5. Empirical Assessment of Construct Measurement

Once the data is collected, the verification of this model is conducted through a series of statistical techniques. The statistical assessments follow the outline given in Figure 5-1 and the rationale of this outline will be described as follows.

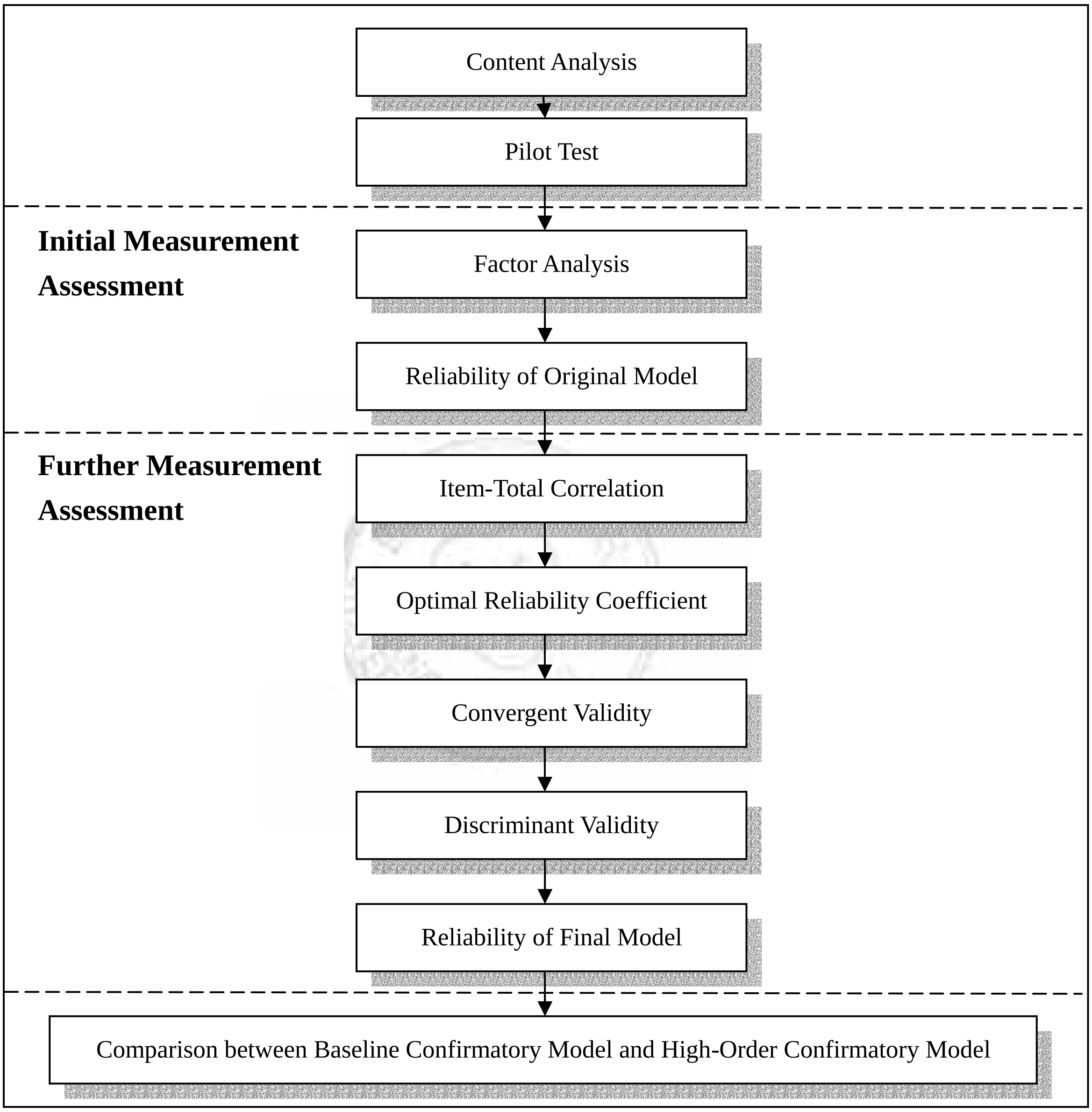

Figure 5-1. Outline of Statistical Assessments

According to Byrd and Turner 2000, content analysis and pilot test are conducted before the measurement assessment to ensure the measurement is supported by the academic research and the business practices. After that, exploratory factor analysis is conducted on data from the currently implemented scale to initially assess the construct validity of the instrument (Lewis and Byrd 2003). As a part of the data analysis, we first assess initial reliability for each of the dimensions. The reliability coefficient is defined as the proportion of the difference between the total variance and error variance to the total variance itself. The high reliability coefficient warrants further validity investigation (Mahmood and Soon1991). To ensure that the items measure the supply chain capability construct, construct validity of each item is then examined. Item-total correlations and optimal reliability coefficients, which are suggested an efficient method for testing construct validity by previous literature (Mahmood and Soon 1991), are used to modify the research model.

