TABLE 6.1 Descriptive Statistics and Intercorrelations (n = 202)

	Mean	SD	*1*	*2*	*3*	*4*
1. Participation	2.62	1.71	1.00			
2. Willingness to work for the union	10.32	3.88	0.47	1.00		
3. Union loyalty	20.00	5.55	0.39	0.71	1.00	
4. Instrumentality beliefs	19.87	5.60	0.29	0.48	0.61	1.00
5. Subjective norms	18.09	9.99	0.29	0.53	0.51	0.39

a better fit to the data than did the original model, $\chi^2_{\text{difference}}(1) = 30.44$, $p < .01$; $\chi^2(4) = 2.80$, ns; GFI = .99; AGFI = .98; RMSEA = .00; NFI = .99; CFI = 1.00; PNFI = .40.

Standardized parameter estimates for the revised model are presented in Figure 6.4. As shown, participation in union activities was predicted by willingness to work for the union ($\beta = .47, p < .01$), which in turn was predicted by both union loyalty ($\beta = .60, p < .01$) and subjective norms ($\beta = .22, p < .01$). Union loyalty was predicted by both perceptions of instrumentality ($\beta = .49, p < .01$) and subjective norms ($\beta = .32, p < .01$). The model explained 22% of the variance in participation, 54% of the variance in willingness to work for the union, and 46% of the variance in union loyalty.

Note

1. Rank and order conditions refer to the identification of nonrecursive structural models and will not be dealt with further.

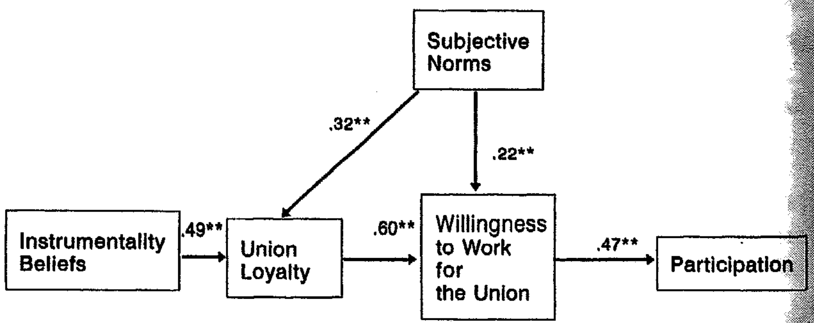

Figure 6.4.

CHAPTER 7 *Latent Variable Path Analysis*

The true power of structural equation modeling is the ability to estimate a complete model incorporating both measurement and structural considerations. In this chapter, we consider such a latent variable path analysis. Latent variable path analysis uses the full LISREL model (all eight matrices) to combine measurement and structural considerations. Thus, in conducting the analysis we will be equally concerned with assessing the proposed measurement relations (i.e., through confirmatory factor analysis) and the proposed structural relations (i.e., through path analysis).

Model Specification

To illustrate the use of latent variable path analysis, we will consider a reduced form of the model of perceived risk and participation in occupational health and safety programs presented by Cree and Kelloway (in press). There are two components to the model. First, the structural model specifies the predictive relationships among the latent variables. Second, the measurement model defines how the latent variables are measured (i.e., represented by indicators).

The structural model we were interested in was based on the hypotheses that two factors, perceived health and safety climate and accident history, predicted perceived risk in the workplace, which in turn predicted willingness to participate in health and safety programs (see Figure 7.1).

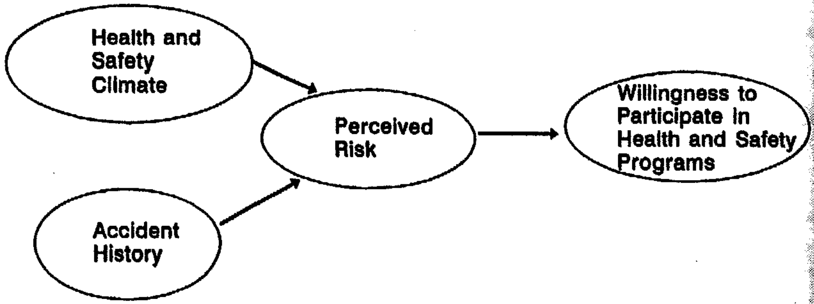

Figure 7.1.

In addition to the structural relations, we also were interested in using latent variables; that is, each construct in the model would be represented by multiple indicators. Bentler (1980, p. 425) notes that

> choosing the right number of indicators for each LV [latent variable] is something of an art; in principle, the more the better; in practice, too many indicators make it difficult if not impossible to fit a model to data.

Moreover, as noted in Chapter 5, Bollen (1989) has suggested that a confirmatory factor analysis model (which uses indicators to represent latent variables or factors) should incorporate at least two indicators per latent variable. For each construct (latent variable) in the model, therefore, we attempted to identify at least two observed indicators (actual items).

Specifically, perceived health and safety climate was assessed with three scales that asked respondents to rate their perceptions of their manager's, supervisor's, and coworkers' commitment to health and safety in the workplace. Accident history was assessed by two questionnaires: one asking about the respondent's own history with accidents in the workplace and the other asking whether respondents had heard about or witnessed accidents in the workplace.

The endogenous variables also were measured with multiple indicators. Perceived risk in the workplace was measured by two questionnaires asking respondents how risky they thought the workplace was (a) for them personally and (b) for their coworkers. Finally, willingness to participate in health and safety programs was measured by a 12-item questionnaire assessing respondents' willingness to participate in a

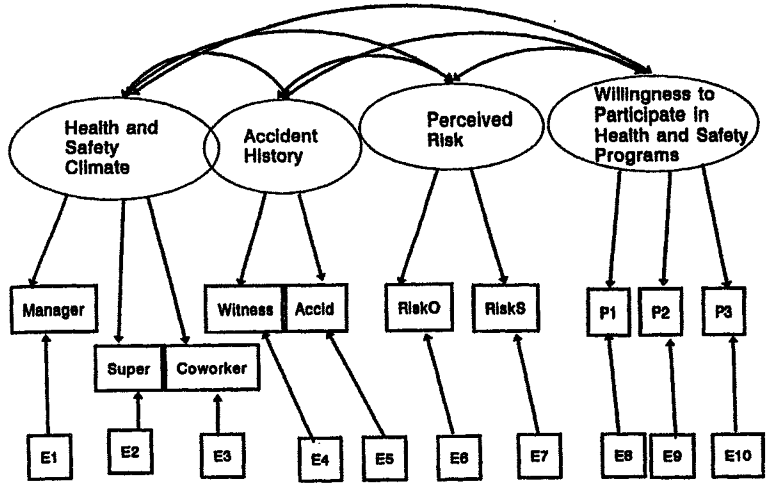

Figure 7.2.

variety of health and safety programs. Because we wanted to generate multiple indicators for this construct, we randomly assigned items to one of three indicator variables (i.e., three subscales with four items per scale). The measurement model described above is given in Figure 7.2. Integrating the structural and measurement models results in the full latent variable path analysis model given in Figure 7.3.

