# Confidence Intervals to Assess Variation in Fat Content at a Fast-Food Restaurant

Hamburgerr, Inc. is a fast-food restaurant serving hamburgers among a few other items. The restaurant claims that the average fat content in the hamburgers is 15 grams.

Section 3.1 gives a brief description of the define phase. Section 3.2 illustrates the measure phase with detailed instructions for using Minitab<sup>®</sup>. The analyze phase is briefly discussed in Section 3.3. Section 3.4 illustrates the improve phase with detailed instructions for using Minitab<sup>®</sup>. Finally, the control phase is briefly discussed in Section 3.5.

# 3.1 Define Phase

A few of the customers complained to the operations manager recently that the fat content in the hamburgers appeared to be higher than the restaurant's claim of 15 grams. The operations manager wishes to use 95% confidence intervals to verify whether the restaurant's claim of 15 grams (average) of fat in the hamburgers is correct. He also wishes to verify his assumption that the standard deviation of the fat content is less than 1 gram.

# 3.2 Measure Phase

The operations manager randomly selects 20 hamburgers and measures the fat content (in grams) in each of them as follows: 15.5, 12.3, 15.4, 16.5, 15.9, 17.1, 16.9, 14.3, 19.1, 18.2, 18.5, 16.3, 20.0, 19.0, 15.6, 13.5, 14.0, 16.5, 19.0, and 18.6.

Before constructing a confidence

interval for the above data, it is important to check whether the data are in statistical control. Because each number is for one hamburger, the appropriate set of control charts is I-MR (individual and moving range) charts. Figure 3.1 shows how to select I-MR charts in Minitab<sup>®</sup>. Doing so will open

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📽 🛙	3   <b>4</b> 5   %	<b>₽ ₽</b>	<u>B</u> asic Statis <u>R</u> egression	stics 1	) ) )	$  \otimes$	?∎]+		0 2 4 ][				<b>%</b>
÷	C1	C2	DOF			C5	C6	C7	CE	3	C9	C10	
	Fat		Control Ck	ante		BOX p		-f	1	1			
1	15.5		Quality Ta	als			ox-Cox fran:	siormation					
2	12.3		Quality 10			V	ariables Cha	rts for <u>S</u> ubgr	oups 🕨				
3	15.4		Neliability/	SULVIVAL		V	ariables Cha	rts for <u>I</u> ndivi	duals 🕨	IMR	I-M <u>R</u>		
4	16.5			te		<u>A</u>	ttributes Cha	arts	+		7-MR		
5	15.9		Time Serie	Time Series		I	ime-Weighte	<u>Z</u> -1911					
6	17.1		lables			Multivariate Charts							
7	16.9		<u>N</u> onparam	netrics	,	R	are Event Ch	arts	•	<u>M</u> R	Moving Rar	ige	
8	14.3		<u>E</u> DA		•								
9	19.1		Power and	l Sample	Size 🕨								
10	18.2												
11	18.5												
12	16.3												
13	20.0												
14	19.0												
15	15.6												
16	13.5												
17	14.0												
18	16.5												
10	19.0								1				

Selection of "I-MR Chart" before improvement.

the dialog box shown in Figure 3.2. Select "Fat" for "Variable", and click on "OK." The I-MR charts shown in Figure 3.3 will be the result. As is evident, the data are in statistical process control.

Now that the data are in statistical control, the operations manager wishes to construct the 95% confidence interval for the mean of fat content in

Individuals-Moving Range	Chart		x
C1 Fat	<u>V</u> ariables:		
	Fat		~
			-
	-		
	Scale	Labels	
	Multiple Graphs	Data Options	I-MR Options
Select			
Help		<u>O</u> K	Cancel

#### FIGURE 3.2

Variable of "Fat" for I-MR chart before improvement.



