

Level 5 – Continuous Improvement with Industry 4.0

Analyse 2 – Confidence Intervals, Two sample T tests





Forthcoming Events

MADE

For your diaries:-

Test #1

Friday 10th February (covering Define and Measure)

Test #2

Friday 31st March (covering complete course materials)

Open from 1pm on the Friday – close midnight following Monday

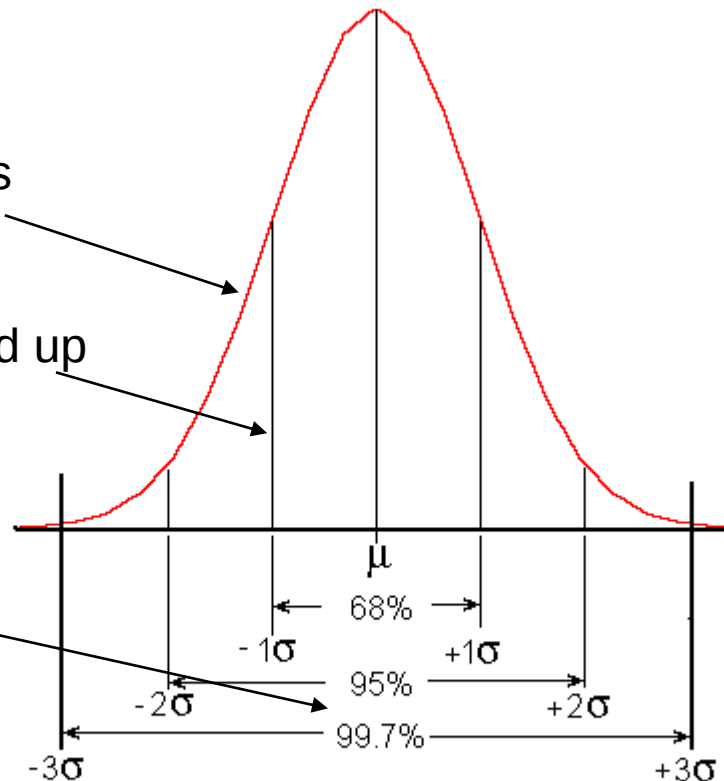
1 hour duration, multi-choice (approx. 40 questions)

Analyse - “Normal data” bell shaped curve

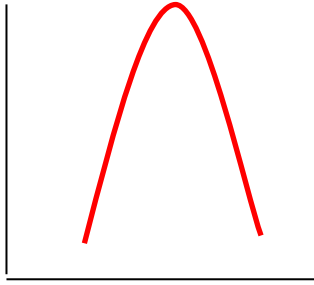
Add up about 30 of most things
and you start to be “normal”

Normal distributions are divided up
into 3 standard deviations on
each side of the mean

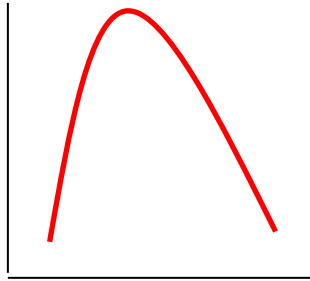
Once you have that, you
know a lot about
what is going on



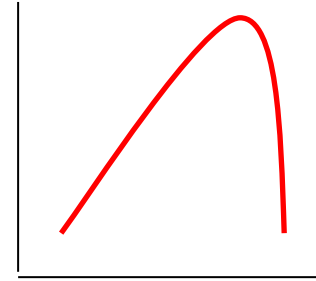
Analyse – distribution shapes



Normal
Distribution



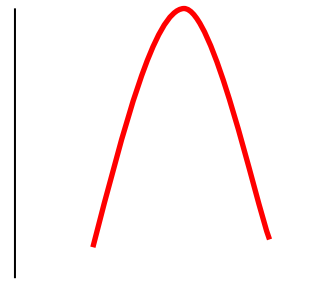
Skewed to
the right



Skewed to
the left

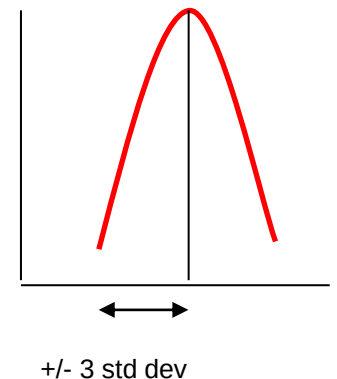
Not all continuous random variables are normally distributed

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



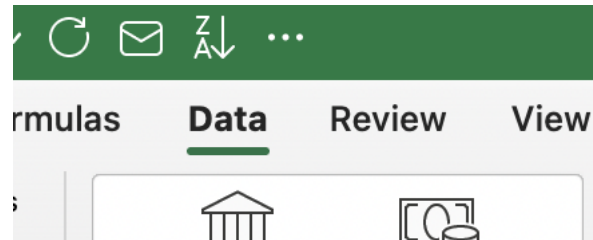
How can we tell?

- 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)

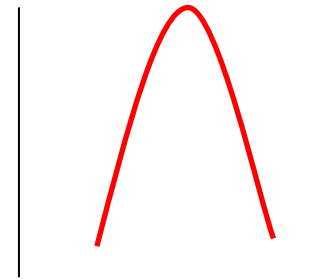
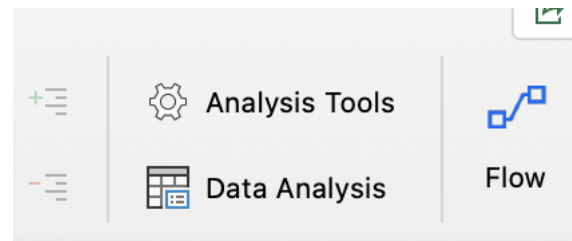


Analyse – Testing for Normality in Excel

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

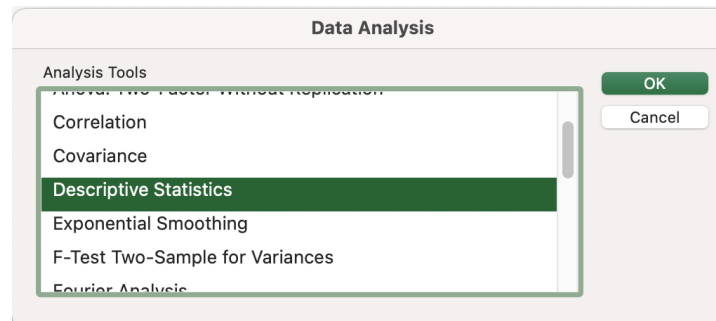


- Click on the 'Data Analysis' icon

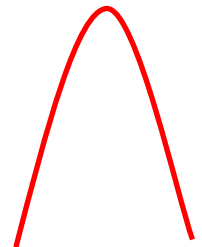
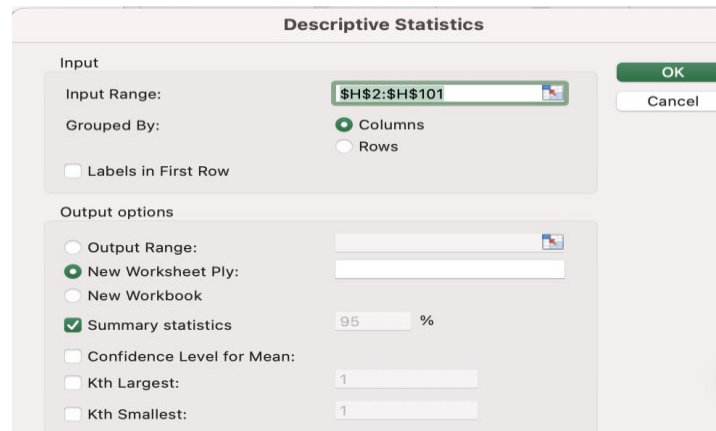


Analyse – Testing for Normality in Excel

- 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

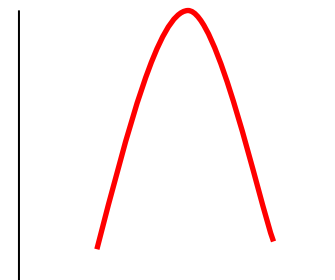
73
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72
73

Master Final Round 2021

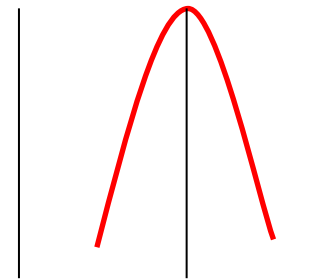
Mean	71.28
Standard Error	0.38952963
Median	72
Mode	70
Standard Deviation	1.94764815
Sample Variance	3.79333333
Kurtosis	0.8140209
Skewness	-0.760273
Range	8
Minimum	66
Maximum	74
Sum	1782
Count	25

