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Introducing SAS[®] Structural Equation Modeling for JMP[®]: A New User Interface That Brings the Power of SAS/STAT[®] Software to JMP Software

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ABSTRACT

Structural equation modeling evaluates how well a theory in the form of a model fits data. Models might involve a number of interrelated variables and include latent variables, which cannot be measured directly, along with other variables that are directly measured. A new application, SAS[®] Structural Equation Modeling for JMP[®] 1.1, features a graphical model builder that is useful for creating these interrelated models. The user interface appears in JMP software, and the calculations are performed by the SAS/STAT[®] CALIS procedure. You create models by dragging variables onto a diagram, perform the analysis, and save and reuse the results.

INTRODUCTION

A structural equation model can be as simple as a regression model of a single predictor, or it can involve a number of interrelated variables. In addition to variables that can be directly measured, such as height or weight, structural equation modeling (SEM) also accommodates the inclusion of variables that cannot be measured directly, called latent variables. For example, consider the concept of intelligence. It cannot be measured as height or weight can. You can use an IQ test score to represent intelligence, but an IQ test is an imperfect measure of the concept of intelligence. One advantage of SEM is that you can incorporate measurement error into a model.

SAS/STAT software has offered the CALIS procedure, which uses commands to perform SEM, since SAS/STAT 6. For elaborate models, a graphical specification can be more helpful. Integrating SAS and JMP software, SAS Structural Equation Modeling for JMP provides a graphical user interface (GUI) that enables you to build a model graphically, uses PROC CALIS to analyze the model, and displays the results on the GUI.

A typical scenario for a SEM user is to specify a model, analyze it for fit, and iteratively make minor changes to the model to see if the fit improves. To facilitate this process, the SAS Structural Equation Modeling for JMP user interface is designed to make it easy to specify a model, to duplicate a model, and to switch back and forth between results for several models. You can use a model specification repeatedly, with different sets of data, and also create a model specification before data are available.

SAS STRUCTURAL EQUATION MODELING FOR JMP WINDOWS

SAS Structural Equation Modeling for JMP provides the following windows for working with models:

- The Single-Group Analysis window enables you to create models, analyze them, and store results for later use.
- The Model Library window enables you to create models either with or without data and store them. However, you cannot use this window to perform an analysis. You analyze these models with the Single Group Analysis window.
- The User Profile window enables you to set preferences and default settings that are used by the Single Group Analysis and Model Library windows.

Introducing SAS Structural Equation Modeling for JMP, continued

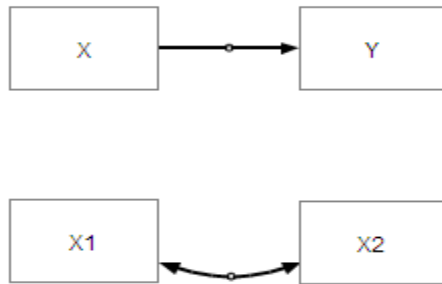
MODEL SPECIFICATION

Creating models is an important aspect of SEM. The ability to define a model specification graphically is very helpful, especially when you have a model that consists of a number of interrelated variables.

A model specification consists of variables and relationships among variables. The variables might include latent variables in addition to observed variables. Relationships can be one-directional, such as regression coefficients, or two-directional, such as covariances and correlations.

An example of a simple model specification is the variable X predicting the variable Y. This model specification is represented by a one-directional relationship from X to Y as shown by the top pair of variables in Figure 1. A correlational relationship is represented by a two-directional relationship between X and Y as shown by the bottom pair of variables in Figure 1.

Figure 1. Two Simple Models



The example shown in Figure 2 has three variables: X, Y, and Z. You believe that X influences Y, so you create a one-directional relationship from X to Y. You believe that Y influences Z, so you create a one-directional relationship from Y to Z. You do not believe that X has a direct effect on Z, so you do not create a relationship between X and Z.

Figure 2. Another Simple Model

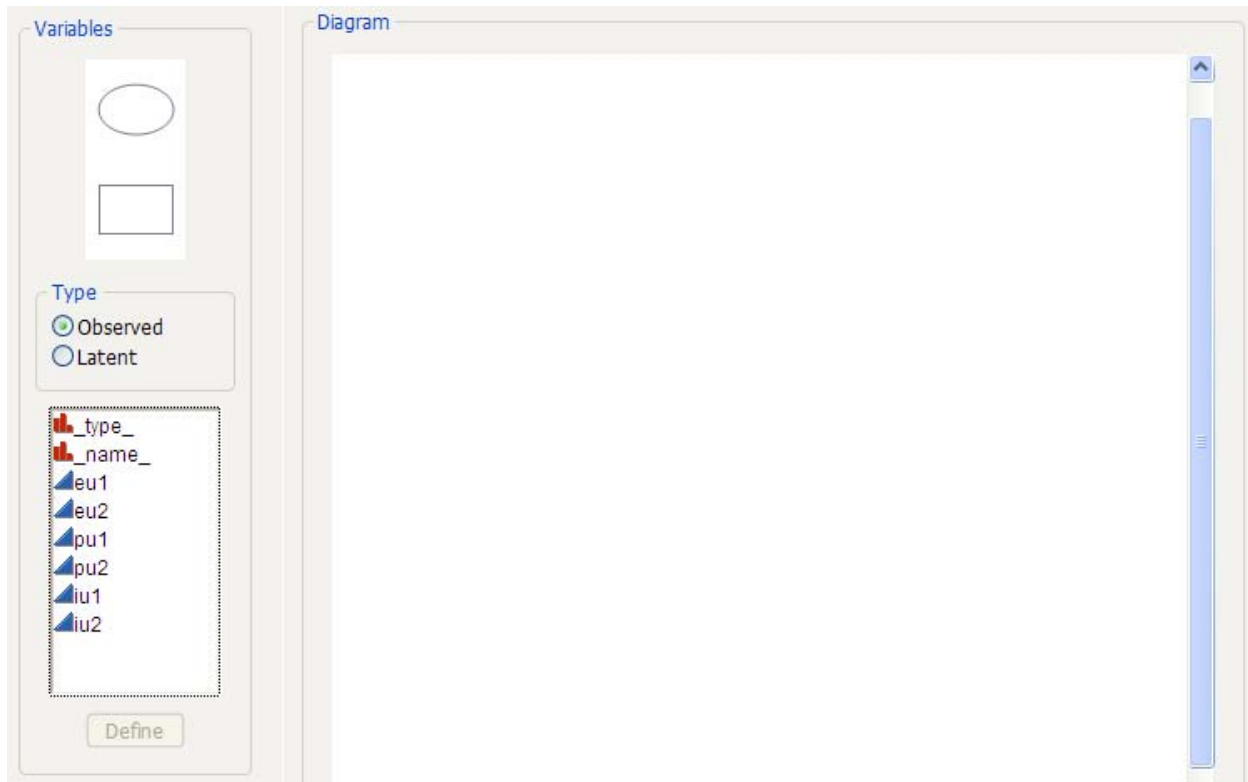


GRAPHICAL MODEL BUILDING

The graphical model builder in SAS Structural Equation Modeling for JMP consists of a diagram-drawing area and several tools for defining model specifications, as shown in Figure 3. To define a model, you add variables to the diagram and define relationships among variables. You also define properties for the variables and the relationships.

