The Delayed Shipment Scenario

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ABSTRACT

The case involves a fictitious manufacturing company. Products are arriving late to the shipping department. Statistical techniques such as descriptive statistics, control charts, ANOVA, and hypothesis testing are used to help resolve this late shipping issue. The case can be used in statistics, analytics, or operations management courses for learning purposes. A case activities guide is provided.

Keywords: ANOVA, statistics, control charts, Tableau, hypothesis testing

This is a fictitious case. All information contained herein was fabricated by the author(s). Any similarity contained herein to actual persons, businesses, events, etc. is purely coincidental and is the responsibility of the author(s). Please contact the case author(s) directly with any concerns.

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INTRODUCTION

A manufacturing case scenario is presented. The case contains data that can be analyzed to help address reasons why products are arriving late to a shipping department. Students can run statistical analysis and build visualizations from the case data to help address the case dilemma. The case can be used in statistics, analytics, or operations management courses to teach concepts such as visualization, control charts, ANOVA, and hypothesis testing.

The case scenario is first presented and then an activities guide is discussed. The activities guide provides some recommendations on possible assignments for the students. For example, students in a statistics course can use the case scenario data to run hypothesis tests and ANOVA. Students in an analytics course can create visualizations in Tableau or Excel. Finally, students in operations management can use the data to create SPC charts and determine whether the process is in control or not in control.

SCENARIO

Products are arriving late to the shipping department at a company and as a result are being shipped later than expected to the customers. The company manufactures five products: A, B, C, D, and E. The products go through four stages of processing before arriving at the shipping department. Table 1 (Appendix) contains the maximum expected total process time for products A, B, C, D, and E. For example, the maximum amount of time for Product A through all the four stages should be 145 minutes.

Jamie has a summer internship with the company. Jamie's supervisor has asked Jamie to go through product records to see what may be causing the delay in products arriving at the shipping department. The supervisor recommends that Jamie first review the two products that have the largest percentage of items arriving late to the shipping department, the amount of rework for the products, and how much time is being spent at each stage for these products. The supervisor also recommends that Jamie use statistical analysis and control charts.

Tables 2 and 3 (Appendix) contain a snapshot of the data that Jamie will be analyzing to help address the issue of why products are arriving late to the shipping department. The record number, product, operator id at each stage, time in each stage, total time, and any rework at each stage are given in Tables 2 and 3 (Appendix). For example, the first record is Product D, took 180.1 minutes through all the stages, and rework was required in Stage 2.

Jamie will create some visualizations using Excel and/or Tableau and do some statistical analysis (ANOVA, hypothesis testing) in order to determine what is causing the delay to the shipping department.

CASE ACTIVITIES

The following are some recommended case activities for students.

1) Show the percentage of products that are arriving late to the shipping department and the amount of rework for the products at the different stages. Have the students identify which two products have a significant number of items arriving late to the shipping department and also the amount of rework at each stage for the five products. This can be completed in Excel or Tableau. Figure 1 (Appendix) shows that a large percentage of Products A and D are running late to the

shipping department compared to the other products. Figure 2 (Appendix) shows the amount of rework for each product at the different stages.

2) Identify the stages where it is taking longer than usual for the two products under review. Tables 4 and 5 (Appendix) show sample statistics for Products A and D at the four stages. The expected average and max time at each stage are given. In addition, the actual min, max, number of items over the expected max time, sample mean, median, and sample standard deviation are given for each stage for these products. Product A items in Stages 1 and 3 have the largest number of items over the expected maximum time. Product D items in Stages 2 and 4 have the largest number of items over the expected maximum time.

3) Run hypothesis tests to see if the expected average time is correct for the stages taking longer than usual. Suppose Jamie takes some recent samples of size 50 for Product A at Stages 1 and 3 and Product D at Stages 2 and 4 since these stages had a large number of product items over the expected maximum time. This sample data can be found in Table 6 (Appendix). Assume the data follows a normal distribution with an unknown population standard deviation. In Stage 1 the hypothesized value is 30 and for Stage 3 it is 52. These are the expected average times from Table 4 (Appendix) for Product A Stages 1 and 3. The hypothesis test results can be found in Table 7 (Appendix). The results show that the null hypothesis: H_o: $\mu = 30$ and H_o: $\mu = 52$ should be rejected in both cases. The Product D Stage 2 hypothesized value is 63.5 and Stage 4 hypothesized value is 28. These are the expected average times from Table 5 (Appendix) for Product D Stages 2 and 4. The results in Table 8 (Appendix) conclude that the null hypothesis H_o: $\mu = 63.5$ and H_o: $\mu = 28$ should also be rejected in both cases.