The amount in the tails of distribution

Measure of symmetry

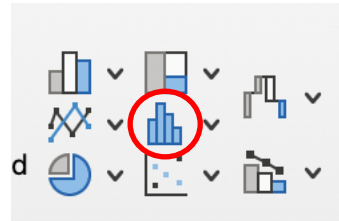


- Kurtosis used to be considered the amount of 'peakness' within a distribution but is now considered to be the amount of the distribution within the tails
- 0 or close to – assumed to be normal
- Less than 0 – distribution has light tails
- Greater than 0 – distribution has heavier tails
- Skewness is a measure of the distributions symmetry
- 0 = normal
- Between -0.5 and 0.5 - fairly symmetrical
- Between -1.0 and 1.0 - moderately skewed
- Less than -1 and greater than 1 - highly skewed

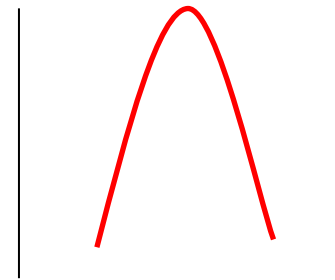


Analyse – Testing for Normality in Excel

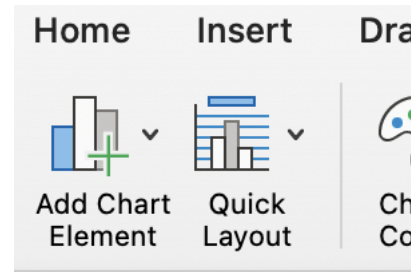
- Paint in numbers choose 'Insert' tab click on histogram icon



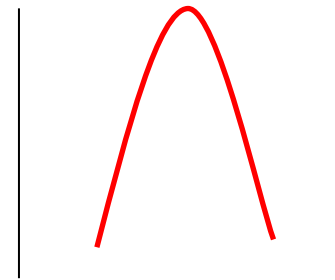
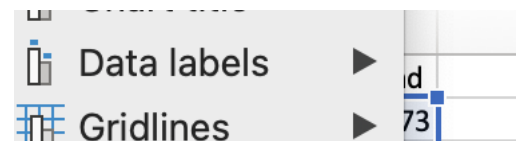
- Choose 'Box and Whisker'



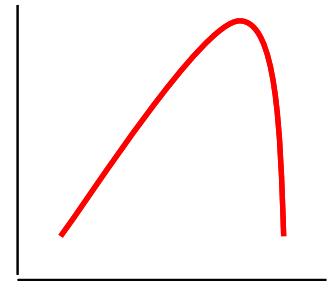
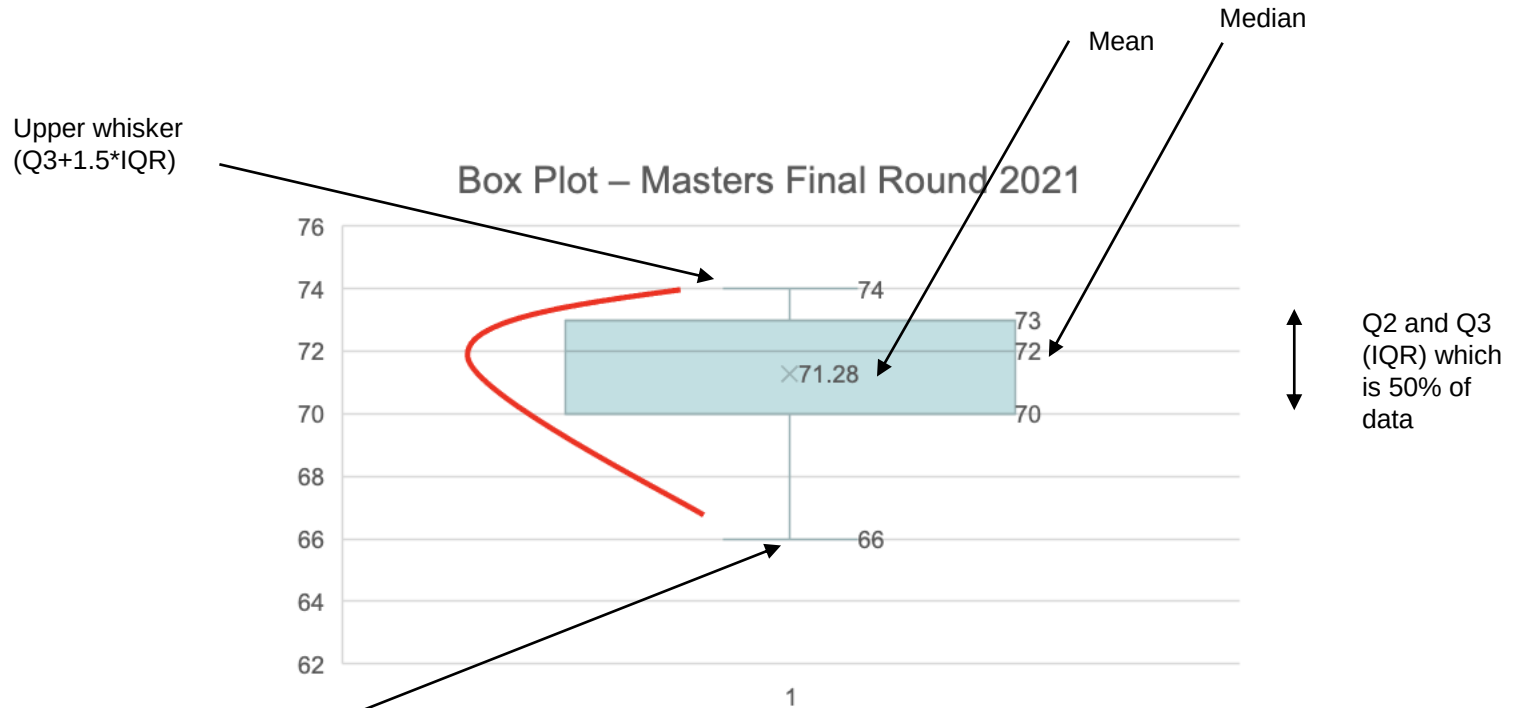
- Choose 'add chart element'



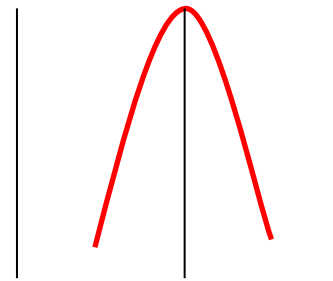
- Choose 'Data Labels' to display values on chart



Analyse – Testing for Normality in Excel

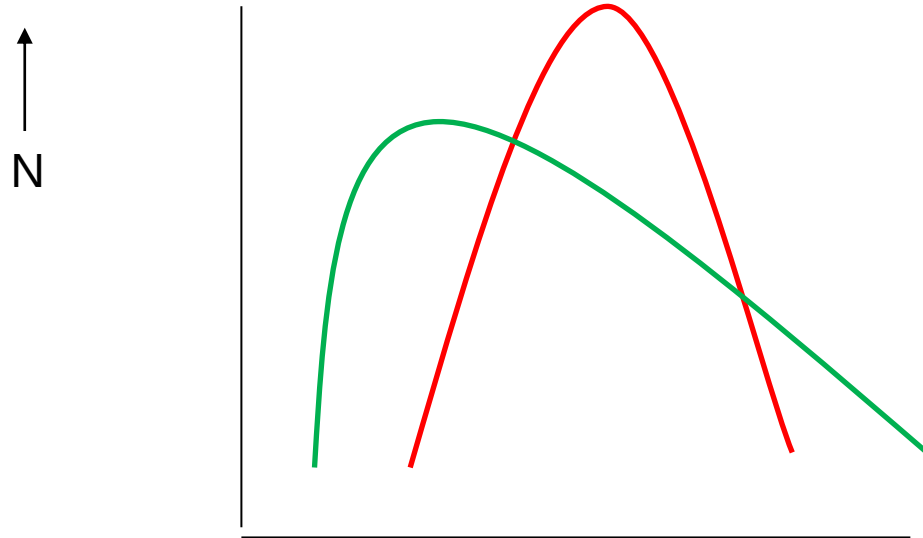


- Those people lucky enough to have Minitab software can undertake the following:-
- Populate the spreadsheet in column
- Choose test for normality 'Anderson-Darling'
- Click 'OK' this will generate a graph and show the distribution
- If P value greater than 0.05, you can consider to have a normal distribution!