To further assess the measurement, previous studies suggest a series of measurement assessments ((Byrd and Turner 2000, Sethi and King 1994). From a theoretical standpoint, the measurement properties of a construct can be evaluated using a variety of techniques, including internal and external validity, theoretical meaningfulness, internal consistency of operationalization, convergent validity, discriminant validity, and nomological validity. From an operational standpoint, however, the following minimal subset is considered important: unidimensionality and convergent validity, reliability, and discriminant validity. At last, we employ the confirmatory factor analysis to assess the efficacy of measurement among scale items and the consistency of a pre-specified structural equation model with its associated network of theoretical concepts (Byrd and Turner 2000, Lewis and Byrd 2003, Segars and Grover 1998, Sethi and King 1994).

5.1 Initial Measurement Assessment

The completeness issue is first investigated. Items in this study are selected based on a broad review of literature which satisfies the content validity. The pilot test is done with six executives that are directly responsible of IOS collaborations. Such methodology assures that the model is complete. We then conduct the factor analysis on data from the currently implemented survey to initially assess the instrument. After that, reliability is assessed by computing the internal consistency, Cronbach’s alpha coefficient, for each of the dimensions determined from the factor analysis.

5.1.1 Factor Analysis

Factor analysis is used to identify underlying constructs from a large number of interrelated variables. Angeles and Nath (2000) recommend a case-to-variables ratio of 5:1 to guarantee a reliable factor analysis procedure; however, some researchers (Fuller and Swanson 1992) have worked with ratios as low as 2:1. In our study, a total usable 55 cases are collected for the 26 items. The case-to-variables ratio is 2.1:1, satisfying the least requirement of running the factor analysis. The result is a solution with four factors, each with eigenvalues greater than 1.0. Two items (TC3 and TC4) are excluded from the original model as their factor loadings are less than 0.4 (0.35 recommended by Churchill (1979)), and three items (TC6, TC7, and TC8) that measure the information technology infrastructure are removed to Factor2, resulting in a 24-item model (Table 5-1).

Table 5-1. Matrix of Factor Loadings*

Items**	Factor1	Factor2	Factor3	Factor4
TC1	0.448			
TC2	0.604			
TC5	0.442			
TC6		0.612		
TC7		0.715		
TC8		0.785		
TR1		0.726		
TR2		0.626		
TR3		0.578		
TR4		0.720		
GR1			0.600	
GR2			0.704	
GR3			0.696	
GR4			0.701	
GR5			0.412	
GR6			0.529	
GR7			0.465	
GR8			0.617	
GR9			0.556	
GR10			0.623	
EC1				0.777
EC2				0.486
EC3				0.733
EC4				0.608

* The following are the four factors: 1: Develop Technology Capability, 2: Reduce Transaction Related Risk, 3: Promote Good Relationship, and 4: Manage Environment Change.

** Loadings below 0.4 are not shown, and the items (TC6, TC8, and TC9) of dimension are adjusted by the result of factor analysis.

According to the results of the factor analysis, we point out that the Factor1 measures the technology capability which related the IOSs, the Factor2 presents the technological and managerial capabilities to reduce the transaction related risk, the Factors3 contributes the abilities to promote the good supply chain relationships, and the Factor4 expresses the capabilities to handle the uncertainties of the environment change.

5.1.2 Reliability

After factor analysis, the internal consistency method is used to ensure model reliability. Reliability is assessed by Cronbach's α coefficient for each of the dimensions determined from the factor analysis. The reliability coefficient for each of the factors is presented in Table 5-2. The alpha coefficient for each factor is above 0.8 except TC, indicating an acceptable reliability (Lewis and Byrd 2003). For the factor TC, its low Cronbach's alpha indicates that the sample of items captures the construct poorly and some items should be eliminated. Further validity assessment is targeted mainly at eliminating redundant items from the model to increase its overall as well as individual reliability.

Table 5-2. Measurement Properties of Proposed Model

Overall Model					
Measures of Model Fit					
X^2 (246)= 2.126			Adjusted Goodness of Fit = 0.504		
Independence Model X^2 (276) = 4.994			Root Mean Square Residual = 0.096		
Goodness of Fit = 0.593			Factor Reliability = 0.940		
Develop Technology Capability					
Item	Mean	Standard Deviation	ML Estimate	t-value	p-level
TC1	4.36	2.19	0.448	14.812	$p < 0.0001$
TC2	2.58	1.87	0.604	10.224	$p < 0.0001$
TC5	4.38	1.77	0.442	18.370	$p < 0.0001$
Measures of Model Fit					
Independence Model X^2 (3) = 2.967			Factor Reliability = 0.473		
Reduce Transaction Related Risk					
Item	Mean	Standard Deviation	ML Estimate	t-value	p-level
TC6	5.29	1.50	0.612	26.176	$p < 0.0001$
TC7	6.16	1.44	0.715	31.807	$p < 0.0001$
TC8	5.78	1.66	0.785	25.781	$p < 0.0001$
TR1	5.05	1.93	0.726	19.437	$p < 0.0001$
TR2	5.24	1.55	0.626	25.036	$p < 0.0001$
TR3	5.20	1.62	0.578	23.715	$p < 0.0001$
TR4	6.02	1.59	0.720	28.023	$p < 0.0001$

