

Chapter 241

Individuals and Moving Range Charts

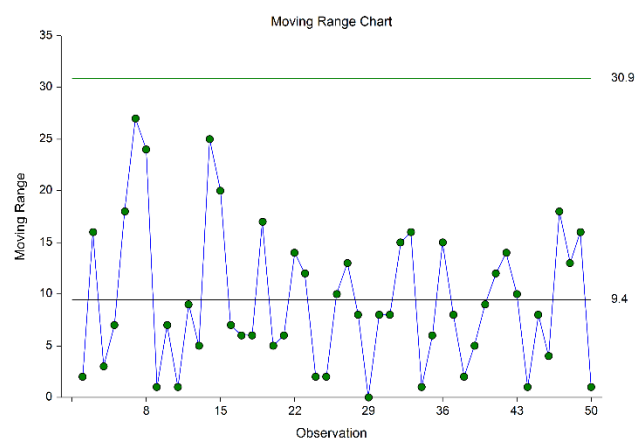
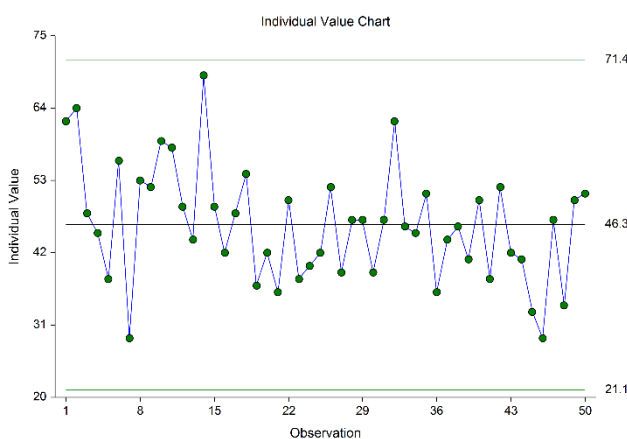
Introduction

This procedure generates individual value and moving range control charts. The format of the control charts is fully customizable. This procedure permits the defining of stages. For the individuals chart, the center line can be entered directly or estimated from the data, or a subset of the data. Similarly, sigma may be estimated from the data or a standard sigma value may be entered. A list of out-of-control points can be produced in the output, if desired, and ranges may be stored to the spreadsheet.

Individuals and Moving Range Control Charts

Individuals and moving range charts are used to monitor individual values and the variation of a process based on samples taken from a process over time (hours, shifts, days, weeks, months, etc.). Typically, an initial series of observations is used to estimate the mean and standard deviation of a process. The mean and standard deviation are then used to produce control limits for the individual values and ranges. During this initial phase, the process should be in control. If points are out-of-control during the initial (estimation) phase, the assignable cause should be determined and the observation should be removed from estimation.

Once the control limits have been established of the individuals and moving range charts, these limits may be used to monitor the values and variation of the process going forward. When a point is outside these established control limits it indicates that the mean (or variation) of the process is out-of-control. An assignable cause is suspected whenever the control chart indicates an out-of-control process.



Other Control Charts for the Individuals

Two additional control charts available for monitoring the process mean for individual observations are the cumulative sum (CUSUM) and exponentially weighted moving average (EWMA) charts. The CUSUM and EWMA charts differ from the individuals charts in that they take into account the information of previous observations rather than just the current value. The CUSUM and EWMA charts are more sensitive to smaller shifts in the mean since they use the cumulative information of the sequence of values. However, CUSUM and EWMA methods also assume a reliable estimate or known value for the true standard deviation is available.

Control Chart Formulas

Suppose we have k observations from a process. Let x_i represent the measurement of the i^{th} individual.

Formulas for the Points on the Chart

The value for each point of the individuals chart is simply the measurement value x_i .

Each moving range is calculated as

$$R_i = |x_i - x_{i-1}|,$$

which is the absolute value of each value minus the previous value.

Estimating the Individuals Chart Center Line

In the Individuals Charts procedure, the average value may be input directly, or it may be estimated from a series of values. If it is estimated from the values, the formula for the average is

$$\bar{x} = \frac{\sum_{i=1}^k x_i}{k}.$$

Estimating Sigma

The true standard deviation (sigma) may be input directly, or it may be estimated from the moving ranges by

$$\hat{\sigma} = \frac{\bar{R}}{d_2}$$

where

$$\bar{R} = \frac{\sum_{i=2}^k R_i}{k-1}$$

$$d_2 = \frac{E(R)}{\sigma} = \frac{\mu_R}{\sigma}$$

The calculation of $E(R)$ requires the knowledge of the underlying distribution of the x_i 's. Making the assumption that the x_i 's follow the normal distribution with constant mean and variance, the values for d_2 are derived through the use of numerical integration. It is important to note that the normality assumption is used and that the accuracy of this estimate requires that this assumption be valid.

Individuals Chart Limits

The lower and upper control limits for the individuals chart are calculated using the formulas

$$LCL = \bar{x} - m\hat{\sigma}$$

$$UCL = \bar{x} + m\hat{\sigma}$$

where m is a multiplier (usually set to 3) chosen to control the likelihood of false alarms (out-of-control signals when the process is in control).