Introducing SAS Structural Equation Modeling for JMP, continued

Figure 3. Diagram and Tools



ADDING VARIABLES

You can add variables to a diagram in any of the following ways:

- Drag a rectangular or oval shape from the palette shown in Figure 3 to the diagram. You must provide a variable name as one of the variable properties.
- Display a context menu by right-clicking on the diagram and selecting **Add observed** or **Add latent** from the menu. You must provide a variable name as one of the variable properties.
- Drag a variable name from the variables list shown in Figure 3 to the diagram or to a variable already in the diagram. The variable name of the new variable is automatically set. If you drag a variable name to a variable in the diagram, the variable is created and a one-directional relationship is drawn between the two variables. By default, the arrow is drawn from the variable already on the diagram to the new variable. This direction is a preference that you can change.

Rectangles represent observed variables, and ovals represent latent variables. The shapes that represent observed and latent variables are preferences that you can change.

Introducing SAS Structural Equation Modeling for JMP, continued

DEFINING RELATIONSHIPS

A relationship between two variables can be one-directional or two-directional. To define a relationship, position the cursor over the variable from which you want to draw the relationship. A pop-up palette of relationships represented by arrows is displayed as shown adjacent to the X variable in Figure 4.

Figure 4. Arrows Palette

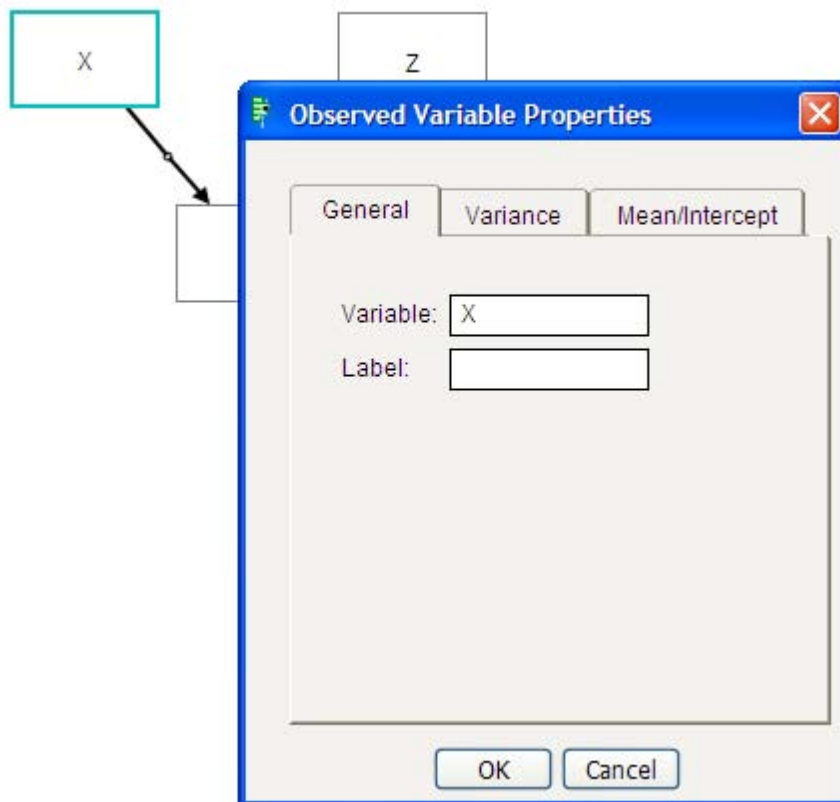


- To define a one-directional relationship, select the one-directional arrow from the arrows palette, and drag the arrow to the other variable.
- To define a two-directional relationship, start with either variable, select the two-headed arrow from the arrows palette, and drag it to the other variable.

SETTING PROPERTIES

Variables have the following properties: the variable name, a label, a variance parameter, and a mean parameter. To set the properties for a variable, either double-click the variable shape or right-click the variable shape in the diagram and select **Set variable properties** from the pop-up menu. A properties dialog box appears. Figure 5 shows the properties dialog box for observed variables.

Figure 5. Observed Variables Properties Dialog Box



Introducing SAS Structural Equation Modeling for JMP, continued

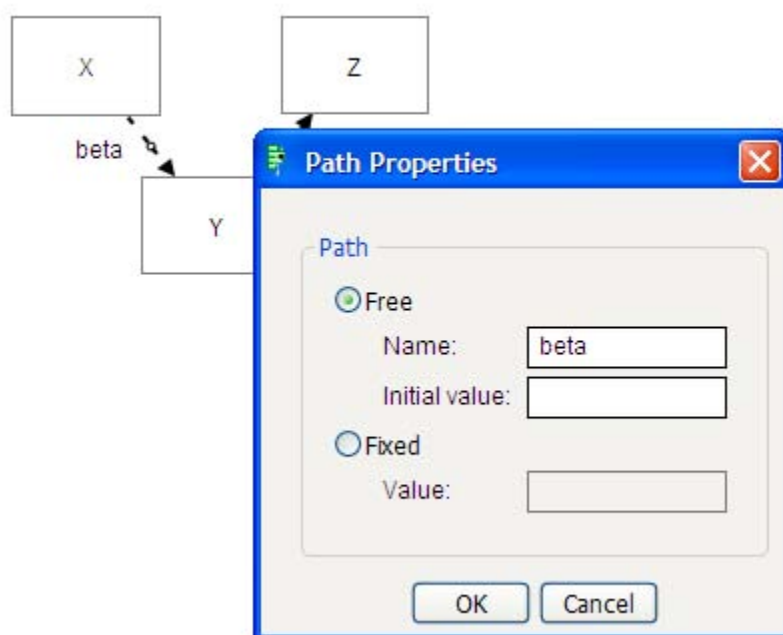
The variable name is required. For an observed variable, it is the name of the variable in the data set being analyzed. For a latent variable, it is a valid variable name that is distinct from all variables in the data set being analyzed. A valid variable name consists of a letter or underscore followed by letters, digits, or underscores; it must be unique from other variable names within the first thirty-two characters. Variable names are case-insensitive.

You can provide a label that differs from the variable name. It is used in the diagram but not in the analysis results.

The variance and mean parameters can either be a fixed value or a parameter to be estimated. If estimated, you can optionally specify a parameter name and an initial value. Like a variable name, a valid parameter name consists of a letter or underscore followed by letters, digits, or underscores and must be unique from other parameter names within the first thirty-two characters. Parameter names are also case-insensitive.

The relationships between variables also have properties. To set the properties for a relationship, right-click the arrow that represents the relationship between two variables. From the pop-up menu, select **Set path properties** for a one-directional relationship or **Set covariance properties** for a two-directional relationship. A dialog box for the selected relationship appears; Figure 6 shows the dialog box that appears when you select **Set path properties**.