4) Are the operator times the same for Stages 1 and 3 of Product A and Stages 2 and 4 of Product D? Run ANOVA single factor tests to see if the operator times are the same for a product at a particular stage. Tables 9 through 12 (Appendix) show the sample data and the Excel Data Analysis ANOVA Single Factor results. Assume the data follows a normal distribution and that the ANOVA assumptions hold. There appears to be a difference in times for the operators based on the ANOVA results.

5) Identify which operators are having the most rework and create control charts for these operators to see if the process is in control. Table 13 (Appendix) shows each operator at Product A for Stages 1 and 3 and Product D for Stages 2 and 4. Operators M1235 and R5262 have a large percentage of rework in Stage 1 and Operators C2225 and J4222 have a large percentage of rework in Stage 3. Operators S5232 and Z3522 in Stage 2 and Operators N2521 and V2521 in Stage 4 have a large percentage of rework. Figures 3 and 4 (Appendix) contain Tableau visualizations of an individual value control chart and moving range control chart for Operator M1235 for Product A Stage 1. Figures 5 and 6 (Appendix) contain Tableau visualizations of an individual value control chart and moving range control chart for Operator N2521 for Product D Stage 4. Additional control charts can be created for the other operators. Students can determine whether the process is in control or not for these operators.

CASE DATA AND SOLUTION

One may contact the author to receive the complete dataset and solution. The solution will include ANOVA, hypothesis testing, descriptive statistics, control charts, and Tableau visualizations.

REFERENCES

Microsoft Excel 365
Tableau Desktop Professional Edition

APPENDIX

Table 1: Maximum Expected Total Process Time

Product	Maximum Expected Total Process Time
A	145
B	175
C	180
D	155
E	185

Table 2: Subset of the Case Data

Record #	Product	Operator ID Stage 1	Operator ID Stage 2	Operator ID Stage 3	Operator ID Stage 4	Stage 1 Time	Stage 2 Time
1	D	R2521	Z3522	C2635	K1241	16.8	58.5
2	D	M3252	A3252	F2525	E2673	34.9	72.1
3	E	M1235	Z3522	F2525	N2521	25.0	88.5
4	D	M1235	A3252	F2525	E2673	14.6	74.8
5	D	P2525	A3252	J4222	N2521	37.9	56.5
6	A	M3252	D1252	J4222	N2521	29.6	64.9
7	E	M1235	A3252	C2225	N2521	32.4	66.0
8	B	R2521	A3252	C2225	V2521	35.9	62.7
9	D	M1235	A3252	F2525	V2521	25.4	64.7
10	D	R5262	S5232	C2225	V2521	22.2	85.6
11	C	P2525	A3252	C2635	K1241	41.1	62.5
12	B	M1235	S5232	C2225	Q1534	31.8	72.7
13	E	R5262	Z3522	C2635	N2521	26.0	59.6
14	E	M3252	A3252	C2225	N2521	31.6	70.8
15	D	R2521	S5232	C2225	N2521	40.7	62.5

Table 3: Subset of the Case Data Continued

Record #	Stage 3 Time	Stage 4 Time	Total Time	Rework Stage 1	Rework Stage 2	Rework Stage 3	Rework Stage 4
1	57.5	47.3	180.1	No	Yes	No	No
2	62.2	30.6	199.8	Yes	No	No	No
3	50.8	38.5	202.7	No	Yes	Yes	No
4	73.1	45.1	207.6	No	No	No	No
5	56.8	57.9	209.1	No	No	Yes	No
6	14.5	26.1	135.0	No	No	Yes	No
7	73.3	22.7	194.3	No	No	No	Yes
8	47.9	18.5	165.0	No	No	No	Yes
9	44.0	29.8	163.9	No	No	No	Yes
10	44.2	29.4	181.5	Yes	Yes	No	Yes
11	67.6	26.3	197.4	Yes	Yes	No	No
12	50.6	37.1	192.2	No	No	No	No
13	20.7	6.6	112.8	No	No	No	No
14	39.6	23.8	165.7	No	No	Yes	Yes
15	34.7	32.5	170.4	No	Yes	No	Yes

