



Godfrey Hirst



C A R P E T



6 Sigma

**Kuster Colour
Variation
Carpet Colour
Measurement**

Jason Maher
Quality & Improvement Manager

Godfrey Hirst offers a wide range of high quality residential and commercial carpets. Australasia's largest carpet supplier, we have operations in Australia, New Zealand and North America. Our range of modular carpet tiles and broadloom carpet is extensive and provides a variety of floor covering options. Nylon, triexta and wool carpets are all produced by Godfrey Hirst.

What Makes a Good Lean Six Sigma Project?

- There is no known solution
- The root cause is not known
- The problem is complex and needs statistical analysis
- The problem is part of a process
- The process is repeatable
- A defect can be defined
- Project will take 3-6 months
- There is data available

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DMAIC DEFINE

Project Name:

Kuster Colour Variation Reduction

Business Case

Colour variation from the Kuster continuous dyeing operation drives the consumption of \$650,000 of carpet greige per annum plus 6-8hrs/day of labour/machine time to complete production line sampling.

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DMAIC DEFINE

Elements

- Dyes & mixing variation – recipe calibration
- Yarn dye uptake variation – recipe calibration
- Process Control
- Recipe Management
- Carpet Colour Measurement

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DMAIC DEFINE

Elements

Dyes & mixing variation – recipe calibration



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DMAIC DEFINE

Elements

Yarn dye uptake variation – recipe calibration

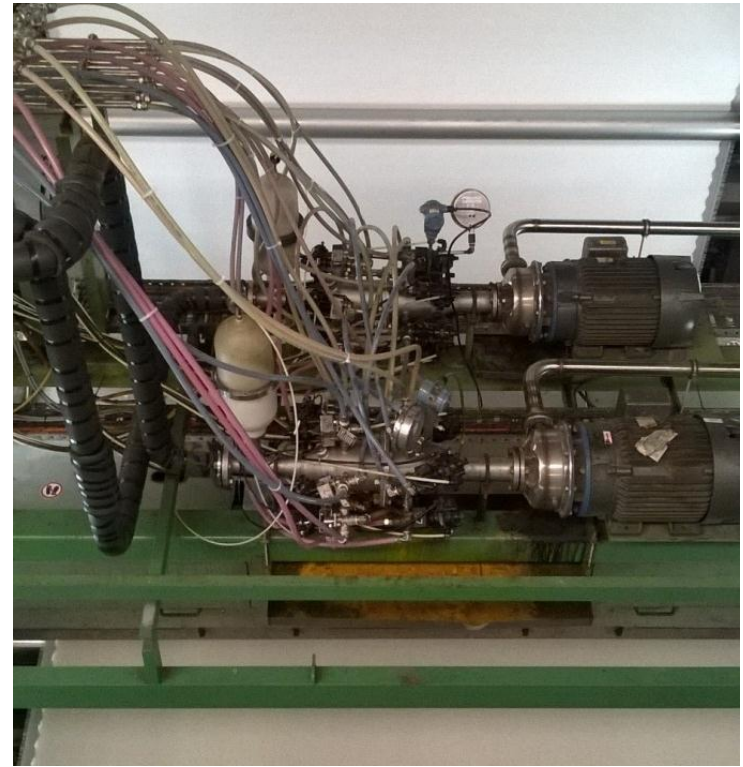


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DMAIC DEFINE

Elements

Process Control



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Elements

Recipe Management

Formula: SORONA 550 1356

Loop	Colour	Tank	%G/ml	G/ml	Adds %	Setpoint	Lab SP
Loop A	Hi Yellow	8	0.0100950	0.32590	0.00	7457	32.28
Loop B	Hi Red	10	0.0100690	0.19791	0.00	4540	19.66
Loop C	Hi Blue	12	0.0097000	0.26553	0.00	6323	27.37

Total Flow - (Loop A Setpoint + Loop B Setpoint + Loop C Setpoint) = 213 L/min

Run Date (time @ end) 08/04/2015 11:10:57 AM

Last Formula Edit 07/04/2015

Loop #	g/lit	Adds	SP
Loop A	0.33086	0.00	0
Loop B	0.19499	0.00	7,571
Loop C	0.26553	0.00	0

Run Date (time @ end) 18/02/2015 06:14:23 PM

Last Formula Edit 18/02/2015

Loop #	g/lit	Adds	SP
Loop A	0.33086	0.00	0
Loop B	0.19306	1.00	7,665
Loop C	0.26553	0.00	0

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DMAIC DEFINE

Elements

Carpet Colour Measurement



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DMAIC DEFINE

Project Name:

Kuster Colour Variation Reduction
Colour Measurement

Business Case

An accurate & reproducible measurement system to objectively determine carpet colour is required to drive improvement in Kuster colour variation.

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DMAIC DEFINE

TEAM/PROJECT CHARTER

Project Name:	Kuster Colour Variation Reduction - Colour Measurement
Date (Last Revision):	11/04/2014
Prepared By:	Jason Maher
Approved By:	Jason Maher, Aaron Dawson, Norm Kotsopoulos, Anthony Legault, Darren Morrison

Business Case:				Opportunity Statement (High Level Problem Statement):	
The colour variation of the Kuster continuous dyeing operation necessitates the consumption of 6-8hrs per day of Kuster labour/capacity and resulted in 21,900blm of Kuster dyed greige samples going to waste recyclers over the 12 months ending February 2014.				Variation in colour measurement of the textured carpet pile	
				Defect Definition: To be determined following measurement and analysis of data	
Goal Statement:				Project Scope:	
Contribute to the 50% reduction in production line sampling				Process Start Point: Carpet colour measurement	
Expected Savings/Benefits: Contribution of this element is unknown at this time Estimate 20%				Process End Point: Development of std work	
				In Scope: Carpet colour measurement	
				Out of Scope: Supporting project elements	
Project Plan:				Team:	
Task/Phase	Start Date	End Date	Actual End	Name:	Commitment (%):
Define	9/04/14	16/04/14		Jason	20
Measure	16/04/14	30/04/14			
Analyse	30/04/14	7/05/14			
Improve	7/05/14	28/05/14			
Control	28/05/14	25/06/14			