Figure 6. Path Properties Dialog Box



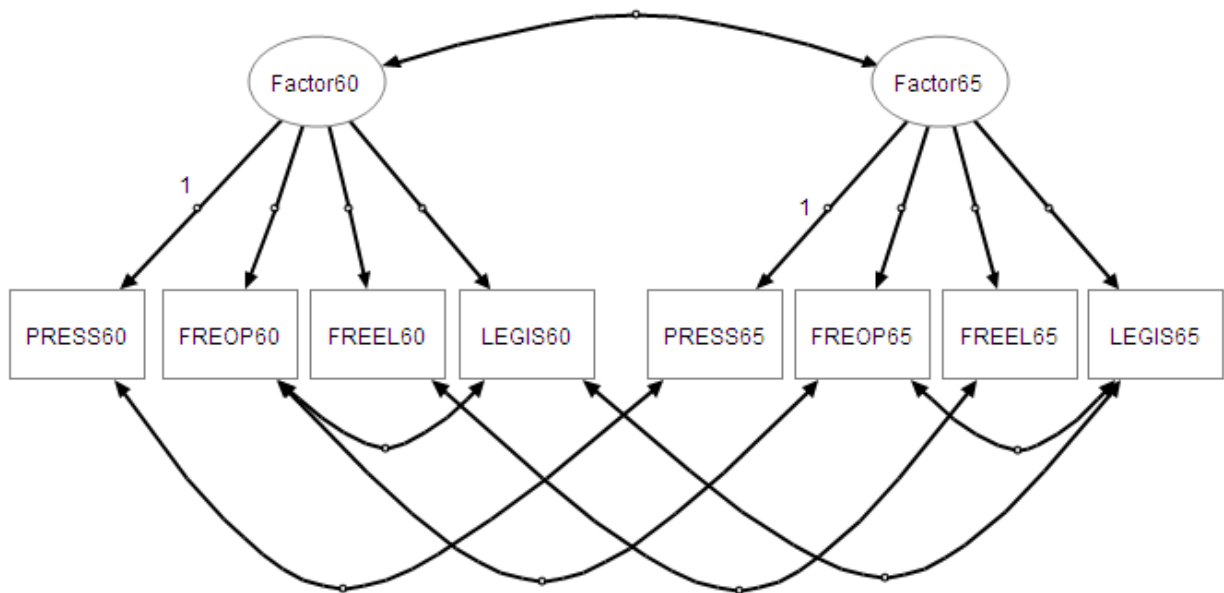
Both a path and a covariance can be either a fixed value or a parameter to be estimated. As is the case for variances and means, if it is estimated, you can optionally specify a parameter name and an initial value. You are not required to provide a parameter name for variances, paths, covariances, or means; if you do not provide a parameter name, a unique one is created for you.

If you want to constrain a parameter to be the same for several paths, use the same parameter name for all those paths. You can do the same for parameters for covariances, variances, and means. For example, if you want to constrain the variance for three variables to be the same parameter, select all three variables, open the properties window, and edit the variance properties. The variance information you provide in the properties window is used for all three variables.

Introducing SAS Structural Equation Modeling for JMP, continued

Figure 7 shows an example of a model with two latent variables and eight observed variables.

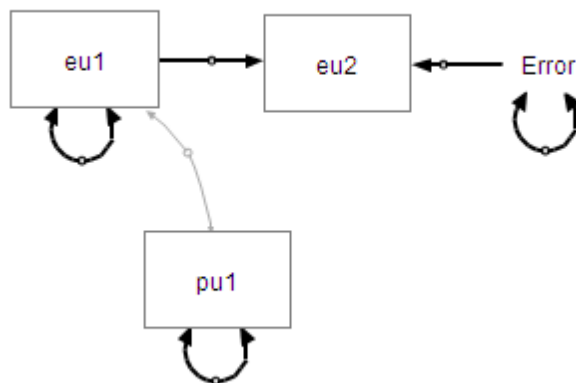
Figure 7. Example of a Model Specification



CUSTOM VIEWS FOR THE DIAGRAM

You can see one or more custom views by right-clicking in the diagram area and selecting the custom view from the pop-up menu. Figure 8 shows the three custom views.

Figure 8. Custom Views for Error Variables, Variance Paths, and Default Covariances



- You can show explicit error variables for each endogenous variable by selecting **Show error variables** from the pop-up menu. Figure 8 shows an error variable for the eu2 variable.
- You can show explicit variance paths by selecting **Show variance paths** from the pop-up menu. The variance path is represented by a double-headed arrow to and from the same variable. Figure 8 shows variance paths for the eu1, pu1, and error variables.
- You can show the assumed covariances between exogenous variables by selecting **Show default covariances** from the pop-up menu. These covariances are estimated even if you do not specify them. Figure 8 shows a default covariance between the eu1 and pu1 variables.

Introducing SAS Structural Equation Modeling for JMP, continued

SINGLE-GROUP ANALYSIS WINDOW

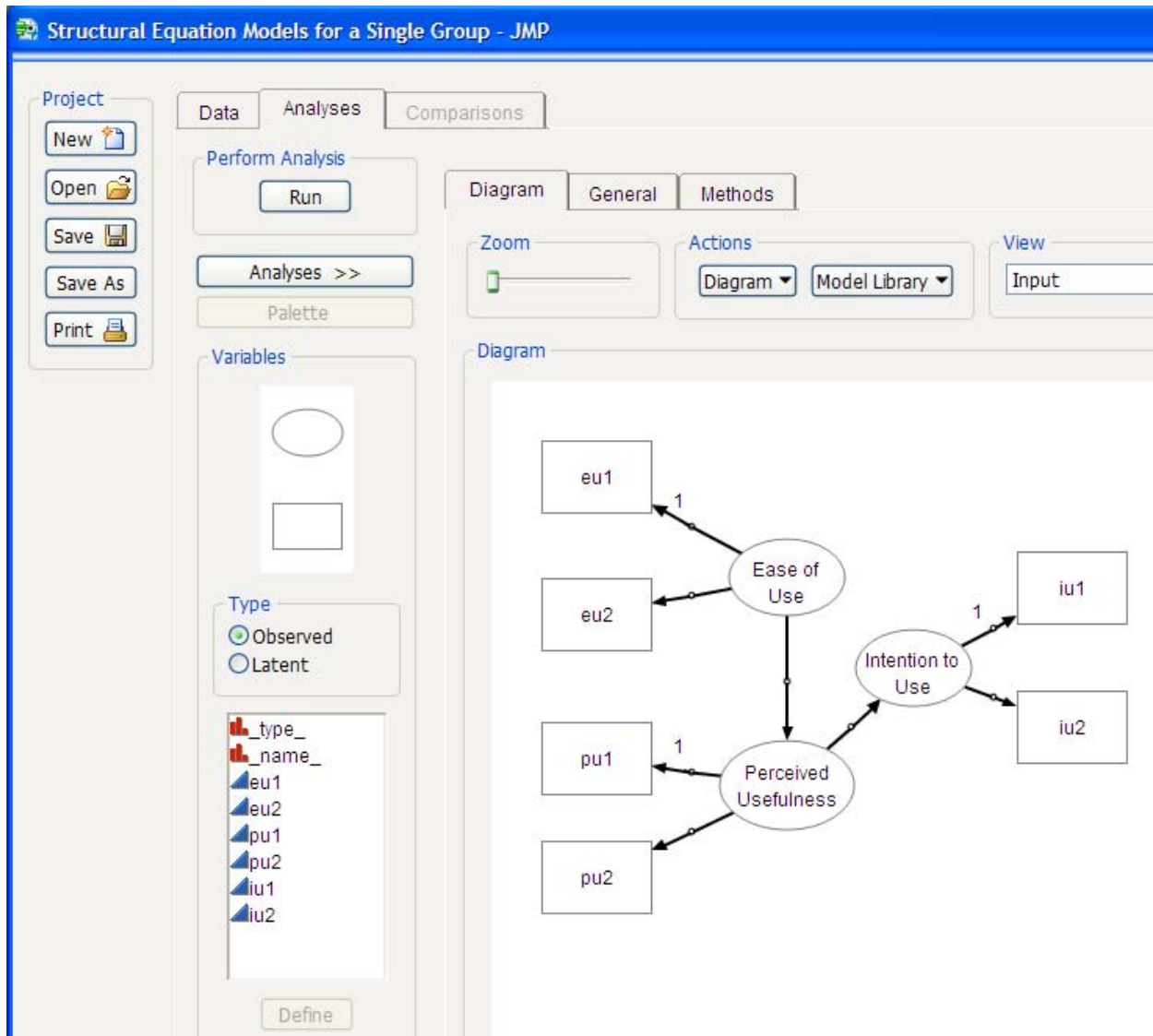
A single-group analysis involves fitting a structural equation model to a single sample. Inferences are drawn for a single population. In contrast, a multiple-group analysis involves more than one sample. Multiple-group analysis can be performed using the CALIS procedure, but it is not available in the first release of SAS Structural Equation Modeling for JMP.

