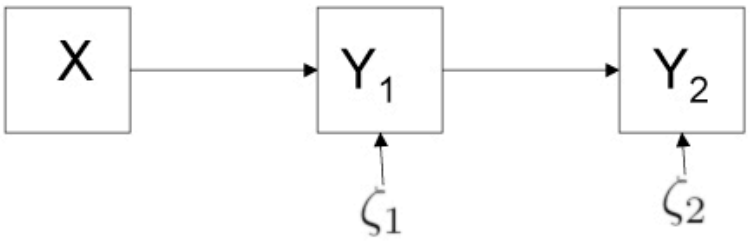
Introduction to SAS `proc calis`

```
/* path1.sas */
%include 'SenicRead.sas';
title2 'Path Analysis Example for 3 Observed Variables';

/*********************************************************************
*                                                                    *
* Cases are hospitals                                                *
*                                                                    *
*        stay     Average length of stay in days.                    *
*        infrisk  Estimated probability of getting a respiratory     *
*                 infection in hospital.                             *
*        xratio   Chest X-rays of patients with no sign of pneumonia *
*********************************************************************/

proc calis cov;          /* Analyze the covariance matrix (Default is corr) */
     title3 'Stay -> Infrisk -> Xratio';
     var stay infrisk xratio;  /* Observed vars are in the data set */
     lineqs              /* Simultaneous equations, separated by commas */
          infrisk = gamma stay + e1,
          xratio  = beta infrisk + e2;
     std                  /* Variances (not standard deviations) */
          stay = phi,
          e1 = psi1,
          e2 = psi2;
     /* Specify covariances of exogenous vars with the cov
        statement. Unmentioned pairs get covariance zero.  */

     bounds 0.0 < phi psi1 psi2; /* Variances are greater than zero */

proc calis cov;
     title3 'Backwards: Xratio -> Infrisk -> Stay';
     var stay infrisk xratio;
     lineqs
          infrisk = gamma xratio + e1,
          stay  = beta infrisk + e2;
     std                  /* Variances (not standard deviations) */
          xratio = phi,
          e1 = psi1,
          e2 = psi2;

bounds 0.0 < phi psi1 psi2; /* Variances are greater than zero */

proc calis cov;
     title3 'Just Identified (Saturated) Model';
     var stay infrisk xratio;
     lineqs
          infrisk = gamma1 stay + e1,
          xratio  = gamma2 stay + beta infrisk + e2;
     std                  /* Variances (not standard deviations) */
          stay = phi,
          e1 = psi1,
          e2 = psi2;

     bounds 0.0 < phi psi1 psi2; /* Variances are greater than zero */
```



$$
\begin{aligned}
Y_1 &= \gamma X + \zeta_1 \\
Y_2 &= \beta Y_1 + \zeta_2
\end{aligned}
$$

$$E(X) = E(\zeta_1) = E(\zeta_2) = 0$$

$$V(X) = \phi, V(\zeta_1) = \psi_1, V(\zeta_2) = \psi_2$$

X, ζ_1, ζ_2 are independent

Everything is normal

```
proc calis cov;          /* Analyze the covariance matrix (Default is corr) */
     title3 'Stay -> Infrisk -> Xratio';
     var stay infrisk xratio;  /* Observed vars are in the data set */
     lineqs              /* Simultaneous equations, separated by commas */
          infrisk = gamma stay + e1,
          xratio  = beta infrisk + e2;
     std                  /* Variances (not standard deviations) */
          stay = phi,
          e1 = psi1,
          e2 = psi2;
     /* Specify covariances of exogenous vars with the cov
        statement. Unmentioned pairs get covariance zero.  */

     bounds 0.0 < phi psi1 psi2; /* Variances are greater than zero */
```

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

LINEQS Model Statement

		Matrix	Rows	Columns	------Matrix Type-------	
Term 1	1	_SEL_	3	5	SELECTION	
	2	_BETA_	5	5	EQSBETA	IMINUSINV
	3	_GAMMA_	5	3	EQSGAMMA	
	4	_PHI_	3	3	SYMMETRIC	

The 2 Endogenous Variables

Manifest	infrisk	xratio
Latent		

The 3 Exogenous Variables

Manifest	stay	
Latent		
Error	e1	e2

The CALIS Procedure
Covariance Structure Analysis: Pattern and Initial Values

Manifest Variable Equations with Initial Estimates

```
infrisk =        .*stay    +  1.0000 e1
                  gamma
xratio  =        .*infrisk +  1.0000 e2
                  beta
```

Variances of Exogenous Variables

Variable	Parameter	Estimate
stay	phi	.
e1	psi1	.
e2	psi2	.