Table 5-2. Measurement Properties of Proposed Model (Continued)

Reduce Transaction Related Risk

<u>Measures of Model Fit</u>

X^2 (14)= 3.553	Adjusted Goodness of Fit = 0.658
Independence Model X^2 (21) = 15.260	Root Mean Square Residual = 0.064
Goodness of Fit = 0.829	Factor Reliability = 0.818

Promote Good Relationship

Item	Mean	Standard Deviation	ML Estimate	t-value	p-level
GR1	5.10	1.44	0.600	26.152	p < 0.0001
GR2	4.82	1.53	0.704	23.376	p < 0.0001
GR3	5.29	1.63	0.696	24.083	p < 0.0001
GF4	5.05	1.43	0.701	26.165	p < 0.0001
GR5	4.51	1.54	0.412	21.742	p < 0.0001
GR6	4.53	1.45	0.529	23.138	p < 0.0001
GR7	4.76	1.50	0.465	23.511	p < 0.0001
GR8	4.87	1.62	0.617	22.276	p < 0.0001
GR9	4.02	1.83	0.556	16.278	p < 0.0001
GR10	4.55	1.82	0.623	18.482	p < 0.0001

<u>Measures of Model Fit</u>

X^2 (35)= 2.504	Adjusted Goodness of Fit = 0.616
Independence Model X^2 (45) = 10.036	Root Mean Square Residual = 0.067
Goodness of Fit = 0.755	Factor Reliability = 0.838

Manage Environment Change

Item	Mean	Standard Deviation	ML Estimate	t-value	p-level
EC1	4.53	1.39	0.777	24.227	p < 0.0001
EC2	4.62	1.58	0.486	21.663	p < 0.0001
EC3	4.49	1.35	0.733	24.755	p < 0.0001
EC4	5.04	1.45	0.608	25.715	p < 0.0001

<u>Measures of Model Fit</u>

X^2 (2)= 1.394	Adjusted Goodness of Fit = 0.885
Independence Model X^2 (6) = 15.588	Root Mean Square Residual = 0.030
Goodness of Fit = 0.977	Factor Reliability = 0.842

5.2 Further Measurement Assessment

To further improve reliability, item-total correlation and optimal reliability coefficients are suggested for use (Mahmood and Soon 1991). Then, the construct validity of each item is examined to ensure that the items included in the model measure the construct. To establish the construct validity of a measure, the literature suggests that the analysis also must determine convergent validity and discriminant validity (Hart and Saunders 1998, Mahmood and Soon 1991). In this study, the examination of the convergent validity and discriminant validity of the modified model is using the multi-trait/multi-method matrix (Mahmood and Soon 1991). At last, the reliability of the final model is checked.

5.2.1 Item-Total Correlation

The item-total correlation of an item is derived from its correlations with the overall score of its group (Mahmood and Soon 1991). We calculate it for each dimension by using the CORR procedure of SAS (Version 8.02). Table 5-3 facilitates the identification of dispensable variables with the expected resultant alpha in the third column. We delete the item when the deletion can increase the value of alpha, because this indicates that the item is not measuring the same construct as the rest of the items do. Under this procedure, no items are dropped from the model, and therefore the model is still a 24-item model. The item-total correlations of the remaining items are quite high, ranging from 0.4085 to 0.8104, which suggests that these items are significantly correlated with the domain of their construct. Table 5-3 shows the item-total correlation for the remaining items.

Table 5-3. Item-Total Correlation of Proposed Model

Items	Item-Total Correlation	Alpha
TC1	0.4532	0.9527
TC2	0.4089	0.9540
TC5	0.6442	0.9493
TC6	0.4085	0.9518
TC7	0.7930	0.9477
TC8	0.6072	0.9497
TR1	0.6780	0.9489
TR2	0.7936	0.9476
TR3	0.7530	0.9480
TR4	0.8104	0.9473

Table 5-3. Item-Total Correlation of Proposed Model (Continued)

Items	Item-Total Correlation	Alpha
GR1	0.7899	0.9478
GR2	0.7397	0.9482
GR3	0.6100	0.9497
GR4	0.7587	0.9481
GR5	0.6733	0.9489
GR6	0.6910	0.9488
GR7	0.7652	0.9480
GR8	0.7750	0.9477
GR9	0.6710	0.9490
GR10	0.6890	0.9487
EC1	0.5004	0.9507
EC2	0.6229	0.9495
EC3	0.6780	0.9490
EC4	0.7491	0.9482