If the population is not normal we can apply the 'Central Limit Theorem'

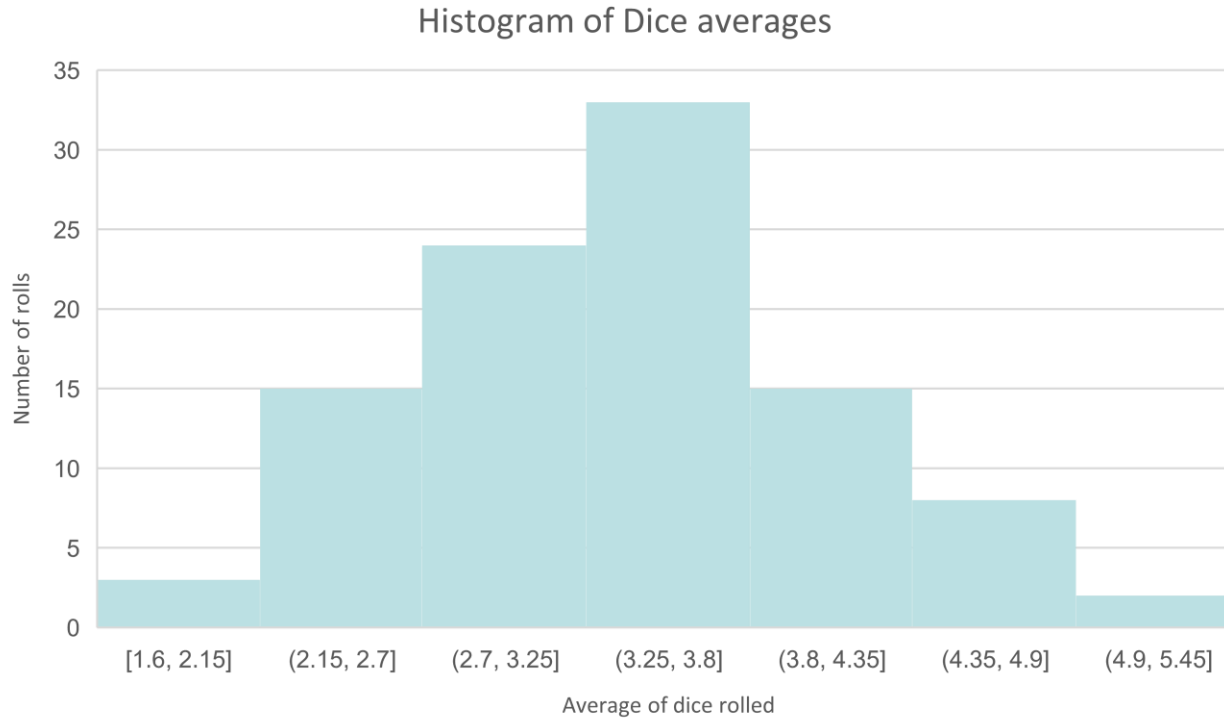
We take the sample means from the population and the distribution of these will move towards the normal distribution as long as the sample size is big enough



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



Analyse – Central Limit Theorem - example

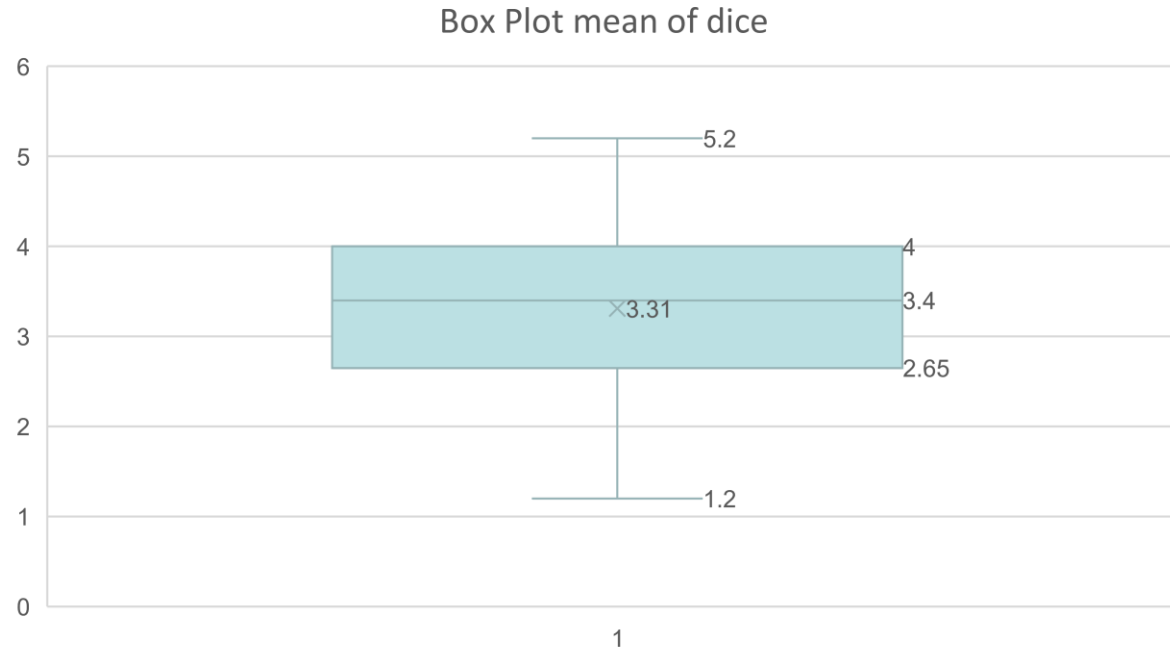


Analyse – Central Limit Theorum - example

Column1	
Mean	3.31
Standard Error	0.08689364
Median	3.4
Mode	3.6
Standard Deviation	0.86893642
Sample Variance	0.75505051
Kurtosis	-0.4025302
Skewness	-0.0878595
Range	4
Minimum	1.2
Maximum	5.2
Sum	331
Count	100



Analyse – Central Limit Theorem - example



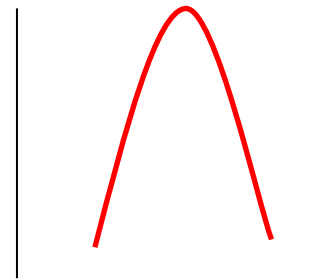
Different types of Probability distributions