The Single-Group Analysis window enables you to create and analyze one or more model specifications, view the results, and save the properties and results of the analyses as a SEM project for later use.

From the main JMP menu, select **Analyze** ► **Structural Equation Modeling** ► **Single Group Analysis**. The Single-Group Analysis window appears; see Figure 9. The window is organized in three tabs:

- Use the **Data** tab to specify characteristics of the data that are to be used by all analyses.
- Use the **Analyses** tab to create model specifications, specify analysis methods, and view analysis results.
- Use the **Comparisons** tab to compare fit statistics for the analyses in the project.

Figure 9. Single-Group Analysis Window

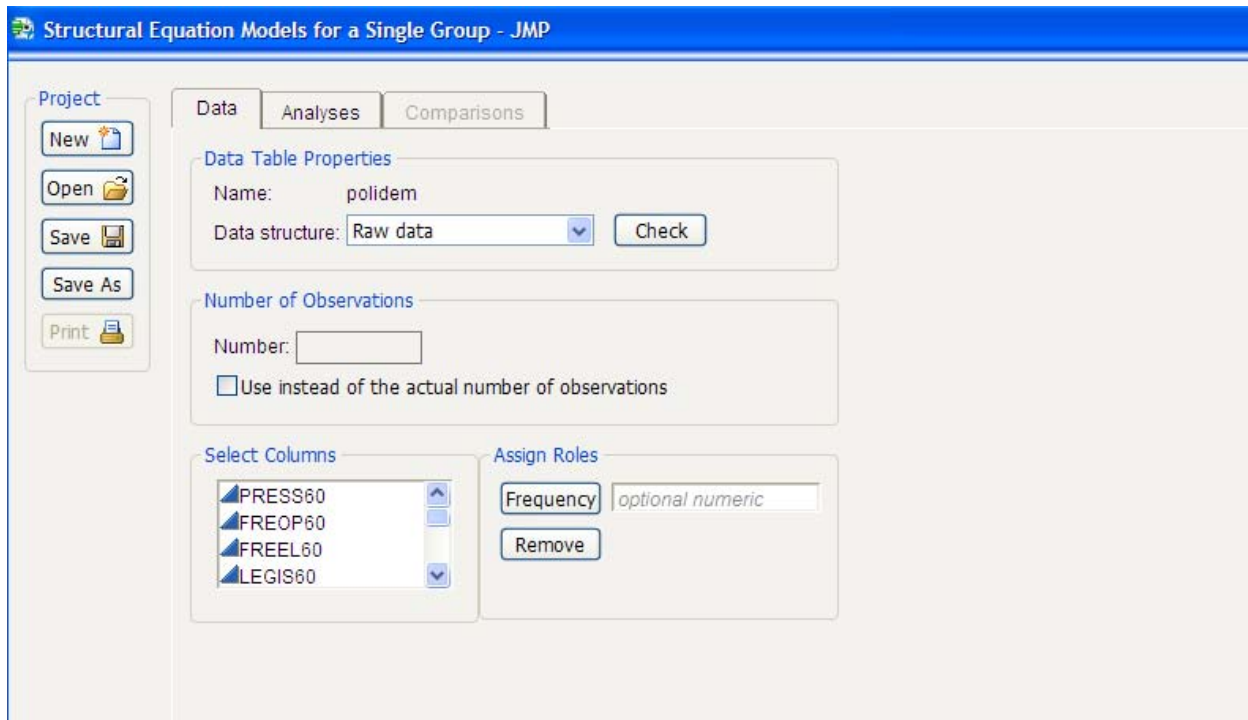


Introducing SAS Structural Equation Modeling for JMP, continued

DATA TAB

The **Data** tab is shown in Figure 10. The current JMP data table is used, and its name is listed in the **Data Table Properties** group box. SAS data sets can be opened as JMP tables.

Figure 10. Data Tab



You can analyze either raw data or covariances or correlations. Raw data consist of variables that are organized as columns with values of individual observations arranged in rows. Covariances or correlations are arranged in a data set in matrix form as shown in Figure 11. Select either **Raw data** or **Covariances, correlations** from the **Data structure** list.

Figure 11. JMP Data Table That Contains Covariances

	type	_name_	eu1	eu2	pu1	pu2	iu1	iu2
1	COV	eu1	0.762					
2	COV	eu2	0.343	0.77614				
3	COV	pu1	0.1765	0.17593	0.543035			
4	COV	pu2	0.237405	0.2326569	0.5586766	1.2466638		
5	COV	iu1	0.22061	0.26181978	0.1477111	0.2775858	0.7432742	
6	COV	iu2	0.0383891	0.0366413	0.0747004	0.1092836	0.191975	0.1884983

Introducing SAS Structural Equation Modeling for JMP, continued

The correlations or covariances must conform to a specific structure. The data table must contain two variables: `_name_` and `_type_`. It must also contain a specific JMP data table property: `SASTYPE`. The value of the `SASTYPE` variable must be either `COV` or `CORR`.

If the data set does not contain the appropriate structure, you must create the variables and data table property with the appropriate values. An example of a data table that contains covariances in the appropriate structure is shown in Figure 11.

In some circumstances, the Single-Group Analysis window can determine that the data table contains a covariance or correlation matrix and automatically supply the required variables and `SASTYPE` property. The most likely case is a data table that contains the same number of rows as the number of numeric variables. For example, with the data table as the current JMP data table, open the Single-Group Analysis window. On the **Data** tab, the **Data Structure** list is set to **Raw data** by default. From the **Data Structure** list, select **Covariances, correlations**. A dialog box is displayed that indicates that the data set does not have the necessary structure and asks whether you want the application to provide the appropriate variables to correct the problem. If you answer **Yes**, you are asked whether the input data set contains covariances or correlations. The necessary information is added to the data table.