5.2.2 Optimal Reliability Coefficients

To ensure that redundant items are not included in different variables, the optimal reliability coefficient criterion is used (Mahmood and Soon 1991). By this method, the item-total correlations of items are ranked in a descending order in each dimension. This is followed by a computation of the reliability coefficient of items with the highest, the next-highest, and so on. The reliability for each dimension is then plotted on a graph which is presented in Figure 5-2. If the pattern of the curves is increasing constantly, it indicates that each item contributes to the reliability. For example, the optimal reliability analysis for the dimension TC shows that all three items (TC1, TC2 and TC5) together provide the highest reliability coefficient value possible, and therefore, they are all included in the model. Similarly, for the dimension TR, GR, and EC, all items are retained in the model. There is no item dropped in this procedure, and therefore the model is still a 24-item model.

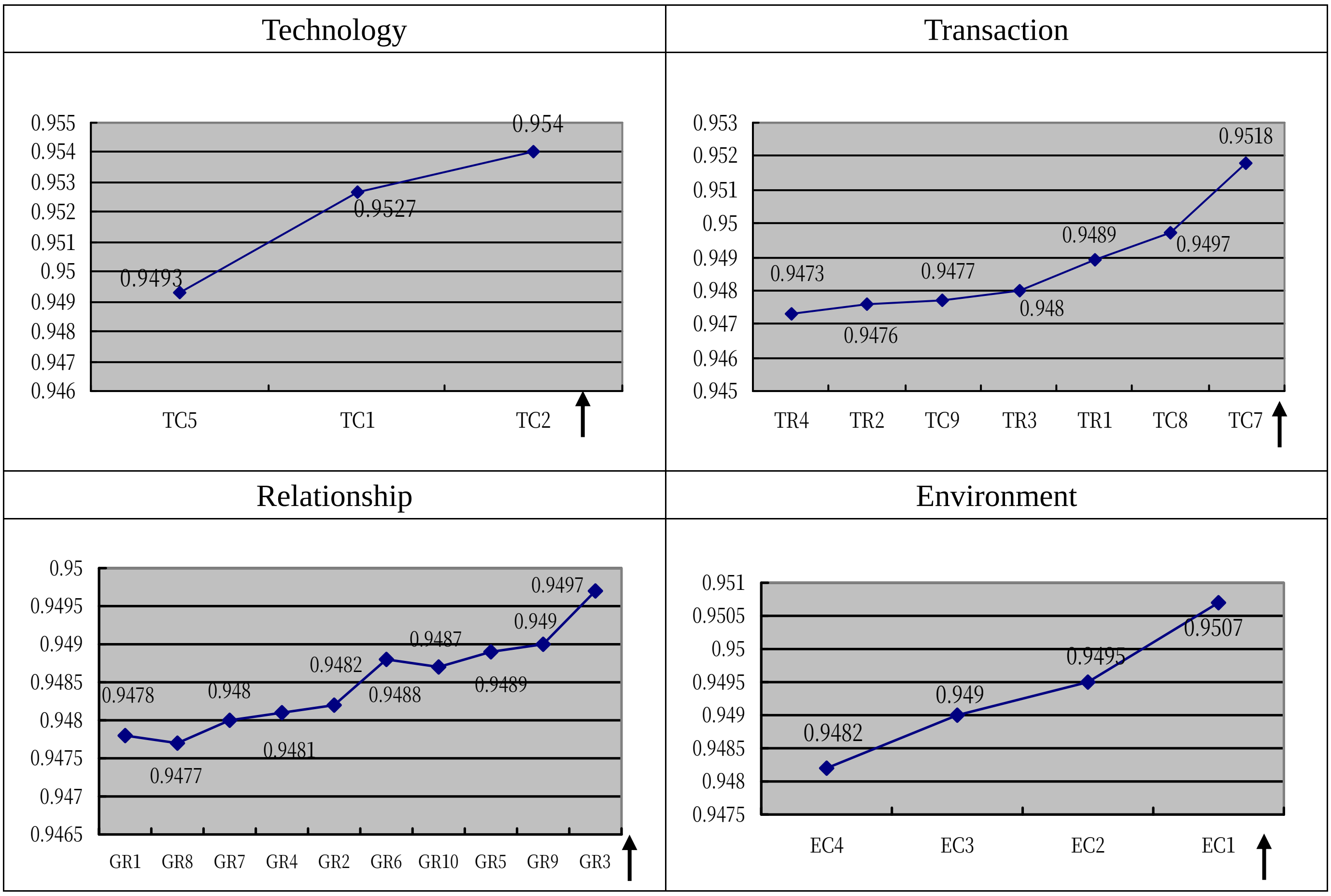

Figure 5-2. Optimal Reliability Coefficients of Proposed Model

5.2.3 Convergent Validity

A multi-trait/multi-method (MTMM) is used for convergent and discriminant validity of the model. This method uses the correlations matrix of construct indicators observed in the sample (Appendix B). We look at the patterns of inter-correlations among the items; correlations between theoretically similar items should be high while correlations between theoretically dissimilar items should be low.