Study of the Efficacy of Nosocomial Infection Control (SENIC) 3
Path Analysis Example for 3 Observed Variables
Stay -> Infrisk -> Xratio

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Observations	113	Model Terms	1
Variables	3	Model Matrices	4
Informations	6	Parameters	5

	Variable	Mean	Std Dev
stay	Av length of hospital stay, in days	9.64832	1.91146
infrisk	Prob of acquiring infection in hospital	4.35487	1.34091
xratio	# x-rays / # no signs of pneumonia	81.63009	19.36674

Set Covariances of Exogenous Manifest Variables

stay

NOTE: Some initial estimates computed by two-stage LS method.

Study of the Efficacy of Nosocomial Infection Control (SENIC) 4
Path Analysis Example for 3 Observed Variables
Stay -> Infrisk -> Xratio

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Vector of Initial Estimates

	Parameter	Estimate	Type
1	beta	10.35236	Matrix Entry: _BETA_[2:1]
2	gamma	0.37422	Matrix Entry: _GAMMA_[1:1]
3	phi	3.65366	Matrix Entry: _PHI_[1:1]
4	psi1	1.28638	Matrix Entry: _PHI_[2:2]
5	psi2	324.04169	Matrix Entry: _PHI_[3:3]

Path Analysis Example for 3 Observed Variables
Stay -> Infrisk -> Xratio

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Levenberg-Marquardt Optimization

Scaling Update of More (1978)

Parameter Estimates	5
Functions (Observations)	6
Lower Bounds	3
Upper Bounds	0

Optimization Start

Active Constraints	0	Objective Function	0.1191390524
Max Abs Gradient Element	0.0422313093	Radius	1

Iter	Rest arts	Func Calls	Act Con	Objective Function	Obj Fun Change	Max Abs Gradient Element	Lambda	Actual Over Pred Change
1	0	2	0	0.03878	0.0804	0.000248	0	1.000
2	0	3	0	0.03537	0.00341	1.15E-15	0	1.057

Optimization Results

Iterations	2	Function Calls	4
Jacobian Calls	3	Active Constraints	0
Objective Function	0.0353716706	Max Abs Gradient Element	1.150916E-15
Lambda	0	Actual Over Pred Change	1.0570208096
Radius	0.1607096852		

ABSGCONV convergence criterion satisfied.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function	0.0354
Goodness of Fit Index (GFI)	0.9774
GFI Adjusted for Degrees of Freedom (AGFI)	0.8641
Root Mean Square Residual (RMR)	2.1241
Parsimonious GFI (Mulaik, 1989)	0.3258
Chi-Square	3.9616
Chi-Square DF	1
Pr > Chi-Square	0.0465
Independence Model Chi-Square	67.227
Independence Model Chi-Square DF	3
RMSEA Estimate	0.1626
RMSEA 90% Lower Confidence Limit	0.0168
RMSEA 90% Upper Confidence Limit	0.3435
ECVI Estimate	0.1280
ECVI 90% Lower Confidence Limit	.
ECVI 90% Upper Confidence Limit	0.2218
Probability of Close Fit	0.0779
Bentler's Comparative Fit Index	0.9539
Normal Theory Reweighted LS Chi-Square	3.8924
Akaike's Information Criterion	1.9616
Bozdogan's (1987) CAIC	-1.7658
Schwarz's Bayesian Criterion	-0.7658
McDonald's (1989) Centrality	0.9870
Bentler & Bonett's (1980) Non-normed Index	0.8617
Bentler & Bonett's (1980) NFI	0.9411
James, Mulaik, & Brett (1982) Parsimonious NFI	0.3137
Z-Test of Wilson & Hilferty (1931)	1.7067
Bollen (1986) Normed Index Rho1	0.8232
Bollen (1988) Non-normed Index Delta2	0.9553
Hoelter's (1983) Critical N	110

Study of the Efficacy of Nosocomial Infection Control (SENIC) 7
Path Analysis Example for 3 Observed Variables
Stay -> Infrisk -> Xratio

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Estimates

```
infrisk =   0.3742*stay     +  1.0000 e1
Std Err     0.0561 gamma
t Value     6.6744
xratio  =   6.5469*infrisk  +  1.0000 e2
Std Err     1.2165 beta
t Value     5.3819
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
stay	phi	3.65366	0.48824	7.48
e1	psi1	1.28638	0.17190	7.48
e2	psi2	298.00337	39.82238	7.48

Study of the Efficacy of Nosocomial Infection Control (SENIC) 8
Path Analysis Example for 3 Observed Variables
Stay -> Infrisk -> Xratio

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Standardized Estimates

