

## **A Structural Equation Model of Supply Chain Information Integration**

### **Introduction**

Supply chain coordination and integration have been shown to create greater efficiencies, are believed to be key to sustainable competitive advantage (Chopra & Meindl, 2001; Cooper, Lambert, & Pagh, 1997), and provide greater flexibility in responding to demand shifts (Chandra & Kumar, 2001) with the bullwhip effect significantly reduced by cooperative decision making (Frank, Drezner, Ryan, & Simchi-Levi, 2000). Coordination also significantly reduces inventory and expediting costs, system inventory levels, and the probability of using expediting (Huggins & Olsen, 2003).

Information technology (IT) integration and alignment between and among supply chain members make coordination possible. IT alignment between supplier and buyer has a direct positive impact on both strategic and operational performance measures as well as an indirect impact as it encourages integration between firms (Sanders, 2005).

Supply chains with full information, including inventory data, are more efficient than those in which the supplier only sees the retailer order (Cachon & Fisher, 2000; Chen & Zheng, 1994; Graves, 1996).

Since SCs are created and managed by people, such systems will always suffer from inherent friction. It is difficult to imagine a SC that will share risks and rewards objectively among its constituents (Singh, 2005). Competitive decision making negatively impacts supply chain efficiency from both local and echelon inventory perspectives (Cachon & Zipkin, 1999), with lack of coordination decreasing expected

profits by 10–15% in two stage supply chains (Gupta & Weerawat, 2006). For these reason, strong cooperation between supply chain partners is critical to any analysis of supply chain integration.

Advancements in IT capabilities have significantly improved extent of internal and external organizational information sharing. It has been positively linked to firm performance and shown to have potential of providing a significant competitive advantage to firms. Similarly, firm collaboration has been shown to have a positive impact on performance (Sanders & Premus, 2005).

This research will develop a model for supply chain information integration incorporating constructs measuring information technology integration, information flow integration and supply chain partner integration.

### **Information Technology Integration**

Information technology integration refers to the degree to which automatic data capture systems are used throughout the supply chain, whether data and data definitions are consistent across the supply chain and whether data reentry is needed at each point (or, conversely, data is transmitted from other stages and systems within the supply chain) as well as whether these interorganizational applications communicate in real time.

Supply chain management (SCM) including logistics and other processes are supported by coordination and integration mechanisms which give competitive advantage through overall supply chain efficiency. IT, by way of collecting, sharing and gathering data,

exchanging info, and optimizing process through packaged software, is becoming one of key developments to success of these collaboration strategies (Neubert, Ouzrout, & Bouras, 2004).

When examining the impact of a new supply chain management (SCM) system on logistics performance, information quality and IT commitment were found to be related to perceived service performance (Moberg, Whipple, Cutler, & Spech, 2004).

Prater and Ghosh studied United States firms with European operations and found both small and very large firms' SCM were facilitated by strong IT (Prater & Ghosh, 2006), while Kuo et al found that IT and information sharing lead to synchronized SC operations and improved performance of SMEs (Kuo, Wen-Hsien, & Smits, 2005).

IT has led to centralized information, shorter lead times and smaller batch sizes (Fiala, 2005) and is one of four component found to be most critical in supporting delivery planning decisions (Lockamy III & McCormack, 2004).

IT is deemed so critical to successful supply chain operations that if transaction costs are perceived as high by both buyer and supplier of a logistics asset, these parties will enter into a fourth-party logistics network formation where use of IT systems is of critical importance (Bourlakis & Bourlakis, 2005).

The classic IT problems are present in these interorganizational systems. The introduction of shared databases in a timber industry supply network had a suboptimal impact due to the common IT implementation problem of poor communication of change management processes (Hannes, Gudela, & Oliver, 2006).

### **Information Flow Integration**

Information flow integration refers to the degree of information sharing and visibility throughout the supply chain including sharing of delivery schedules, performance metrics, and sales information, as well as collaboration on demand forecasting, transparency of inventory data, and order tracking throughout the supply chain.

Information sharing is a critical component of a tightly integrated supply chain, with concomitant increases in efficiency (Lee & Kumara, 2007) and competitive advantage (Li & Lin, 2006). Sharing demand and inventory data facilitates improved order quantity decisions (Bourland, Powell, & Pyke, 1996; Chen, 1998; Gavirneni, 1999), resulting in significant inventory reduction and cost savings (Lee, So, & Tang, 2000; Moberg et al., 2004) and reducing suppliers' demand variance (Strong, Lee, & Wang, 1997). Sharing shipment information benefits sender, receiver, and downstream tier (Zhang, Tan, Robb, & Zheng, 2006).