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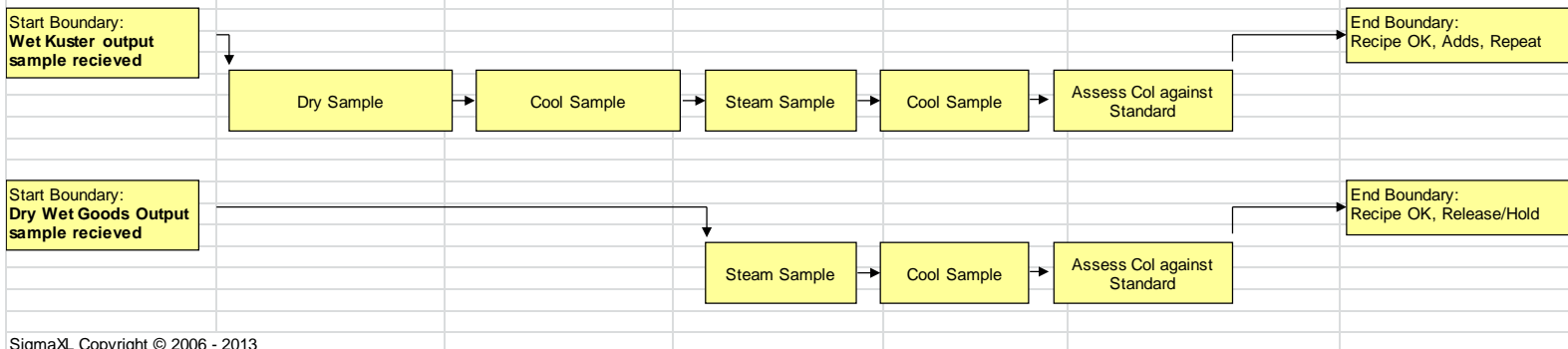
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DMAIC DEFINE

SIPOC DIAGRAM

Process/Project Name:	Kuster Colour Variation Reduction - Colour Measurement
Date:	28/04/2014
Prepared By:	Jason Maher

Suppliers	Inputs		Process	Outputs		Customers
Provider	Input Description	Input Requirements (optional)		Output Description	Output Requirements (optional)	Recipient of Output
Kuster Output	Wet production sample run	300mm x 300mm	See High Level Process Steps Below	ColourAssessment	Visual Assessment (Experience) Sample matches Std Sample does not match standard Production within tolerance Production outside tolerance	Int. - Run Production Int. - Adjust recipe, repeat Finishing Hold - Corrective action
Wet Goods Output	Dry production run	300mm x 300mm				
Dryer	Sample Dryer	Fan 170°C - Time				
Fan	Cooling Fan	On/Off - Time				
Steamer	Moisturising Steamer	Water 80-90°C - Time				

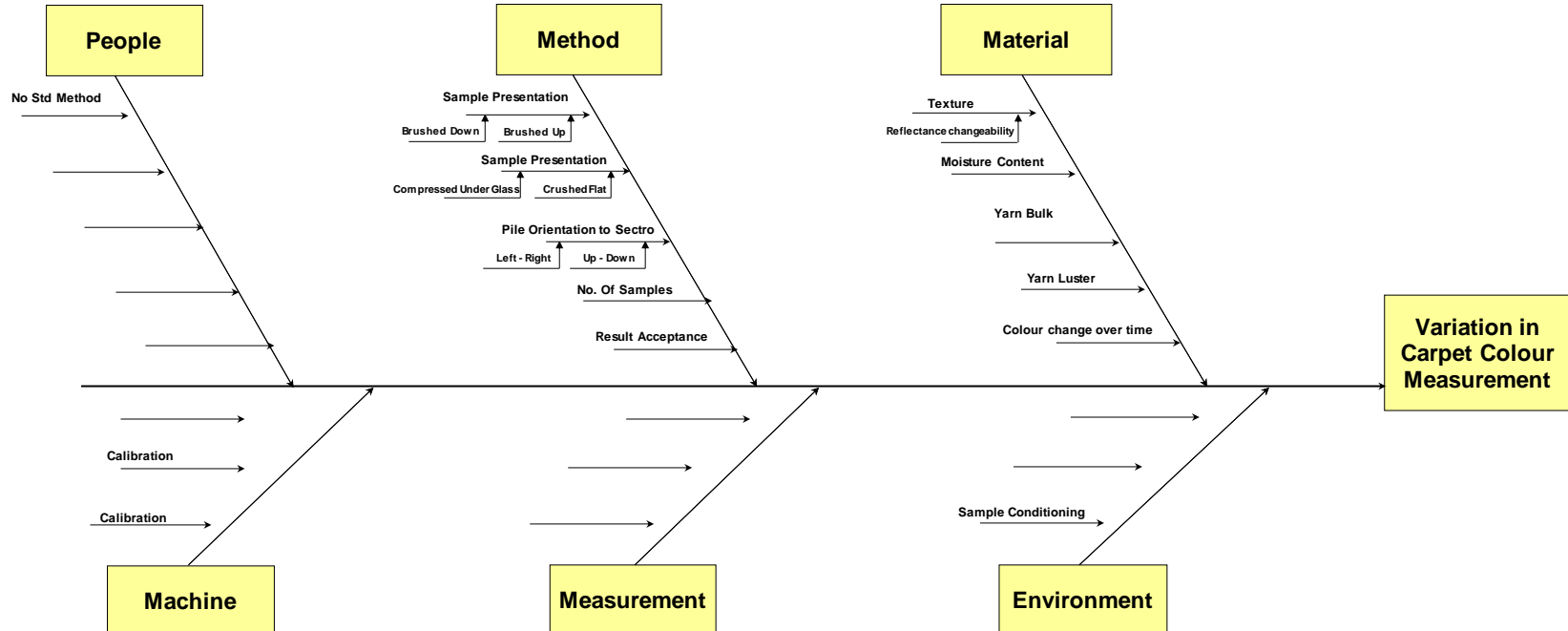


DMAIC DEFINE

CAUSE & EFFECT (FISHBONE) DIAGRAM

Process/Project Name:	Kuster Colour Variation Reduction - Colour Meas
Date:	15/04/2014
Prepared By:	Jason Maher

Problem Statement/Effect:	Variation in Carpet Colour Measurement
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DMAIC MEASURE