**FIGURE 3.3** I-MR charts before improvement.

population of the hamburgers. He also wishes to check whether the data are normally distributed before relying on the confidence interval. The "Graphical Summary" option in Minitab<sup>®</sup> produces both the normality test result as well as the confidence interval. Figure 3.4 shows to how to select the graphical summary. Doing so will open the dialog box shown in Figure 3.5. Select "Fat" for "Variable" and click on "OK". The graphical summary shown in Figure 3.6 will be the result. Because the *P*-value (0.624) of the Anderson–Darling normality test is greater than 0.05, the data are normally distributed. Notice that the population mean is estimated to be between 15.625 grams and 17.595 grams. The entire confidence interval (15.625, 17.595) is greater than the claim of 15 grams, therefore the operations manager considers this a serious issue.

The operations manager then proceeds to verify his assumption that the standard deviation of the fat content is less than 1 gram. Figure 3.7 shows how to select "1 Variance" in Minitab<sup>®</sup>. Doing so will open the dialog box shown in Figure 3.8. Select "Samples in columns" for "Data" and "Fat" for "columns". Click on "Options" and it opens the dialog box shown in Figure 3.9. Select "less than" for "Alternative" because the operations manager is interested in the standard deviation being less than 1 gram. Click on "OK" and it takes you back to the dialog box shown in Figure 3.8. Click on "OK" and the output shown in Figure 3.10 is the result. Because the data are normally distributed, we must look at the upper bound (2.89 grams) of the standard deviation given by the chi-square method. This means that 95% of

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	C1		<u>A</u> NOVA	풉 <u>G</u> raphical Summary				
+	CI	UZ.	<u>D</u> OE •	17 1-Sample 7				
	Fat		Control Charts	de 1 Semulat				
1	15.5		Quality Tools					
2	12.3		Reliability/Sunvival	2t 2-Sample t				
3	15.4		Mali in in	tet Paired t				
4	16.5		Time Series	1P 1 Proportion				
5	15.9		Time Series					
6	17.1 16.9		Tables •	s <sup>1</sup> <sub>p</sub> 1-Samp <u>l</u> e Poisson Rate				
7			Nonparametrics					
8	14.3		<u>E</u> DA •	S <sup>P</sup> 2-Sample Poisson Rate				
9	19.1		Power and Sample Size	σ² 1 Varianc <u>e</u>				
10	18.2			<sup>ອ</sup> ້ <sub>າວຂຶ້</sub> 2 V <u>a</u> riances				
11	18.5			Correlation				
12	16.3							
13	20.0							
14	19.0			▲ <u>N</u> ormality Test				
15	15.6			$\chi^2$ Goodness-of-Fit Test for Poisson				
16	13.5							
17	14.0							
18	16.5							

Selection of "Graphical Summary" before improvement.

X
Variables:
Fat 🔺
-
By variables (optional):
*
Confidence level: 95.0
<u>O</u> K Cancel

# FIGURE 3.5

Variable of "Fat" for graphical summary before improvement.



Graphical summary before improvement.

] <b>⊞</b> <u>F</u> i	ile <u>E</u> dit D <u>a</u>	ata <u>C</u> alc	<u>Stat</u> <u>G</u> raph E <u>d</u> itor	<u>T</u> ools	<u>W</u> indow <u>H</u> elp Assista <u>n</u> t			
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		Ţ	<u>R</u> egression	•	Store Descriptive Statistics			
]]			<u>A</u> NOVA	•	뿔밭 <u>G</u> raphical Summary			
+	C1	C2	DOE	•	17 1-Sample 7			
	Fat		Control Charts	•	1± 1 Complet			
1	15.5		Quality Tools	•	It i-sample t			
2	12.3		Reliability/Survival	•	2t 2-Sample t			
3	15.4		Multivariate	•	<b>t⊷t</b> <u>P</u> aired t			
4	16.5		Time Series		1P 1 Proportion			
5	15.9		Tables		2P 2 Proportions			
6	17.1		Tables		S <sup>1</sup> 1-Sample Poisson Rate			
7	16.9		<u>N</u> onparametrics	•				
8	14.3		<u>E</u> DA	•	S p 2-Sample Poisson Rate			
9	19.1		Power and Sample	Size ▶	σ² 1 Varianc <u>e</u>			
10	18.2				<sup>م</sup> ُ <sub>ضُ2</sub> 2 V <u>a</u> riances			
11	18.5				FOR Correlation			
12	16.3							
13	20.0							
14	19.0				TEST Normality Test			
15	15.6				V <sup>2</sup> Goodness-of-Fit Test for Poisson			
16	13.5				A occurrence of the certor roussoning			
17	14.0							
18	16.5							
19	19.0							
	-							

#### FIGURE 3.7

Selection of "1 Variance" before improvement.