Engaging in local forecasting, that is, sharing all static data (e.g., characteristics of consumer demand processes, characteristics of individual forecasting processes and the correlation between them, and cost structure) provides substantial benefits (Aviv, 2001).

In situations with different inventory systems for different supply chain partners information sharing and coordination leads to lower costs (Liang & Huang, 2006).

In a survey of Korean first-tier automotive suppliers, Ki-Chan and others found that high quality of exchanged information enables better SC coordination, which in turn supports product modularization (Ki-Chan, Changsoo, Roemer, & Yassine, 2006)

In interorganizational SC procurement context, the interactive effect of information processing needs and capabilities has a significant effect on performance (Premkumar, Ramamurthy, & Saunders, 2005).

Petersen et al surveyed purchasing executives whose firms are involved in collaborative planning w/suppliers and found that effective collaborative planning is dependent on the level of trust and the quality of information shared between firms (Petersen, Ragatz, & Monczka, 2005).

Conversely, the slow and inefficient reaction to competitive pressures of small garment manufacturers in the United Kingdom was associated with inaccurate and untimely information sharing among trading partners (Anon, 2005).

### **Partner Integration**

Partner integration refers to arrangements for information exchange and cooperation in development of quality initiatives as well as sharing of process and cost data, best practices, and new technologies and markets.

In behavioral/managerial components, commitment, trust, relationship were significantly related to cost or service performance when examining impact of new SCM on logistics performance (Moberg et al., 2004). Lee and Ji found that explicitly considering trust in technology led to improved SC performance and protection against loss of trust between SC members. (Lee & Ji, 2005).

When supply chain members engage in collaborative forecasting, i.e., joint maintenance of a single forecasting process which can be integrated into their individual replenishment policies, benefits are even greater than in local forecasting scenarios (Aviv, 2001).

Three studies of Taiwanese firms support the value of strong supply chain partner relationships. Chwen et al found supplier-retailer business relationships as measured by interdependence, intensity, and trust affects long-term orientation and SC architecture as

measured by information sharing, inventory systems, IT capabilities, and coordination structure (Chwen, Rebecca, & Bongsug, 2006). Chinho et al showed the importance of integrating manufacturing operations with suppliers and customers (Chinho & Hojung, 2006) and Wang et al demonstrated that greater environmental uncertainty motivates tighter collaboration with suppliers and stronger IT (Wang, Tai, & Wei, 2006).

Existing formative contexts between partners both enable and constrain the effect of IT on interorganizational collaboration (Chae, HsiuJu, & Chwen, 2005).

Information exchange is very important issue for coordinating actions of units. New business practices and IT make coordination even closer (Fiala, 2005).

Daekwan et al found that if a SC partner is not critical to a firm's success, coordination activities of that partner are a prerequisite to being able to leverage the benefits of IT adoption (Daekwan, Cavusgil, & Calantone, 2005).

McCarter et al's survey of fifty-one (51) senior-level SC managers across five channel positions found that people are deemed more crucial to effective SC integration than is IT (McCarter, Fawcett, & Magnan, 2005).

