Hypothesis Testing

Z Test

1. Company has established norms for the competency of Executives in an aptitude test. The historic population data suggests that average 73.2 with a standard deviation of 8.6. If 45 randomly selected persons and have an average 76.7, test the null hypothesis μ= 73.2 against the alternative hypothesis μ> 73.2 at the 0.01 level of significance

One-Sample Z

Descriptive Statistics

N	Mean	SE Mean	99% CI for μ
45	76.70	1.28	(73.40, 80.00)

μ: mean of Sample
Known standard deviation = 8.6

Test

Null hypothesis	H_0: μ = 73.2
Alternative hypothesis	H_1: μ ≠ 73.2

Z-Value	P-Value
2.73	0.006

2. Tests performed with a random sample of 40 diesel engines produced by a large manufacturer show that they have a mean thermal efficiency of 31.4% with a standard deviation of 1.6% . At the 0.01 level of significance , test the null hypothesis μ = 32.3% against the alternative hypothesis μ <> 32.3%

One-Sample Z

Descriptive Statistics

N	Mean	SE Mean	99% CI for μ
40	31.400	0.253	(30.748, 32.052)

μ: mean of Sample
Known standard deviation = 1.6

Test

Null hypothesis	H_0: μ = 32.3
Alternative hypothesis	H_1: μ ≠ 32.3

Z-Value	P-Value
-3.56	0.000

1t

3. The cycle time data of a process has been collected for 10 samples. The target cycle time is 180 sec. (File: Hypothesis Testing_Practicedata.xls; Data Set 1)
   - Have we hit the target?

One-Sample T: Cycle Time

Descriptive Statistics

N	Mean	StDev	SE Mean	95% CI for μ
10	181.033	2.100	0.664	(179.530, 182.535)

μ: mean of Cycle Time

Test

Null hypothesis $H_0: \mu = 180$
Alternative hypothesis $H_1: \mu \neq 180$

T-Value	P-Value
1.56	0.154

- If the results are that we cannot prove a difference, what is the power of the test to detect 1sec difference?

Power and Sample Size

1-Sample t Test
Testing mean = null (versus ≠ null)
Calculating power for mean = null + difference
α = 0.05 Assumed standard deviation = 2.1

Results

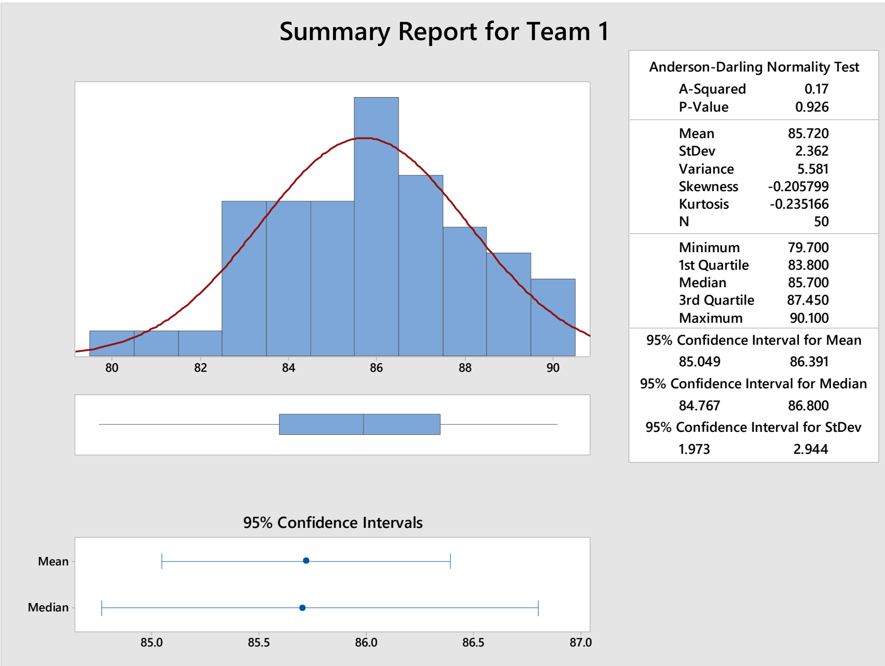
Difference	Sample Size	Power
1	10	0.270673