1 Variance	x
C1 Fat	Data: Samples in columns
	Columns: Fat
	Perform hypothesis test     Value:     Hypothesized standard deviation
Select	Options
Help	QK Cancel

Selection of "Fat" variable before improvement.

the hamburgers have fat content with a standard deviation that is lower than 2.89 grams. Inasmuch as 2.89 grams is much greater than the assumption of 1 gram, the operations manager considers this also a serious issue.

Before proceeding to the improve phase, the operations manager wishes to check how many of the customers are dissatisfied. To this end, he randomly selects 1,000 customers who bought hamburgers and finds that 83 of them are dissatisfied with the food quality. He then proceeds to construct a confidence interval for the proportion of all customers who are dissatisfied. Figure 3.11 shows how to select "1 Proportion" in Minitab<sup>®</sup>. Doing so will open the dialog box shown in Figure 3.12. Enter "83" for "Number of events" and "1000" for "Number of trials". Click on "Options" and the dialog box shown in Figure 3.13 opens. Select "less than" for "Alternative" because the operations manager is interested in lowering the proportion of all customers who are dissatisfied. Also, check the box for "Use test and interval based on normal distribution". Click on "OK" and it takes you back to the dialog box shown in Figure 3.12. Click on "OK" and the output shown in Figure 3.14 is

1 Variance - Options	x
Confidence level:	95.0
<u>A</u> lternative:	less than
Help	<u>O</u> K Cancel

#### FIGURE 3.9

Selection of "less than" option for estimating standard deviation before improvement.

# Test and CI for One Variance: Fat

```
Method
The chi-square method is only for the normal distribution.
The Bonett method is for any continuous distribution.
Statistics
Variable N StDev Variance
Fat 20 2.11 4.43
95% One-Sided Confidence Intervals
                   Upper
                   Bound
                    for Upper Bound
Variable Method StDev for Variance
                            8.33
Fat Chi-Square 2.89
        Bonett
               2.81
                               7.92
```

# FIGURE 3.10

One-sided 95% confidence interval for standard deviation before improvement.

<u> </u>	<u>Stat</u> <u>G</u> raph E <u>d</u> itor <u>T</u> ools	Window Help Assistant		
28 5 X B 8	Basic Statistics	$R_{S}$ Display Descriptive Statistics		
	Regression •	호유 Store Descriptive Statistics		
	ANOVA •	雪葉 <u>G</u> raphical Summary		
2/24/0042 4	<u>D</u> OE •	17 1-Sample Z		
	Control Charts	1t 1-Sample t		
Welcome to Minitab, pr	Quality Tools	2t 2-Sample t		
Results for: CASE STU	Reliability/Survival	tut Paired t		
	<u>M</u> ultivariate	FL Force m		
Summary for Fat	Time <u>S</u> eries	1P 1 Proportion		
	Tables	2P 2 Proportions		
	Nonparametrics	<sup>1</sup> <sub>S P</sub> 1-Samp <u>l</u> e Poisson Rate		
lest and Gi for One va	<u>E</u> DA ►	s <sup>2</sup> <sub>P</sub> 2-Sample Po <u>i</u> sson Rate		
Method	Power and Sample Size 🕨	σ² 1 Varianc <u>e</u>		
The chi-square method	is only for the normal d	್ಕ್ 2 V <u>a</u> riances		
Ine Bonett method 18 1	or any continuous distri	COR Correlation		
<b>a</b>		COV Covariance		
Variable N StDey V	ariance	TEST Normality Test		
Fat 20 2.11	4.43	$\chi^2$ Goodness-of- <u>F</u> it Test for Poisson		

#### FIGURE 3.11

Selection of "1 Proportion" before improvement.