The values of the `_name_` variable must contain the name of the variable for the corresponding row. For example, the value for the second row of the `eu1` variable is 0.343. It is the covariance between the `eu1` and `eu2` variables.

The values of the `_type_` variable must contain the value `COV` or `CORR`, which indicate that the values for the variables in that row are covariances or correlations, respectively. A value of `N` for the `_type_` variable indicates a row of the number of observations, and a value of `MEAN` indicates a row of means.

If the data table contains covariances or correlations and does not contain a number of observations row, use the **Number** box on the **Data** tab to specify the value. You can also control the degrees of freedom for the analysis by selecting the **Use instead of the actual number of observations** check box and specifying the appropriate value in the **Number** box.

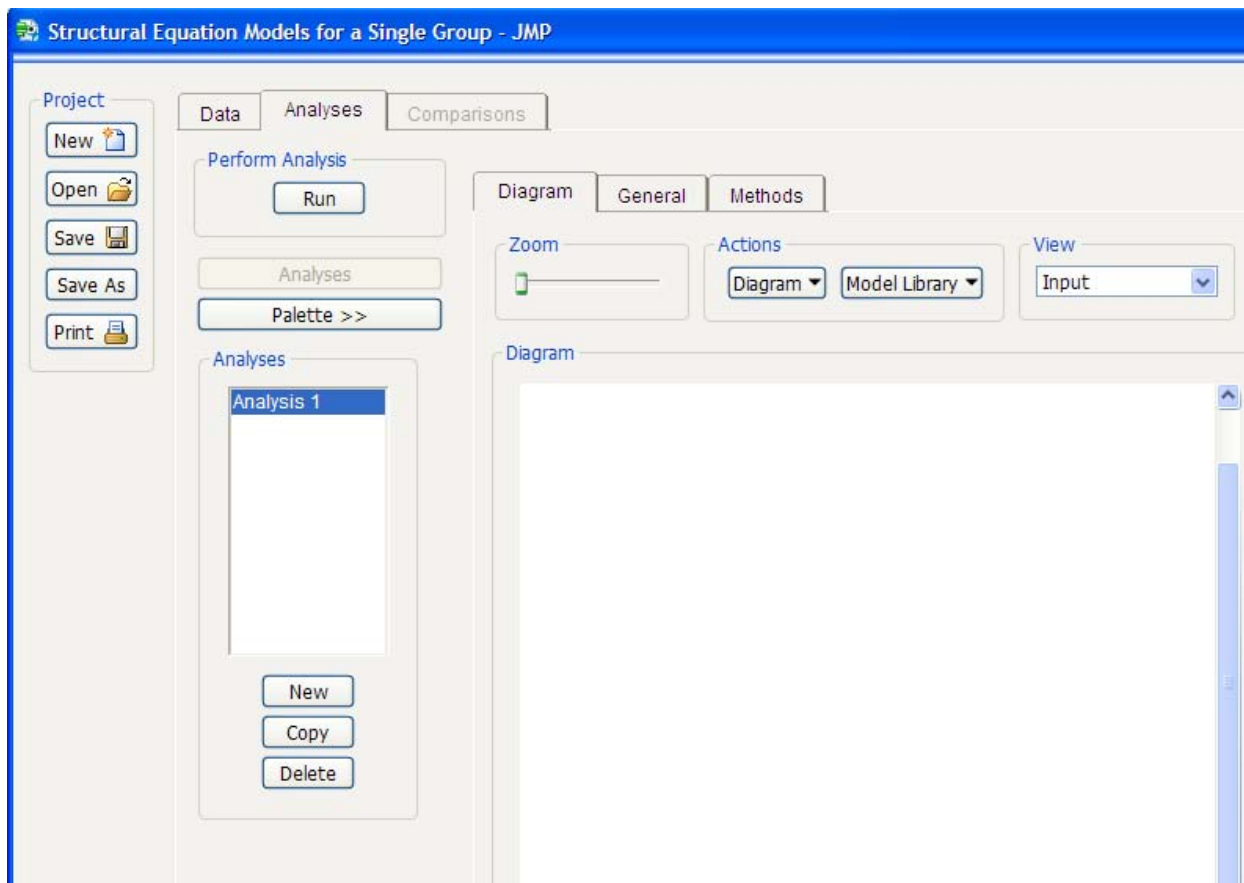
If the data set contains a frequency variable, select the name of the variable in the **Select Columns** list and either click **Frequency** or drag the variable into the field beside **Frequency**.

Introducing SAS Structural Equation Modeling for JMP, continued

ANALYSES TAB

Use the **Analyses** tab to create one or more analyses. An analysis consists of a model specification, a selection of analysis methods, and after the analysis has been performed, several results. These are arranged as tabs within the **Analyses** tab as shown in Figure 12.

Figure 12. Analyses Tab



Creating and Running an Analysis

To create an analysis, click **New** beneath the **Analyses** list to the left of the diagram. The name of the analysis appears in the **Analyses** list. The first analysis in a SEM project is automatically created for you and named "Analysis 1". You can change the name of the analysis and add notes on the **General** tab.

You can create a model specification on the **Diagram** tab in any of the following ways:

- Use the graphical model builder as described in the section "Graphical Model Building."
- Copy a model specification from the Model Library by clicking **Model Library** and selecting **Get a model**.
- Copy an existing analysis by clicking **Copy**. Copying an analysis also copies the analysis methods.

Select the appropriate analysis methods on the **Methods** tab.

Perform the analysis by clicking **Run**. When the analysis has been run, the **Results**, **SAS Log**, and **SAS Code** tabs appear beside the **Diagram**, **General**, and **Method** tabs as shown in Figure 13.

Introducing SAS Structural Equation Modeling for JMP, continued

Figure 13. Analysis Results

The screenshot displays the 'Structural Equation Models for a Single Group - JMP' window. The 'Results' tab is selected, showing the following information:

- The Calis Procedure**
 - Modeling Specification**
 - Modeling Information**
 - Data Set: WORK.TAM
 - N Obs: 160
 - Model Type: PATH
 - Analysis: Covariances
 - Covariance Structure Analysis: Maximum Likelihood Estimation
 - Fit**
 - Fit Summary**
 - Absolute Index: 8.2961
 - Chi-Square: 6
 - Chi-Square DF: 6
 - Pr > Chi-Square: 0.2172
 - Parsimony Index: 0.0491
 - RMSEA Estimate: 0.0491
 - Covariance Structure Analysis: Maximum Likelihood Estimation
 - Covariance Structure Analysis: Maximum Likelihood Estimation
 - ML Estimation**
 - PATH List**