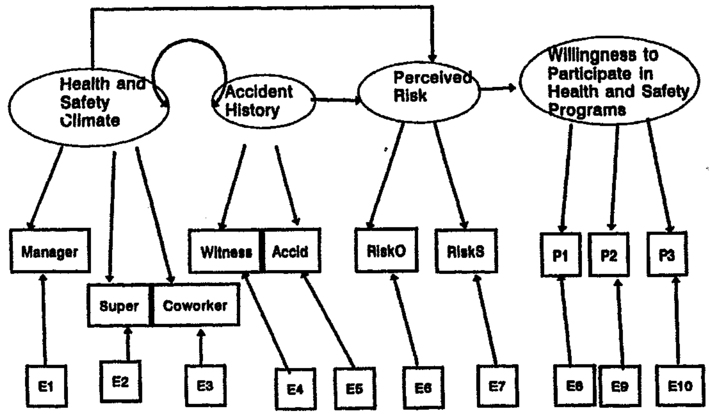

Figure 7.3.

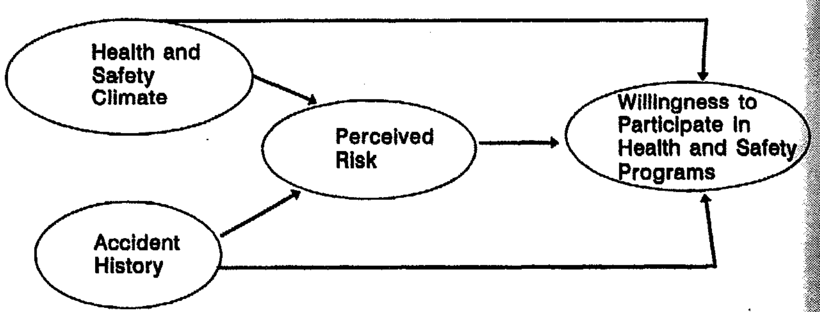

Figure 7.4.

Alternative Model Specifications

The central hypothesis of our model is that risk perceptions mediate the relationships between health and safety climate and accident history, as the predictors, and willingness to participate in health and safety programs in the workplace, as the outcome. Consistent with the discussion of mediated relationships in the previous chapter, two plausible rival model specifications are the partially mediated (which adds paths from the two predictors to willingness to participate, see Figure 7.4) and nonmediated (which deletes the path from risk perception to willingness to participate, see Figure 7.5) models.

Model Testing Strategy

There is a major complication in testing latent variable models. If the model does not fit, the lack of fit can be attributable to (a) an ill-fitting

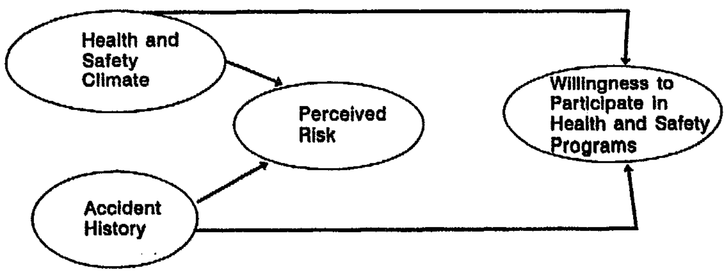

Figure 7.5.

measurement model, (b) an ill-fitting structural model, or (c) both (Anderson & Gerbing, 1988). Accordingly, Anderson and Gerbing recommend a strategy of two-stage modeling in which one first assesses the fit of the measurement model and then moves to a consideration of the structural model.

The strategy is based on the observation that the latent variable structural model incorporates the measurement model. In fact, at least with respect to the relationships among the latent variables, one can think of the measurement model as a saturated or just-identified model. That is, the measurement model allows a relationship (i.e., a correlation, see Figure 7.2) between each pair of latent variables.

This being the case, the fit of the measurement model provides a baseline for the fit of the full latent variable model. The full model, incorporating both structural and measurement relationships, cannot provide a better fit to the data than does the measurement model.

Incorporating Anderson and Gerbing's (1988) suggestions with our three hypothesized structural models suggests a sequence of model tests in which we first establish the fit of the measurement model and then move to a consideration of the structural parameters of interest. The remainder of this chapter, therefore, provides the assessment of the measurement model, followed by assessment of the full model.

From Pictures to LISREL

The translation of the path diagrams proceeds just as in previous examples. First, we will translate the measurement model. For purposes of illustration, we will assess the measurement model on the endogenous (*Y*) side of the LISREL model. (Note that it should not matter whether one operationalizes the factor analysis on the endogenous or exogenous side of the model.)

Operationalizing a confirmatory factor analysis on the endogenous side of the LISREL model still requires that you specify a scale of measurement for the latent variables. Recall that in Chapter 5 we specified the scale of measurement by declaring PH = ST, which assigned the latent variables to be standardized. This option is not available on the endogenous side of the model (you cannot declare PS = ST). The scale of measurement therefore is assigned by fixing one of the latent variable-indicator paths to equal 1.0 for each latent variable. In effect, this specification tells LISREL that the latent variable is on the same scale of measurement as the indicator. It should not make a great deal of difference which indicator is chosen to represent the scale of measure-

TABLE 7.1 Lambda Y (Factor Loadings for Y)

	Health and Safety Climate	*Accident History*	*Perceived Risk*	*Willingness to Participate*
1. Manager commitment	1.00	FIxed	FIxed	FIxed
2. Supervisor commitment	FRee	FIxed	FIxed	FIxed
3. Coworker commitment	FRee	FIxed	FIxed	FIxed
4. Own accident history	FIxed	1.00	FIxed	FIxed
5. Witnessed accidents	FIxed	FRee	FIxed	FIxed
6. Risk for self	FIxed	FIxed	1.00	FIxed
7. Risk for others	FIxed	FIxed	FRee	FIxed
8. Participate 1	FIxed	FIxed	FIxed	1.00
9. Participate 2	FIxed	FIxed	FIxed	FRee
10. Participate 3	FIxed	FIxed	FIxed	FRee

ment for the latent variable (assuming that the indicators are all measured along a similar scale).