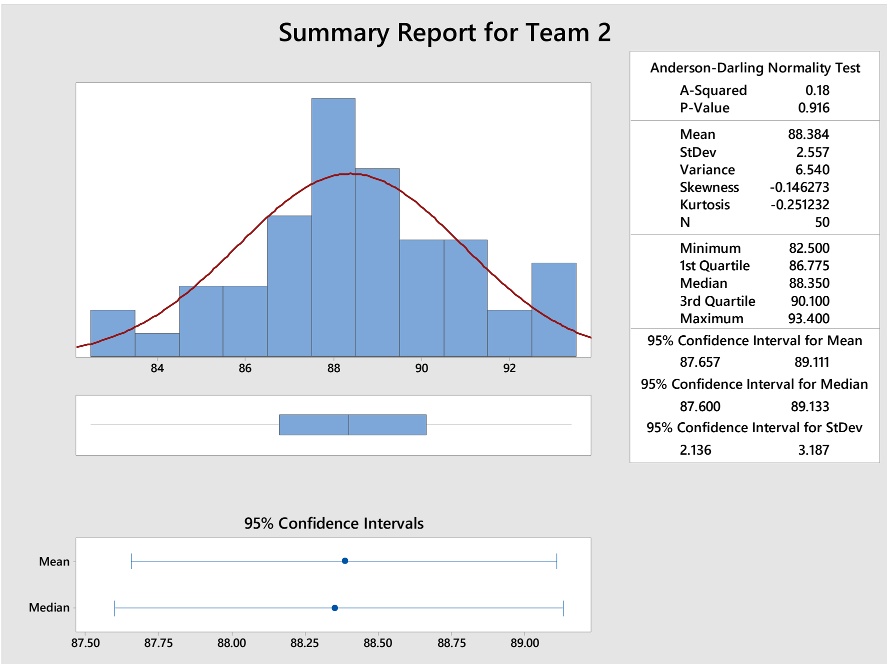
Power Curve for 1-Sample t Test

2t

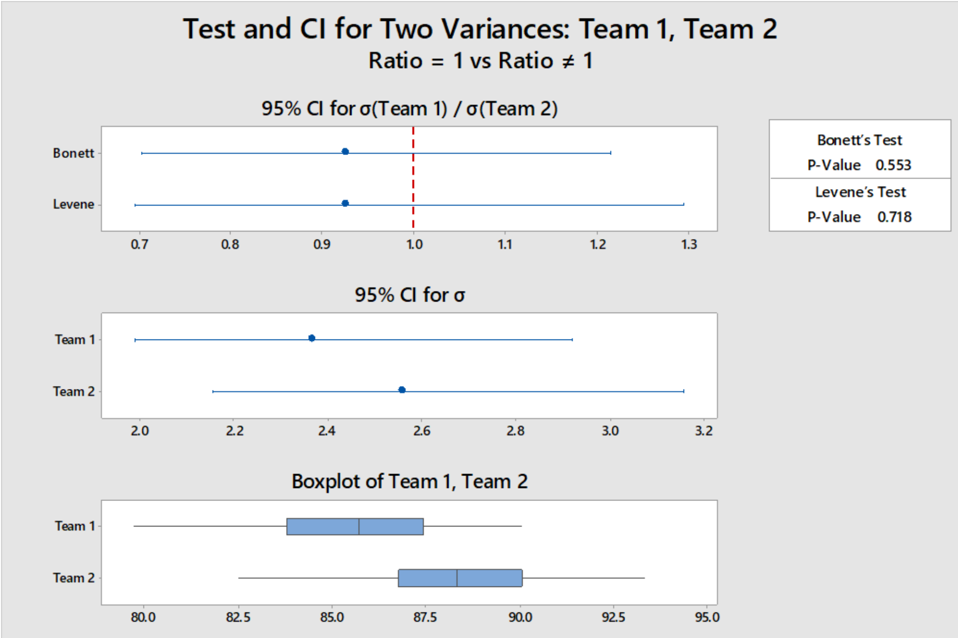
4. You are helping of your teams to improve their performance (Productivity %). You are comparing the data of these teams with few samples. Is there a difference between the team's performance. (File: Hypothesis Testing_Practicedata.xls; Data Set 2)