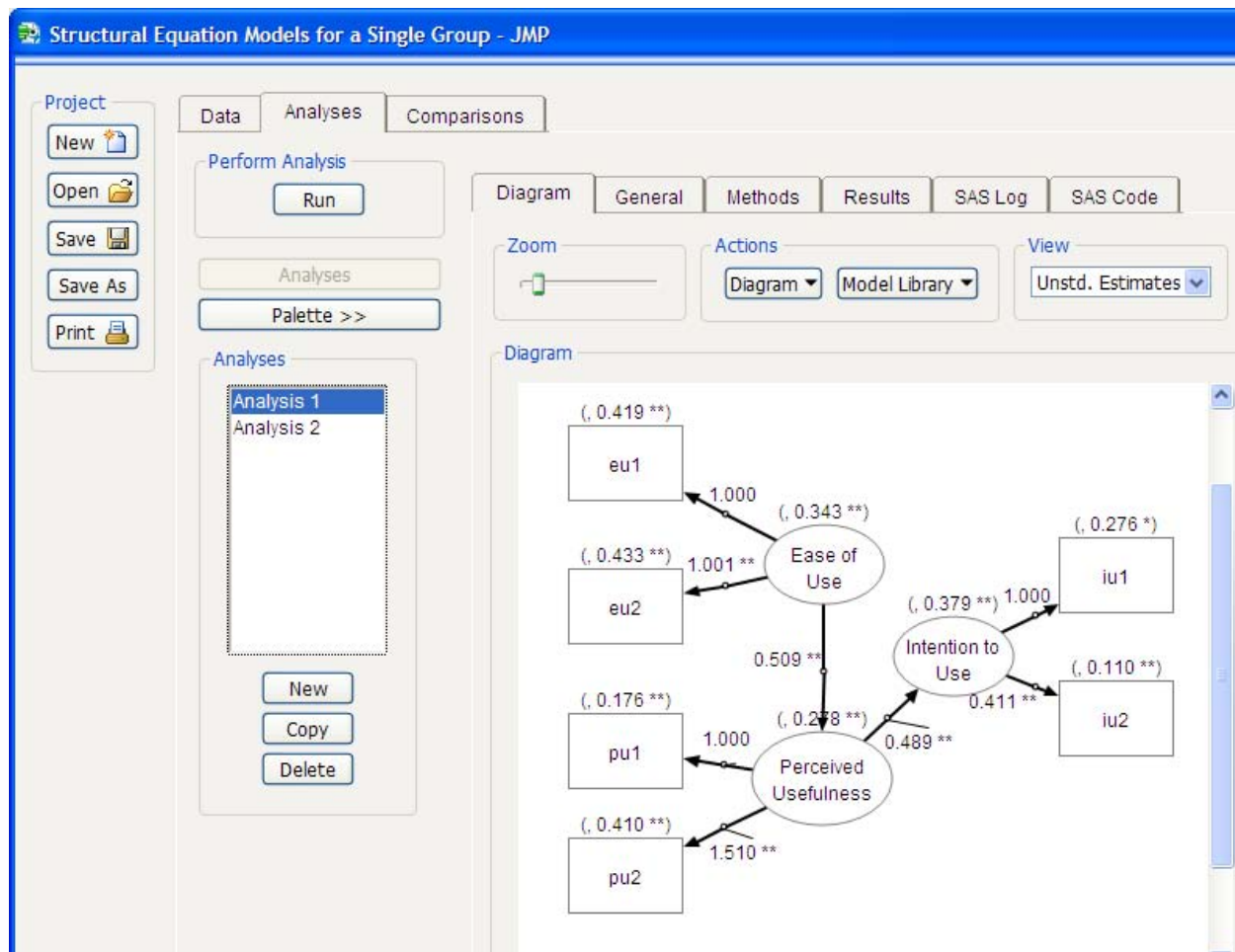
Path	Parameter	Estimate	Sta
eu1	<--- EaseOfUse	1	
eu2	<--- EaseOfUse	_Parm1	1.10624 0.:
IntentionToUse	<--- EaseOfUse	_Parm2	0.67186 0.:

Several views of the model are available on the **Diagram** tab:

- The input view shows the input specification including the variable names or labels and any information that you specify about the paths, covariances, variances, and means. You use this view to create a model specification. Select **Input** from the **View** list.
- After an analysis is run, the unstandardized parameter estimates for paths, covariances, variances, and means are displayed. Select **Unstd. Estimates** from the **View** list. The unstandardized estimates are shown in Figure 14.
- Also, after an analysis is run, the standardized parameter estimates for paths, covariances, and variances are available. Select **Std. Estimates** from the **View** list.

Introducing SAS Structural Equation Modeling for JMP, continued

Figure 14. Unstandardized Estimates



Creating Additional Analyses

You can create additional models by clicking **New** under the **Analyses** list. You can also copy the model of an existing analysis by clicking **Copy**. Copying an analysis also copies the analysis methods.

Introducing SAS Structural Equation Modeling for JMP, continued

COMPARISONS TAB

You can compare the results of several analyses in a SEM project. To compare models, select the **Comparisons** tab. A table of fit statistics is displayed for all analyses in the project, as shown in Figure 15. You also can customize which fit statistics you want to appear in the table.

Figure 15. Comparisons Tab

Structural Equation Models for a Single Group - JMP

Project

Data Analyses Comparisons

Model Comparison Statistics

Analysis	Akaike Information Criterion	Bozdogan CAIC	Schwarz Bayesian Criterion	RMSEA Estimate
Analysis 1	48.0637	105.116	91.1161	0.10834
Analysis 2	38.2961	99.4237	84.4237	0.04906

Sort

Sort by: Original order

Show

Default parsimony statistics

User-selected fit statistics [Customize](#)