The forms of the three matrices (LY, PS, and TE) are presented below. Because there are four latent variables with ten indicators, LY will have four columns and ten rows. PS will be a 4 × 4 symmetric matrix. Note that PS has all elements freed; that is, we are going to estimate both the variances for the latent variables and the covariances among the latent variables. Because we will again assume that there are no correlated errors of measurement among the indicator variables, TE is declared to be diagonal and free; that is, TE is a vector with ten elements (one for each observed variable).

Identification and Estimation

The model meets Bollen's (1989) criteria for identification. That is, each latent variable has at least two indicators, and the latent variables are allowed to correlate freely with one another. Moreover, like all confirmatory factor analysis models, the model is recursive. (The causal flow is always from the latent variables to the observed indicators.)

TABLE 7.2 PSI (Covariances for E)

	Health and Safety Climate	*Accident History*	*Perceived Risk*	*Willingness to Participate*
1. Health and safety climate	FRee			
2. Accident history	FRee	FRee		
3. Perceived risk	FRee	FRee	FRee	
4. Willingness to participate	FRee	FRee	FRee	FRee

TABLE 7.3 TE (Unique Factors for the Endogenous Variables)

1. Manager commitment	FRee
2. Supervisor commitment	FRee
3. Coworker commitment	FRee
4. Own accident history	FRee
5. Witnessed accidents	FRee
6. Risk for self	FRee
7. Risk for others	FRee
8. Participate 1	FRee
9. Participate 2	FRee
10. Participate 3	FRee

The source code used to estimate the model is given below.

```
TI MEASUREMENT MODEL
DA NI = 13 NO = 115 MA = CM
```

Note: There are 10 indicators and 115 observations, and I want to analyze the covariance matrix.

```
ME
     10.7 8.9 10.9 18.6 3.8 5.5 5.7 5.5 1.7 0.9
```

Note: These are the item means.

```
SD
     2.7 3.1 2.9 7.3 1.5 1.4 1.2 1.2 1.7 0.8
```

Note: These are the item standard deviations.

```
KM SY
    1.00
     .76  1.00
     .78   .68  1.00
    -.05   .01  -.05  1.00
     .10   .09   .08   .52  1.00
     .01   .08   .14  -.28  -.22  1.00
```

```
          .20   .18   .29  -.44  -.29   .54  1.00
          .22   .25   .29  -.42  -.31   .57   .65  1.00
          .00   .00  -.05   .42   .22  -.13  -.26  -.20  1.00
          .12   .03   .11   .26   .30  -.12  -.20  -.17   .47
     1.00
```

Note: This is the lower half of the correlation matrix.

```
LA
  p1 p2 p3 risks riskc mgr super cow own witness
```

Note: These are variable labels for the indicator variables.

```
MO NY = 10 NE = 4 PS = SY,FR
```

Note: The model declares 10 indicators and 4 latent variables. By declaring NY and NE, LISREL selects a confirmatory factor analysis on the endogenous side of the model involving matrices LY, PS, and TE.

```
LE
  part risk climate accid
```

Note: These are labels for the latent variables.

```
VA 1.0 LY(1,1) LY(4,2) LY(6,3) LY(9,4)
```

Note: This statement inserts the value 1.0 in the designated locations, thereby declaring a scale for the latent variables. Recall that matrix LY has all elements FIxed by default, so no further specification is necessary.

```
FR LY(2,1) LY(3,1) LY(5,2) LY(7,3) LY(8,3) LY(10,4)
```

Note: Frees the remaining parameters specified in the measurement model.

```
OU ML SC TV MI
```

Note: Asks for maximum likelihood estimation. I want to see the completely standardized solution, the *t* values, and the modification indices.

Edited Output

```
NUMBER OF INPUT VARIABLES 10
NUMBER OF Y - VARIABLES   10
NUMBER OF X - VARIABLES    0
NUMBER OF ETA - VARIABLES  4
NUMBER OF KSI - VARIABLES  0
NUMBER OF OBSERVATIONS   115
```

COVARIANCE MATRIX TO BE ANALYZED

	p1	p2	p3	risks	riskc	plant
p1	7.30					
p2	6.27	9.27				
p3	6.05	5.93	8.21			
risks	-1.03	0.20	-1.11	53.60		
riskc	0.40	0.43	0.34	5.68	2.23	
plant	0.04	0.35	0.59	-2.99	-0.47	2.08
super	0.67	0.67	1.03	-3.97	-0.54	0.96
cow	0.70	0.90	0.98	-3.61	-0.54	0.96
dir	-0.02	-0.01	-0.24	5.21	0.55	-0.31
vic	0.26	0.08	0.25	1.53	0.36	-0.14

COVARIANCE MATRIX TO BE ANALYZED

	super	cow	dir	vic
super	1.55			
cow	0.95	1.39		
dir	-0.55	-0.39	2.82	
vic	-0.20	-0.17	0.64	0.66

PARAMETER SPECIFICATIONS

LAMBDA-Y

	part	risk	climate	accid
p1	0	0	0	0
p2	1	0	0	0
p3	2	0	0	0
risks	0	0	0	0
riskc	0	3	0	0
plant	0	0	0	0
super	0	0	4	0

cow	0	0	5	0
dir	0	0	0	0
vic	0	0	0	6

PSI

	part	risk	climate	accid
part	7			
risk	8	9		
climate	10	11	12	
accid	13	14	15	16

THETA-EPS

p1	p2	p3	risks	riskc	plant
17	18	19	20	21	22

THETA-EPS

super	cow	dir	vic
23	24	25	26

Number of Iterations = 9

LISREL ESTIMATES (MAXIMUM LIKELIHOOD)

LAMBDA-Y

	part	risk	climate	accid
p1	1.00	- -	- -	- -
p2	1.00	- -	- -	- -
	(0.09)			
	11.18			
p3	0.97	- -	- -	- -
	(0.08)			
	11.68			
risks	- -	1.00	- -	- -
riskc	- -	0.15	- -	- -
		(0.03)		
		4.93		
plant	- -	- -	1.00	- -
super	- -	- -	1.05	- -
			(0.16)	
			6.68	
cow	- -	- -	1.03	- -
			(0.15)	
			6.75	

dir	- -	- -	- -	1.00
vic	- -	- -	- -	0.37
				(0.10)
				3.62

COVARIANCE MATRIX OF ETA

	part	risk	climate	accid
part	6.22			
risk	-0.14	38.39		
climate	0.68	-3.51	0.90	
accid	0.10	4.84	-0.43	1.73