Estimating the Moving Range Chart Center Line

If a standard sigma (standard deviation) value is entered by the user, the Moving Range Chart center line is computed using

$$\bar{R} = d_2\sigma$$

If the standard deviation is estimated from a series of values, the R chart center line is given by

$$\bar{R} = \frac{\sum_{i=2}^k R_i}{k-1}$$

Moving Range Chart Limits

The lower and upper control limits for the Moving Range chart are calculated using the formula

$$LCL = \bar{R} - md_3\hat{\sigma}$$

$$UCL = \bar{R} + md_3\hat{\sigma}$$

where m is a multiplier (usually set to 3) chosen to control the likelihood of false alarms, and d_3 is a constant that is calculated by numerical integration and is based on the assumption of normality. The relation for d_3 is

$$d_3 = \frac{\sigma_R}{\sigma}$$

Runs Tests

The strength of control charts comes from their ability to detect sudden changes in a process that result from the presence of assignable causes. Unfortunately, the individuals chart is poor at detecting drifts (gradual trends) or small shifts in the process. For example, there might be a positive trend in the last ten subgroups, but until a mean goes above the upper control limit, the chart gives no indication that a change has taken place in the process.

Runs tests can be used to check control charts for unnatural patterns that are most likely caused by assignable causes. Runs tests are sometimes called “pattern tests”, “out-of-control” tests, or “zones rules”.

While runs tests may be helpful in identifying patterns or smaller shifts in the mean, they also increase the likelihood of false positive indications. The rate of false positives is typically measured using the average run length (the average length of a run before a false positive is indicated). When several runs tests are used the average run length of the control chart becomes very short. Two alternatives to consider before using runs tests are the CUSUM and EWMA control charts. Runs tests are generally advised against when there is only one observation per subgroup. In this case, the rate of false positives is quite high (average run length is short).

In order to perform the runs tests, the control chart is divided into six equal zones (three on each side of the centerline). Since the control limit is three sigma limits (three standard deviations of the mean) in width, each zone is one sigma wide and is labeled A, B, or C, with the C zone being the closest to the centerline. There is a

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lower zone A and an upper zone A. The same is true for B and C. The runs tests look at the pattern in which points fall in these zones.

The runs tests used in this procedure are described below.

Test 1: Any Single Point Beyond Zone A

This runs test simply indicates a single point is beyond one of the two three-sigma limits.

Test 2: Two of Three Successive Points in Zone A or Beyond

This usually indicates a shift in the process average. Note that the two points have to be in the same Zone A, upper or lower. They cannot be on both sides of the centerline. The third point can be anywhere.

Test 3: Four of Five Successive Points in Zone B or Beyond

This usually indicates a shift in the process average. Note that the odd point can be anywhere.

Test 4: Eight Successive Points in Zone C or Beyond

All eight points must be on one side of the centerline. This is another indication of a shift in the process average.

Test 5: Fifteen Successive Points Fall in Zone C on Either Side of the Centerline

Although this pattern might make you think that the variation in your process has suddenly decreased, this is usually not the case. It is usually an indication of stratification in the sample. This happens when the samples come from two distinct distributions having different means. Perhaps there are two machines that are set differently. Try to isolate the two processes and check each one separately.

Test 6: Eight of Eight Successive Points Outside of Zone C

This usually indicates a mixture of processes. This can happen when two supposedly identical production lines feed a single production or assembly process. You must separate the processes to find and correct the assignable cause.

There are, of course, many other sets of runs tests that have been developed. You should watch your data for trends, zig-zags, and other nonrandom patterns. Any of these conditions could be an indication of an assignable cause and would warrant further investigation.

Data Structure

In this procedure, the data should be entered as a single column. If stages are used, a column defining the stage may be used.

Example dataset

Response	Stage
2	1
6	1
3	1
8	1
5	1
8	2
8	2
7	2
7	2
9	2
6	3
2	3
.	.
.	.
.	.

Procedure Options

This section describes the options available in this procedure. To find out more about using a procedure, go to the Procedures chapter.

Variables Tab

This panel specifies the variables that will be used in the analysis.

Variables

Response Variable

Specify the column containing the data values.

Stages

Number of Stages

Specify whether the analyses and charts are to be produced based on a single set of observations, or a series of sets of observations. Typically a single stage is used unless you wish to have separate estimation for various segments of the observations. When using multiple stages, the software requires that there be at least two observations in every stage specified.

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Stage Specification

Specify whether the various stages will be defined using a variable (column) with a unique value for each stage, or by entering a range of rows for each stage.

- **Stage Variable**

X1	Stage
5	1
3	1
4	1
6	1
3	1
5	2
2	2
3	2
4	2
.	.
.	.
.	.

- **Enter a range for each stage**

1-50, 51-100, 101-150

This would produce three stages. The first stage would be made up of rows 1 to 50, the second stage would be rows 51 to 100, and the third stage would be rows 101 to 150.

Stage Variable

Specify the variable (column) that contains the identifiers for each stage.

X1	Stage Variable
5	1
3	1
4	1
6	1
3	1
5	2
2	2
3	2
4	2
.	.
.	.
.	.

A new stage is created for each change in the Stage Variable, going down.

Stage Ranges

Enter a range for each stage using a dash. Separate each stage with a comma.