Discrete

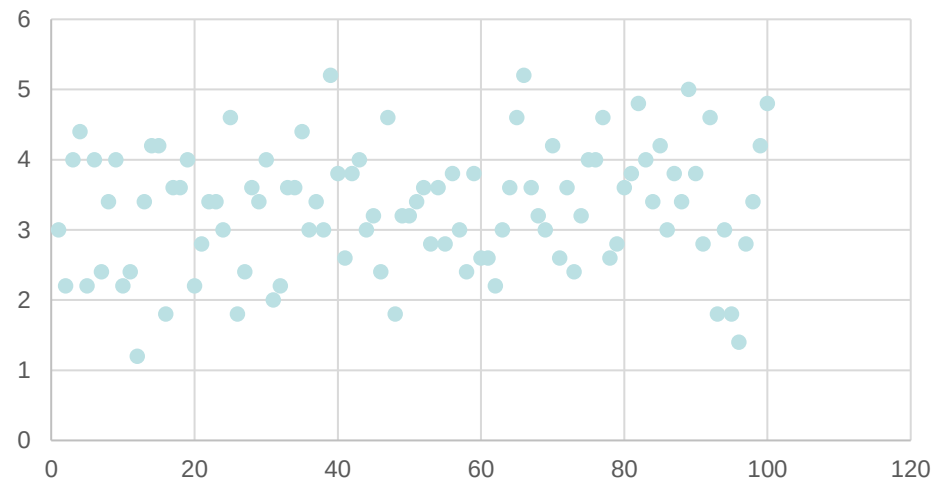
- Binominal
- Hypergeometric
- Poisson

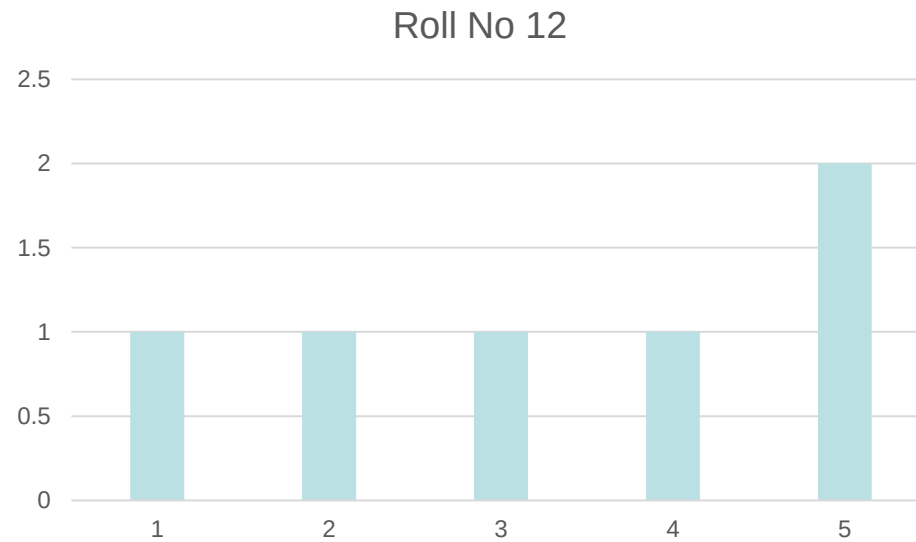
Continuous

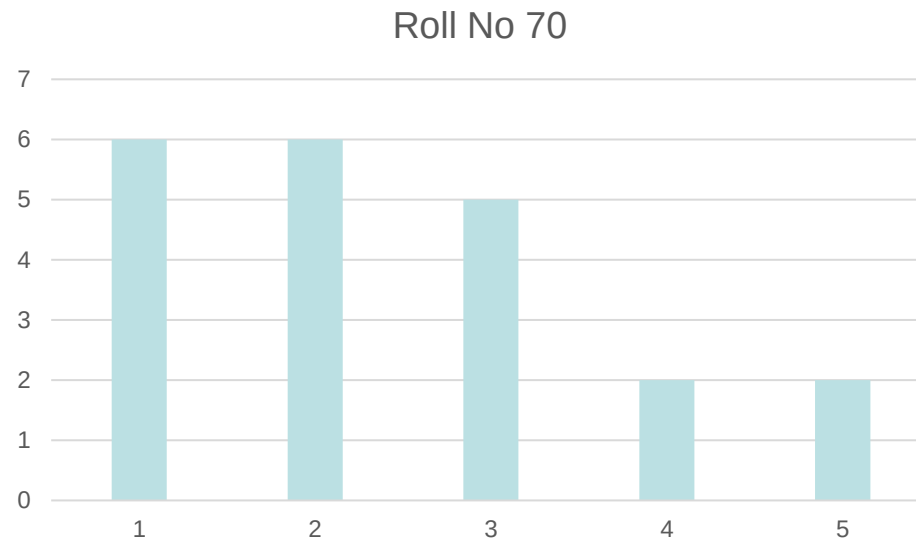
- Normal
- Uniform
- Exponential



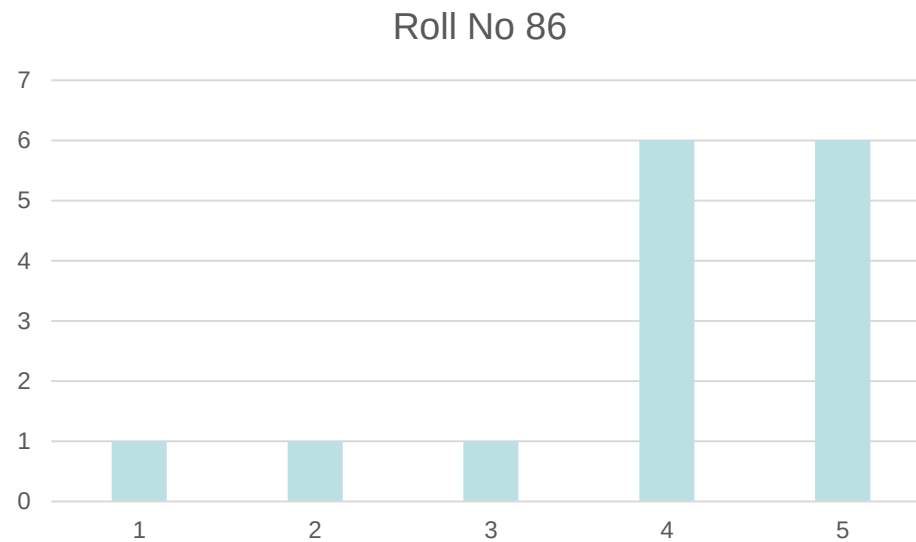
Scatter plot of means rolled



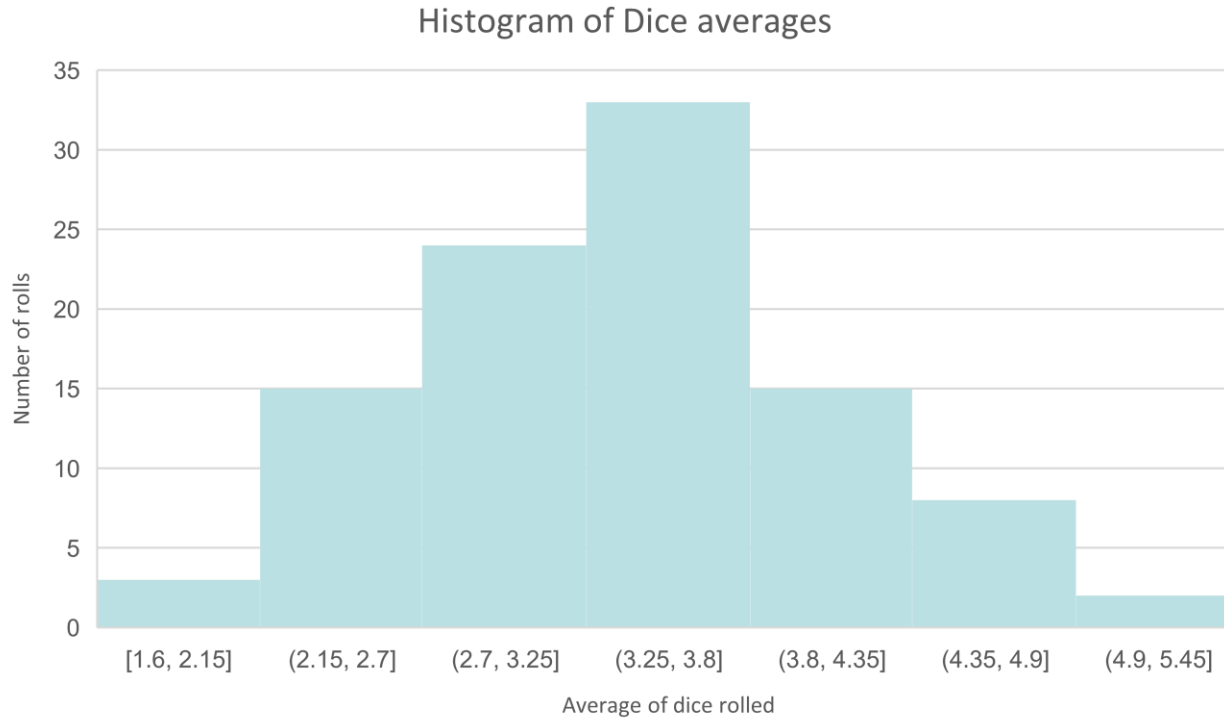




Analyse – Different Distributions



Analyse – Central Limit Theorem - example



Level 5 – Continuous Improvement with Industry 4.0

Analyse 2 – Confidence Intervals, Two sample T tests



Hypothesis testing is where we determine where specific values of interest sit within a calculated range (this range is known as the confidence interval)

If the value sits within this range you can conclude that these are the same

If the value sits outside the range you can conclude that these are different

Common applications of this are:-

To see if two means are equal – two sets of data from the same population will not always be the same

This testing will highlight if there are real differences between two sets of data from the populations

The 'Null Hypothesis' H_0 is a statement to determine whether something is true or not

It is expressed as a formula

$$H_0: \mu_1 (\text{ave}) = \mu_2 (\text{ave})$$

or

$$H_0: \mu_1 (\text{ave}) - \mu_2 (\text{ave}) = 0$$

The 'Alternative Hypothesis' H_a is a statement to determine whether we can reject the null hypothesis

It is expressed as a formula

$$H_a: \mu_1 (\text{ave}) \neq \mu_2 (\text{ave})$$

or

$$H_a: \mu_1 (\text{ave}) - \mu_2 (\text{ave}) \neq 0$$

Analyse – Types of Errors

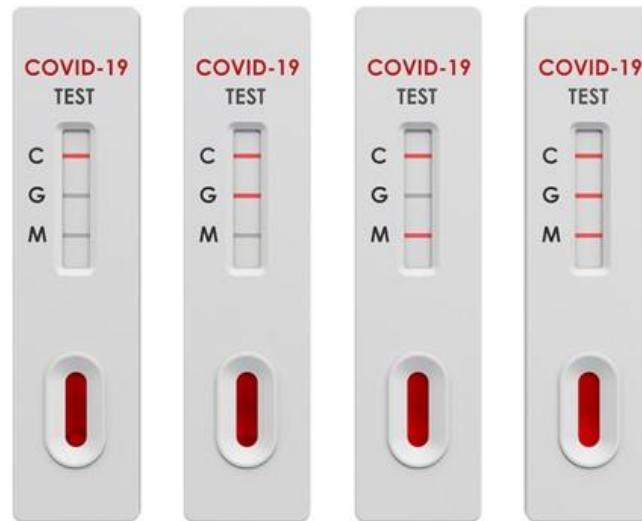
	Do not reject H_0	Reject H_0
H_0 is true	Correct	Type I Error You think there is a difference when there isn't Alpha risk
H_0 is false	Type II Error You think there is no difference when there is Beta risk	Correct



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

Analyse – Types of Errors



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[Home](#) > [Coronavirus \(COVID-19\)](#) > [Testing for coronavirus \(COVID-19\)](#)

Press release

New analysis of lateral flow tests shows specificity of at least 99.9%

New analysis reinforces that lateral flow tests are accurate and reliable and have extremely low false positive rates.