SAVING AND OPENING SINGLE-GROUP ANALYSIS PROJECTS

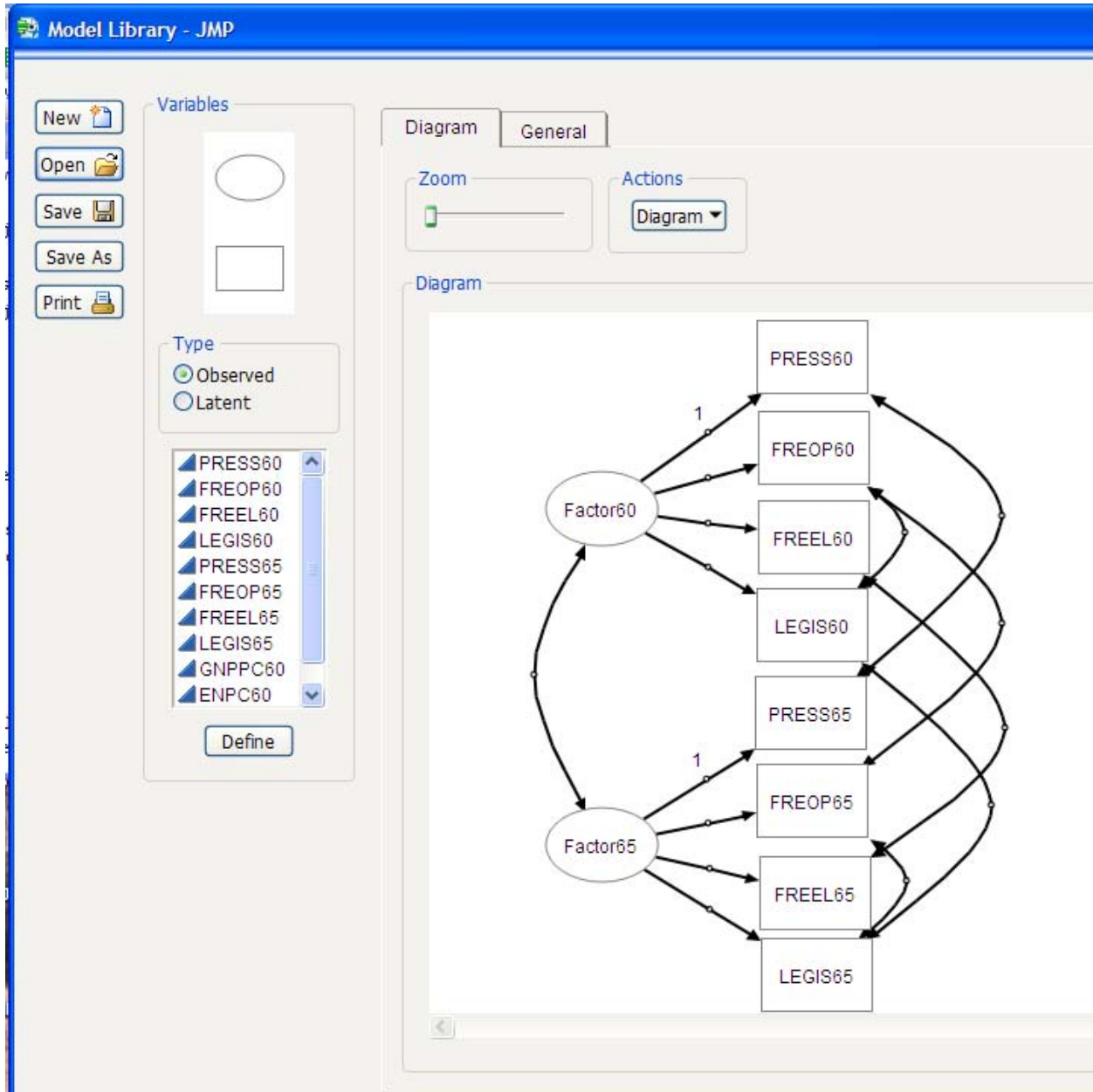
You can save the analyses that you have created as a single-group analysis project in a single JMP project file. Click **Save** or **Save As** to save the project. You can view or edit the single-group analysis project at another time by clicking **Open** and selecting the project file. Name your single-group analysis project files so that you can distinguish them from other JMP project files and SEM model files which are described in the section “Saving Model Projects.”

Introducing SAS Structural Equation Modeling for JMP, continued

MODEL LIBRARY WINDOW

The Model Library window enables you to create a model specification, but you cannot use this window to perform an analysis. You must use the Single-Group Analysis window to analyze models. In the Model Library window you can optionally choose to use the variables that are contained in the current JMP data table. However, a data table is not required, so you can use the Model Library window to create all or part of a model specification without access to the data. To open the Model Library window, select **Analyze** ► **Structural Equation Modeling** ► **Model Library** from the main JMP menu. The Model Library window is shown in Figure 16.

Figure 16. Model Library Window



Introducing SAS Structural Equation Modeling for JMP, continued

CREATING AND OPENING MODEL SPECIFICATIONS

You can create a new model specification or open an existing model specification for editing or viewing:

- To create a new model, click **New**. If a data table is open in JMP, you are asked whether you want to use the names of the variables in the current JMP data table. Variable names are useful for dragging onto the diagram to create a model.
- To open an existing model, click **Open**. Select the model project file that you want to open.
- To create a model specification, use the graphical model builder as described in the section “Graphical Model Building.”

SAVING MODEL PROJECTS

You can save a model specification as a SEM model in a single JMP project file. Click Save or Save As to save the project. Name your model project files so that you can distinguish them from other JMP project files and single-group analysis project files described in the section “Saving and Opening Single-Group Analysis Projects.”

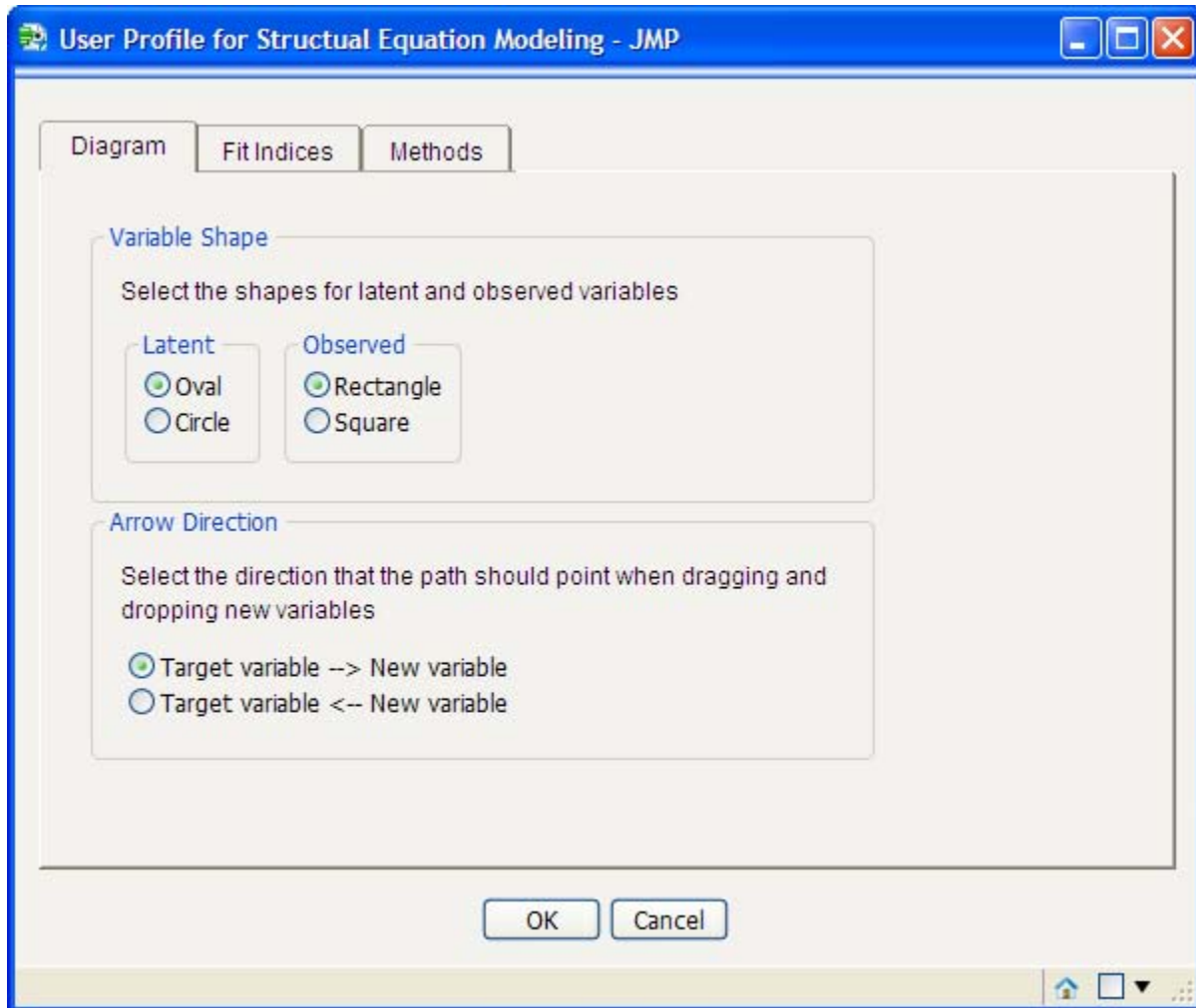
Introducing SAS Structural Equation Modeling for JMP, continued

USER PROFILE WINDOW

You can use the User Profile window to set preferences for the Model Library and Single-Group Analysis windows.