Example: 1-50, 51-100, 101-150

This would produce three stages. The first stage would be made up of rows 1 to 50, the second stage would be rows 51 to 100, and the third stage would be rows 101 to 150.

Specify Rows in Calculations

Specification Method

Select which method will be used to specify the rows of the data to be used.

- **All Rows**
All rows in the response column(s) will be used.
- **Enter First Row and Last Row**
Specify the first row and the last row of the data for use in calculations.
- **First N Rows (Enter N)**
The data beginning at Row 1 and ending at Row N will be used in calculations.
- **Last N Rows (Enter N)**
The observations come from the last N rows of the dataset.
- **Keep Rows Variable**
Specify a variable and a value in that variable column that will be used to determine which rows are used.
- **Remove Rows Variable**
Specify a variable and a value in that variable column that will be used to determine which rows will not be used.

First Row

Specify the beginning row to be used for the first observation.

Last Row

Specify the last row to be used for the last observation.

N

Enter the number of rows to be used.

Keep Rows Variable

This variable (column) is used to specify which rows of the data will be used for the calculations.

Keep Rows Value

This value determines which rows of the Keep Rows Variable will be used in the calculation portion of the analysis.

Remove Rows Variable

This variable (column) is used to specify which rows of the data will not be used for the calculations.

Remove Rows Value

This value determines which rows of the Remove Rows Variable will not be used in the calculation portion of the analysis.

Specify Rows in Charts

Specification Method

Select which method will be used to specify the rows of the data to be used for the charts.

Individuals and Moving Range Charts

- **All Rows**
All rows in the response column(s) will be used.
- **Enter First Row and Last Row**
Specify the first row and the last row of the data for use in the plots.
- **First N Rows (Enter N)**
The data beginning at Row 1 and ending at Row N will be used in the plots.
- **Last N Rows (Enter N)**
The observations come from the last N rows of the dataset.
- **Keep Rows Variable**
Specify a variable and a value in that variable column that will be used to determine which rows are used.
- **Remove Rows Variable**
Specify a variable and a value in that variable column that will be used to determine which rows will not be used.

First Row

Specify the beginning row to be used for the first observation.

Last Row

Specify the last row to be used for the last observation.

N

Enter the number of rows to be used.

Keep Rows Variable

This variable (column) is used to specify which rows of the data will be used for the plots.

Keep Rows Value

This value determines which rows of the Keep Rows Variable will be used in the plots.

Remove Rows Variable

This variable (column) is used to specify which rows of the data will not be used for the plots.

Remove Rows Value

This value determines which rows of the Remove Rows Variable will not be used in the plots.

Labels (Optional)

Observation Label Variable

Specify a variable (column) that contains the desired x axis (observation) labels for plots. If left blank, the plot will use the row number. The format of the labels is controlled on the x axis tab of the plot format window.

Point Label Variable

Specify a variable (column) that contains the desired individual point labels for plots. If left blank, no point labels are shown. The format of the labels is controlled on the main chart tab of the plot format window.

Lines & Limits Tab

The options on the Lines & Limits tab are used to specify the center line method, the limit multipliers, and the method by which sigma is estimated.

Individuals Chart Options – Center Line Options

Center Line Specification

Specify whether the Individuals chart center line will be estimated from the data, or whether it will be specified directly.

- **From Rows in Calculations Data**
Estimate the center line from the rows specified for calculations.
- **Enter Center Line Value(s)**
Specify directly the center line for the Individuals chart. If multiple stages are used, separate the center line values for each stage by spaces.
- **Use a Variable with Center Line Value(s)**
Specify a column containing the center line value in row 1. If multiple stages are used, a center line value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

Center Line Value(s)

Enter the value to be used for the center line of the Individuals chart. If multiple stages are used, separate the center line values for each stage by spaces.

Center Line Variable

Specify a column containing the center line value in row 1. If multiple stages are used, a center line value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

Individuals Chart Options – Specification Limits

Lower Limit

Enter an optional lower specification limit for display on the Individuals chart. These limits are not the control limits.

Upper Limit

Enter an optional upper specification limit for display on the Individuals chart. These limits are not the control limits.

Target Specification

Enter an optional target value for display on the Individuals chart.

Sigma Estimation Options

Sigma Specification

Specify the method by which Sigma will be estimated for use in the charts.

- **From Rows in Calculations Data - Range Estimate**
Estimate sigma based on the mean range. Only the rows specified for use in calculations will be used.

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- **Enter Standard Sigma Value(s)**
In this case the sigma value is entered directly. The corresponding R-bar value for plots is back-calculated from this value. If multiple stages are used, separate the sigma values for each stage by spaces.
- **Use a Variable with Standard Sigma Value(s)**
Specify a column containing the standard sigma value in row 1. The corresponding R-bar value for plots is back-calculated from this value. If multiple stages are used, a sigma value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

Sigma Value(s)

Enter the value to be used for the standard sigma. If multiple stages are used, separate the sigma values for each stage by spaces.

Sigma Variable

Specify a column containing the standard sigma value in row 1. The corresponding R-bar or s-bar value for plots is back-calculated from this value. If multiple stages are used, a sigma value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

Limit Multipliers

Primary Limit Multiplier

This option specifies the multiplier of sigma for the primary control limits. For the well-known 3-sigma limits, the multiplier is set to 3.