PSI

	part	risk	climate	accid
part	6.22			
	(1.01)			
	6.14			
risk	-0.14	38.39		
	(1.74)	(9.44)		
	-0.08	4.07		
climate	0.68	-3.51	0.90	
	(0.27)	(0.88)	(0.25)	
	2.46	-4.00	3.63	
accid	0.10	4.84	-0.43	1.73
	(0.39)	(1.22)	(0.17)	(0.56)
	0.26	3.97	-2.53	3.09

THETA-EPS

p1	p2	p3	risks	riskc	plant
1.07	3.04	2.34	15.20	1.39	1.19
(0.36)	(0.53)	(0.44)	(6.84)	(0.23)	(0.19)
2.95	5.78	5.27	2.22	5.95	6.41

THETA-EPS

super	cow	dir	vic
0.55	0.44	1.09	0.43
(0.12)	(0.11)	(0.46)	(0.08)
4.63	4.10	2.33	5.13

```
SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES
     p1        p2        p3      risks     riskc     plant
   ------    ------    ------   ------    ------    ------
    0.85      0.67      0.72     0.72      0.38      0.43

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES
  super      cow       dir       vic
  ------    ------    ------    ------
   0.64      0.68      0.61      0.36

GOODNESS OF FIT STATISTICS
     CHI-SQUARE WITH 29 DEGREES OF FREEDOM =  30.89 (P = 0.37)
   ESTIMATED NON-CENTRALITY PARAMETER (NCP) =  1.89
     90 PERCENT CONFIDENCE INTERVAL FOR NCP =  (0.0 ; 19.50)
                  MINIMUM FIT FUNCTION VALUE =  0.27
 POPULATION DISCREPANCY FUNCTION VALUE (F0) =  0.017
      90 PERCENT CONFIDENCE INTERVAL FOR F0 =  (0.0 ; 0.17)
ROOT MEAN SQUARE ERROR OF APPROXIMATION (RMSEA) =  0.024
   90 PERCENT CONFIDENCE INTERVAL FOR RMSEA =  (0.0 ; 0.077)
    P-VALUE FOR TEST OF CLOSE FIT (RMSEA < 0.05) =  0.73
      EXPECTED CROSS-VALIDATION INDEX (ECVI) =  0.73
    90 PERCENT CONFIDENCE INTERVAL FOR ECVI =  (0.71 ; 0.88)
                   ECVI FOR SATURATED MODEL =  0.96
                 ECVI FOR INDEPENDENCE MODEL =  4.41
  CHI-SQUARE FOR INDEPENDENCE MODEL WITH 45
                         DEGREES OF FREEDOM = 482.66
                           INDEPENDENCE AIC = 502.66
                                  MODEL AIC =  82.89
                              SATURATED AIC = 110.00
                          INDEPENDENCE CAIC = 540.11
                                 MODEL CAIC = 180.26
                             SATURATED CAIC = 315.97
              ROOT MEAN SQUARE RESIDUAL (RMR) =  0.27
                             STANDARDIZED RMR =  0.050
                  GOODNESS OF FIT INDEX (GFI) =  0.95
         ADJUSTED GOODNESS OF FIT INDEX (AGFI) =  0.90
       PARSIMONY GOODNESS OF FIT INDEX (PGFI) =  0.50
                     NORMED FIT INDEX (NFI) =  0.94
                NON-NORMED FIT INDEX (NNFI) =  0.99
            PARSIMONY NORMED FIT INDEX (PNFI) =  0.60
                 COMPARATIVE FIT INDEX (CFI) =  1.00
                 INCREMENTAL FIT INDEX (IFI) =  1.00
```



```
              RELATIVE FIT INDEX (RFI) =  0.90
                    CRITICAL N (CN) = 184.00

MODIFICATION INDICES AND EXPECTED CHANGE MODIFICATION
INDICES FOR LAMBDA-Y
             part      risk     climate    accid
            ------    ------    ------    ------
    p1       - -       0.02      2.74      0.28
    p2       - -       0.39      0.00      0.00
    p3       - -       0.54      3.56      0.38
 risks      2.51       - -       0.12      0.22
 riskc      2.51       - -       0.12      0.22
 plant      3.42       0.64      - -       0.60
 super      0.15       0.79      - -       1.47
   cow      1.01       0.05      - -       0.36
   dir      1.75       1.84      0.01      - -
   vic      1.75       1.84      0.01      - -

EXPECTED CHANGE FOR LAMBDA-Y
             part      risk     climate    accid
            ------    ------    ------    ------
    p1       - -       0.00     -0.30      0.07
    p2       - -       0.02      0.00      0.00
    p3       - -      -0.02      0.38     -0.09
 risks     -0.55       - -      -0.63      0.63
 riskc      0.08       - -       0.09     -0.09
 plant     -0.09       0.02      - -       0.09
 super      0.02      -0.02      - -      -0.11
   cow      0.04       0.01      - -       0.05
   dir     -0.11       0.72      0.02      - -
   vic      0.04      -0.27     -0.01      - -

STANDARDIZED EXPECTED CHANGE FOR LAMBDA-Y
             part      risk     climate    accid
            ------    ------    ------    ------
    p1       - -       0.02     -0.28      0.09
    p2       - -       0.13      0.00      0.00
    p3       - -      -0.14      0.36     -0.12
 risks     -1.38       - -      -0.59      0.83
 riskc      0.20       - -       0.09     -0.12
 plant     -0.23       0.14      - -       0.11
```

super	0.04	-0.14	- -	-0.15
cow	0.10	0.03	- -	0.07
dir	-0.27	4.46	0.02	- -
vic	0.10	-1.66	-0.01	- -

COMPLETELY STANDARDIZED EXPECTED CHANGE FOR LAMBDA-Y

	part	risk	climate	accid
p1	- -	0.01	-0.10	0.03
p2	- -	0.04	0.00	0.00
p3	- -	-0.05	0.13	-0.04
risks	-0.19	- -	-0.08	0.11
riskc	0.14	- -	0.06	-0.08
plant	-0.16	0.10	- -	0.08
super	0.03	-0.11	- -	-0.12
cow	0.08	0.03	- -	0.06
dir	-0.16	2.66	0.01	- -
vic	0.12	-2.03	-0.01	- -