1 Proportion (Test and	Confidence Interval)	x
	C Samples in <u>c</u> olumns:	-
		Ŧ
	Summarized data     Number of events: 83     Number of trials: 1000	
	Perform hypothesis test <u>Hypothesized proportion:</u>	
Select	Options	
Help	<u>O</u> K Cancel	

Entry of "Number of events" and "trials" before improvement.

1 Proportion - Options
Confidence level: 95.0
Alternative: less than
☑ Use test and interval based on normal distribution
Help <u>QK</u> Cancel

#### FIGURE 3.13

Selection of "less than" option for estimating population proportion before improvement.

Test an	d CI	for O	ne Proport	ion	
Sample 1	X 83	N 1000	Sample p 0.083000	95% Upper Bound 0.097350	
Using t	che n	ormal	approximat	ion.	

# FIGURE 3.14

One-sided 95% confidence interval for population proportion before improvement.

the result. It is clear that that there is a 95% probability that the proportion of all customers who are dissatisfied is less than 0.097 (or 9.7%). The operations manager wishes to lower this upper bound estimate.

# 3.3 Analyze Phase

The operations manager analyzes the process and discovers that the fat content and its variation are highly affected by the amount of oil used by the employees on the three different grills used to make hamburgers.

# 3.4 Improve Phase

The operations manager standardizes the process so that the use of oil on the three different grills is controlled. An automatic machine is bought and installed to dispense oil on a grill each time a hamburger is made.

In order to check whether the process has really improved, the operations manager randomly selects 20 hamburgers and measures the fat content (in grams) in each of them as follows: 14.9, 15.0, 15.4, 15.3, 15.2, 15.1, 14.9, 14.8, 15.6, 14.5, 15.3, 15.8, 15.0, 15.0, 14.3, 15.3, 15.2, 14.7, 15.1, and 14.7.

Open the CHAPTER\_3\_AFTER.MTW worksheet that has the above data (the worksheet is available at the publisher's website; the data from the worksheet are also provided in the Appendix). Before constructing a confidence interval for the above data, it is important to check whether the data are in statistical control. Because each number is for one hamburger, the appropriate set of control charts is I-MR (individual moving range) charts. The I-MR charts for the above data are shown in Figure 3.15. As is evident, the data are in statistical process control.

Now that the data are in statistical control, the operations manager wishes to construct the 95% confidence interval for the mean of fat content in the population of hamburgers. He also wishes to check whether the data are normally distributed before relying on the confidence interval. Figure 3.16 shows the graphical summary. Because the *P*-value (0.925) of the Anderson–Darling normality test is greater than 0.05, the data are normally distributed. Notice that the population mean is estimated to be between 14.887 grams and 15.223 grams. Inasmuch as the claim of 15 grams is within the interval (14.887, 15.223), it is clear that the process has improved with respect to the mean fat content.

The operations manager then proceeds to verify his assumption that the standard deviation of the fat content is less than 1 gram. As is clear from the



**FIGURE 3.15** I-MR charts after improvement.



FIGURE 3.16

Graphical summary after improvement.

```
      Test and CI for One Variance: Fat

      Method

      The chi-square method is only for the normal distribution. The Bonett method is for any continuous distribution.

      Statistics

      Variable
      N StDev Variance
Fat

      95% One-Sided Confidence Intervals

      Variable
      Method for StDev for Variance
Fat

      Pariable
      Method for StDev for Variance
Fat

      Mathematical Method for StDev for Variance
Fat
      0.492

      Mathematical Method for StDev for Variance
Fat
      0.504

      Mathematical Method for StDev for Variance
      0.242

      Method
      0.504
      0.254
```

One-sided 95% confidence interval for standard deviation after improvement.

output shown in Figure 3.17, the upper bound is 0.492 gram for the standard deviation (given by the chi-square method). This means that 95% of the hamburgers have fat content with a standard deviation that is lower than 0.492 gram. Because 0.492 gram is less than the assumption of 1 gram, it is evident that the process has improved with respect to the standard deviation as well.