Secondary Limit Multiplier

This option specifies the multiplier of sigma for the optional, secondary control limits. The secondary limits may be shown on the plot by checking the 'Secondary Limit' option on the plot format window.

Reports Tab

The following options control the format of the reports.

Specify Reports

Chart Summary (Control Limits and Estimation) Section

This report gives the numeric values of the center lines and limits, as well as the sigma estimation section.

Out-of-Control List Section

This report shows the out-of-control points and the corresponding reason (runs test or outside control limit).

Report Options

Precision

Specify the precision of numbers in the report. A single-precision number will show seven-place accuracy, while a double-precision number will show thirteen-place accuracy. Note that the reports are formatted for single precision. If you select double precision, some numbers may run into others. Also note that all calculations are performed in double precision regardless of which option you select here. This is for reporting purposes only.

Variable Names

This option lets you select whether to display variable names, variable labels, or both.

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Page Title

This option specifies a title to appear at the top of each page.

Plot Subtitle

This option specifies a subtitle to appear at the top of each plot.

I-MR Charts Tab

This panel sets the options used to define the appearance of the Individuals chart and the Moving Range chart.

Select Plots

Individuals Chart and Moving Range Chart

Each chart is controlled by three form objects:

1. A checkbox to indicate whether the chart is displayed.
2. A format button used to call up the plot format window (see Quality Control Chart Format Options below for more formatting details).
3. A second checkbox used to indicate whether the chart can be edited during the run.

Storage Tab

The options on this panel control the automatic storage of the ranges on the current dataset.

Storage Columns

Store Ranges in Column

You can automatically store the range of each value (minus the previous value) into the column specified here.

Warning: Any data already in this column is replaced. Be careful not to specify columns that contain important data.

Quality Control Chart Format Window Options

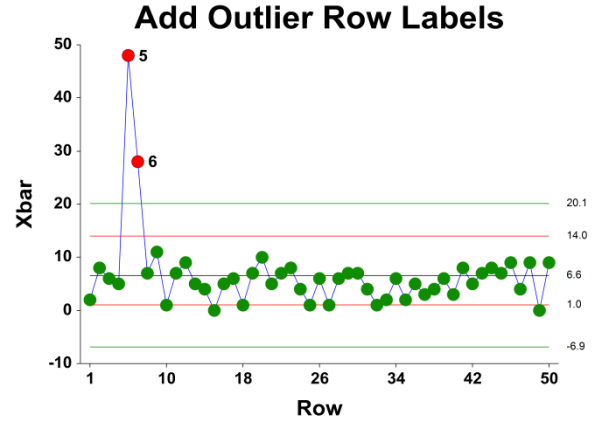
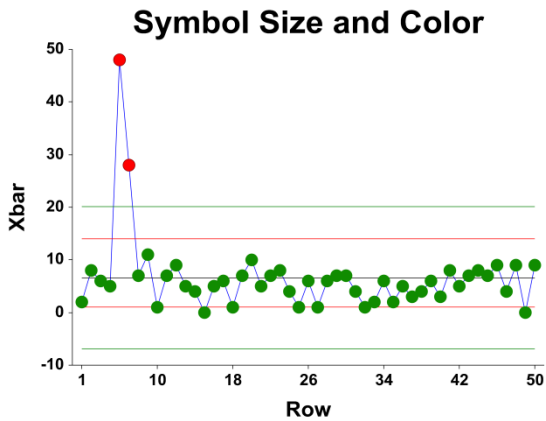
This section describes a few of the specific options available on the first tab of the control chart format window, which is displayed when a quality control chart format button is pressed. Common options, such as axes, labels, legends, and titles are documented in the Graphics Components chapter.

The screenshot displays the 'X-bar Chart' format window. On the left is a navigation pane with options like 'Titles', 'Legend', 'X Axis', 'Y Axis', 'Grid Lines', 'Add Extras', 'Background', 'Painting Order', and 'Example Data'. The main area is divided into 'Symbols' and 'Lines' sections. The 'Symbols' section includes checkboxes for 'Mean Symbols', 'Label Out-of-Control Points', 'Outside Primary Control Limits', 'Out-of-Control by Runs Test', and 'Point Labels', along with dropdown menus for 'In-Control' (green circle), 'Out-of-Control' (red circle), and 'Position' (Right of Symbol, Above Symbol). The 'Lines' section includes checkboxes for 'Reference Labels', 'Connect Means', 'Mean Line', 'Trend Line', 'Primary Limits', 'Secondary Limits', 'Zone A Limits', 'Zone B Limits', 'Zone C Limits', and 'Spec Limits', each with a corresponding line style and fill color/transparency selector. The 'Plot Preview (Sample Data)' window shows a line graph with 50 data points, a mean line at 7.0, and control limits at 12.1 and 1.9. A point at x=5 is highlighted with a red dot and labeled '5'. The plot preview window has a 'Show in New Window' button. At the bottom of the main window are 'Edit this plot with actual data while the procedure is running', 'Notes', 'OK', and 'Cancel' buttons.

[Xbar] / [Range] Chart Tab

Symbols Section

You can modify the attributes of the symbols using the options in this section.