NO NON-ZERO MODIFICATION INDICES FOR PSI

MODIFICATION INDICES FOR THETA-EPS

	p1	p2	p3	risks	riskc	plant
p1	- -					
p2	4.07	- -				
p3	0.24	4.67	- -			
risks	3.32	1.24	0.13	- -		
riskc	0.28	0.00	0.25	- -	- -	
plant	5.22	0.17	0.87	0.99	0.02	- -
super	0.01	0.97	1.42	0.28	0.05	0.28
cow	0.18	1.38	0.00	0.00	0.25	1.54
dir	0.01	0.20	1.08	5.47	4.24	0.45
vic	0.88	1.81	1.24	4.94	3.74	0.02

MODIFICATION INDICES FOR THETA-EPS

	super	cow	dir	vic
super	- -			
cow	4.18	- -		
dir	0.59	0.57	- -	
vic	0.06	0.10	- -	- -

EXPECTED CHANGE FOR THETA-EPS

	p1	p2	p3	risks	riskc	plant
p1	- -					
p2	2.80	- -				
p3	0.71	-2.54	- -			
risks	-1.46	1.13	0.33	- -		
riskc	0.09	0.00	0.10	- -	- -	
plant	-0.37	0.09	0.18	0.63	-0.02	- -
super	0.01	-0.16	0.17	-0.27	0.02	0.08
cow	-0.05	0.17	0.01	0.02	-0.05	0.17
dir	-0.02	0.11	-0.24	2.66	-0.39	0.10
vic	0.09	-0.17	0.13	-1.10	0.17	-0.01

EXPECTED CHANGE FOR THETA-EPS

	super	cow	dir	vic
super	- -			
cow	-0.35	- -		
dir	-0.09	0.09	- -	
vic	-0.01	-0.02	- -	- -

COMPLETELY STANDARDIZED EXPECTED CHANGE FOR THETA-EPS

	p1	p2	p3	risks	riskc	plant
p1	- -					
p2	0.34	- -				
p3	0.09	-0.29	- -			
risks	-0.07	0.05	0.02	- -		
riskc	0.02	0.00	0.02	- -	- -	
plant	-0.09	0.02	0.04	0.06	-0.01	- -
super	0.00	-0.04	0.05	-0.03	0.01	0.04
cow	-0.02	0.05	0.00	0.00	-0.03	0.10
dir	0.00	0.02	-0.05	0.22	-0.16	0.04
vic	0.04	-0.07	0.06	-0.18	0.14	-0.01

COMPLETELY STANDARDIZED EXPECTED CHANGE FOR THETA-EPS

	super	cow	dir	vic
super	- -			
cow	-0.24	- -		
dir	-0.04	0.04	- -	
vic	-0.01	-0.02	- -	- -

MAXIMUM MODIFICATION INDEX IS 5.47 FOR ELEMENT (9, 4) OF THETA-EPS

STANDARDIZED SOLUTION

LAMBDA-Y

	part	risk	climate	accid
p1	2.49	- -	- -	- -
p2	2.50	- -	- -	- -
p3	2.42	- -	- -	- -
risks	- -	6.20	- -	- -
riskc	- -	0.92	- -	- -
plant	- -	- -	0.95	- -
super	- -	- -	1.00	- -
cow	- -	- -	0.98	- -
dir	- -	- -	- -	1.32
vic	- -	- -	- -	0.49

CORRELATION MATRIX OF ETA

	part	risk	climate	accid
part	1.00			
risk	-0.01	1.00		
climate	0.29	-0.60	1.00	
accid	0.03	0.59	-0.35	1.00

PSI

	part	risk	climate	accid
part	1.00			
risk	-0.01	1.00		
climate	0.29	-0.60	1.00	
accid	0.03	0.59	-0.35	1.00

COMPLETELY STANDARDIZED SOLUTION

LAMBDA-Y

	part	risk	climate	accid
p1	0.92	- -	- -	- -
p2	0.82	- -	- -	- -
p3	0.85	- -	- -	- -
risks	- -	0.85	- -	- -
riskc	- -	0.61	- -	- -
plant	- -	- -	0.66	- -
super	- -	- -	0.80	- -
cow	- -	- -	0.83	- -
dir	- -	- -	- -	0.78
vic	- -	- -	- -	0.60

CORRELATION MATRIX OF ETA

	part	risk	climate	accid
part	1.00			
risk	-0.01	1.00		
climate	0.29	-0.60	1.00	
accid	0.03	0.59	-0.35	1.00

PSI

	part	risk	climate	accid
part	1.00			
risk	-0.01	1.00		
climate	0.29	-0.60	1.00	
accid	0.03	0.59	-0.35	1.00

THETA-EPS

p1	p2	p3	risks	riskc	plant
0.15	0.33	0.28	0.28	0.6	0.57

THETA-EPS

super	cow	dir	vic
0.36	0.32	0.39	0.64

Assessment and Modification

As specified, the measurement model provides an acceptable fit to the data [$\chi^2(29) = 30.89$, ns; GFI = .95; AGFI = .90; RMSEA = .02; NFI = .94; CFI = 1.00; PNFI = .60; PGFI = .50], and all estimated parameters are significant. We can proceed, therefore, with the assessment of the structural model.

From Pictures to LISREL

Although the measurement model was estimated entirely on the endogenous side of the LISREL model, the full latent variable model requires the use of both the exogenous and endogenous sides of the model. We begin by setting up the measurement of the exogenous and endogenous variables (thereby using both methods of setting a scale of measurement for the latent variables) and then proceed to set up the structural model. The setups are shown in Tables 7.4–7.11.

Note that the correlation between risk and willingness to participate is fixed in the PS matrix (PS 2, 1). Recall that PS appears in both the measurement model for the endogenous variables and the structural model. Because we are estimating a path between risk and willingness to participate [BE (2, 1], we cannot simultaneously estimate the correlation between the two factors. Thus, PS takes the form appropriate for the structural model.