Inference: Both data sets are normal





Canopus
Business Management Group



Two-Sample T-Test and CI: Team 1, Team 2

Method

μ_1: mean of Team 1
μ_2: mean of Team 2
Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Team 1	50	85.72	2.36	0.33
Team 2	50	88.38	2.56	0.36

Estimation for Difference

Difference	Pooled StDev	95% CI for Difference
-2.664	2.462	(-3.641, -1.687)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.41	98	0.000

Paired t

5. The weight of components from two different mold cavities are compared. Data is available to validate if there is any weight difference between cavities. (File: Hypothesis Testing_Practicedata.xls; Data Set 3)

Paired T-Test and CI: Cavity 1, Cavity 2

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Cavity 1	10	51.98	5.23	1.65
Cavity 2	10	39.19	2.21	0.70

Estimation for Paired Difference

Mean	StDev	SE Mean	95% CI for μ_difference
12.79	5.11	1.62	(9.13, 16.45)

μ_difference: mean of (Cavity 1 - Cavity 2)

Test

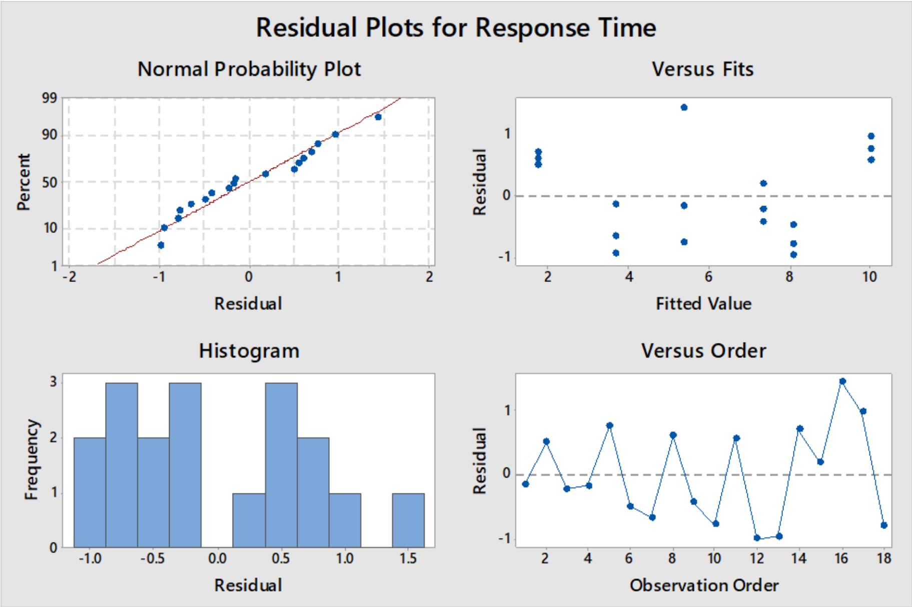
Null hypothesis	H_0: μ_difference = 0
Alternative hypothesis	H_1: μ_difference ≠ 0

T-Value	P-Value
7.91	0.000

ANOVA & GLM

ANOVA (B)

6. The data of response time for updating several files on different servers have been collected. As servers are of different configurations and the file sizes vary, you wish to know if their or both of them have an impact on response time. (File: Hypothesis Testing_Practicedata.xls; Data Set 4)



ANOVA: Response Time versus File in TB, Server

Factor Information

Factor	Type	Levels	Values
File in TB	Fixed	2	1.6, 1.9
Server	Fixed	3	4, 8, 12

Analysis of Variance for Response Time

Source	DF	SS	MS	F	P
File in TB	1	17.209	17.2089	26.69	0.000
Server	2	123.143	61.5717	95.48	0.000
Error	14	9.028	0.6448		
Total	17	149.380			