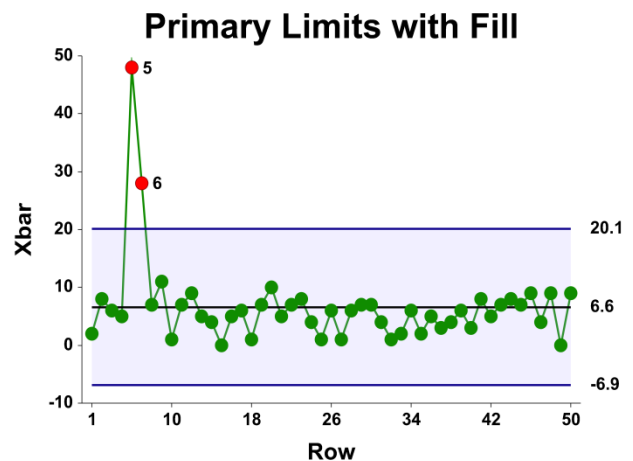
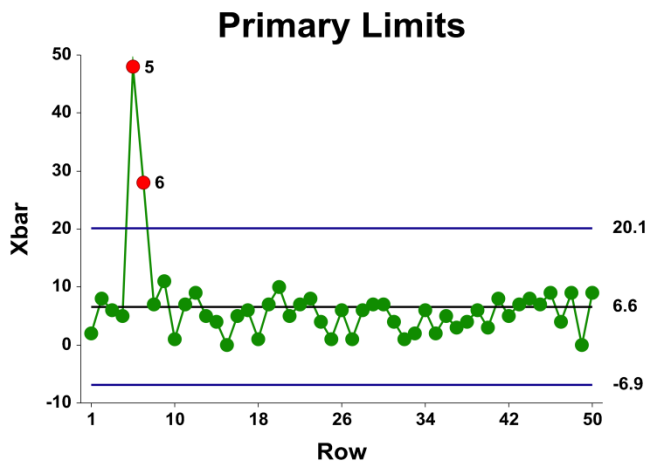


A wide variety of sizes, shapes, and colors are available for the symbols. The symbols for in-control and out-of-control points are specified independently. There are additional options to label out-of-control points. The label for points outside the primary control limits is the subgroup number. The label for points that are out-of-control based on the runs test is the number of the first runs test that is signaled by this point.

The user may also specify a column of point labels on the procedure variables tab, to be used to label all or some of the points of the chart. The raw data may also be shown, based on customizable raw data symbols.

Lines Section

You can specify the format of the various lines using the options in this section. Note that when shading is desired, the fill will be to the bottom for single lines (such as the mean line), and between the lines for pairs of lines (such as primary limits).



Lines for the zones, secondary limits, and specification limits are also specified here.

Titles, Legend, Numeric Axis, Group Axis, Grid Lines, and Background Tabs

Details on setting the options in these tabs are given in the Graphics Components chapter. The legend does not show by default, but can easily be included by going to the Legend tab and clicking the Show Legend checkbox.

Example 1 – Individuals and Moving Range Charts

This section presents an example of how to produce individuals and moving range charts in NCSS. The data represent 50 ordered width observations. The data used are in the Width dataset. We will analyze the variable Width of this dataset.

You may follow along here by making the appropriate entries or load the completed template **Example 1** by clicking on Open Example Template from the File menu of the Individuals and Moving Range Charts window.

1 Open the Width dataset.

- From the File menu of the NCSS Data window, select **Open Example Data**.
- Click on the file **Width.NCSS**.
- Click **Open**.

2 Open the Individuals and Moving Range Charts window.

- Using the Analysis or Graphics menu or the Procedure Navigator, find and select the **Individuals and Moving Range Charts** procedure.
- On the menus, select **File**, then **New Template**. This will fill the procedure with the default template.

3 Specify the variables.

- On the Individuals and Moving Range Charts window, select the **Variables tab**.
- Double-click in the **Response Variable** text box. This will bring up the variable selection window.
- Select **Width** from the list of variables and then click **Ok**. “Width” will appear in the Response Variable box.

4 Run the procedure.

- From the Run menu, select **Run Procedure**. Alternatively, just click the green Run button.

Center Line Section

Center Line Section for All Observations

Number of Observations 50

Center Line	Estimate
Estimated Grand Average	46.26
R-bar	9.448979

This section displays the center line values that are to be used in the individuals and moving range charts.

Estimated Grand Average

This value is the average of all the observations.

R-bar

This is the average of the ranges.

Primary Control Limit Section

Primary Control Limit Section for All Observations

Chart Type	Primary Control Limits	
	Lower	Upper
Individuals	21.12974	71.39027
Moving Range	0	30.8851

This report gives the lower and upper limits for each of the charts.

Individuals Lower and Upper Primary Control Limits

These limits are the primary control limits of the Individuals chart, as defined in the sub-section Individuals Chart Limits of the Control Chart Formulas section toward the beginning of this chapter.

Moving Range Lower and Upper Primary Control Limits

These limits are the primary control limits of the moving range chart, as defined in the sub-section Moving Range Chart Limits of the Control Chart Formulas section toward the beginning of this chapter. Since the lower limit for the R chart is less than 0, it has been reset to 0.

Sigma Estimation Section

Sigma Estimation Section for All Observations

Estimation Type	Estimated Value	Estimated Sigma
Moving Ranges (R-bar)*	9.448979	8.376755

* Indicates the estimation type used in this report.