One can also simulate confidence intervals using Minitab<sup>®</sup>. The operations manager wishes to perform the simulation for 10 normally distributed samples with a sample size of 20 hamburgers. Doing what is shown in Figure 3.18 opens the dialog box shown in Figure 3.19. Select "20" for "Number of rows of data to generate". Enter "C3-C12" for "Store in column(s)". Because, after process improvement, the population mean is approximately 15 grams and the population standard deviation is approximately 0.5 grams, enter "15" for "mean" and "0.5" for "Standard deviation". Click on "OK" and the data shown in Figure 3.20 are the result.

Before proceeding to simulation, it is a good idea to check whether the data generated are in statistical control. The sample size is greater than 10, therefore the appropriate control charts are Xbar-S charts (sample means and sample standard deviations). Figure 3.21 shows how to select "Xbar-S". Doing so will open the dialog box shown in Figure 3.22. Select "Observations for a subgroup are in one row of columns" from the drop-down menu, and select "C3-C12" in the empty box below the menu. Click on "OK" and the Xbar-S charts shown in Figure 3.23 are the result. It is clear that the data are in statistical control.

j⊞≞ Ei	ile <u>E</u> dit D	<u>a</u> ta	<u>C</u> alc	<u>S</u> tat	<u>G</u> raph	E <u>d</u> itor	<u>T</u> ools	Chi-Sguare	
🖻 🖬	a 🚭 🕷		C 🖩	a <u>l</u> cula	tor			<u>N</u> ormal	) 🖻
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+	C1		x=0 St	andar	dize			<u> </u>	1 (
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2	15.0		N	lake N	les <u>h</u> Data	a		Bernoulli	
3	15.4		888 N	lake <u>I</u> r	dicator \	/ariables		<u>B</u> inomial	
4	15.3		Se	et <u>B</u> ase	2			Geometric	
5	15.2		R	andon	n Data	-	•	Negative Binomial	
6	15.1		P	robabi	ility Distri	ibutions	•	Hypergeometric	
7	14.9					in actions		Discrete	
8	14.8		N	atrice	s		+	Integer	
9	15.6							Integer	
10	14.5							Poisson	
11	15.3							Bet <u>a</u>	
12	15.8							Cauch <u>y</u>	
13	15.0							E <u>x</u> ponential	
14	15.0							<u>G</u> amma	
15	14.3							Laplace	
16	15.3							Largest Extreme Value	
17	15.2							Logistic	
18	14.7							Loglogi <u>s</u> tic	
19	15.1							Lognormal	
20	447						1		

Selection of "Normal" to generate normally distributed data.

Normal Distribution		<u> </u>
	Number of rows of data to generate: 20	
	Store in column(s):	
	C3-C12	
	<u>M</u> ean: 15	
	Standard deviation: 0.5	
Select		
Help	QK Cancel	]

#### FIGURE 3.19

Mean and standard deviation for generation of random samples.