MEASUREMENT PLAN

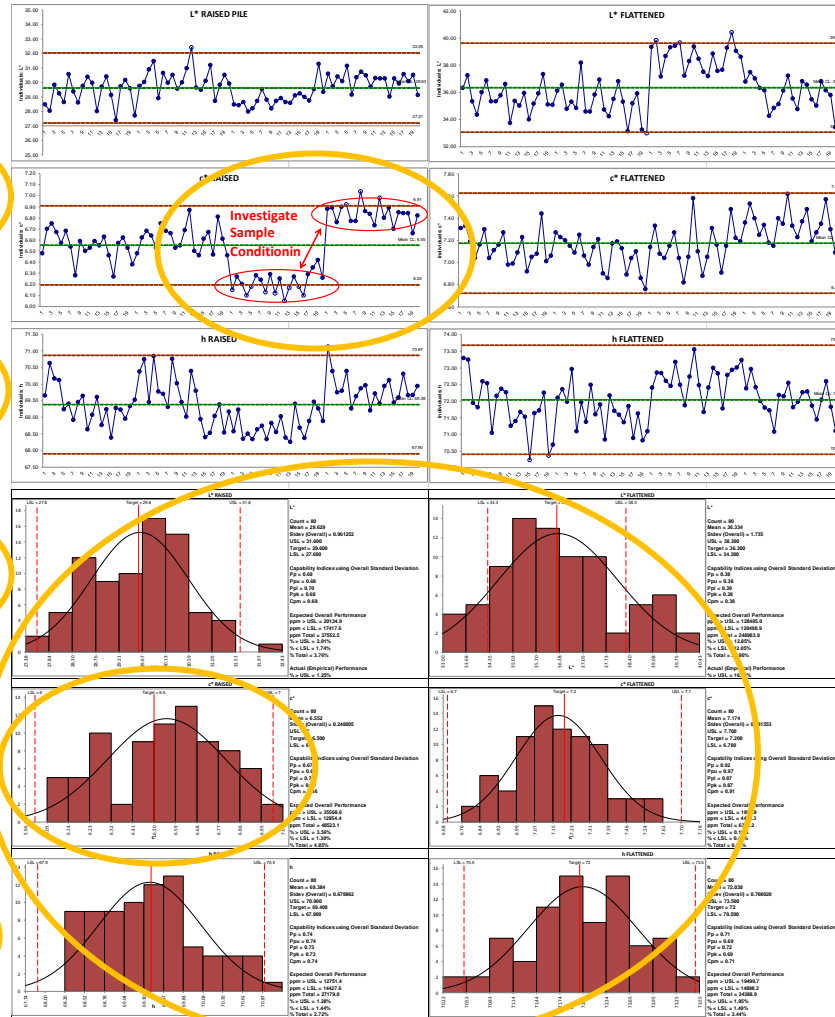
Project Name:	Kuster Colour Variation Reduction - Colour Measurement
Date:	15/04/2014
Prepared By:	Jason Maher
Notes:	

Measurement/ Metric	X or Y	Operational Definition	Type of Data Discrete/ Continuous	Data Source and Location	Sample Size	Who Will Collect the Data?	When Will Data be Collected?	How Will Data be Collected?	Is the Meas. System Capable?	Graphical and/or Statistical Tools to be Used
Pile Orientation to Spectro	x	Left/Right/Up/Down	Cont.	Colour Spectro	Std Size	Jason	17-Mar	Meas. Stds/Samples	That is what we are working on	Mean, St Dev, Multi Vari
Pile Brushed Up	x	Vertical Pile	Cont.	Colour Spectro	Std Size	Jason	17-Mar	Meas. Stds/Samples		Mean, St Dev, Control Charts, Histogram
Pile Brushed Down	x	Angled Pile	Cont.	Colour Spectro	Std Size	Jason	17-Mar	Meas. Stds/Samples		Mean, St Dev, Control Charts, Histogram
Sample Conditioning	x	Repeat of above after conditioning	Cont.	Colour Spectro	Std Size	Jason	24-Mar	Meas. Stds/Samples		Mean, St Dev, Control Charts, Histogram
Pile Crushed Flat	x	Flattened Pile	Cont.	Colour Spectro	50mm x 50mm	Jason	11-Apr	Meas. Stds/Samples		Control Chart
Pile Compressed Under Glass	x	Compressed against glass	Cont.	Colour Spectro	50mm x 50mm	Jason	14-Apr	Meas. Stds/Samples		Mean, St Dev, Control Charts, Histogram
Moisture Content	x	Moist / Dry	Cont.	Colour Spectro	50mm x 50mm	Jason	14-Apr	Meas. Stds/Samples		Mean, St Dev
L*	y	Lightness Value	Cont.	Colour Spectro						
c*	y	Chroma	Cont.	Colour Spectro						
h	y	Hue	Cont.	Colour Spectro						
a*	y	Red/Green	Cont.	Colour Spectro						
b*	y	Blue/Yellow	Cont.	Colour Spectro						