This report gives the estimation of the population standard deviation (sigma) based on the moving range average.

Estimation Type

The formula for estimating sigma based on the moving ranges is shown earlier in this chapter in the Control Chart Formulas section.

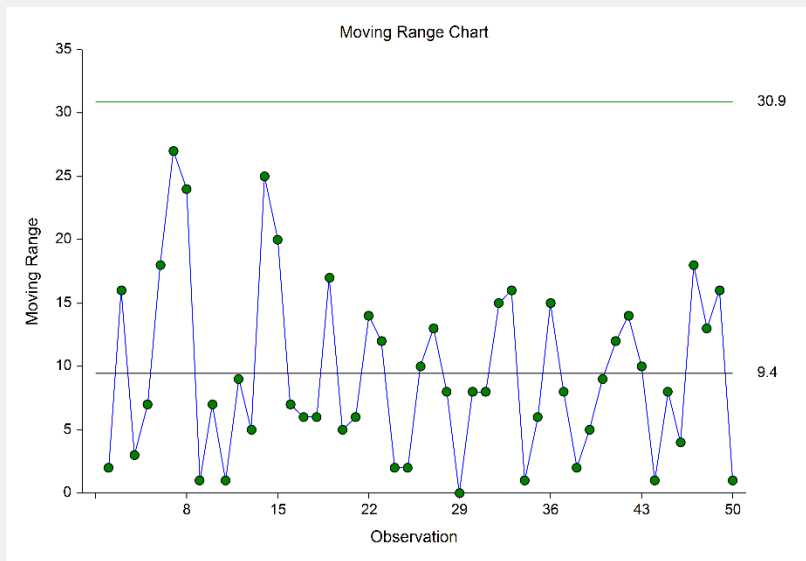
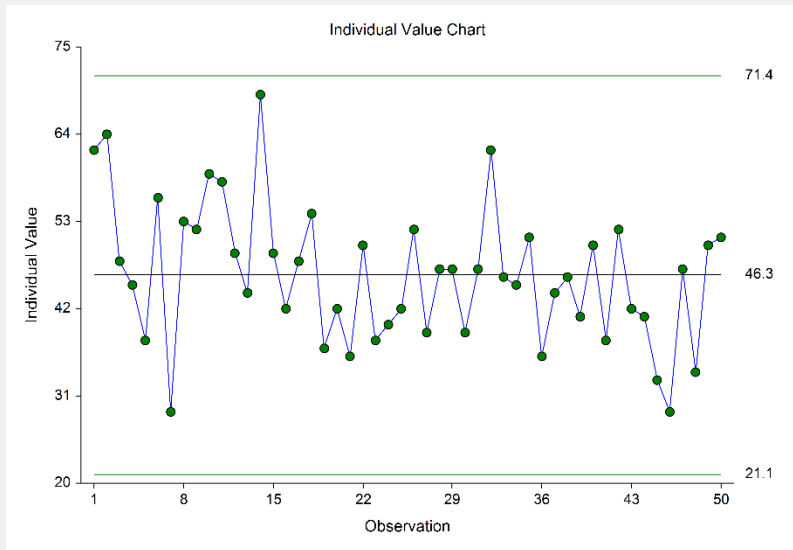
Estimated Value

This column gives the R-bar estimate based on the corresponding formulas.

Estimated Sigma

This column gives the estimate of the population standard deviation (sigma) based on moving range estimation.

X-bar and R Charts



The first plot shows the observation values, as well as the center line and control limits for the process mean, based on the 50 observations. This process appears to be in control. The second plot shows the moving range for each observation (starting with the second observation), as well as the corresponding center line and limits. The Moving Range chart seems to indicate the variation is also in control.

Out-of-Control List

Out-of-Control List for Subgroups 1 to 50

Obs	Value	Range	Obs Label	Reason
8	53	24	8	Range: 2 of 3 in zone A
9	52	1	9	Range: 2 of 3 in zone A