Model Summary

S	R-sq	R-sq(adj)
0.803020	93.96%	92.66%

Residual Plots for Response Time

7. The procurement team wants to use data to finalize their strategy to achieve the budget for the year. Procurement Managers have worked out 4 different approaches for few parts and estimated the potential saving per part. They haven't taken all parts as it is not practical for initial stage. Is there a distinct strategy evolving from this data? (File: Hypothesis Testing_Practicedata.xls; Data Set 5)

Mixed Effects Model: Saving per part versus Part_1, ... rement Strategy

Method

Variance estimation	Restricted maximum likelihood
DF for fixed effects	Kenward-Roger

Factor Information

Factor	Type	Levels	Values
Part_1	Random	8	A, B, C, D, E, F, G, H
Procurement Strategy	Fixed	4	Alternate Sourcing, Redesign, Renegotiation, Vendor Rationalization

Variance Components

Source	Var	% of Total	SE Var	Z-Value	P-Value
Part_1	0.208122	18.71%	0.279692	0.744110	0.228
Error	0.904219	81.29%	0.337217	2.681412	0.004
Total	1.112341				

-2 Log likelihood = 67.988086

Tests of Fixed Effects

Term	DF Num	DF Den	F-Value	P-Value
Procurement Strategy	3.00	15.45	16.02	0.000

Model Summary

S	R-sq	R-sq(adj)
0.950904	77.13%	73.70%

Coefficients

Term	Coef	SE Coef	DF	T-Value	P-Value
Constant	18.589432	0.272178	6.96	68.298848	0.000
Procurement Strategy					
Alternate Sourcing	1.792343	0.342736	14.77	5.229519	0.000
Redesign	0.875676	0.342736	14.77	2.554960	0.022
Renegotiation	-1.303587	0.407283	15.84	-3.200692	0.006

Marginal Fits and Diagnostics for Unusual Observations

Obs	Saving per part	Fit	Resid	Std Resid	
7	21.700000	19.465107	2.234893	2.319255	R
17	15.000000	17.225000	-2.225000	-2.255314	R

R Large residual

Conditional Fits and Diagnostics for Unusual Observations

Obs	Saving per part	Fit	Resid	Std Resid	
7	21.700000	19.937538	1.762462	2.166182	R
17	15.000000	16.846587	-1.846587	-2.218831	R

R Large residual

Inference: Mixed Effects Models was used as Part No has to be generalized for other parts not covered in this analysis. Parts are not significant however procurement strategy is.

8. Data of whether a team meets its daily production target or not is collected for 90 days along with few factors which are considered to have an association. Using chi-square tests, identify these factors. (File: Hypothesis Testing_Practicedata.xls; Data Set 6)

Chi-Square Test for Association: Daily Production Target ... jor Reasons

Rows: Daily Production Target (Met/No Columns: Line stopper Major Reasons

	Machine Breakdown	Manpower Issue	Material Shortage	Quality Issue	All
Met	5	18	1	2	26
	5.778	6.644	7.511	6.067	
Not Met	15	5	25	19	64
	14.222	16.356	18.489	14.933	
All	20	23	26	21	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF	P-Value
Pearson	39.209	3	0.000
Likelihood Ratio	39.943	3	0.000

Chi-Square Test for Association: Daily Production Target ... h Changed

Rows: Daily Production Target (Met/No Columns: Sch Changed

	N	Y	All
Met	11	15	26
	8.67	17.33	
Not Met	19	45	64
	21.33	42.67	
All	30	60	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF	P-Value
Pearson	1.325	1	0.250
Likelihood Ratio	1.298	1	0.255

Chi-Square Test for Association: Daily Production Target ... e-stoppers

Rows: Daily Production Target (Met/No Columns: Line-stoppers

	0	1	2	3	4	5	6	7	8	9	10
Met	18	2	3	1	1	0	1	0	0	0	0
	8.667	3.178	3.178	1.733	2.600	1.733	2.600	0.867	0.578	0.289	0.289
Not Met	12	9	8	5	8	6	8	3	2	1	1
	21.333	7.822	7.822	4.267	6.400	4.267	6.400	2.133	1.422	0.711	0.711
All	30	11	11	6	9	6	9	3	2	1	1

	12	All
Met	0	26
	0.289	
Not Met	1	64
	0.711	
All	1	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF
Pearson	23.655	11
Likelihood Ratio	26.540	11

8 cell(s) with expected counts less than 1.
Chi-Square approximation probably invalid.
18 cell(s) with expected counts less than 5.