### **Data Analysis**

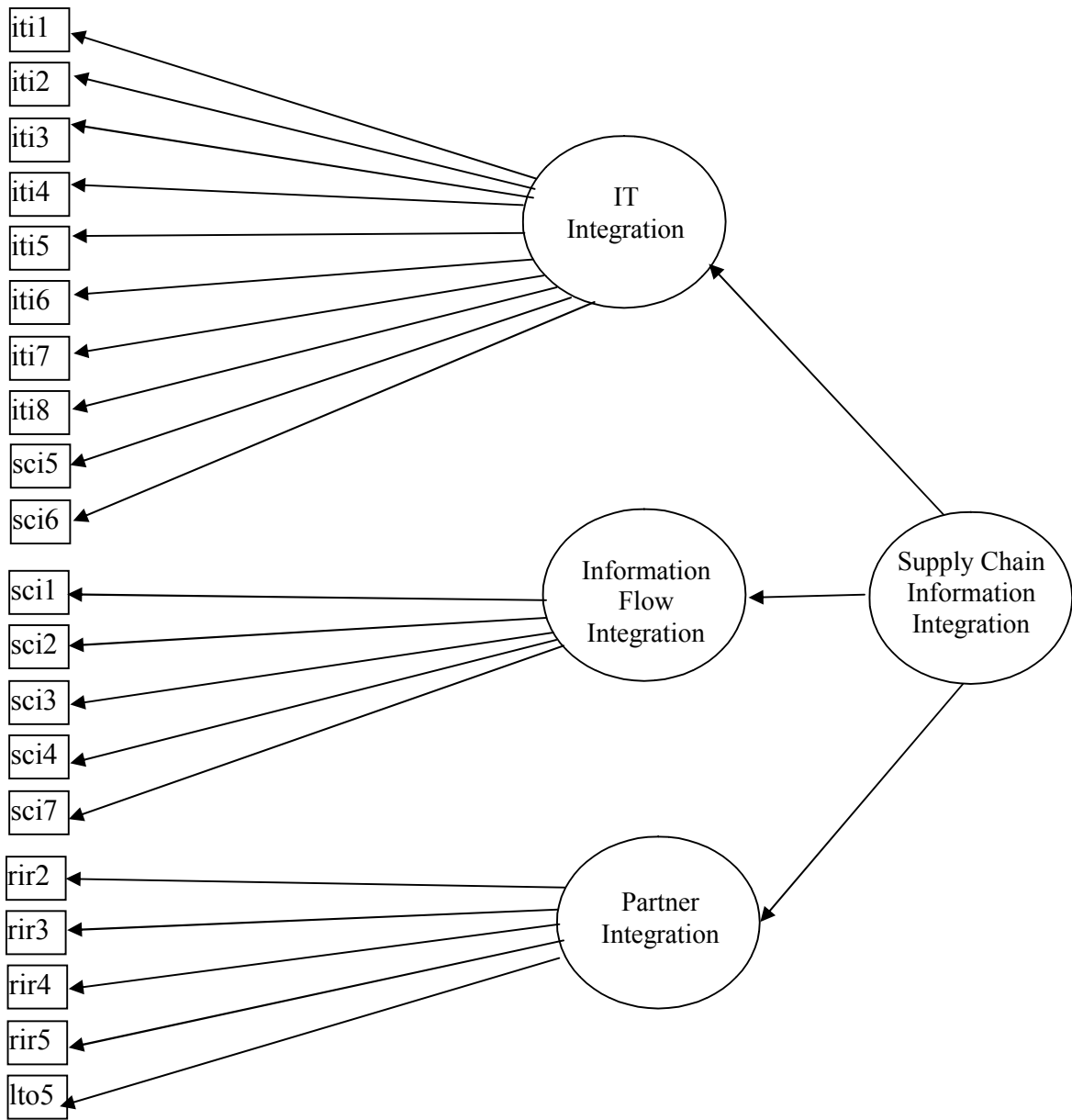
Structural equation modeling (SEM) will be used to explore the existence of a higher level construct of supply chain information integration. These models provide an opportunity to achieve greater parsimony in explaining relationships among observed variables and constructs. They also provide greater flexibility than methods such as regression as they enable relaxation of conditions of normality of data, among others. To date, no SEM model has been developed of supply chain information integration. Moreover, with a single exception (Byrd & Davidson, 2003), extant supply chain

structural equation models neglect the requirement that at least three lower level constructs are required to comprise each higher level construct (Garson). Most of these models show antecedent or causal relationships not higher order structural relationships. The proposed structural model is shown in Figure 1.

Data analyzed was obtained from research done by Arun Rai, Ravi Patnayakuni, and Nainika Seth in which 110 supply chain and logistics managers were surveyed on a number of dimensions relating to the impact of IT-related capabilities on firm performance (Rai, Patnayakuni, & Seth, 2006). Four of the thirteen categories of data collected for that study were tapped for the current research; the data items used are shown in Appendix 1. Six cases had some missing data and were excluded from analysis.

Bivariate correlations between each pair of supply chain integration variable were run with the results shown in Table 1.