<u>S</u> tat <u>G</u> raph	tat <u>G</u> raph E <u>d</u> itor <u>T</u> ools <u>W</u> indow <u>H</u> elp Assista <u>n</u> t									
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P   🕨 🛷 -	N ∅ + P ≠									
C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	(
14.5005	15.0615	15.3180	15.0453	15.6137	15.2391	15.1003	14.4816	15.3697	15.5550	
15.8619	15.0352	15.4866	15.4720	14.7087	15.0590	15.7989	14.9403	14.5047	14.8268	
16.0734	15.5290	14.9963	14.4413	15.1784	14.5252	15.6091	14.7555	15.1575	15.2456	
15.0604	14.0656	15.9527	14.7279	15.4551	15.2834	14.6864	14.7153	15.6713	14.9993	
15.0238	14.9675	14.4500	14.9712	15.9254	14.9253	14.8719	15.3898	14.6208	15.9183	
15.5331	14.9850	14.8421	15.1611	15.1169	14.4918	14.6385	15.0241	15.2196	15.5929	
15.0069	14.9272	14.9978	14.2482	14.5279	14.4722	14.5577	14.9531	15.5514	16.3353	
15.6438	15.3550	15.5513	15.0008	14.7496	14.3828	15.8827	13.4386	15.5228	15.2980	
14.8808	15.2983	14.9399	14.6704	15.5762	14.7267	14.9465	15.3734	15.1594	15.2588	
14.7897	15.5399	14.7708	15.3025	15.0310	14.4046	14.8088	14.6081	15.3152	15.1458	
14.5837	15.7337	15.0453	15.1426	14.7760	14.9770	14.6273	14.3773	15.9340	14.2630	
14.5624	13.9011	14.5378	15.4423	15.4841	15.7054	14.7800	15.6339	15.2047	15.1385	
14.9980	15.5109	14.8571	15.4504	14.8212	15.6376	15.4373	15.1999	14.5589	15.0355	
15.4724	15.6305	16.1623	14.8468	16.2342	14.2581	13.8463	14.7384	15.0293	15.0925	
14.2872	15.8478	15.1231	15.6011	14.8971	15.5123	14.2790	15.4921	14.7830	15.5205	
14.5219	16.2434	14.5973	15.1377	15.5711	15.7814	14.4165	15.1727	15.5683	15.7207	
16.1166	14.7879	15.8140	14.3520	15.5345	14.7504	15.5359	14.8842	15.8614	15.5887	
14.7562	14.9886	14.9110	15.0878	14.9427	15.3621	15.8416	15.3940	15.4287	14.7872	
15.2872	14.7014	14.5969	15.7314	16.6402	15.3543	14.5002	15.0465	15.1714	15.0964	

Ten random samples with sample size of 20.

For simulating the confidence intervals for the 10 samples generated, select "Interval Plot" as shown in Figure 3.24. Doing so opens the dialog box shown in Figure 3.25. Select "Simple" under "Multiple Ys" and click on "OK". That will open the dialog box shown in Figure 3.26. Select "C3-C12" columns for "Graph variables" and click on "OK". The intervals plot (95% confidence intervals) for the 10 samples shown in Figure 3.27 are created. As shown in Figure 3.28, right-click anywhere on the interval plot and select "Reference Lines". This opens the dialog box shown in Figure 3.29. Enter "15" for "Show reference lines at Y values" and click on "OK". This adds the reference line of 15, as shown in Figure 3.30. Because most of the confidence intervals contain the population mean of 15 grams. If the simulation is performed for a large number of samples, 95% of the confidence intervals are expected to contain the population mean of 15 grams.

The operations manager now wishes to check how many of the customers are dissatisfied after the process has improved. To this end, he randomly selects 1,200 customers who bought hamburgers and finds that 25 of them are dissatisfied with the food quality. He then proceeds to construct a confidence interval for the proportion of all customers who are dissatisfied. In the dialog box shown in Figure 3.31, enter "25" for "Number of events" and