Table 4: Descriptive Statistics Product A

Stage	Expected Max Time	Expected Average Time	Number Over the Expected Max Time	Sample Mean	Min	Max	Median	Sample Standard Deviation
1	35.0	30.0	140	32.1	18.5	59.7	31.2	7.8
2	80.0	60.0	14	60.1	30.1	88.3	60.8	11.2
3	75.0	52.0	110	53.9	14.5	98.5	48.4	18.5
4	43.0	27.0	4	24.6	3.7	45.8	24.4	7.9

Table 5: Descriptive Statistics Product D

Stage	Expected Max Time	Expected Average Time	Number Over the Expected Max Time	Sample Mean	Min	Max	Median	Sample Standard Deviation
1	50.0	27.0	6	30.4	3.0	58.6	30.5	9.6
2	72.0	63.5	112	65.4	48.2	99.8	62.7	11.4

3	75.0	50.0	7	44.4	2.8	94.7	44.2	14.3
4	43.0	28.0	97	30.8	16.4	61.2	27.0	12.4

Table 6: Sample Data for Products A and D

Product A Stage 1	Product A Stage 3	Product D Stage 2	Product D Stage 4
35.9	58.4	69.9	36.2
17.2	41.7	70.3	42.5
43.7	59.3	87.7	32.3
14.3	37.7	68.5	45.6
43.3	57.4	61.8	30.7
50.3	44.1	84.7	28.5
32.6	62.7	64.8	44.9
29.9	75.6	66.6	22.5
32.7	57.9	67.2	33.7
38.4	45.8	66.8	27.4
26.4	31.8	69.3	23.2
21.2	58.9	51.4	35.6
47.8	82.4	55.7	40.5
46.8	47.8	87.5	25.1
31.8	57.4	62.8	23.4
27.2	61.1	81.4	13.9
40.1	63.5	73.3	31.6
16.8	54.6	74.4	35.4
37.6	51.2	57.4	30.9
39.9	57.9	70.6	39.2
49.3	61.2	46.8	22.7
27.3	47.1	66.8	37.3
45.5	71.5	66.8	31.8
18.3	39.5	92.4	15.4
44.9	45.5	78.4	33.7
37.4	53.2	54.3	27.5
48.5	54.6	74.9	21.6
39.9	55.2	73.6	21.7
26.2	81.1	59.3	22.3
20.9	63.8	68.7	32.7
26.3	58.1	64.8	20.2
37.6	46.9	62.5	32.4
32.6	60.1	68.1	33.7

26.2	54.4	74.5	43.9
22.9	68.4	70.9	29.5
19.9	66.6	72.8	35.5
29.9	59.8	70.1	33.4
44.6	64.6	70.8	34.7
42.7	49.4	83.6	37.7
34.9	54.6	87.4	26.9
40.5	55.2	67.2	33.1
38.5	51.9	80.9	29.5
42.9	28.5	61.1	24.2
15.7	65.5	70.2	23.4
55.1	44.4	44.1	28.2
36.6	62.9	58.3	39.2
28.8	62.1	72.6	39.8
41.6	52.5	89.9	27.4
43.8	61.3	71.4	24.7
38.9	74.9	58.2	26.8

Table 7: Hypothesis Tests Product A Stages 1 and 3

Stage 1	
Hypothesized value	30
Sample mean	34.64
Sample standard deviation	10.31
Sample size	50
Test statistic	3.184
Level of significance	0.05
p-value	0.00253
Stage 3	
Hypothesized value	52
Sample mean	56.44
Sample standard deviation	11.17
Sample size	50
Test statistic	2.810
Level of significance	0.05
p-value	0.00709

Table 8: Hypothesis Tests Product D Stages 2 and 4

Stage 2	
Hypothesized value	63.5
Sample mean	69.47
Sample standard deviation	10.65
Sample size	50
Test statistic	3.962
Level of significance	0.05
p-value	0.00024
Stage 4	
Hypothesized value	28
Sample mean	30.68
Sample standard deviation	7.37
Sample size	50
Test statistic	2.572
Level of significance	0.05
p-value	0.01320

Table 9: ANOVA Product A Stage 1

	Operators			
M1235	M3252	P2525	R2521	R5262
43.8	30.9	42.2	42.7	62.5
51.3	28.4	19.2	37.4	58.7
56.5	42.1	17.7	52.7	45.9
53.5	31.9	25.2	44.1	47.2
48.6	17.9	40.2	34.2	51.6
58.9	39.4	51.6	39.3	58.9
52.1	44.9	35.5	25.2	54.3
54.3	26.8	52.2	29.4	57.5
47.5	50.4	47.5	42.9	48.9
59.8	54.1	31.7	35.7	51.5