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DMAIC MEASURE

BEFORE STEAMING / CONDITIONING											
Product		California Gully		Pile Lay Out		Pile Lay Out		Pile Lay Out		Pile Lay Out	
Colour		Blue		100%		100%		100%		100%	
Symbol		100%		100%		100%		100%		100%	
Name		100%		100%		100%		100%		100%	
Customer		100%		100%		100%		100%		100%	
BEFORE STEAMING / CONDITIONING		BEFORE STEAMING / CONDITIONING		BEFORE STEAMING / CONDITIONING		BEFORE STEAMING / CONDITIONING		BEFORE STEAMING / CONDITIONING		BEFORE STEAMING / CONDITIONING	
#	SP	SP	SP	#	SP	SP	SP	#	SP	SP	SP
1	A	28.04	6.48	68.85	1	A	36.51	7.33	72.29		
2	C	28.83	6.75	70.16	3	C	35.33	7.33	71.94		
3	D	29.04	6.77	70.29	4	D	34.53	7.04	71.61		
4	F	28.65	6.57	68.22	2	F	48.86	6.38	71.31		
5	B	29.06	6.75	70.29	6	B	36.12	7.04	71.61		
6	E	29.06	6.75	70.29	5	E	36.12	7.04	71.61		
7	A	28.72	6.57	68.23	17	A	42.14	7.11	71.71		
8	B	29.06	6.75	70.29	6	B	36.12	7.04	71.61		
9	A	28.72	6.57	68.23	17	A	42.14	7.11	71.71		
10	B	30.38	6.50	67.1	8	B	36.62	7.27	72.2		
11	C	29.06	6.75	70.29	6	C	33.74	6.98	72.25		
12	D	29.06	6.75	70.29	6	D	35.88	6.98	71.97		
13	F	29.06	6.75	70.29	6	F	35.88	6.98	71.97		
14	B	29.06	6.75	70.29	6	B	35.88	6.98	71.97		
15	A	28.72	6.57	68.23	17	A	38.99	6.93	71.82		
16	D	29.06	6.75	70.29	6	D	35.88	6.98	71.97		
17	A	28.72	6.57	68.23	17	A	35.92	7.08	71.92		
18	B	30.16	6.62	68.95	18	B	37.12	7.44	72.77		
19	D	29.06	6.75	70.29	6	D	35.11	7.00	71.86		
20	D	29.06	6.75	70.29	6	D	35.11	7.00	71.86		
21	A	28.72	6.57	68.23	17	A	35.92	7.08	71.92		
22	A	30.04	6.62	70.74	2	B	36.56	7.17	72.35		
23	C	30.91	6.68	70.43	3	C	34.77	7.20	72.56		
24	D	31.48	6.64	70.84	4	D	35.29	7.15	72.56		
25	A	28.91	6.53	69.77	5	A	34.83	7.09	71.09		
26	B	29.06	6.75	70.29	6	B	36.12	7.04	71.61		
27	C	29.96	6.68	69.51	7	C	34.58	7.06	71.97		
28	D	30.53	6.66	70.75	8	D	34.58	6.98	72.49		
29	A	29.57	6.53	70.24	9	A	35.81	6.9	71.44		
30	B	30.00	6.55	69.47	10	B	36.94	7.21	71.89		
31	D	30.96	6.60	70.78	11	D	34.72	6.90	71.80		
32	D	32.42	6.87	71.31	12	D	34.22	6.86	72.17		
33	A	29.60	6.50	69.73	13	A	35.90	7.17	71.90		
34	B	29.48	6.46	69.6	14	B	36.80	7.19	71.89		
35	C	30.10	6.61	68.4	15	C	35.29	7.13	71.38		
36	D	31.31	6.67	68.5	16	D	33.12	6.98	71.83		
37	A	28.73	6.47	69.0	17	A	35.19	7.04	70.88		
38	B	29.84	6.61	69.1	18	B	35.91	7.10	71.77		
39	C	30.54	6.63	69.3	19	C	35.11	7.00	71.86		
40	D	30.71	6.64	69.3	20	D	35.11	7.00	71.86		
41	A	28.42	6.27	69.2	2	B	39.83	7.33	72.94		
42	B	28.83	6.57	70.16	3	C	37.67	7.46	72.66		
43	C	29.04	6.77	70.29	4	D	32.71	7.04	71.61		
44	D	29.04	6.77	70.29	4	D	32.71	7.04	71.61		
45	E	29.04	6.77	70.29	4	D	32.71	7.04	71.61		
46	F	29.04	6.77	70.29	4	D	32.71	7.04	71.61		
47	A	28.72	6.57	68.23	17	A	35.92	7.08	71.92		
48	B	29.06	6.75	70.29	6	B	36.12	7.04	71.61		
49	C	29.06	6.75	70.29	6	C	36.12	7.04	71.61		
50	D	29.06	6.75	70.29	6	D	36.12	7.04	71.61		
51	E	29.06	6.75	70.29	6	E	36.12	7.04	71.61		
52	F	29.06	6.75	70.29	6	F	36.12	7.04	71.61		
53	A	28.74	6.29	68.88	17	A	39.28	7.15	72.38		
54	B	29.51	6.45	69.42	18	B	40.42	7.45	73.04		
55	C	31.29	6.82	69.26	19	C	39.04	7.45	73.04		
56	D	29.39	6.48	71.13	1	A	39.73	7.19	72.31		
57	B	29.72	6.89	70.39	2	B	37.47	7.33	72.94		
58	C	30.40	7.26	70.00	3	C	37.00	7.40	72.58		
59	D	30.67	6.90	69.79	4	D	36.32	7.25	72.00		
60	E	29.69	6.76	69.89	5	E	36.89	7.19	71.89		
61	F	29.69	6.76	69.89	5	E	36.89	7.19	71.89		
62	A	29.71	6.86	69.79	6	A	36.10	7.15	71.85		
63	B	30.31	6.73	69.53	7	B	35.53	7.13	71.85		
64	C	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
65	D	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
66	E	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
67	F	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
68	A	29.71	6.86	69.79	6	A	36.10	7.15	71.85		
69	B	30.31	6.73	69.53	7	B	35.53	7.13	71.85		
70	C	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
71	D	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
72	E	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
73	F	30.29	6.98	69.49	8	C	34.75	7.23	71.85		
74	A	30.58	6.84	70.30	17	A	36.82	7.35	72.04		
75	B	30.08	6.84	70.30	18	B	36.14	7.35	72.04		
76	C	30.42	6.66	69.66	19	C	35.94	7.35	71.82		
77	D	30.42	6.66	69.66	19	C	35.94	7.35	71.82		
78	E	30.42	6.66	69.66	19	C	35.94	7.35	71.82		
79	F	30.42	6.66	69.66	19	C	35.94	7.35	71.82		
80	A	29.63	6.55	69.36	10	A	36.33	7.17	72.04		
81	B	29.96	6.52	69.68	11	B	35.73	6.98	71.71		
82	C	27.74	6.07	68.85	12	C	32.93	6.82	70.65		
83	D	31.51	6.76	70.73	13	D	39.79	7.51	73.43		
84	E	27.38	6.05	68.04	14	E	31.03	6.76	70.43		
85	F	32.43	7.04	71.13	15	F	40.42	7.40	73.55		



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DMAIC ANALYSE

Pile Orientation to Colour Spectro

Test the following hypothesis:

H₀: there is no difference in colour measurement for different orientations of the sample (*Null Hypothesis*)

H₁: at least one orientation gives a different colour measurement. (*Alternative Hypothesis*)



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DMAIC ANALYSE

Pile Orientation to Colour Spectro

Is the result affected by the selection of an attribute?