To ascertain convergent validity, the items' inter-correlations of within-dimension should be relatively high. On the hetero-trait/mono-dimension triangles of the correlation matrix, the inter-correlations for all item pairings in within-dimension are comparative high. Overall, the correlation coefficients in the validity diagonal are significantly higher than zero (p <0.0001). The smallest within-dimension correlations for TC, TR, GR, and EC are 0.21, 0.38, 0.43, and 0.51. These correlations are significantly higher than zero and indicate convergent validity (Mahmood and Soon 1991), allowing investigators to proceed further with the discriminant validity of the model.

5.2.4 Discriminant Validity

To establish discriminant validity, the relationship between measures from different dimensions should be very low. Using the MTMM approach, discriminant validity for each item is tested by counting the number of times each inter-correlation more highly with an item of a different variable than with items of its parent dimension. For example, the lowest within-dimension inter-correlation for TC1 is 0.23, which happens to be with TC5. This inter-correlation is higher than TC1's inter-correlation with other items from outside its dimension in 5 out of 21 cases. The recommended value for this count should be greater than fifty percent of each comparison (Mahmood and Soon 1991). It is notable that all items of TC are dropped, eliminating the dimension from the model. Table 5-4 shows the results of these comparisons. After above procedures, six items are dropped from the 24-item model, making it an 18-item model.

Table 5-4. Discriminant Validity Test

Item-Pair	Correlation	Number of Violation	Percentage of Non-Violation	
TC1*TC5	0.23	17	19.05	Dropped
TC2*TC5	0.21	18	14.29	Dropped
TC5*TC2	0.21	21	0.00	Dropped
TC6*TR2	0.38	1	94.12	
TC7*TC6	0.55	5	70.59	
TC8*TR2	0.54	0	100.00	
TR1*TC6	0.44	5	70.59	
TR2*TC6	0.38	15	11.76	Dropped
TR3*TC6	0.48	8	52.94	
TR4*TC6	0.53	7	58.82	
GR1*GR9	0.53	7	50.00	
GR2*GR5	0.50	7	50.00	
GR3*GR5	0.43	5	64.29	
GR4*GR7	0.50	9	29.41	Dropped
GR5*GR3	0.43	7	50.00	
GR6*GR3	0.43	7	50.00	
GR7*GR3	0.48	9	29.41	Dropped
GR8*GR3	0.55	6	57.14	
GR9*GR3	0.46	5	64.29	
GR10*GR2	0.53	4	71.43	

Table 5-4. Discriminant Validity Test (Continued)

Item-Pair	Correlation	Number of Violation	Percentage of Non-Violation
EC1*EC2	0.54	0	100.00
EC2*EC3	0.51	7	65.00
EC3*EC2	0.51	9	55.00
EC4*EC2	0.52	10	50.00

5.2.5 Reliability for Final Model

After a series of measurement assessment, Figure 5-3 presents the alternations results of each step and Table 5-5 shows the reliability coefficient values for the final model. The reliability of two factors, TR and GR, is increased and the factor, EC, without adjusted items is leveling off. All the items in the factor TC are dropped because they violate the discriminant validity. In summary, the adjusted model with an overall reliability of 0.943 represents good instrument validity.