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
M1235	10	526.3	52.63	25.75789
M3252	10	366.8	36.68	130.1284
P2525	10	363	36.3	160.6378
R2521	10	383.6	38.36	61.96489
R5262	10	537	53.7	31.07333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3121.631	4	780.4078	9.527339	0.0000	2.578739
Within Groups	3686.061	45	81.91247			
Total	6807.692	49				

Table 10: ANOVA Product A Stage 3

	Operators			
C2225	C2635	F2525	J4222	R6321
66.5	48.2	65.3	73.8	50.3
69.8	39.7	56.8	84.8	57.5
73.5	42.3	55.1	31.8	52.3
72.1	65.4	49.5	73.4	69.6
77.8	70.9	53.9	58.2	72.6
65.8	54.2	47.9	68.5	52.4
69.8	53.2	36.7	68.6	53.3
67.1	45.3	43.3	68.5	58.1
62.3	61.6	52.2	56.1	44.5
57.8	44.7	61.2	55.1	56.8

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
C2225	10	682.5	68.25	32.59833
C2635	10	525.5	52.55	110.0206
F2525	10	521.9	52.19	70.03433
J4222	10	638.8	63.88	210.0729
R6321	10	567.4	56.74	73.44711

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2020.7668	4	505.1917	5.09088	0.001802399	2.578739
Within Groups	4465.559	45	99.23464			
Total	6486.3258	49				

Table 11: ANOVA Product D Stage 2

	Operators			
A3252	D1252	S5232	V2521	Z3522
55.9	77.1	78.5	65.1	57.3
69.3	70.5	75.6	47.1	79.4
65.1	75.4	73.6	60.3	67.9
63.7	67.5	79.8	67.1	59.2
70.8	57.3	80.5	70	70.9
50	61.9	77.5	73.6	59.9
64.5	58.3	78.9	66.8	68.4
72.6	68.2	73.6	63.4	60.9
68.4	66.2	75.2	57.9	100.8
60.6	68.1	74.6	72.2	72.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A3252	10	640.9	64.09	49.14322
D1252	10	670.5	67.05	42.68056
S5232	10	767.8	76.78	6.644
V2521	10	643.5	64.35	61.07833
Z3522	10	697.1	69.71	168.0499

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1087.415	4	271.8538	4.149223	0.006041791	2.578739
Within Groups	2948.364	45	65.5192			
Total	4035.779	49				

Table 12: ANOVA Product D Stage 4

	Operators			
E2673	K1241	N2521	Q1534	V2521
27.7	30.5	39.5	29.7	33.5
29.7	38.7	40.3	17.5	36.5
35.8	33.2	43.5	21.5	29.5
23.4	35.5	42.5	24.4	36.5
23	23.2	47.5	44.6	40.5
35.4	25.8	44.3	45.2	39.6
21.7	15.8	38.7	18.6	36.8
28.7	28.1	39.6	31.3	37.5
39.4	15.4	37.5	34.7	38.5
33.4	24.4	46.5	38.7	39.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
E2673	10	298.2	29.82	36.76844
K1241	10	270.6	27.06	60.40489
N2521	10	419.9	41.99	11.59211
Q1534	10	306.2	30.62	103.304
V2521	10	368.5	36.85	10.78722

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1463.4388	4	365.8597	8.208408	0.000046	2.578739
Within Groups	2005.71	45	44.57133333			
Total	3469.1488	49				

Table 13: Operator Rework Products A and D

Product A, Stage 1 Operators	Total	Yes	Percentage Of Rework		Product A, Stage 3 Operators	Total	Yes	Percentage of Rework
M1235	107	72	67%		C2225	78	51	65%
M3252	81	16	20%		C2635	58	11	19%
P2525	45	8	18%		F2525	86	14	16%
R2521	64	14	22%		J4222	123	90	73%
R5262	116	65	56%		R6321	68	13	19%
Product D, Stage 2 Operators	Total	Yes	Percentage of Rework		Product D, Stage 4 Operators	Total	Yes	Percentage of Rework
A3252	88	18	20%		E2673	76	5	7%
D1252	71	12	17%		K1241	77	10	13%
S5232	90	67	74%		N2521	103	82	80%
V2521	81	11	14%		Q1534	51	9	18%
Z3522	73	60	82%		V2521	96	73	76%

Figure 1: Tableau Visualization of the Percentage of Products Late to the Shipping Department