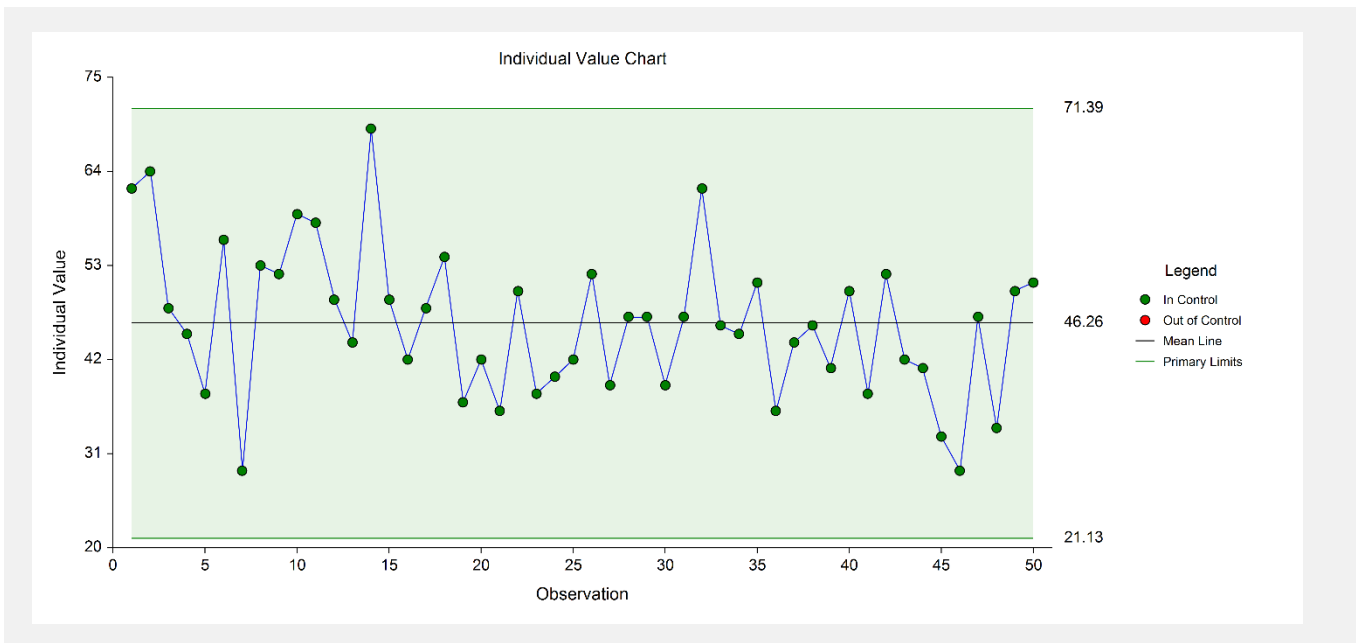
This report provides a list of the observations that failed one of the runs tests (including points outside the control limits). The report shows that observations 8 and 9 are the the final points of 2 out of 3 points in Zone A. This run does not appear to indicate a clear shift in the process variation.

Example 2 – Individuals Chart with Additional Formatting

This example uses the same setup as Example 1, except that a variety of improvements are made in the plot format. These improvements are made by clicking the Individuals Chart format button on the I-MR Charts tab.

You can load the completed template **Example 2** by clicking on Open Example Template from the File menu of the Individuals and Moving Range Charts window.

Individuals Chart



As shown here, a variety of enhancements can be made to the formatting of the control charts to make the chart as easy to read as possible.

Example 3 – Individuals and Moving Range Charts with Stages

This section presents Individuals and Moving Range charts for the scenario of multiple stages in a process. In the Width Stage dataset a significant change had been made in the process after observation 70. This change merits a new evaluation of the process mean and standard deviation, beginning at observation 71. In this example, the process mean and standard deviation for each stage are to be determined based on the first 30 subgroups.

You may follow along here by making the appropriate entries or load the completed template **Example 3** by clicking on Open Example Template from the File menu of the Individuals and Moving Range Charts window.

1 Open the Width Stage dataset.

- From the File menu of the NCSS Data window, select **Open Example Data**.
- Click on the file **Width Stage.NCSS**.
- Click **Open**.

2 Open the Individuals and Moving Range Charts window.

- Using the Analysis or Graphics menu or the Procedure Navigator, find and select the **Individuals and Moving Range Charts** procedure.
- On the menus, select **File**, then **New Template**. This will fill the procedure with the default template.

3 Specify the variables.

- On the Individuals and Moving Range Charts window, select the **Variables tab**.
- Double-click in the **Response Variable** text box. This will bring up the variable selection window.
- Select **Width** from the list of variables and then click **Ok**. “Width” will appear in the Response Variable box.

4 Specify the stages.

- On the Individuals and Moving Range Charts window, select the **Variables tab**.
- For **Number of Stages** select **Multiple Stages**.
- For **Stage Variable** select **Stage**.

5 Specify the Rows in Calculations.

- Under Specify Rows in Calculations, set the **Specification Method** to **Keep Rows Variable**.
- Enter **Use all rows where variable CalcRows** equals **1**.

6 Run the procedure.

- From the Run menu, select **Run Procedure**. Alternatively, just click the green Run button.

Individuals and Moving Range Charts

Center Line, Control Limits, and Estimation Sections

Center Line Section where CalcRows equals 1 in Stage 1

Number of Observations 30

Center Line	Estimate
Estimated Grand Average	70.63333
R-bar	7.827586

Primary Control Limit Section where CalcRows equals 1 in Stage 1

Chart Type	Primary Control Limits	
	Lower	Upper
Individuals	49.81528	91.45139
Moving Range	0	25.58538

Sigma Estimation Section where CalcRows equals 1 in Stage 1

Estimation Type	Estimated Value	Estimated Sigma
Moving Ranges (R-bar)*	7.827586	6.93935

* Indicates the estimation type used in this report.