From the main JMP menu, select **Analyze** ► **Structural Equation Modeling** ► **User Profile**. The User Profile window is organized in several tabs as shown in Figure 17.

Figure 17. User Profile Window with Diagram Tab



Changes in preferences do not take effect until the User Profile is closed and the Model Library window or Single-Group Analysis window is next opened.

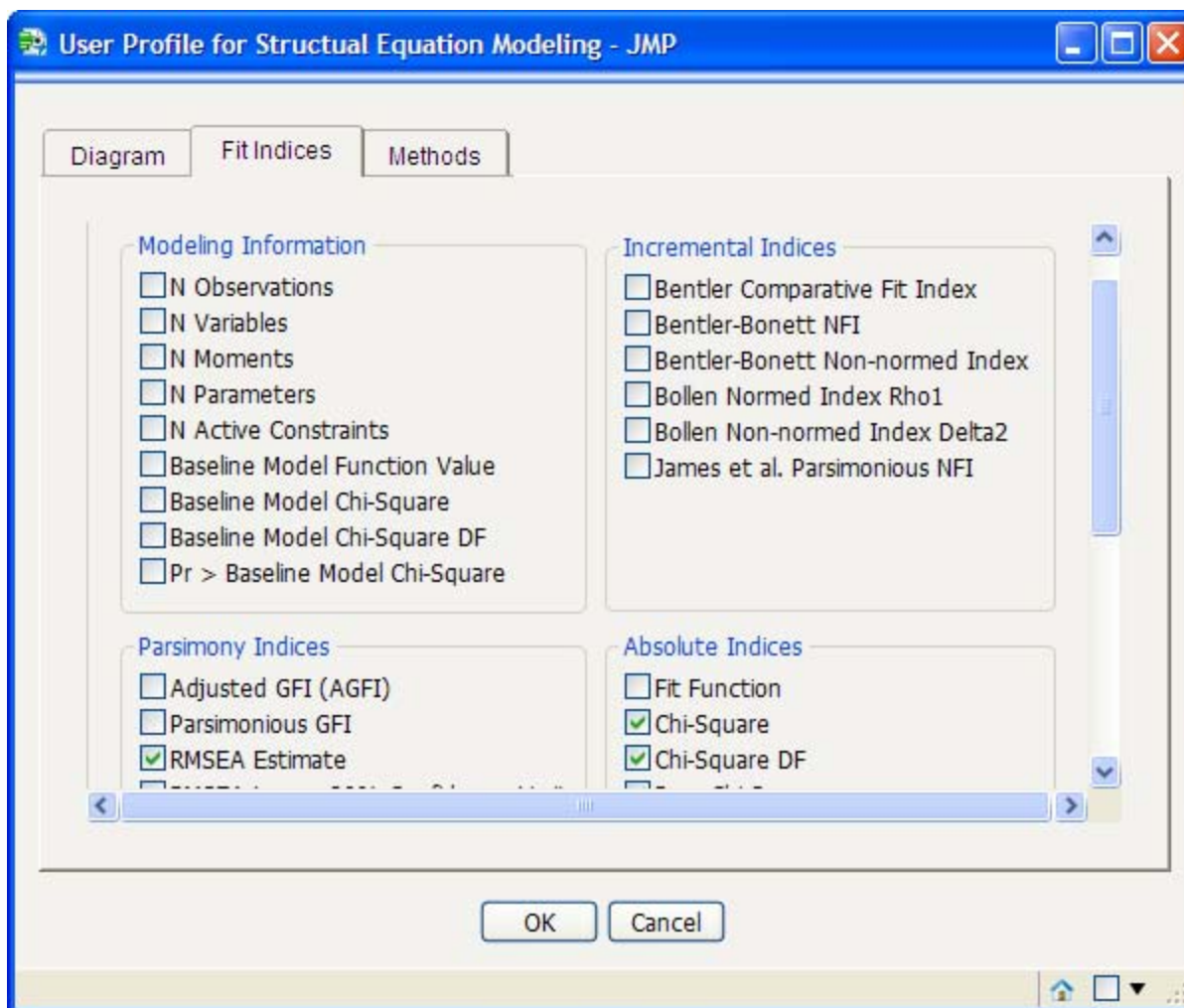
As shown in Figure 17, the **Diagram** tab shows several preferences that you can select for creating a model specification in both the Model Library and Single-Group Analysis windows. You can use either a circle or an oval to represent a latent variable and a rectangle or a square to represent an observed variable.

When you drag a variable name from the variables list to a variable shape in the diagram, the variable is created in the diagram and a path is drawn between the variable that was dragged and the variable that was the target of the drag. The **Arrow Direction** preference enables you to specify whether you want the arrow to be drawn from the target variable to the new variable or from the new variable to the target variable.

The **Fit Indices** tab lists the fit indices that are displayed in the results table, as shown in Figure 18. For each fit index that you want displayed on the **Results** tab of the Single-Group Analysis window, select the corresponding check box. Clear the check boxes that correspond to any selected fit indices that you do not want displayed.

Introducing SAS Structural Equation Modeling for JMP, continued

Figure 18. User Profile Window with Fit Indices Tab



The **Methods** tab contains options for the Single-Group Analysis window. You can choose to analyze the correlations or covariances. If you are analyzing covariances, you can choose to analyze mean structure. You can also choose from several estimation and optimization methods.

SYSTEM REQUIREMENTS AND INSTALLATION

SAS Structural Equation Modeling for JMP is available for PCs that run the Microsoft Windows 7, XP, and Vista operating systems. It requires JMP 9.0.2 or later and SAS/STAT 9.22 or later. You can use SAS software that is installed on your PC, or you can access it from a remote machine.

SAS Structural Equation Modeling for JMP and JMP software must be installed on the client machine. The installation of SAS Structural Equation Modeling for JMP occurs automatically if Foundation SAS is installed on the client machine. If you are using SAS from a remote server, you must use the SAS Deployment Wizard to install SAS Structural Equation Modeling for JMP on the client machine. The order of the JMP and SAS Structural Equation Modeling for JMP installations is not important.

CONCLUSION

SAS Structural Equation Modeling for JMP combines the power of SAS/STAT software with the JMP user interface to provide a new user interface that makes creating and analyzing structural equation models easy. You can use its graphical model builder to efficiently create models. You can perform a single-group structural equation model analysis and save the results for later use.

Introducing SAS Structural Equation Modeling for JMP, continued

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