	initia four	01001 1.001		1							
lc [	<u>Stat</u> <u>G</u> raph	E <u>d</u> itor <u>T</u> o	ols	Windo	w <u>H</u> elp A	Assista <u>n</u> t					
3	<u>B</u> asic Stat	istics	•	0	? 🗊 🖂	366(	DDD	*: E		5   f <sub>*</sub>   -	ᆲᇻᆔᄤ
7	<u>R</u> egressio	n	•	<u> </u>				TOO	0 111	4	
닅	<u>A</u> NOVA		►				211	100			
2	DOE		•	C5	C6	C7	C8	C9	C10	C11	C12
_	<u>C</u> ontrol C	harts	Þ	BOX BO	x-Cox Trans	formation	-				
_	Quality To	pols	•		riables Char	te for Subara		1 ∣ 15 1003. ∃ ⊻⊨ B	14 4816	15 3697	15.5550
_	Reliability	/Survival	•	V a	inables chan	is for <u>s</u> ubgro		A <u>D</u> dr-K			14.8268
_	Multivaria	te	•	va	riables Chan	ts for <u>i</u> ndivid		Xb <u>a</u> r-S			15.2456
_	Time Seri	es	•	At	tributes Cha	rts		I-MR-R/S (B	etween/With	nin)	14.9993
_	Tables			I	me-Weighte	d Charts		7 VI			15.9183
	Nonnarar	netrics		M	ultivariate Cl	harts	• 🕅	- <u>A</u> bar			15.5929
	ED A	neures	Ţ.	<u>R</u> a	re Event Cha	arts	► R	□ <u>K</u>			16.3353
	EDA		ſ	5.5513	15.0008	14.7496	14.3 🗟	₫ <u>S</u>			15.2980
	Power an	d Sample Siz	e⊧	.9399	14.6704	15.5762	14.7 🛌	Zone			15.2588
	14.7897	15.5399	14	4.7708	15.3025	15.0310	14.404	0 14.0000	14.0001	15.3152	15.1458
	14.5837	15.7337	1	5.0453	15.1426	14.7760	14.977	0 14.6273	14.3773	15.9340	14.2630
	14.5624	13.9011	14	4.5378	15.4423	15.4841	15.705	4 14.7800	15.6339	15.2047	15.1385
	14.9980	15.5109	14	4.8571	15.4504	14.8212	15.637	6 15.4373	15.1999	14.5589	15.0355
	15.4724	15.6305	10	6.1623	14.8468	16.2342	14.258	1 13.8463	14.7384	15.0293	15.0925
	14.2872	15.8478	1	5.1231	15.6011	14.8971	15.512	3 14.2790	15.4921	14.7830	15.5205
	14.5219	16.2434	14	4.5973	15.1377	15.5711	15.781	4 14.4165	15.1727	15.5683	15.7207
	16.1166	14.7879	1	5.8140	14.3520	15.5345	14.750	4 15.5359	14.8842	15.8614	15.5887
	14.7562	14.9886	14	4.9110	15.0878	14.9427	15.362	1 15.8416	15.3940	15.4287	14.7872
	15.2872	14.7014	14	4.5969	15.7314	16.6402	15.354	3 14.5002	15.0465	15.1714	15.0964

Selection of "Xbar-S".

Xbar-S Chart	1.400 1.100	8.65 6.00	x
C1 Fat C3 C4 C5 C6 C7 C8 C9 C10 C11 C12	Observations for a subg C3-C12	group are in one row of o	columns:
Select	<u>M</u> uluple Graphs		xbar-s Oguons
Help		<u>O</u> K	Cancel

#### FIGURE 3.22

Selection of variables for Xbar-S charts.