Chi-Square Test for Association: Daily Production Target ... t/Non-Met)

Rows: Daily Production Target (Met/No Columns: First hour output (Met/Non-Met)

	Met	Not Met	All
Met	21	5	26
	21.38	4.62	
Not Met	53	11	64
	52.62	11.38	
All	74	16	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF	P-Value
Pearson	0.053	1	0.818
Likelihood Ratio	0.052	1	0.819

1 cell(s) with expected counts less than 5.

Chi-Square Test for Association: Daily Production Target ... el Changes

Rows: Daily Production Target (Met/No   Columns: No. of Model Changes

	3	4	5	6	7	8	9	10	11	All
Met	2	9	5	9	1	0	0	0	0	26
	0.578	3.178	3.178	7.222	5.489	3.178	1.444	0.578	1.156	
Not Met	0	2	6	16	18	11	5	2	4	64
	1.422	7.822	7.822	17.778	13.511	7.822	3.556	1.422	2.844	
All	2	11	11	25	19	11	5	2	4	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF
Pearson	36.109	8
Likelihood Ratio	42.112	8

2 cell(s) with expected counts less than 1.
Chi-Square approximation probably invalid.
11 cell(s) with expected counts less than 5.

Chi-Square Test for Association: Daily Production Target ... Month End

Rows: Daily Production Target (Met/No   Columns: Month End

	Month End	Not Month End	All
Met	23	3	26
	12.71	13.29	
Not Met	21	43	64
	31.29	32.71	
All	44	46	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF	P-Value
Pearson	22.914	1	0.000
Likelihood Ratio	25.122	1	0.000

Chi-Square Test for Association: Daily Production Target ... ay of Week

Rows: Daily Production Target (Met/No   Columns: Day of Week

	Fri	Mon	Sat	Thur	Tue	Wed	All
Met	1	2	0	6	12	5	26
	6.644	0.867	2.022	6.644	4.333	5.489	
Not Met	22	1	7	17	3	14	64
	16.356	2.133	4.978	16.356	10.667	13.511	
All	23	3	7	23	15	19	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF
Pearson	30.894	5
Likelihood Ratio	32.847	5

1 cell(s) with expected counts less than 1.
Chi-Square approximation probably invalid.
5 cell(s) with expected counts less than 5.

Chi-Square Test for Association: Daily Production Target ... t/No, Shift

Rows: Daily Production Target (Met/No   Columns: Shift

	A	B	C	All
Met	17	5	4	26
	14.156	8.667	3.178	
Not Met	32	25	7	64
	34.844	21.333	7.822	
All	49	30	11	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF	P-Value
Pearson	3.284	2	0.194
Likelihood Ratio	3.491	2	0.175

1 cell(s) with expected counts less than 5.

Chi-Square Test for Association: Daily Production Target ... rst Half & 2

Rows: Daily Production Target (Met/No   Columns: Time Window (1 - First Half & 2

	A1	A2	B1	B2	C1	C2	All
Met	15	2	3	2	3	1	26
	8.667	5.489	7.511	1.156	2.889	0.289	
Not Met	15	17	23	2	7	0	64
	21.333	13.511	18.489	2.844	7.111	0.711	
All	30	19	26	4	10	1	90

Cell Contents
Count
Expected count

Chi-Square Test

	Chi-Square	DF
Pearson	16.772	5
Likelihood Ratio	17.473	5

2 cell(s) with expected counts less than 1.
Chi-Square approximation probably invalid.
5 cell(s) with expected counts less than 5.