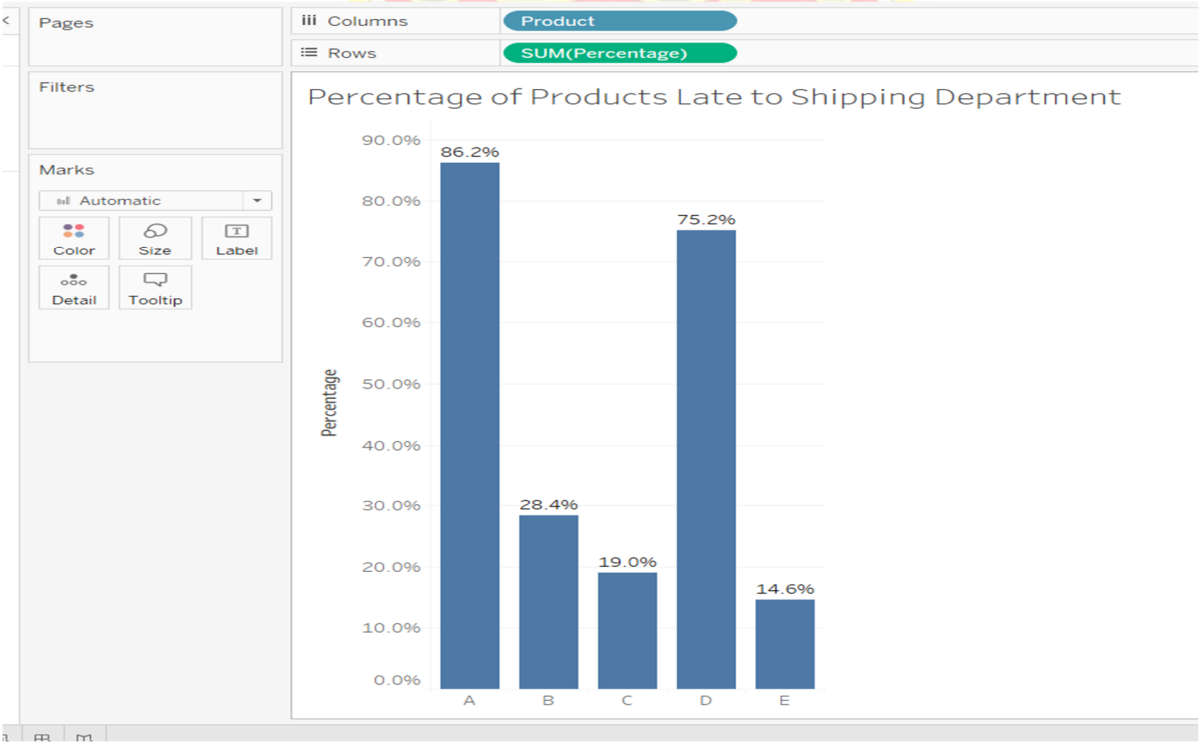

Figure 2: Tableau Visualization of the Amount of Rework for Each Product Through the Four Stages