```
infrisk =   0.5334*stay    +  0.8458 e1
                gamma
xratio  =   0.4533*infrisk +  0.8914 e2
                beta
```

Squared Multiple Correlations

	Variable	Error Variance	Total Variance	R-Square
1	infrisk	1.28638	1.79803	0.2846
2	xratio	298.00337	375.07052	0.2055

For the fairly reasonable forwards path model, the Likelihood Ratio test for goodness of fit yields chisquare = 3.9616. For the bone-headed backwards model, we get

---

```
Study of the Efficacy of Nosocomial Infection Control (SENIC)       14
       Path Analysis Example for 3 Observed Variables
            Backwards: Xratio -> Infrisk -> Stay

                    The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function                                          0.0354
Goodness of Fit Index (GFI)                           0.9774
GFI Adjusted for Degrees of Freedom (AGFI)            0.8641
Root Mean Square Residual (RMR)                       2.1241
Parsimonious GFI (Mulaik, 1989)                       0.3258
Chi-Square                                            3.9616 <-
Chi-Square DF                                              1
Pr > Chi-Square                                       0.0465
Independence Model Chi-Square                         67.227
Independence Model Chi-Square DF                           3
RMSEA Estimate                                        0.1626
RMSEA 90% Lower Confidence Limit                      0.0168
RMSEA 90% Upper Confidence Limit                      0.3435
ECVI Estimate                                         0.1280
ECVI 90% Lower Confidence Limit                            .
ECVI 90% Upper Confidence Limit                       0.2218
Probability of Close Fit                              0.0779
Bentler's Comparative Fit Index                       0.9539
Normal Theory Reweighted LS Chi-Square                3.8924
Akaike's Information Criterion                        1.9616
Bozdogan's (1987) CAIC                               -1.7658
Schwarz's Bayesian Criterion                         -0.7658
McDonald's (1989) Centrality                          0.9870
Bentler & Bonett's (1980) Non-normed Index            0.8617
Bentler & Bonett's (1980) NFI                         0.9411
James, Mulaik, & Brett (1982) Parsimonious NFI        0.3137
Z-Test of Wilson & Hilferty (1931)                    1.7067
Bollen (1986) Normed Index Rho1                       0.8232
Bollen (1988) Non-normed Index Delta2                 0.9553
Hoelter's (1983) Critical N                              110
```

Saturated Model

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Fit Function	0.0000
Goodness of Fit Index (GFI)	1.0000
GFI Adjusted for Degrees of Freedom (AGFI)	.
Root Mean Square Residual (RMR)	0.0000
Parsimonious GFI (Mulaik, 1989)	0.0000
Chi-Square	0.0000
Chi-Square DF	0
Pr > Chi-Square	<.0001
Independence Model Chi-Square	67.227
Independence Model Chi-Square DF	3
RMSEA Estimate	0.0000
RMSEA 90% Lower Confidence Limit	.
RMSEA 90% Upper Confidence Limit	.
ECVI Estimate	0.1111
ECVI 90% Lower Confidence Limit	.
ECVI 90% Upper Confidence Limit	.
Probability of Close Fit	.
Bentler's Comparative Fit Index	1.0000
Normal Theory Reweighted LS Chi-Square	0.0000
Akaike's Information Criterion	0.0000
Bozdogan's (1987) CAIC	0.0000
Schwarz's Bayesian Criterion	0.0000
McDonald's (1989) Centrality	1.0000
Bentler & Bonett's (1980) Non-normed Index	.
Bentler & Bonett's (1980) NFI	1.0000
James, Mulaik, & Brett (1982) Parsimonious NFI	0.0000
Z-Test of Wilson & Hilferty (1931)	.
Bollen (1986) Normed Index Rho1	.
Bollen (1988) Non-normed Index Delta2	1.0000
Hoelter's (1983) Critical N	.

The CALIS Procedure
Covariance Structure Analysis: Maximum Likelihood Estimation

Manifest Variable Equations with Estimates

```
infrisk =   0.3742*stay     +  1.0000 e1
Std Err     0.0561 gamma1
t Value     6.6744
xratio  =   5.0333*infrisk  +  1.9905*stay     +  1.0000 e2
Std Err     1.4130 beta        0.9912 gamma2
t Value     3.5622             2.0081
```

Variances of Exogenous Variables

Variable	Parameter	Estimate	Standard Error	t Value
stay	phi	3.65366	0.48824	7.48
e1	psi1	1.28638	0.17190	7.48
e2	psi2	287.64674	38.43841	7.48