**FIGURE 3.23** Xbar-S charts.

t	Gra	aph E <u>d</u> itor <u>T</u> ools <u>W</u> indow <u>H</u>	elp	Assista <u>n</u> t					
c		Scatterplot	•	€ 📾 🗟 (	DDZZ			5   f <sub>*</sub>   -	물 물 빤 떵
Г	÷	<u>M</u> atrix Plot	F				0 111	- <u> -</u> -	
4	Ē,	Margi <u>n</u> al Plot	H						
_	մհ	Histogram	·	C7	C8	C9	C10	C11	C12
		Dotalat							
14	<u></u>		63	15.6137	15.2391	15.1003	14.4816	15.3697	15.5550
1	20124	Stem-and-Leaf	20	14.7087	15.0590	15.7989	14.9403	14.5047	14.8268
10	1	Probability Plot	13	15.1784	14.5252	15.6091	14.7555	15.1575	15.2456
1	Ł	Empirical CDF	79	15.4551	15.2834	14.6864	14.7153	15.6713	14.9993
1	$\land$	Probability Distribution Plot	12	15.9254	14.9253	14.8719	15.3898	14.6208	15.9183
1	أفمأ	Boynlot	11	15.1169	14.4918	14.6385	15.0241	15.2196	15.5929
1	ly T	<u>B</u> oxplot	82	14.5279	14.4722	14.5577	14.9531	15.5514	16.3353
1	<u>""</u>	Interval Plot	08	14.7496	14.3828	15.8827	13.4386	15.5228	15.2980
14		Individual Value Plot	04	15.5762	14.7267	14.9465	15.3734	15.1594	15.2588
14	×	Line Plot	25	15.0310	14.4046	14.8088	14.6081	15.3152	15.1458
14	Ш	Ba <u>r</u> Chart	26	14.7760	14.9770	14.6273	14.3773	15.9340	14.2630
14	۲	<u>P</u> ie Chart	23	15.4841	15.7054	14.7800	15.6339	15.2047	15.1385
14	1~	Time Series Plot	04	14.8212	15.6376	15.4373	15.1999	14.5589	15.0355
1	1.4	Area Creat	68	16.2342	14.2581	13.8463	14.7384	15.0293	15.0925
14	-	Area Graph	. 11	14.8971	15.5123	14.2790	15.4921	14.7830	15.5205
14	$\mathbf{Z}$	<u>C</u> ontour Plot	77	15.5711	15.7814	14.4165	15.1727	15.5683	15.7207
1	;)-	<u>3</u> D Scatterplot	20	15.5345	14.7504	15.5359	14.8842	15.8614	15.5887
14		3D S <u>u</u> rface Plot	78	14.9427	15.3621	15.8416	15.3940	15.4287	14.7872
1	5.28	72 14.7014 14.5969 15.	7314	16.6402	15.3543	14.5002	15.0465	15.1714	15.0964

Selection of "Interval Plot" for simulation of confidence intervals.

Interval Plots	-	-		x
One Y Simple	With Groups			
II	$ \begin{bmatrix} I & I & I \\ I & I & I \\ B & 1 & 2 & 1 \\ A & 1 & 2 \end{bmatrix} $			
Multiple Y's Simple	With Groups			
<u>I</u> <u>Y</u> 1 Y2	$\begin{array}{  c c c c }\hline & & & & \\ \hline & & & & \\ \hline & & & & \\ A & & & & \\ A & & & & & \\ Y1 & & & & & \\ \end{array}$			
Help		<u>o</u> ĸ	Cano	el

Selection of "Simple" interval plots under "Multiple Y's".

Interval Plot - Multiple Y's,	Simple	8700 G.G.	×
C1 Fat C3 C4 C5 C6 C7 C8 C9 C10 C11 C12	<u>G</u> raph variables: C3-C12	Labels	↓ Data View
Select	Multiple Graphs	Data Options	
Help		<u>o</u> ĸ	Cancel

# FIGURE 3.26

Selection of variables for simulation.



**FIGURE 3.27** Interval plot without reference line.



FIGURE 3.28 Process to show reference line.

Add Reference Lines		x
Show reference lines at <u>Y</u> value 15 Show reference lines at categor	s: rv scale positions:	_
Help	Ōĸ	Cancel







1 Proportion (Test and	d Confidence Interval)	x
	C Samples in <u>c</u> olumns:	*
	Summarized data Number of events: 25 Number of trials: 1200	
	Perform hypothesis test     Hypothesized proportion:	
Select Help	Options QK Cancel	. ] _ ]

Entering number of events and trials after improvement.

"1200" for "Number of trials". Click on "Options" and select "less than" for "Alternative" because the operations manager is interested in lowering the proportion of all customers who are dissatisfied. Also, check the box for "Use test and interval based on normal distribution". Click on "OK" and it takes you back to the dialog box shown in Figure 3.31. Click on "OK" and the output shown in Figure 3.32 is the result. It is clear that that there is a 95% probability that the proportion of all customers who are dissatisfied is less than 0.027 (or 2.7%). The operations manager is satisfied that the process has improved.

# Test and CI for One Proportion95% UpperSample XNSample XN12512000.0208330.027615Using the normal approximation.

#### FIGURE 3.32

One-sided 95% confidence interval for population proportion after improvement.

# 3.5 Control Phase

The operations manager plans to check the hamburger preparation process on the three grills regularly, in order to ensure that the customers consistently get what they are promised.