As we are comparing more than two attributes (Pile: Up, Down, Left, Right) ANOVA (ANalysis Of VAriance) is used instead of completing t-tests for all possible pairs.

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DMAIC ANALYSE

Pile Orientation to Colour Spectro - Raised

Anova: Single Factor						
SUMMARY						
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Column 1	20	588.19	29.4095	0.801826		
Column 2	20	591.8	29.59	0.549747		
Column 3	20	599.83	29.9915	0.506982		
Column 4	20	590.46	29.523	1.780896		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	3.84685	3	1.282283	1.409315	0.246602	2.724944
Within Groups	69.14957	76	0.909863			
Total	72.99642	79				

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DMAIC ANALYSE

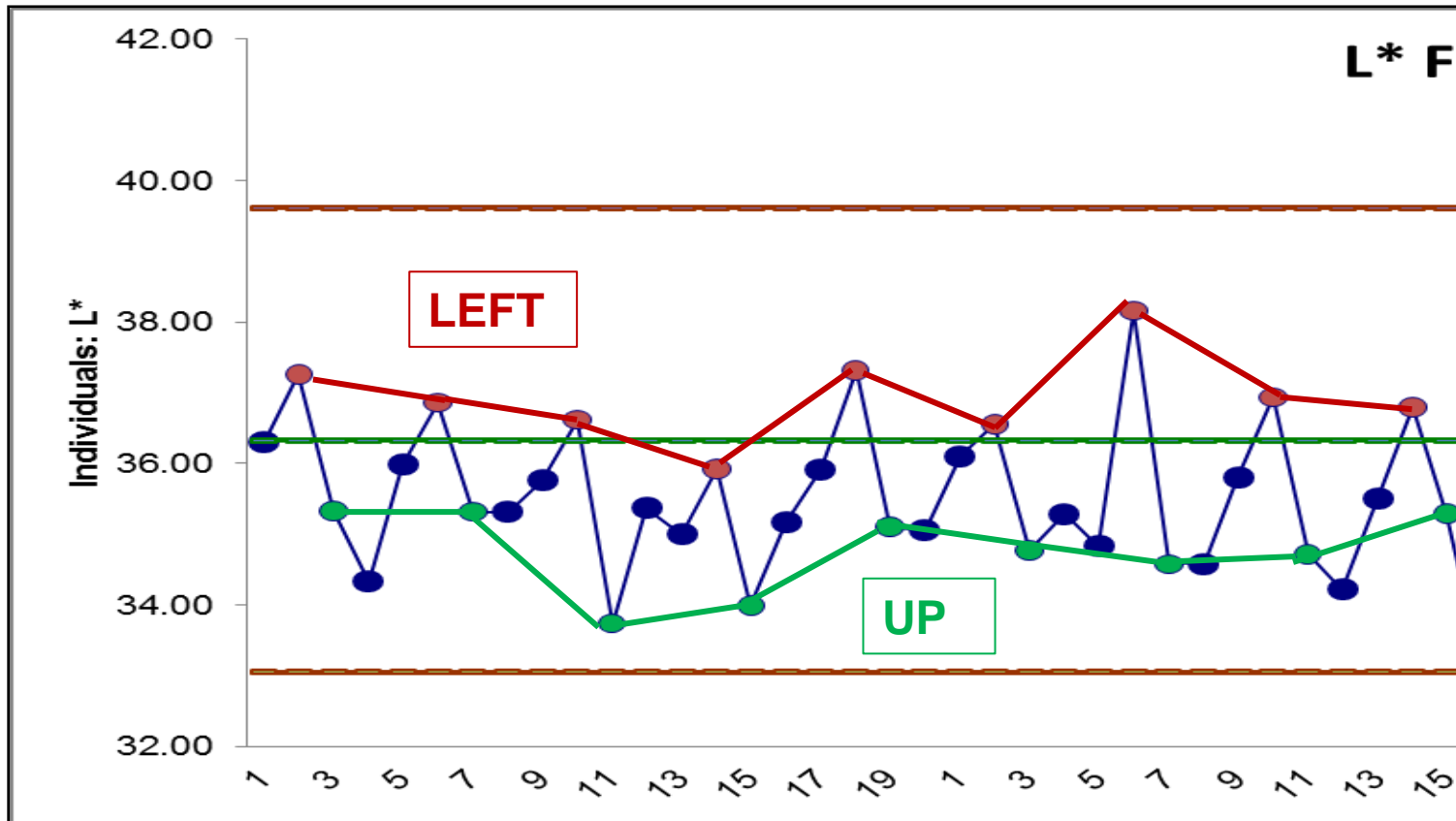
Pile Orientation to Colour Spectro - Flattened

Anova: Single Factor						
SUMMARY						
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Column 1	20	732.48	36.624	1.958594		
Column 2	20	747.85	37.3925	2.33742		
Column 3	20	716.63	35.8315	3.105624		
Column 4	20	709.74	35.487	2.819138		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	43.48875	3	14.49625	5.673248	0.001465	2.724944
Within Groups	194.1947	76	2.555194			
Total	237.6835	79				