TABLE 7.4 LX (Factor Loading for Exogenous Variables)

	Health and Safety Climate	*Accident History*
1. Manager's commitment	FRee	FIxed
2. Supervisor's commitment	FRee	FIxed
3. Coworker's commitment	FRee	FIxed
4. Own accident history	FIxed	FRee
5. Witnessed accidents	FIxed	FRee

Table 7.5 PH (Factor Covariances for Exogenous Variables)

	Health and Safety Climate	*Accident History*
1. Health and safety climate	1.00	
2. Accident history	FRee	1.00

TABLE 7.6 TD (Unique Factors for Exogenous Variables)

1. Manager's commitment	FRee
2. Supervisor's commitment	FRee
3. Coworker's commitment	FRee
4. Own accident history	FRee
5. Witnessed accidents	FRee

TABLE 7.7 LY (Factor Loadings for Endogenous Variables)

	Risk	*Willingness to Participate*
1. Risk for self	1.00	FIxed
2. Risk for Coworkers	FRee	FIxed
3. Participation 1	FIxed	1.00
4. Participation 2	FIxed	FRee
5. Participation 3	FIxed	FRee

TABLE 7.8 TE (Unique Factors for Endogenous Variables)

1. Risk for self	FRee
2. Risk for coworkers	FRee
3. Participation 1	FRee
4. Participation 2	FRee
5. Participation 3	FRee

TABLE 7.9 GA (Relates Exogenous to Endogenous Variables)

	Health and Safety Climate	*Accident History*
1. Risk	FRee	FRee
2. Willingness to participate	FIxed	FIxed

TABLE 7.10 BE (Relates Endogenous to Endogenous Variables)

	Risk	*Willingness to Participate*
1. Risk	FIxed	FIxed
2. Willingness to participate	FRee	FIxed

TABLE 7.11 PS (Factor Covariances for Endogenous Variables)

	Risk	*Willingness to Participate*
1. Risk	FRee	
2. Willingness to participate	FIxed	FRee

Identification and Estimation II

The measurement relationships incorporated in the model have not changed from the previous analysis; therefore, the measurement component of the model is identified. Because the structural model involves only recursive relationships, the structural component also is identified (Bollen, 1989).

The source code used to estimate the model is given below.

```
DA NI = 10 NO = 115 MA = CM
ME
  10.7 8.9 10.9 18.6 3.8 5.5 5.7 5.5 1.7  0.9
SD
  2.7 3.1 2.9 7.3 1.5 1.4 1.2 1.2 1.7  0.8
KM SY
 1.00
  .76  1.00
  .78   .68  1.00
-.05   .01  -.05  1.00
  .10   .09   .08   .52  1.00
  .01   .08   .14  -.28  -.22  1.00
  .20   .18   .29  -.44  -.29   .54  1.00
  .22   .25   .29  -.42  -.31   .57   .65  1.00
  .00   .00  -.05   .42   .22  -.13  -.26  -.20  1.00
  .12   .03   .11   .26   .30  -.12  -.20  -.17   .47 1.00
LA
pl p2 p3 risks riskc plant super cow dir vic
MO NY = 5 NE = 2 NK = 2 NX = 5 PS = DI,FR PH = ST GA = FU,FI BE = FU,FI
LE
  part risk
LK
  climate accid
FR GA(2,1) GA(2,2) BE(1,2)
VA 1.0 LY(1,1) LY(4,2)
FR LY(2,1) LY(3,1) LY(5,2)
FR LX(1,1) LX(2,1) LX(3,1) LX(4,2) LX(5,2)
OU ML SC TV MI
```


Edited Output

```
NUMBER OF INPUT VARIABLES 10
NUMBER OF Y - VARIABLES    5
NUMBER OF X - VARIABLES    5
NUMBER OF ETA - VARIABLES  2
NUMBER OF KSI - VARIABLES  2
NUMBER OF OBSERVATIONS   115

PARAMETER SPECIFICATIONS

LAMBDA-Y
              part     risk
              ----     ----
    pl          0        0
    p2          1        0
    p3          2        0
 risks          0        0
 riskc          0        3

LAMBDA-X
           climate    accid
           -------    -----
 plant          4        0
 super          5        0
   cow          6        0
   dir          0        7
   vic          0        8

BETA
              part     risk
              ----     ----
 part           0        9
 risk           0        0

GAMMA
           climate    accid
           -------    -----
 part           0        0
 risk          10       11
```

PHI

	climate	accid
climate	0	
accid	12	0

PSI

part	risk
13	14

THETA-EPS

p1	p2	p3	risks	riskc
15	16	17	18	19

THETA-DELTA

plant	super	cow	dir	vic
20	21	22	23	24

LISREL ESTIMATES (MAXIMUM LIKELIHOOD)

LAMBDA-Y

	part	risk
p1	1.00	- -
p2	0.98 (0.09) 11.06	- -
p3	0.95 (0.08) 11.48	- -
risks	- -	1.00
riskc	- -	0.14 (0.03) 4.67

LAMBDA-X

	climate	accid
plant	0.97 (0.13) 7.43	- -
super	0.99 (0.11) 9.19	- -
cow	0.97 (0.10) 9.45	- -
dir	- -	1.37 (0.22) 6.15
vic	- -	0.47 (0.09) 5.00

BETA

	part	risk
part	- -	-0.02 (0.04) -0.51
risk	- -	- -

GAMMA

	climate	accid
part	- -	- -
risk	-2.86 (0.72) -3.99	2.69 (0.78) 3.44

COVARIANCE MATRIX OF ETA AND KSI

	part	risk	climate	accid
part	6.39			
risk	-0.89	41.09		
climate	0.08	-3.77	1.00	
accid	-0.08	3.65	-0.34	1.00

PHI

	climate	accid
climate	1.00	
accid	-0.34 (0.12) -2.91	1.00

PSI

part	risk
6.37	20.48

(1.02)	(8.04)
6.25	2.55

SQUARED MULTIPLE CORRELATIONS FOR STRUCTURAL EQUATIONS

part	risk
0.00	0.50

THETA-EPS

p1	p2	p3	risks	riskc
0.90	3.13	2.48	12.51	1.45
(0.38)	(0.54)	(0.46)	(7.52)	(0.24)
2.41	5.83	5.41	1.66	6.11

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

p1	p2	p3	risks	riskc
0.88	0.66	0.70	0.77	0.35

THETA-DELTA

plant	super	cow	dir	vic
1.15	0.56	0.46	0.93	0.45
(0.18)	(0.12)	(0.11)	(0.52)	(0.08)
6.25	4.51	4.14	1.80	5.37

SQUARED MULTIPLE CORRELATIONS FOR X - VARIABLES

plant	super	cow	dir	vic
0.45	0.64	0.67	0.67	0.33

GOODNESS OF FIT STATISTICS

CHI-SQUARE WITH 31 DEGREES OF FREEDOM = 39.60 (P = 0.14)
ESTIMATED NON-CENTRALITY PARAMETER (NCP) = 8.60
90 PERCENT CONFIDENCE INTERVAL FOR NCP = (0.0 ; 28.92)
MINIMUM FIT FUNCTION VALUE = 0.35
POPULATION DISCREPANCY FUNCTION VALUE (F0) = 0.075
90 PERCENT CONFIDENCE INTERVAL FOR F0 = (0.0 ; 0.25)
ROOT MEAN SQUARE ERROR OF APPROXIMATION (RMSEA) = 0.049
90 PERCENT CONFIDENCE INTERVAL FOR RMSEA = (0.0 ; 0.090)
P-VALUE FOR TEST OF CLOSE FIT (RMSEA < 0.05) = 0.48
EXPECTED CROSS-VALIDATION INDEX (ECVI) = 0.77
90 PERCENT CONFIDENCE INTERVAL FOR ECVI = (0.69 ; 0.95)