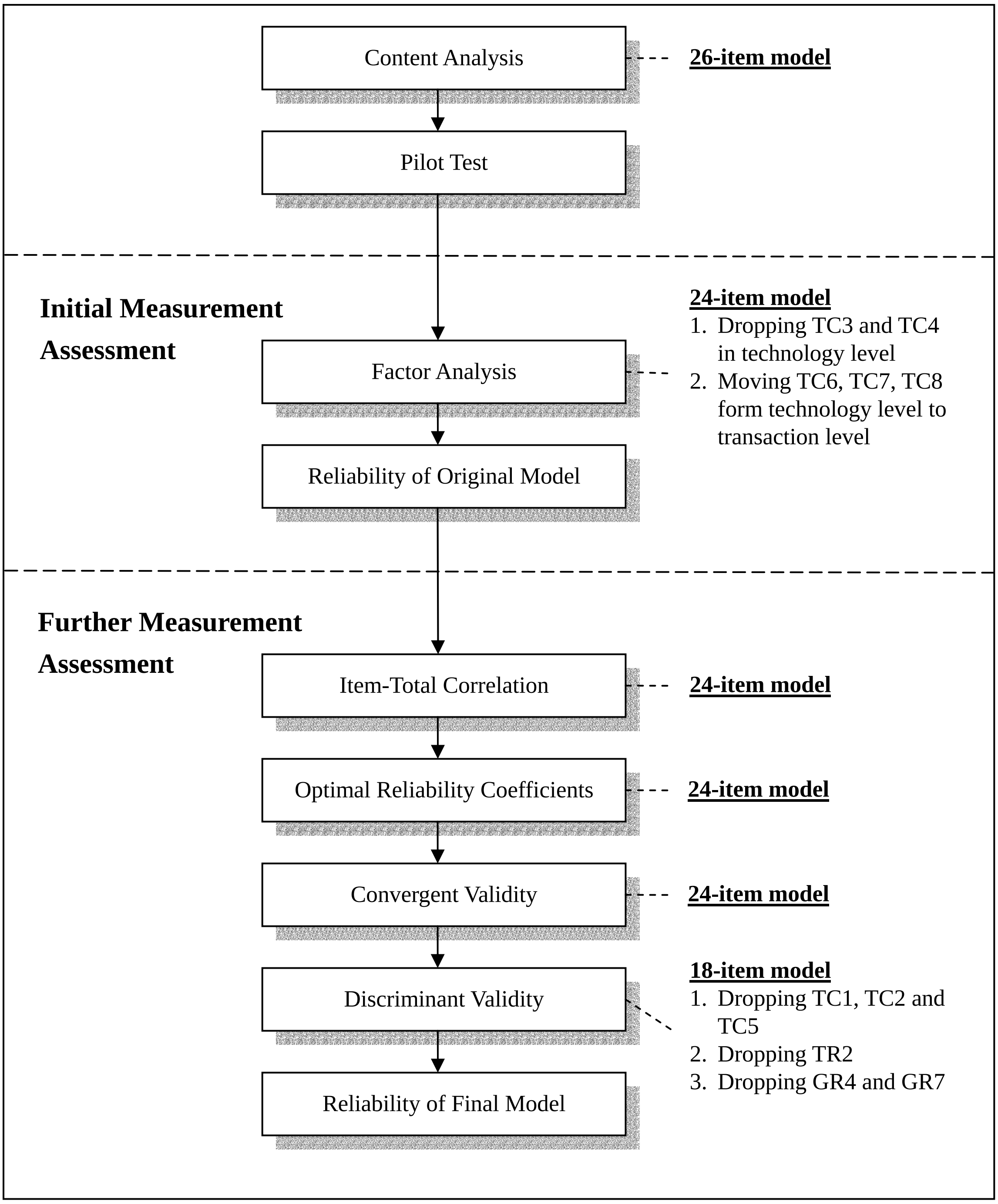

Figure 5-3. Summary of Statistical Assessments

Table 5-5. Measurement Properties of Final Model

Overall Model			
Measures of Model Fit			
X^2 (132)= 1.990		Adjusted Goodness of Fit = 0.717	
Independence Model X^2 (153) = 6.070		Root Mean Square Residual = 0.089	
Goodness of Fit = 0.834		Factor Reliability =0.943	
Reduce Transaction Related Risk			
Item	ML Estimate	Measures of Model Fit	
TC6	0.725	X^2 (9)= 2.928	
TC7	0.738	Independence Model X^2 (15) = 17.310	
TC8	0.827	Goodness of Fit =0.870	
TR1	0.680	Adjusted Goodness of Fit = 0.697	
TR3	0.602	Root Mean Square Residual = 0.056	
TR4	0.755	Factor Reliability = 0.907	
Promote Good Relationship			
Item	ML Estimate	Measures of Model Fit	
GR1	0.609	X^2 (20)= 2.051	
GR2	0.686	Independence Model X^2 (28) = 10.870	
GR3	0.717	Goodness of Fit = 0.866	
GR5	0.515	Adjusted Goodness of Fit = 0.758	
GR6	0.612	Root Mean Square Residual = 0.052	
GR8	0.712	Factor Reliability = 0.920	
GR9	0.667		
GR10	0.771		
Manage Environment Change			
Item	ML Estimate	Measures of Model Fit	
EC1	0.792	X^2 (2)= 1.394	
EC2	0.443	Independence Model X^2 (6) = 15.588	
EC3	0.713	Goodness of Fit = 0.977	
EC4	0.542	Adjusted Goodness of Fit = 0.885	
		Root Mean Square Residual = 0.030	
		Factor Reliability = 0.842	

5.3 Evaluating a Covariation Model of Supply Chain Capability

The further verification of this model is through the use of confirmatory factor analysis. According to Segars and Grover (1998), the analytical framework of confirmatory factor analysis provides an appropriate means of assessing the efficacy of measurement among scale items and the consistency of a pre-specified structural equation model with its associated network of theoretical concepts. The EQS for Windows program (Version 6.0) is utilized as the analytical tool for estimating the measurement and structural equation models developed in this study. Byrd and Turner (2000) write, "One advantage of using EQS over other structural equation modeling tools is that EQS places less stringent assumptions on the multivariate normality of the data. Despite the heftiness of EQS in this area, test of skewness and kurtosis are examined and do not show major departures from normality or excessive kurtosis".