From: [Department of Health and Social Care](#)

Published 10 March 2021



A confidence interval is an 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:-

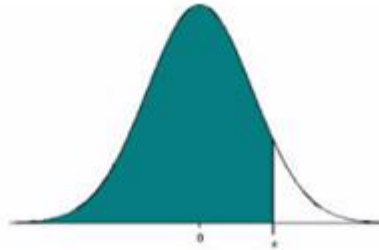
We measured 40 men's height and had a mean of 175cms

The Standard Deviation was 20cms

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

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

0.975 in distribution 0.025 in each tail = 0.05 in both tails

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

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

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!

Now we want to become more confident!:-

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

The Standard Deviation was 20cms

We need 99% confidence so we use a Z value of 2.576

$$CI = 175 \pm 2.576 \frac{20}{\sqrt{40}}$$

$$CI = 175 \pm 8.14 \text{ cms}$$

This is known as the margin of error

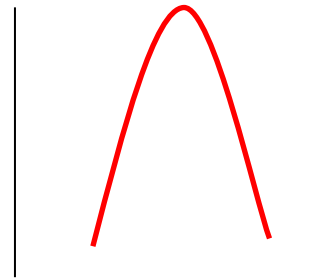
Therefore, we can be 99% confident that our measurement will fall between 166.86 and 183.14cms

Warning :- but 1% could be outside these limits!

Analyse – Confidence Intervals another example



Hideki Matsuyama winner by 1 shot, -10



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

$$CI = 71.28 \pm 0.76$$

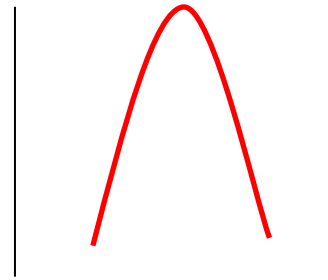
Therefore, we can be 95% confident that the final round shots were between 70.52 and 72.04

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

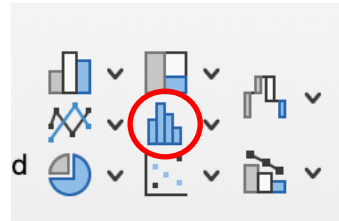
Analyse – T Test



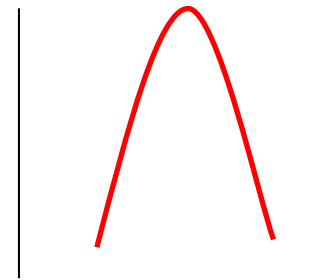
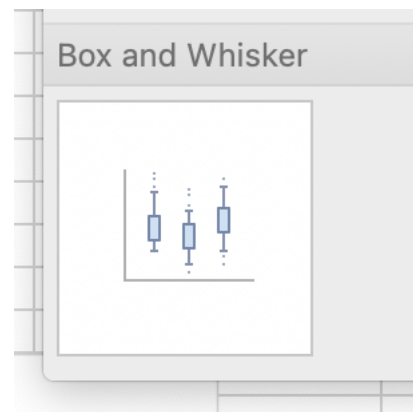
Analyse – T Test

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37	21
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25	18
18	23

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



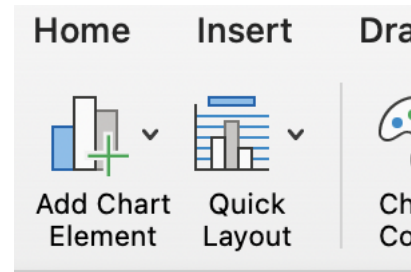
- Choose 'Box and Whisker'



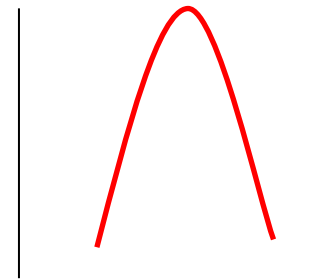
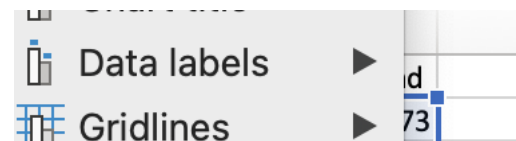
Analyse – T Test

20	20
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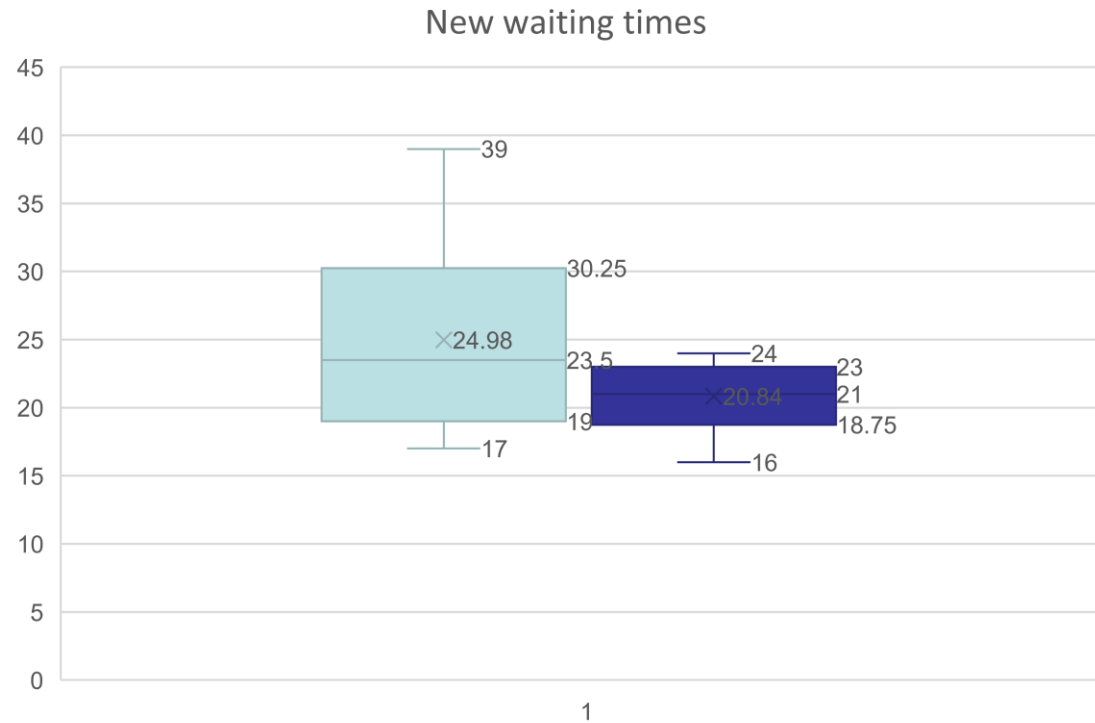
- Choose 'add chart element'



- Choose 'Data Labels' to display values on chart



Analyse – T Test



The new data looks normal but how do we test to see if they are different?

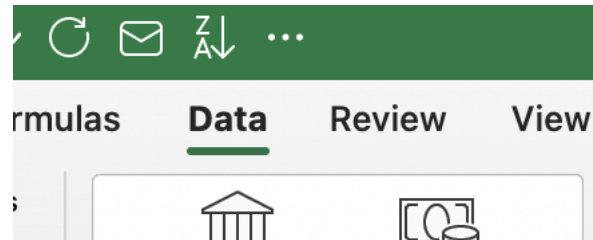
2 sample T test – tests the means of two populations to see if they are equal

Widely used to see if there is an actual difference before and after a change in a process

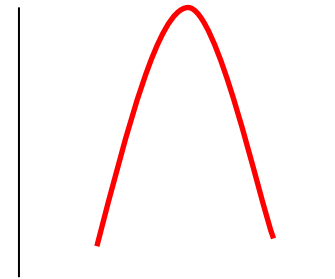
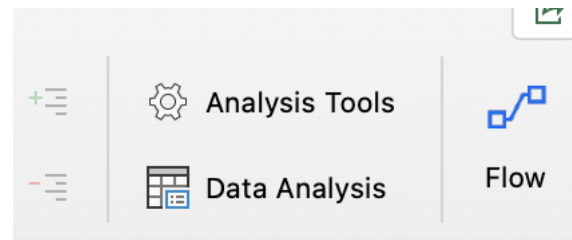
Analyse – T Test in Excel

20	20
22	21
34	24
19	24
19	22
25	23
19	20
29	22
26	18
39	20
18	19
31	16
29	24
22	20
20	23
29	22
18	18
24	24
22	23
32	24
21	18
19	18
18	22
18	23
29	19
30	21
20	17
18	17
24	18
32	18
38	19
20	17
32	24
18	23
24	18
20	24
17	21
34	24
33	20
23	24
29	20
22	23
18	21
33	19
34	21
37	21
18	24
30	20
25	18
18	23

