21:15	0	3	19	7
21:30	11	5	20	10
21:45	0	9	23	0
22:00	7	3	19	1
22:15	4	7	16	8
22:30	5	4	11	7
22:45	3	6	16	8
23:00	12	9	12	10
23:15	6	8	18	8
23:30	4	5	11	6
23:45	10	9	22	8
00:00	9	7	20	1

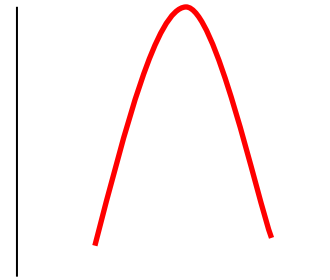
Anova: Single Factor

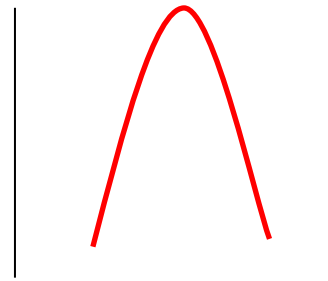
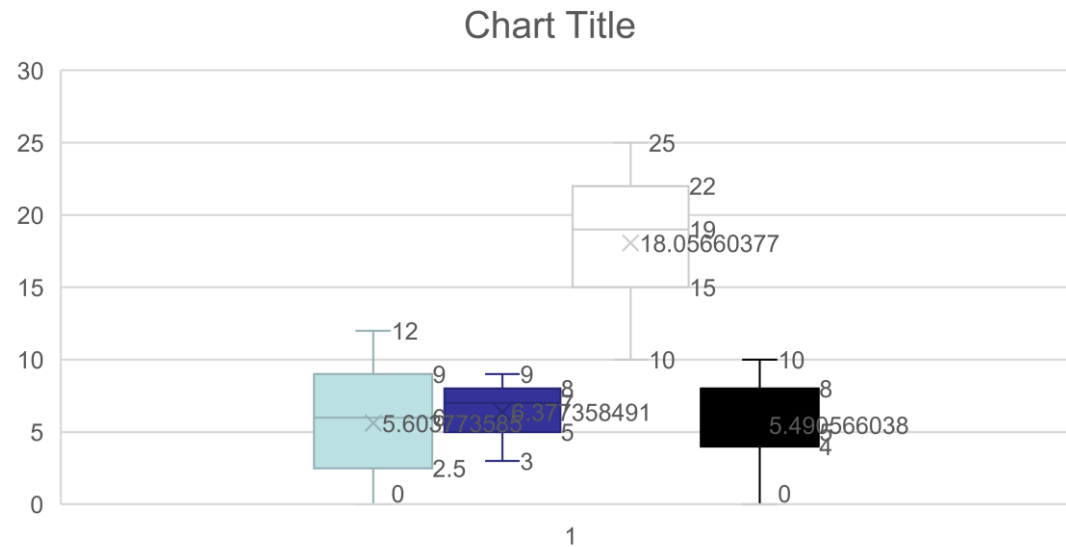
SUMMARY

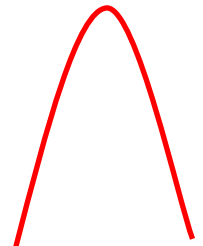
Groups	Count	Sum	Average	Variance
W1	53.00	297.00	5.60	14.51
W2	53.00	338.00	6.38	4.12
W3	53.00	957.00	18.06	18.05
W4	53.00	291.00	5.49	9.91

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5972.84	3.00	1990.95	170.90	0.00	2.65
Within Groups	2423.21	208.00	11.65			
Total	8396.05	211.00				







Analyse – ANOVA

trial 1	trial 2	trial 3	trial 4	
20	20	13	13	
22	21	20	19	
34	24	15	19	
19	24	20	13	
19	22	11	15	
25	23	11	14	
19	20	18	13	
29	22	14	13	
26	18	12	13	
39	20	17	14	
18	19	14	13	
31	16	11	14	
29	24	13	15	
22	20	10	19	
20	23	12	19	
29	22	17	14	
18	18	18	14	
24	24	20	14	
22	23	11	17	
32	24	11	18	
21	18	16	13	
19	18	20	17	
18	22	18	14	
18	23	18	14	
29	19	18	16	
30	21	14	17	
20	17	13	19	
18	17	14	15	
24	21	11	14	
32	20	10	13	
38	19	13	18	
20	15	14	18	
32	24	11	17	
18	23	17	15	
24	18	11	18	
20	24	18	16	
17	21	20	15	
34	24	14	13	
33	15	17	17	
23	24	19	16	
29	20	15	13	
22	23	14	17	
18	21	20	17	
33	19	18	17	
34	21	18	19	
37	15	12	19	
18	24	18	15	
30	20	16	13	
25	18	16	13	
18	23	19	14	

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
trial 1	50.00	1249.00	24.98	41.37		
trial 2	50.00	1034.00	20.68	7.32		
trial 3	50.00	760.00	15.20	10.37		
trial 4	50.00	775.00	15.50	4.66		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3262.02	3.00	1087.34	68.26	0.00	2.65
Within Groups	3122.36	196.00	15.93			
Total	6384.38	199.00				