ECVI FOR SATURATED MODEL = 0.96
ECVI FOR INDEPENDENCE MODEL = 4.41
CHI-SQUARE FOR INDEPENDENCE MODEL WITH 45 DEGREES OF FREEDOM = 482.66
INDEPENDENCE AIC = 502.66
MODEL AIC = 87.60
SATURATED AIC = 110.00
INDEPENDENCE CAIC = 540.11
MODEL CAIC = 177.48
SATURATED CAIC = 315.97
ROOT MEAN SQUARE RESIDUAL (RMR) = 0.35
STANDARDIZED RMR = 0.087
GOODNESS OF FIT INDEX (GFI) = 0.94
ADJUSTED GOODNESS OF FIT INDEX (AGFI) = 0.89
PARSIMONY GOODNESS OF FIT INDEX (PGFI) = 0.53
NORMED FIT INDEX (NFI) = 0.92
NON-NORMED FIT INDEX (NNFI) = 0.97
PARSIMONY NORMED FIT INDEX (PNFI) = 0.63
COMPARATIVE FIT INDEX (CFI) = 0.98
INCREMENTAL FIT INDEX (IFI) = 0.98
RELATIVE FIT INDEX (RFI) = 0.88
CRITICAL N (CN) = 151.25

MODIFICATION INDICES AND EXPECTED CHANGE

MODIFICATION INDICES FOR LAMBDA-Y

	part	risk
p1	- -	0.00
p2	- -	0.45
p3	- -	0.42
risks	0.01	- -
riskc	3.50	- -

MODIFICATION INDICES FOR LAMBDA-X

	climate	accid
plant	- -	0.95
super	- -	1.62
cow	- -	0.23
dir	0.23	- -
vic	0.23	- -

MODIFICATION INDICES FOR BETA

	part	risk
part	- -	- -
risk	3.28	- -

MODIFICATION INDICES FOR GAMMA

	climate	accid
part	7.84	0.30
risk	- -	- -

NO NONZERO MODIFICATION INDICES FOR PHI

MODIFICATION INDICES FOR PSI

	part	risk
part	- -	
risk	3.28	- -

MODIFICATION INDICES FOR THETA-EPS

	p1	p2	p3	risks	riskc
p1	- -				
p2	0.42	- -			
p3	0.45	0.00	- -		
risks	2.05	1.70	0.39	- -	
riskc	0.44	0.00	0.21	3.28	- -

MODIFICATION INDICES FOR THETA-DELTA-EPS

	p1	p2	p3	risks	riskc
plant	3.92	0.39	1.13	0.72	0.03
super	0.17	0.68	1.49	0.21	0.09
cow	0.00	1.73	0.06	0.00	0.14
dir	0.02	0.22	0.88	3.66	3.66
vic	0.92	1.69	1.07	3.87	4.58

MAXIMUM MODIFICATION INDEX IS 7.84 FOR ELEMENT (1, 1) OF GAMMA

COMPLETELY STANDARDIZED SOLUTION

LAMBDA-Y

	part	risk
p1	0.94	- -
p2	0.81	- -
p3	0.84	- -
risks	- -	0.88
riskc	- -	0.59

LAMBDA-X

	climate	accid
plant	0.67	- -
super	0.80	- -
cow	0.82	- -
dir	- -	0.82
vic	- -	0.57

BETA

	part	risk
part	- -	-0.06
risk	- -	- -

GAMMA

	climate	accid
part	- -	- -
risk	-0.45	0.42

CORRELATION MATRIX OF ETA AND KSI

	part	risk	climate	accid
part	1.00			
risk	-0.06	1.00		
climate	0.03	-0.59	1.00	
accid	-0.03	0.57	-0.34	1.00

PSI

part	risk
1.00	0.50

```
THETA-EPS
 p1        p2        p3       risks     riskc
 ----      ----      ----     -----     -----
 0.12      0.34      0.30      0.23      0.65

THETA-DELTA
 plant     super     cow       dir       vic
 ----      ----      ----      ----      ----
 0.55      0.36      0.33      0.33      0.67

REGRESSION MATRIX ETA ON KSI (STANDARDIZED)
             climate    accid
             -------    -----
 part          0.02     -0.02
 risk         -0.45      0.42
```

Assessment and Modification II

This is an interesting case in that although the model provides an acceptable fit to the data [$\chi^2(31) = 39.60$, ns; GFI = .94; AGFI = .89; RMSEA = .05; NFI = .92; CFI = .98; PNFI = .63; PGFI = .53], not all the paths in the model are significant. Risk perceptions do not significantly predict willingness to participate ($\beta = -.06$, ns).

The partially mediated model (resulting from adding paths from both exogenous variables to willingness to participate) provided a significantly better fit to the data [$\chi^2_{\text{difference}}(2) = 8.72$, $p < .02$; $\chi^2(29) = 30.89$, ns; GFI = .95; AGFI = .90; RMSEA = .02; NFI = .94; CFI = 1.00; PNFI = .60; PGFI = .50]. The nonmediated model (which deletes the path from risk perceptions to willingness) also provided a good fit to the data [$\chi^2(30) = 32.07$, ns; GFI = .95; AGFI = .90; RMSEA = .03; NFI = .93; CFI = 1.00; PNFI = .62; PGFI = .52] but did not differ from the partially mediated model, $\chi^2_{\text{difference}}(1) = 1.17$, ns. Given that the partially mediated model and nonmediated model provide equivalent fits to the data, the nonmediated model is accepted based on the consideration of parsimony.