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DMAIC ANALYSE

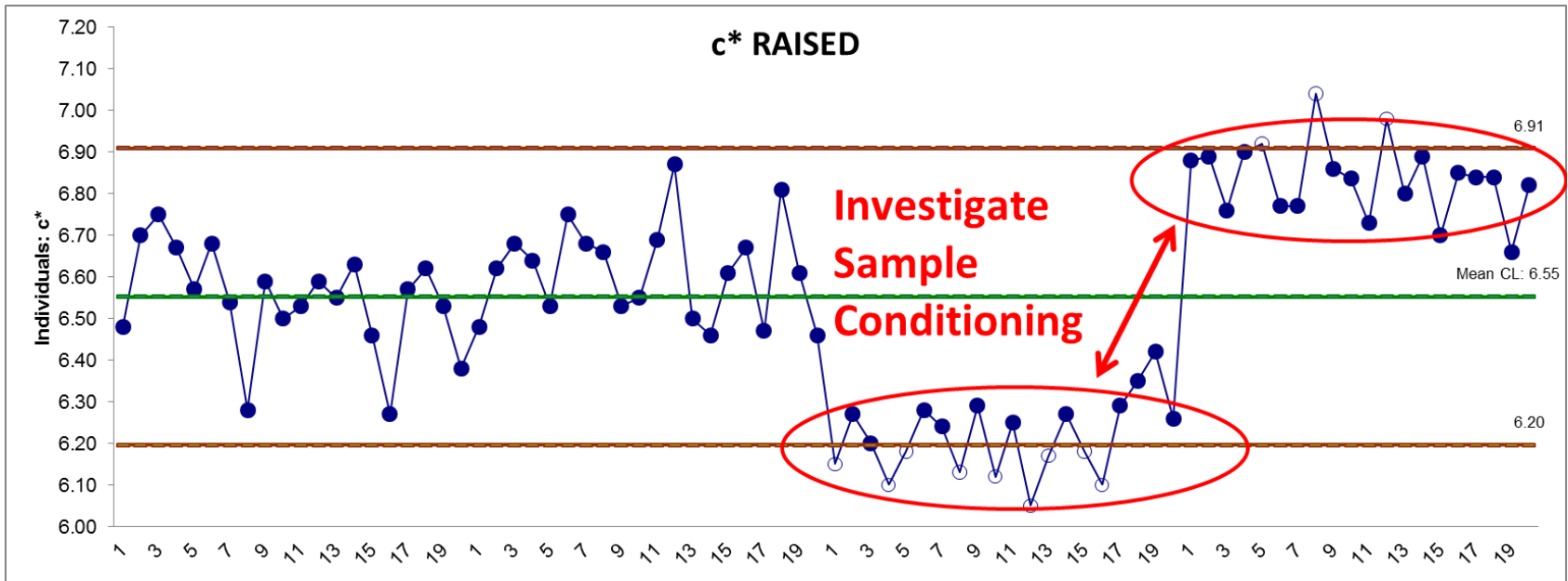
Pile Orientation to Colour Spectro - Flattened



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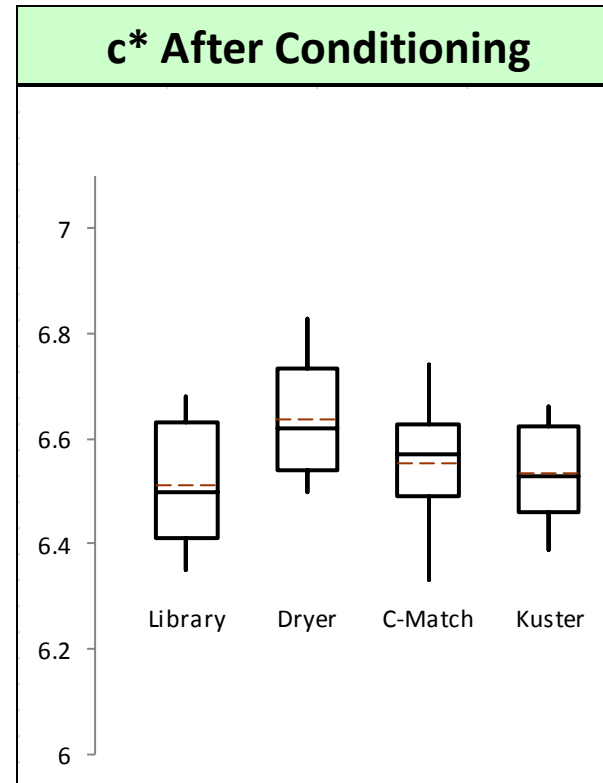
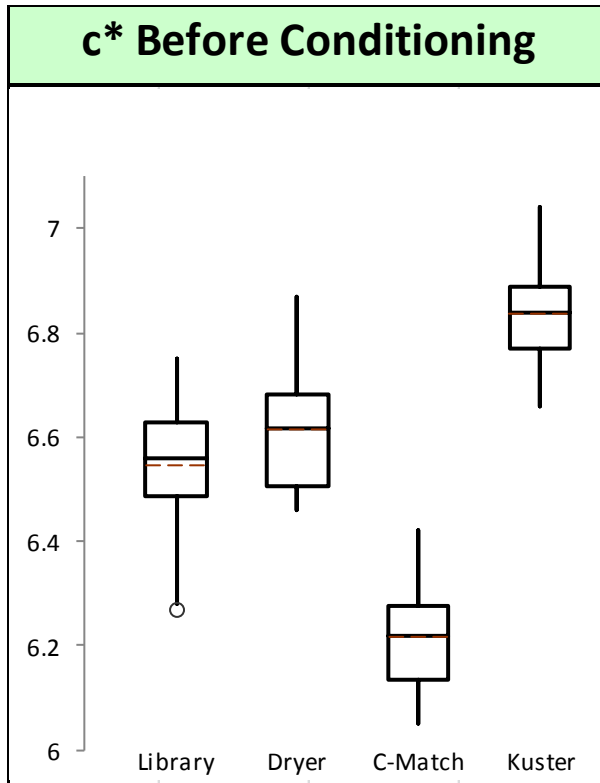
Conditioning