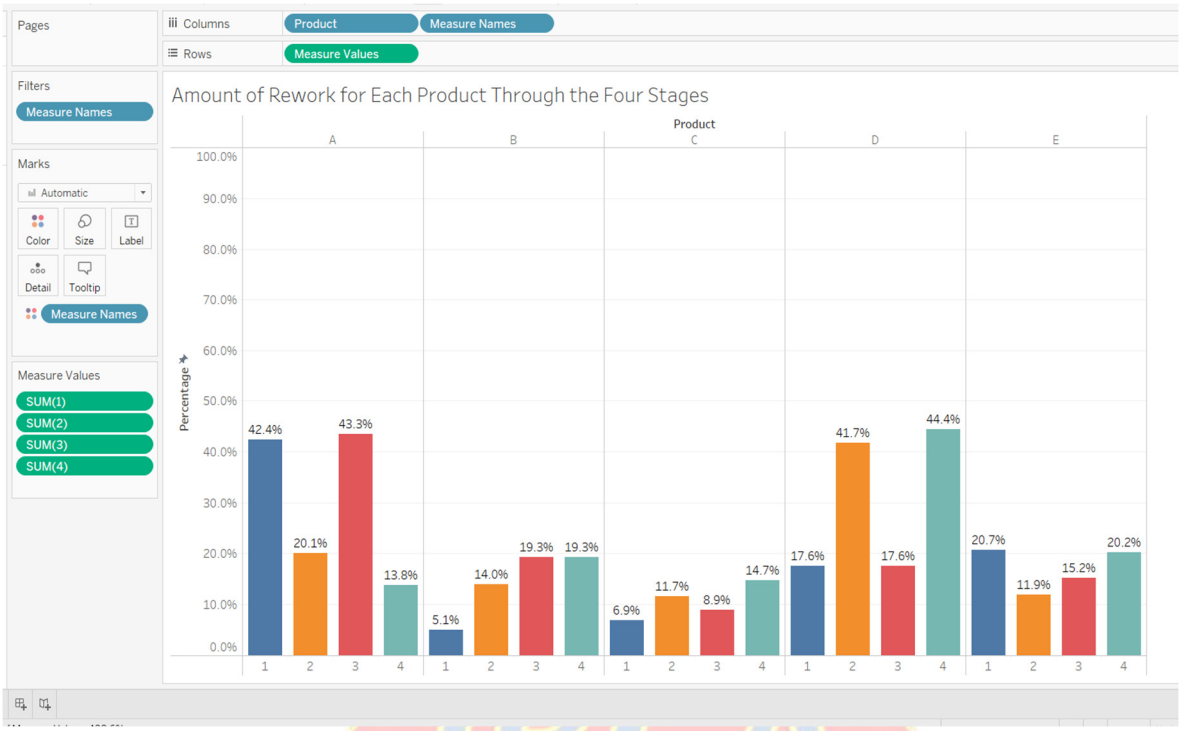

Figure 3: Tableau Visualization of a Control Chart of Individual Values for Product A Stage 1 Operator M1235

Figure 4: Tableau Visualization of a Moving Range Control Chart for Product A Stage 1 Operator M1235

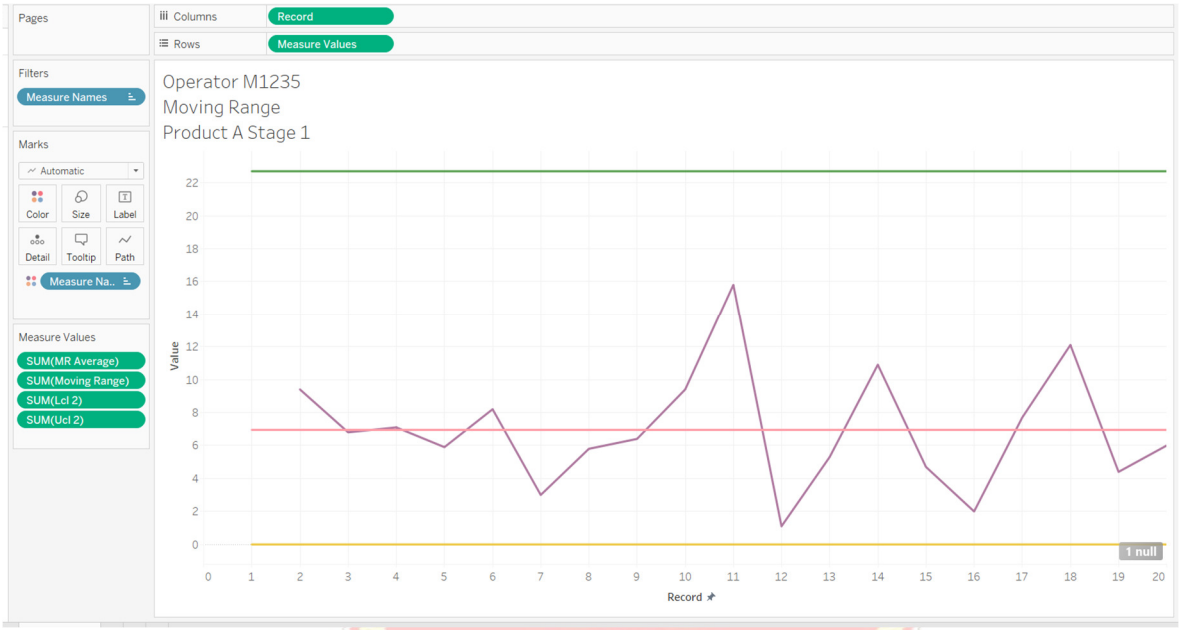

Figure 5: Tableau Visualization of a Control Chart of Individual Values for Product D Stage 4 Operator N2521

Figure 6: Tableau Visualization of a Moving Range Control Chart for Product D Stage 4 Operator N2521