The 18-item model, derived from last section, forms the baseline confirmatory model for the supply chain capability construct. The baseline model suggests that transaction, relationship, as well as environment are independent in their prediction of supply chain capability. Accordingly, the baseline model (Figure 5-4) is estimated using the correlations matrix (Appendix B) of construct indicators observed in the sample. Table 5-6 reports the goodness-of-fit summary for the baseline model. The X^2 divided by its degrees of freedom is 1.99, which is conforming to the recommended 2 (Sethi and King 1994). The goodness-of-fit (GFI) for the baseline model is 0.834, which is below the recommended 0.9 (Sethi and King 1994). However, it is not out of line with other exploratory studies developing measures for complex organizational phenomena. For example, Sethi and King (1994) reported a GFI of 0.76 for their research. The root mean square residual (RMSR) is 0.089, which is below the recommended 0.1 (Sethi and King 1994), providing further evidence of a good fit for this model. The reliability is above the cutoff of 0.8 that is good for exploratory studies. Overall, the fit indicators seem to suggest that each criterion is capturing a significant amount of variation in the latent dimensions of the supply chain capability construct.

Table 5-6. Model Fit Indices for Baseline Model

Number of Latent Variable	3
Total Number of Items	18
X^2 statistics	262.674
Degrees of Freedom	132
X^2/degrees of freedom	1.99
p-value	0.000001
Goodness of Fit	0.834
Root Mean Square Residual	0.089
Factor Reliability	0.943

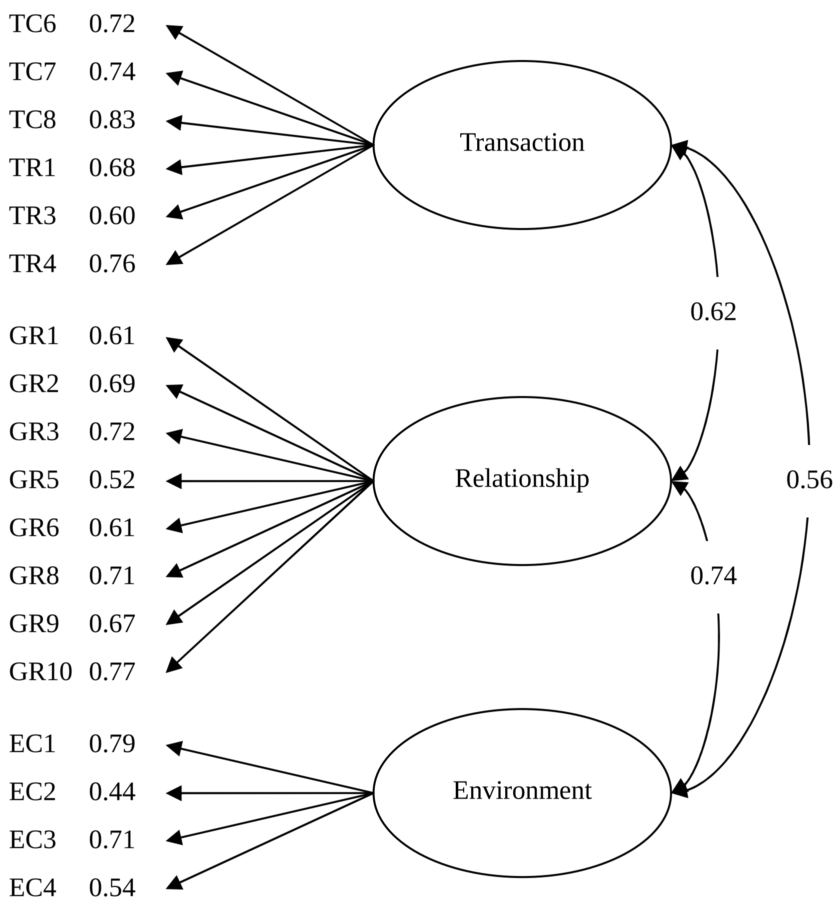

Figure 5-4. Baseline Confirmatory Model for Supply Chain Capability Construct

The comparative methodology contrasts a baseline model with a model featuring a second-order model. The second-order model was iteratively modified to improve its fitness. Table 5-7 shows the model fit indices for the alternative model and the structure is shown in Figure 5-5. The X^2 divided by its degrees of freedom is 2.04, which is conforming to the recommended 2 (Sethi and King 1994). The goodness-of-fit (GFI) is 0.834, which is a little bit below the recommended 0.9 (Sethi and King 1994). The root mean square residual (RMSR) is 0.089, which is below the recommended 0.1 (Sethi and King 1994). The reliability is above the cutoff of 0.8 that is good for exploratory studies. Overall, the fit indices for the second-order model are satisfactory based on the criteria of X^2/ degrees of freedom (df), GFI, RMSR, and reliability.