Post hoc inspection of the model parameters suggested that the nonsignificant path from accident history to willingness to participate could be deleted from the model. Doing so did not change the fit of the model [$\chi^2_{\text{difference}}(1) = 1.70$, ns; $\chi^2(31) = 33.77$, ns; GFI = .95; AGFI = .90; RMSEA = .03; NFI = .93; CFI = .99; PNFI = .64; PGFI = .53]

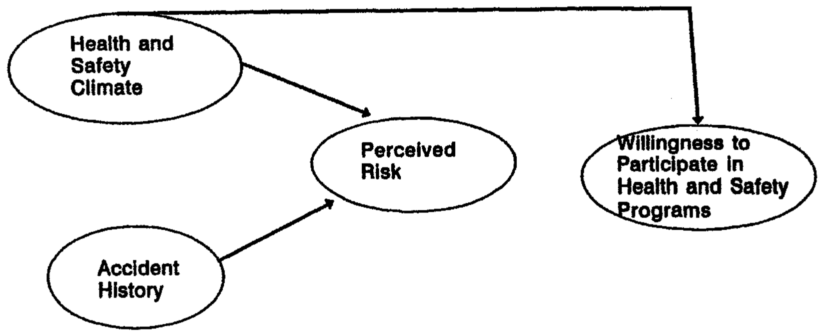

Figure 7.6.

but it did result in a more parsimonious model. The revised nonmediated model is presented in Figure 7.6.

Sample Results Section

A sample results section reflecting these findings is presented below.

Results

Descriptive statistics and intercorrelations for all study variables are presented in Table 7.12. All model tests were based on the covariance matrix and used maximum likelihood estimation as implemented in LISREL VIII (Jöreskog & Sörbom, 1992).

The measurement model provided an acceptable fit to the data [$\chi^2(29) = 30.89$, ns; GFI = .95; AGFI = .90; RMSEA = .02; NFI = .94; CFI = 1.00; PNFI = .60; PGFI = .50]. Standardized parameter estimates for the measurement model are presented in Table 7.13.

Table 7.14 presents the fit indices for the three structural models of interest. As shown, the partially mediated model provided a better fit to the data than did the fully mediated model [$\chi^2_{\text{difference}}(2) = 8.72$, $p < .02$]. The nonmediated model and partially mediated model did not differ [$\chi^2_{\text{difference}}(1) = 1.17$, ns]. Based on the consideration of parsimonious fit, the nonmediated model was retained for further analysis.

TABLE 7.12 Descriptive Statistics and Correlations for All Study Variables (N = 115)

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1. Participation 1										
2. Participation 2	76									
3. Participation 3	78	68								
4. Risk to self	−05	01	−05							
5. Risk to others	10	09	08	52						
6. Manager's commitment	01	08	14	−28	−22					
7. Supervisor's commitment	20	18	29	−44	−29	54				
8. Coworkers' commitment	22	25	29	−42	−31	57	65			
9. Accident history	00	00	−05	42	22	−13	−26	−20		
10. Witnessed accidents	12	03	11	26	30	−12	−20	−17	47	
Mean	10.7	8.9	10.9	18.6	3.8	5.5	5.7	5.5	1.7	0.9
SD	2.7	3.1	2.9	7.3	1.5	1.4	1.2	1.2	1.7	0.8

TABLE 7.13 Standardized Parameter Estimates for the Measurement Model

	Willingness to Participate	*Risk*	*Health and Safety Climate*	*Accident History*	R^2
1. Participation 1	0.92				0.85
2. Participation 2	0.82				0.67
3. Participation 3	0.85				0.72
4. Risk to self		0.85			0.72
5. Risk to others		0.61			0.38
6. Manager's commitment			0.66		0.43
7. Supervisor's commitment			0.80		0.64
8. Coworkers' commitment			0.83		0.68
9. Accident history				0.78	0.61
10. Witnessed accidents				0.60	0.36

TABLE 7.14 Fit Indices for the Three Models

	χ^2	*df*	*GFI*	*AGFI*	*RMSEA*	*NFI*	*CFI*	*PNFI*	*PGFI*
1. Partially mediated	30.9	29	.95	.90	.02	.94	1.00	.60	.50
2. Fully mediated	39.6	31	.94	.89	.05	.92	.98	.63	.53
3. Nonmediated	32.1	30	.95	.90	.03	.93	1.0	.62	.52

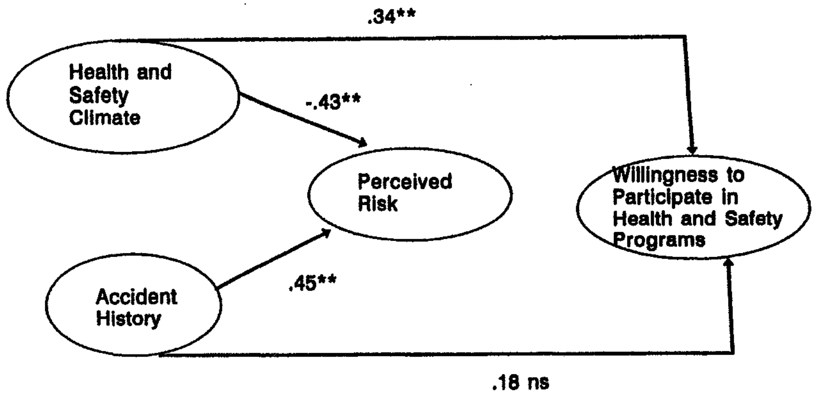

Figure 7.7.

Standardized parameter estimates for the structural model are presented in Figure 7.7. As shown, both risk perceptions ($\beta = -.43$, $p < .01$) and willingness to participate in health and safety programs ($\beta = .34$, $p < .01$) were predicted by perceived health and safety climate. Risk perceptions ($\beta = .45$; $p < .01$) but not willingness to participate ($\beta = .18$, ns) were predicted by respondents' accident history.

Deleting the nonsignificant path from the model did not result in a significant change to model fit, [$\chi^2_{\text{difference}}(1) = 1.70$, ns].

CHAPTER 8 *Concluding Comments*

In previous chapters, we considered the logic and mechanics of structural equation modeling with specific reference to the three most common versions of structural equation models: confirmatory factor analysis, observed variable path analysis, and latent variable path analysis. In this final chapter, I introduce two useful extensions to the procedures discussed thus far.

Single Indicator Latent Variables

As a general rule, one should strive for at least two or three indicators (observed variables) for every latent variable. Following this guideline generally will steer you clear of the shoals of underidentified models. In some cases, this rule must be violated because of either lack of available data or lack of forethought.

Unfortunately, we are sometimes stuck with only one indicator for a construct. Two solutions to this dilemma are possible. First, one can divide the scale items to form multiple indicators, as was done in the previous chapter. The second solution is to declare a latent variable with only one indicator. This is bound to leave us with an identification problem (trying to estimate both a unique and a common factor loading as well as the variance for one construct using only one indicator). The solution is to FIx the common (LY) and unique (TE) factor loadings at predetermined values and to estimate only the variance of the latent variable.