Center Line Section where CalcRows equals 1 in Stage 2

Number of Observations 30

Center Line	Estimate
Estimated Grand Average	88.3
R-bar	12.72414

Primary Control Limit Section where CalcRows equals 1 in Stage 2

Chart Type	Primary Control Limits	
	Lower	Upper
Individuals	54.45921	122.1408
Moving Range	0	41.59033

Sigma Estimation Section where CalcRows equals 1 in Stage 2

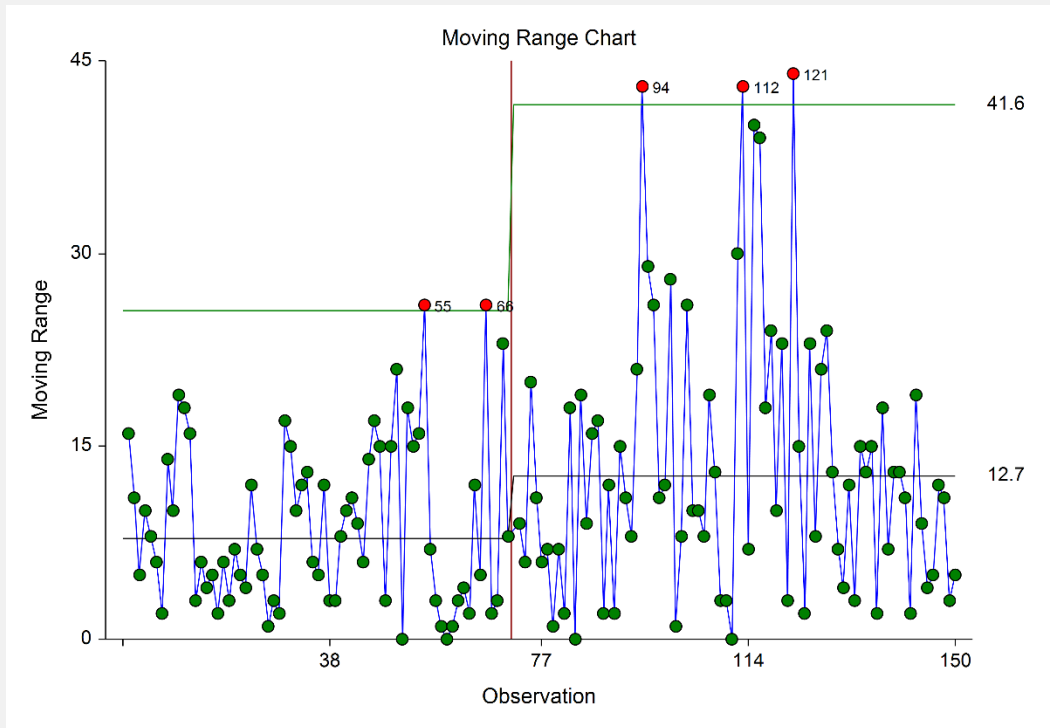
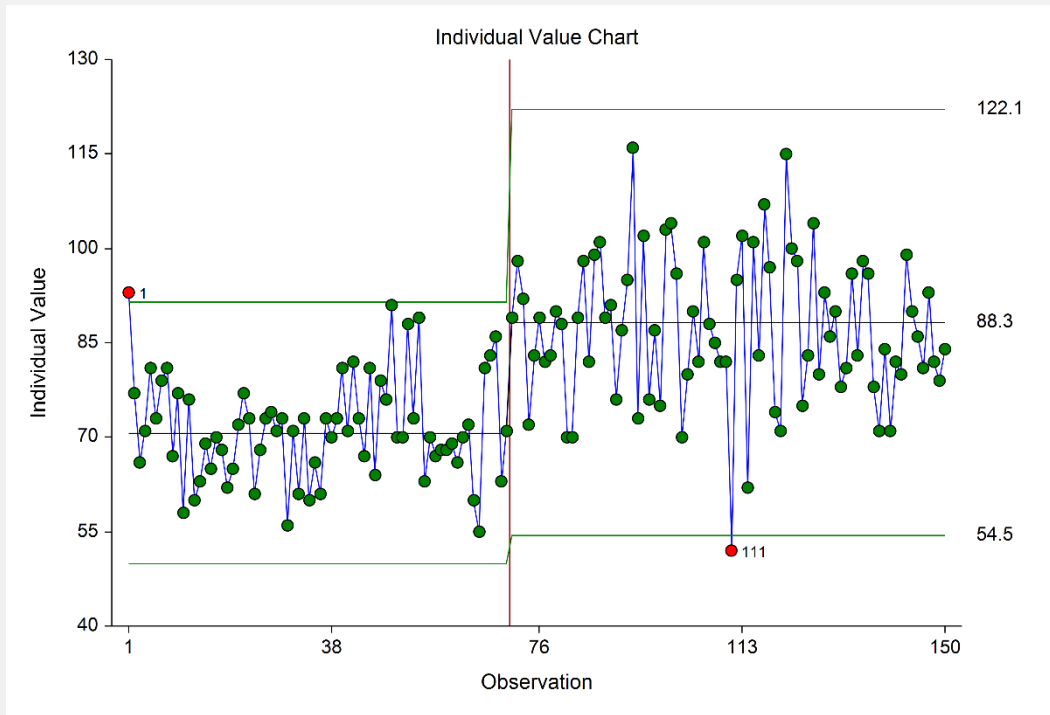
Estimation Type	Estimated Value	Estimated Sigma
Moving Ranges (R-bar)*	12.72414	11.28026

* Indicates the estimation type used in this report.

This report shows the center line, limit, and sigma estimates for each of the two stages. The center line estimate changes from about 71 to about 88. There also appears to be a change in sigma of about 7 to about 11.

Individuals and Moving Range Charts

Individuals and Moving Range Charts



The change in process mean and variation from the first stage to the second is reflected in the individuals and moving range charts. The mean and variation appear to be reasonably stable within the stages.