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DMAIC ANALYSE

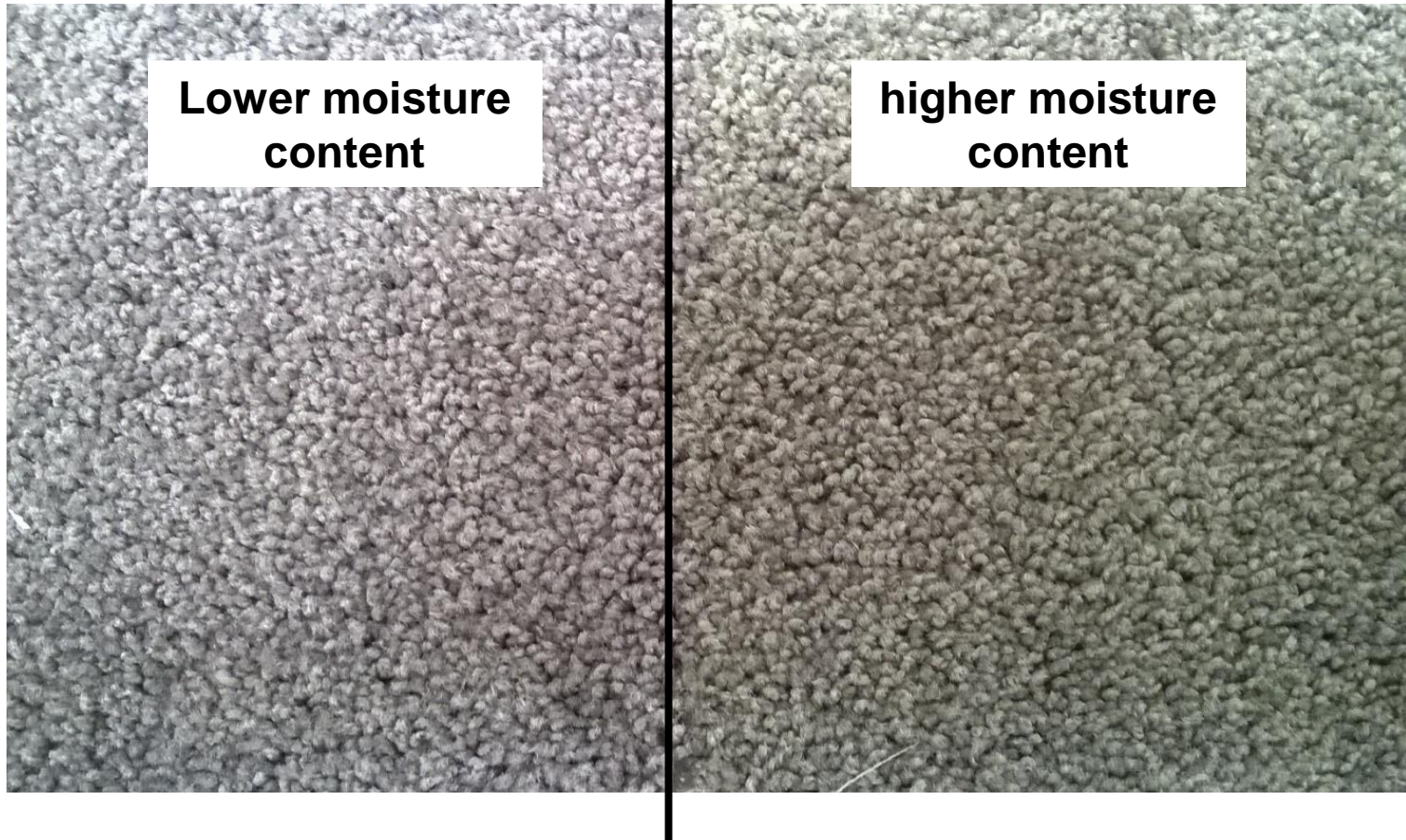
Conditioning



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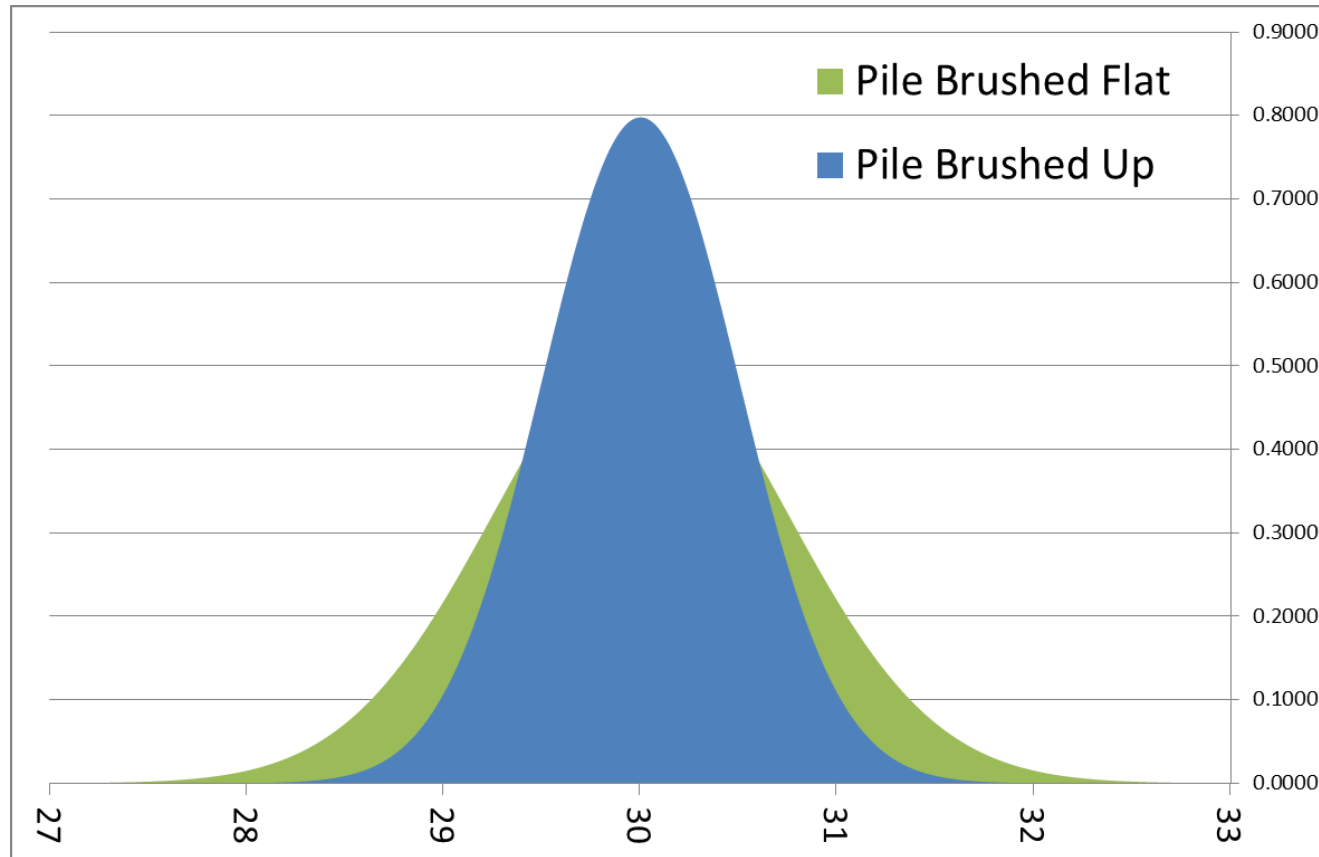
Conditioning