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



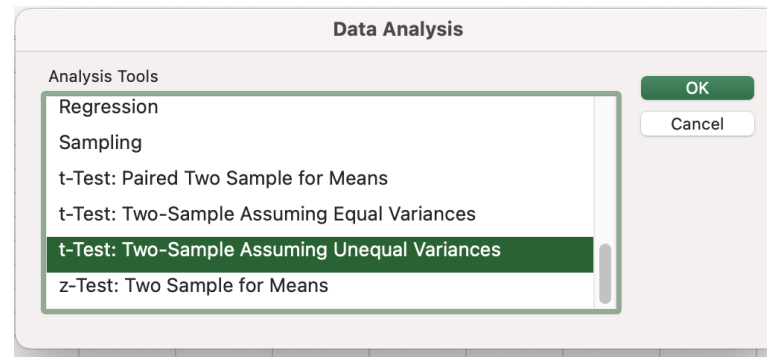
- Click on the 'Data Analysis' icon



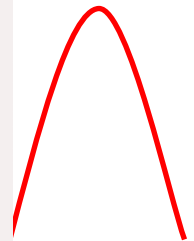
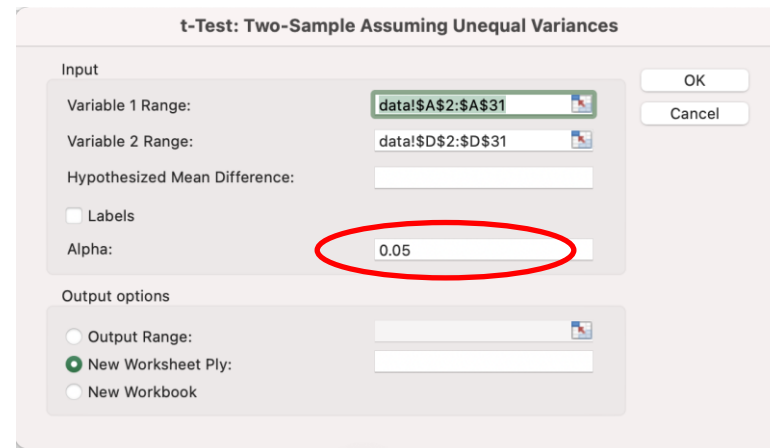
Analyse – T Test in Excel

20	20
22	21
34	24
19	24
19	22
25	23
19	20
29	22
26	18
39	20
18	19
31	16
29	24
22	20
20	23
29	22
18	18
24	24
22	23
32	24
21	18
19	18
18	22
18	23
29	19
30	21
20	17
18	17
24	18
32	18
38	19
20	17
32	24
18	23
24	18
20	24
17	21
34	24
33	20
23	24
29	20
22	23
18	21
33	19
34	21
37	21
18	24
30	20
25	18
18	23

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



- Click on input ranges and paint columns, check alpha 0.05 and click OK

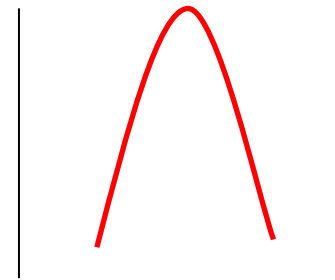


Analyse – T Test in Excel

20	20
22	21
34	24
19	24
19	22
25	23
19	20
29	22
26	18
39	20
18	19
31	16
29	24
22	20
20	23
29	22
18	18
24	24
22	23
32	24
21	18
19	18
18	22
18	23
29	19
30	21
20	17
18	17
24	18
32	18
38	19
20	17
32	24
18	23
24	18
20	24
17	21
34	24
33	20
23	24
29	20
22	23
18	21
33	19
34	21
37	21
18	24
30	20
25	18
18	23

t-Test: Two-Sample Assuming Unequal Variances		
	20.00	20.00
Mean	25.08	20.59
Variance	41.70	7.75
Observations	49.00	49.00
Hypothesized Mean Difference	0.00	
df	65.00	
t Stat	4.47	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.00	

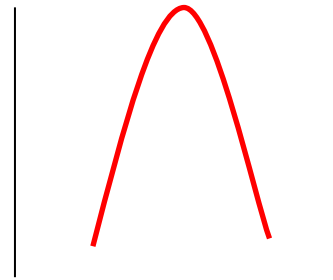
***P less than 0.05
therefore difference is
significant between the
waiting times***



Analyse – Practice – Call Centre Response Times



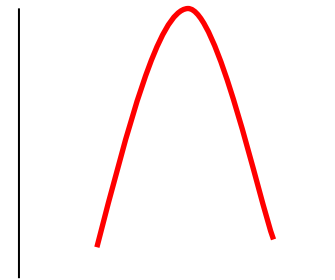
[This Photo](#) by Unknown Author is licensed under [CC BY-SA-NC](#)



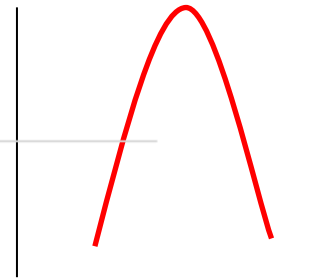
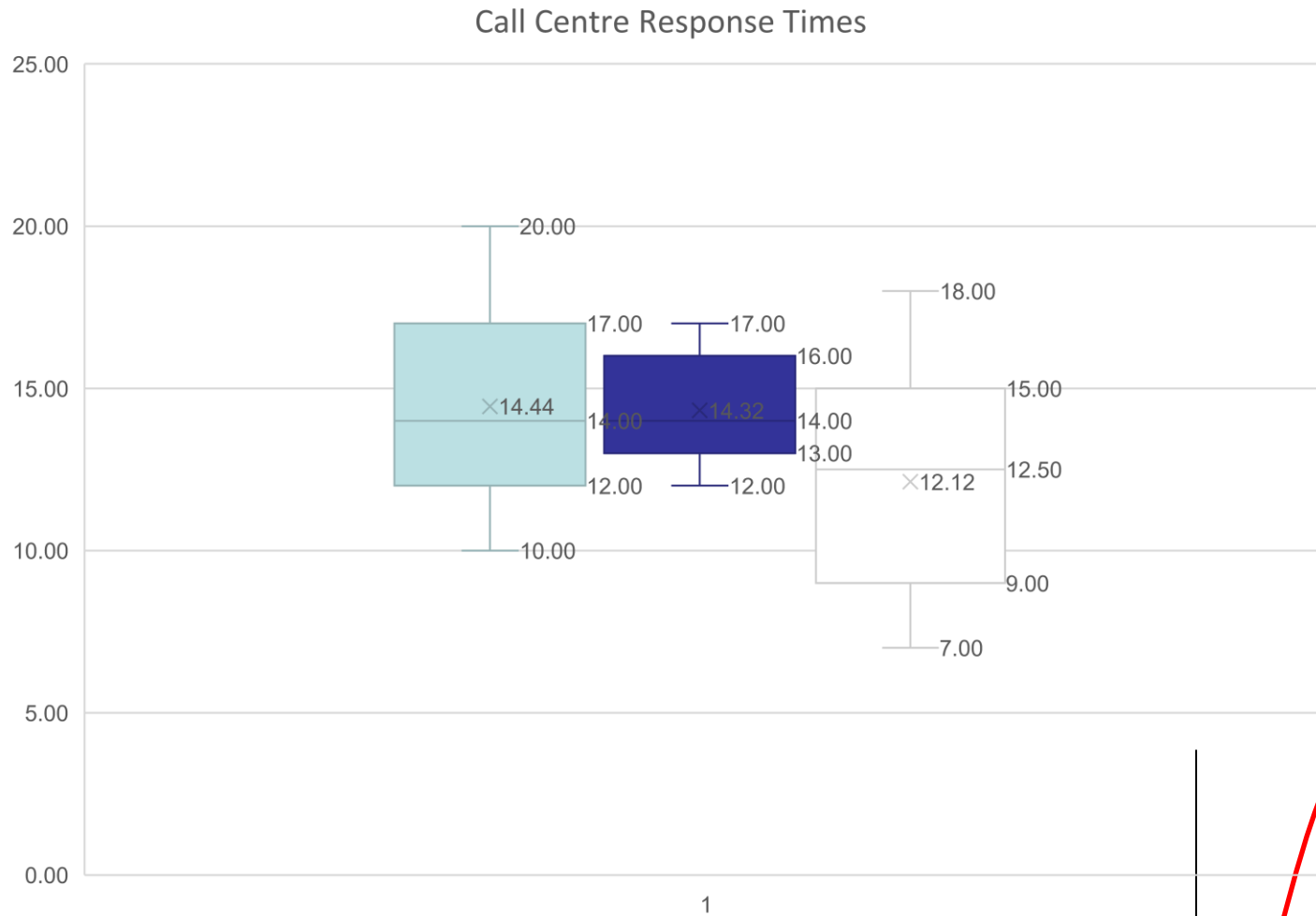
Analyse – Practice – Call Centre Response Times