Table 5-7. Model Fit Indices for Second-Order Confirmatory Model

Number of Latent Variable	5
Total Number of Items	18
X^2 statistics	262.674
Degrees of Freedom	129
X^2/degrees of freedom	2.04
p-value	0.000001
Goodness of Fit	0.834
Root Mean Square Residual	0.089
Factor Reliability	0.943

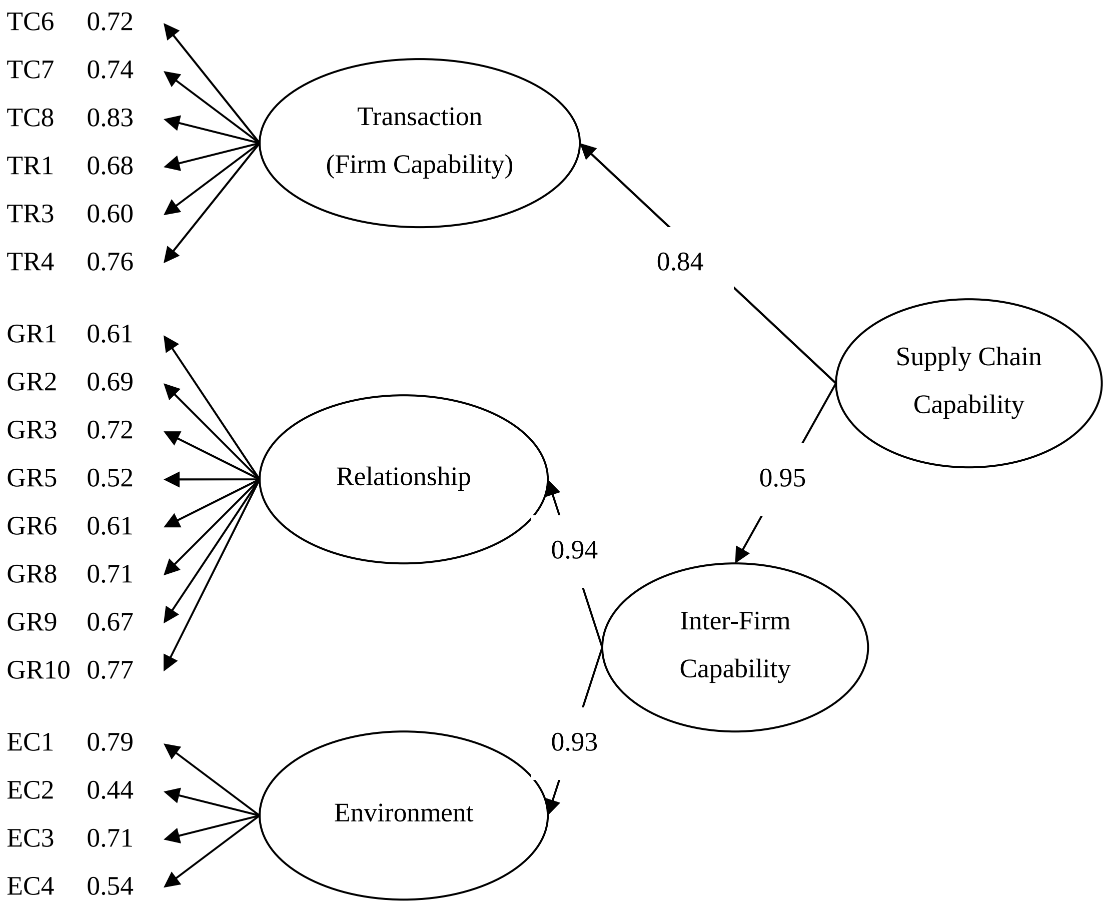

Figure 5-5. Second-Order Confirmatory Model for Supply Chain Capability Construct

Segars and Grover (1998) argue that because the higher-order model explains the covariation in a more parsimonious way, the GFI of the higher-order model can never be better than the corresponding baseline model. In this sense, the baseline model provides a target fit for the higher-order model. It has been suggested that the efficacy of second-order model be assessed through examination of the target (T) coefficient (T = X^2 (baseline model)/

X^2 (alternative model)). The coefficient has a lower bound of 1.0 if the higher-order model is sufficiently captures the factor in the model. In the Table 5-7, the X^2 divided by its degrees of freedom for the second-order model is 2.04. The coefficient between the baseline model and second-order model is 0.98. The value suggests that the addition of the second-order model does increase chi-square. Therefore, the second-order model is a truer representation of the model structure and that the second-order model can be accepted over the baseline model.

The final assessment for acceptance of the higher-order model is found in the magnitude and significance of the estimated parameters in the second-order model. The magnitude for all paths between supply chain capability and the underlying factors is good with significantly high t-values. The paths between supply chain capability and its underlying factors are 0.84 for the transaction that measures the firm capability and 0.95 for the inter-firm capabilities. The relationship level and environment level are sub-dimension of inter-firm capability, and the correlations between inter-firm capability and its underlying factors are 0.94 for the relationship and 0.93 for the environment. In view of this evidence, the second-order confirmatory model is accepted as a good representation of supply chain capability construct with these data.