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DMAIC ANALYSE

Pile Flattened vs Brushed Up



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DMAIC IMPROVE

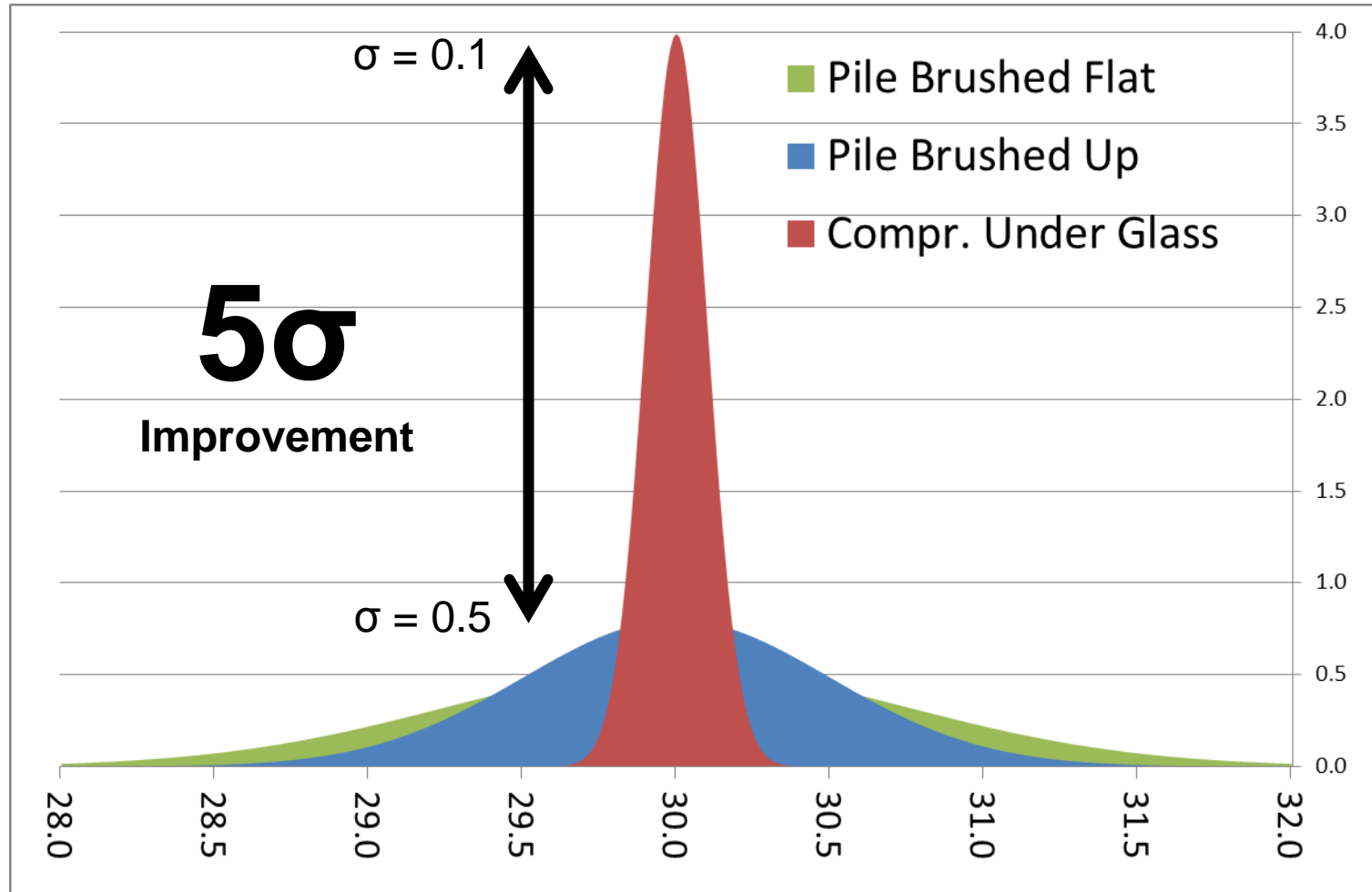
How can we significantly improve the precision?

- Fix pile by compression prior to testing
- Fix pile by compressed under glass aperture



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DMAIC IMPROVE



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DMAIC CONTROL

Equipment

- Glass Aperture
- Compression Clamp



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DMAIC CONTROL

Standard work

- Sample Conditioning
- Sample Testing
- System Calibration

Godfrey Hirst CARPETS

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Print Date: 13/04/2015

GH-TKW-P-200
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Page 1 of 1

Carpet Colour Measurement with UltraScan® XE Spectrophotometer

- 1 Scope**
 - 1.1 This document outlines the method for carpet colour measurement using the Hunterlab UltraScan® XE Spectrophotometer.
- 2 Occupational Health and Safety**
 - 2.1 Refer to [OHS Index](#) page.
- 3 Environmental Management**
 - 3.1 Refer to [GH-EMS-D-001](#) "Environmental Policy".
 - 3.2 Refer to [GH-EMS-D-011](#) "Environmental Aspects Register –GHA".
- 4 General Information**
 - 4.1 **References**
 - 4.1.1 Port insert with glass: Hunterlab Part Number A02-1011-124 for ColorQuest® XE
Compression clamp: Hunterlab Part Number D02-1011-132 for ColorQuest® XE
- 5 Procedure**
 - 5.1 Configure your software to read:
Colour Scale: CIE L*a*b*
Illuminant: D65
Observer: 10°
 - 5.2 Standardise the instrument in Reflectance – Specular Excluded Mode for the large area of viewing using the port insert with glass. First standardise with the light trap, then the white tile.
 - 5.3 Cut a 200mm x 200mm sample. Steam the sample for 30 seconds and allow to condition for 24hours in the conditioned room of the quality control laboratory.
 - 5.5 For cut pile carpet brush the pile down in the direction of pile lay. Centre the carpet sample to be measured over the reflectance port with the pile tip pointing downward. Hold it in place with the compression clamp. Make sure that the area of the sample to be measured faces the port and completely covers the port.
 - 5.6 Take a single colour reading of the sample. Rotate the sample 90° clockwise, move so a different area (where the pile has not already been crushed) covers the sample port and repeat taking four readings in total.
 - 5.7 Average the four readings for a single colour measurement. Averaging multiple readings with rotation between readings minimises measurement variation associated with directionality and non-homogeneity.

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DMAIC DEFINE

Design of experiments

- What variables or combination of variables have the greatest impact on the colour outcome?

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