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

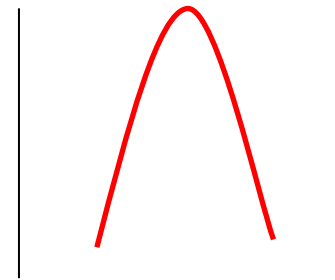


Analyse – Practice – Call Centre Response Times



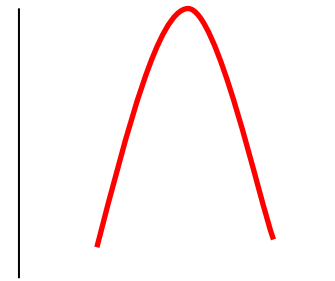
Analyse – Practice – Call Centre Response Times

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	



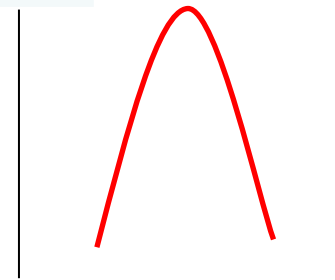
Analyse – Practice – Call Centre Response Times

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	

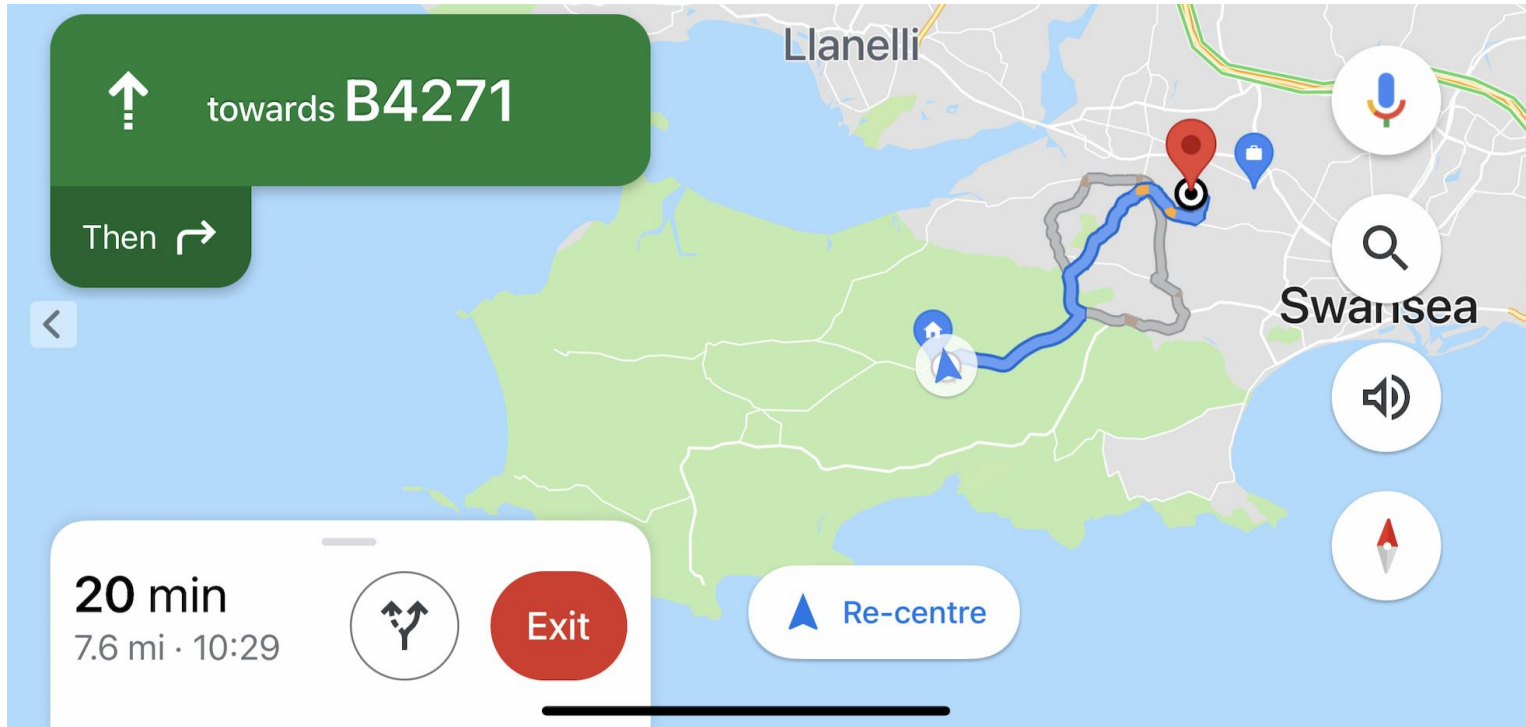


Analyse – Practice – Call Centre Response Times

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	



My Journey to Work



Analyse – T Test

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 – T Test

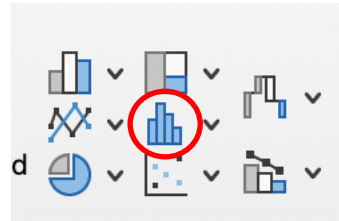
Route A	Route B	Route C	Route D
25	28	30	34
27	32	32	45
27	38	26	43
28	28	34	32
26	36	34	41
26	29	32	34
30	30	31	41
26	35	28	35
29	33	35	35
28	30	32	39
23	34	33	42
26	38	34	41
25	33	35	37
24	30	31	31
26	32	28	37
27	37	34	31
25	29	32	41
26	37	33	34
28	29	31	40
27	34	33	40
26	34	34	38
24	29	34	44
24	35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

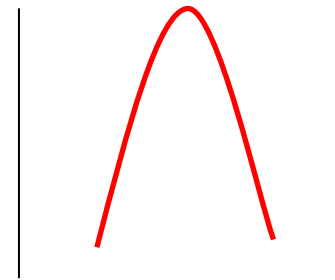
Analyse – T Test

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



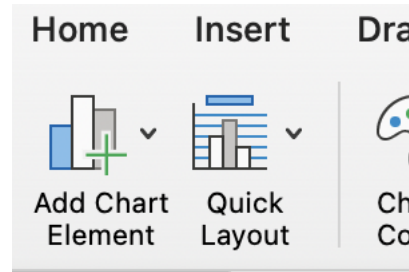
- Choose 'Box and Whisker'



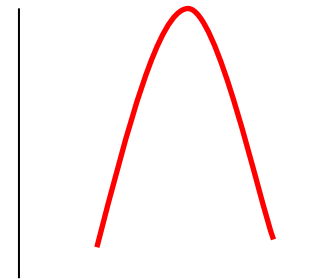
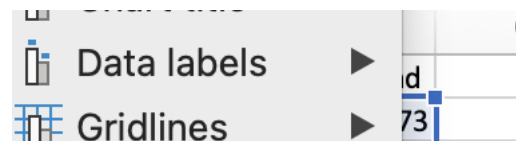
Analyse – T Test

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

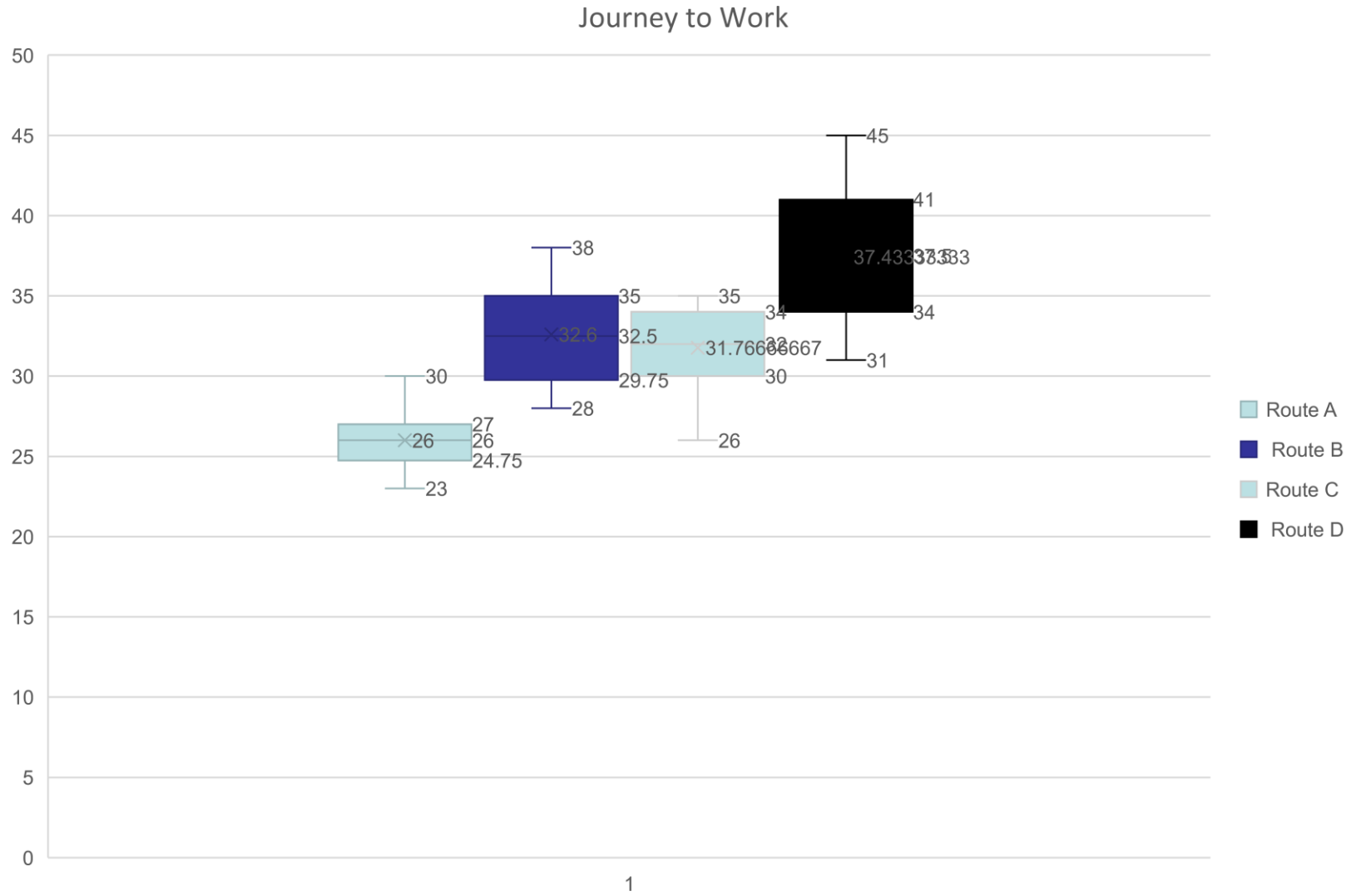
Choose 'add chart element'



Choose 'Data Labels' to display values on chart



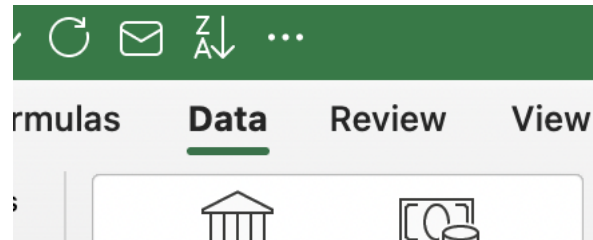
Analyse – T Test



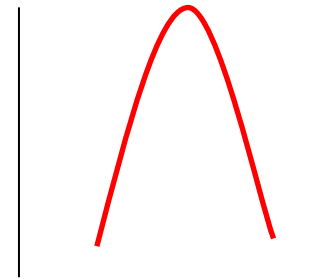
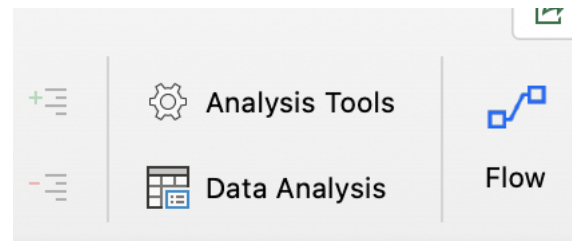
Analyse – T Test

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



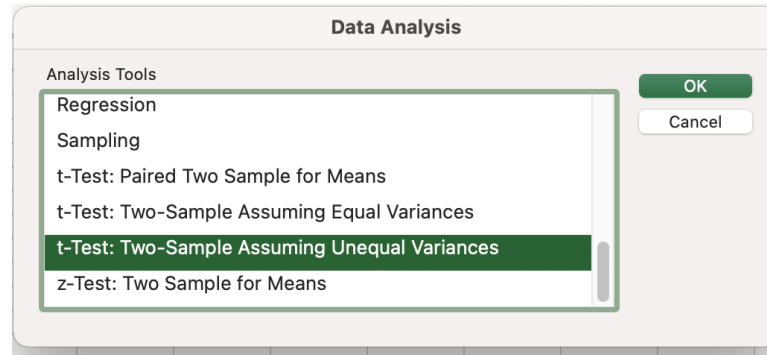
Click on the 'Data Analysis' icon



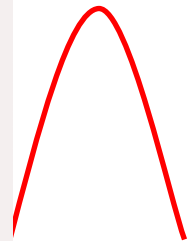
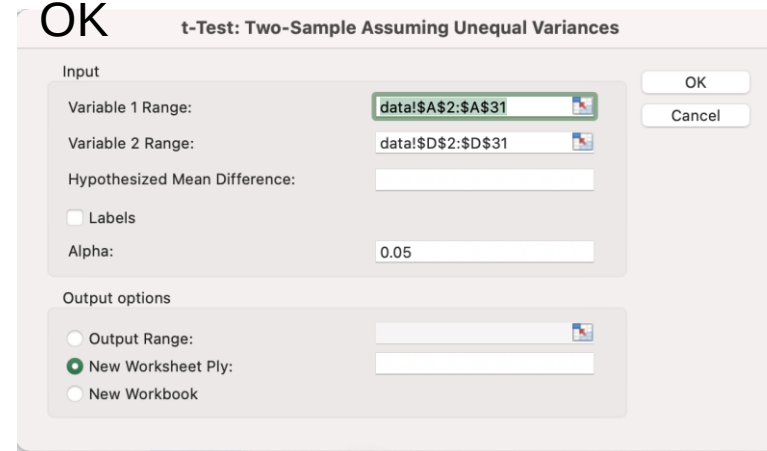
Analyse – T Test

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

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

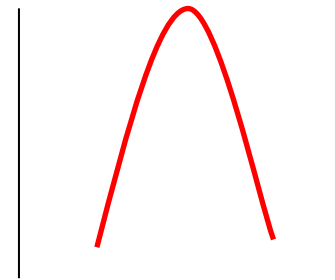
0.0

1.7

0.0

2.0

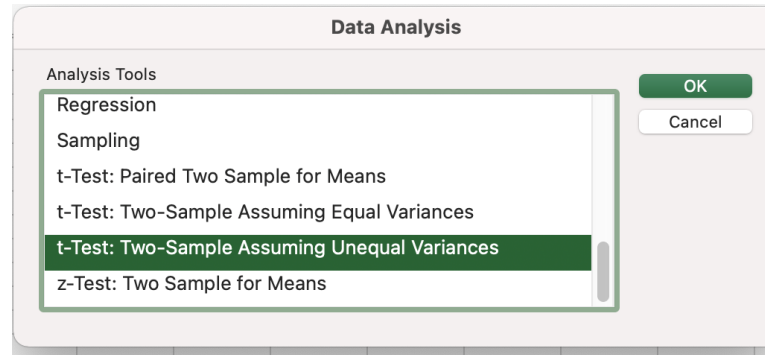
***P less than 0.05
therefore difference is
significant***



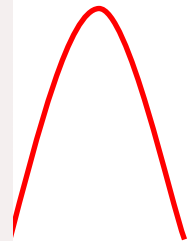
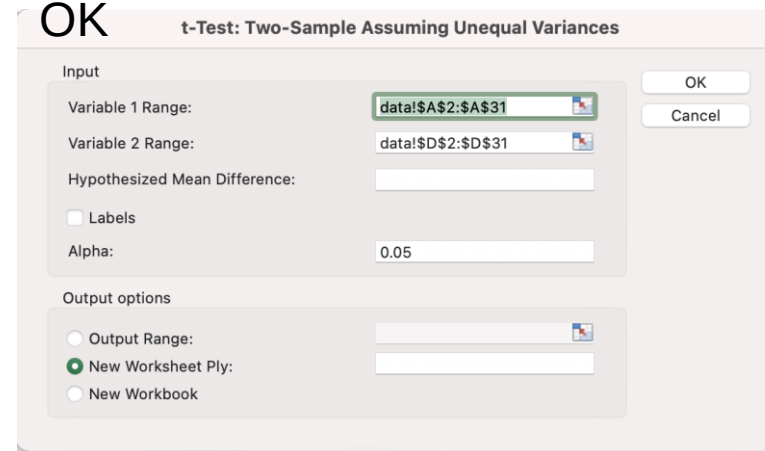
Analyse – T Test

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



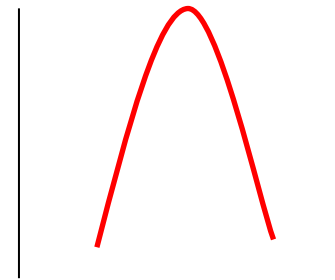
Analyse – T Test

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***



Analysis of variance - ANOVA

Correlation

Regression