**Figure 1**  
**Proposed Structural Model of Supply Chain Information Integration**



**Table 1: Bivariate correlations between each pair of all integration variables**

	iti1	iti2	iti3	iti4R	iti5	iti6	iti7	iti8	lto5	rir2	rir3	rir4	rir5	sci1	sci2	sci3	sci4	sci5	sci6	sci7
iti1	1																			
iti2	.472**	1																		
iti3	.304**	.626**	1																	
iti4r	0.173	.236*	.264**	1																
iti5	.332**	.509**	.405**	0.184	1															
iti6	.267**	.457**	.443**	.232*	.654**	1														
iti7	.256**	.399**	.418**	0.161	.604**	.652**	1													
iti8	.191*	.337**	.329**	0.135	.493**	.573**	.599**	1												
lto5	0.095	0.189	0.13	.235*	0.119	0.025	0.115	0.038	1											
rir2	0.075	.205*	.211*	0.182	0.076	0.137	.300**	0.153	.225*	1										
rir3	0.119	.368**	.330**	0.175	0.159	.192*	.221*	.243*	.212*	.625**	1									
rir4	0.145	.330**	.369**	.216*	0.189	.285**	.358**	.290**	.363**	.630**	.745**	1								
rir5	0.175	.385**	.308**	.288**	.209*	0.106	.203*	0.119	.359**	.537**	.679**	.693**	1							
sci1	.199*	.368**	.407**	0.071	.371**	0.132	.242*	.287**	.230*	.253**	.319**	.342**	.388**	1						
sci2	0.157	.440**	.448**	.230*	.285**	0.077	0.11	.233*	.318**	.208*	.351**	.376**	.461**	.640**	1					
sci3	.243*	.457**	.382**	0.162	.293**	0.103	0.124	.211*	.195*	.284**	.388**	.358**	.401**	.455**	.666**	1				
sci4	.242*	.203*	.272**	0.172	.209*	0.15	.241*	.210*	.244*	0.17	.264**	.280**	.284**	.294**	.397**	.535**	1			
sci5	.299**	.538**	.464**	0.175	.510**	.450**	.514**	.509**	.326**	.292**	.292**	.381**	.383**	.455**	.436**	.421**	.392**	1		
sci6	.263**	.453**	.462**	.316**	.381**	.407**	.405**	.411**	.282**	.261**	.369**	.350**	.287**	.420**	.418**	.401**	.419**	.606**	1	
sci7	0.11	.217*	.265**	0.067	.291**	.223*	.204*	0.18	0.089	0.141	0.155	0.13	0.153	.363**	.249**	.213*	.199*	.409**	.484**	1

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

Principal axis factoring was employed in SPSS to detect the data structure of these measured variables; that is, to ascertain the fewest number of factors which could account for the common variance among the twenty supply chain integration variables. Principal axis factoring is preferred to principal components analysis (PCA) because the former analyses covariation among variables, facilitating additions to and deletions from the model without impacting original model variables' factor loadings (Garson).

The results of the factor analysis are shown in Table 2.

While it is common practice in exploratory research to remove variables with loadings falling below some arbitrary threshold (e.g., .4), the goal of the current research is not exploration of what variables contribute to supply chain information integration but to confirm that the model supports existing research. This fact, combined with the relative magnitude of the factor loadings (i.e., all are above .35), results in retention of all measured variables.

**Table 2: Factor Matrix, Extraction Method: Principal Axis Factoring**

iti1	Automatic data capture	0.356	0.179	-0.075	0.308
iti2	Consistent Data Definitions	0.699	0.191	-0.117	0.470
iti3	Data Consistent Across Databases	0.624	0.126	-0.088	0.208
iti4R	Data Reentry-Reversed	0.383	0.008	-0.009	0.161
iti5	Supply Chain Planning Applications	0.582	0.500	-0.047	-0.006
iti6	Supply Chain Transaction Applications	0.524	0.604	0.270	0.044
iti7	SC with Internal Applications	0.582	0.482	0.304	-0.128
iti8	CRM with Internal Applications	0.509	0.399	0.131	-0.184
lto5	Information Shared	0.426	-0.202	0.002	-0.049
rir2	Formal and Informal Arrangements	0.507	-0.348	0.380	-0.070
rir3	Involved in Quality Initiatives	0.630	-0.452	0.333	0.061
rir4	Share Best Practices	0.684	-0.401	0.456	-0.038
rir5	Learn From Partners	0.642	-0.465	0.171	0.106
sci1	Share Delivery Schedules	0.624	-0.147	-0.321	-0.216
sci2	Share Performance Metrics	0.639	-0.299	-0.470	-0.034
sci3	Collaborate on Demand Forecasts	0.607	-0.250	-0.360	0.055
sci4	Actual Sales Data Shared Downstream	0.483	-0.093	-0.192	-0.090
sci5	Visibility of Inventory Data	0.749	0.173	-0.099	-0.197
sci6	Orders Tracked	0.674	0.103	-0.113	-0.154
sci7	Information Moves Faster	0.366	0.084	-0.145	-0.239

Cronbach's alphas for each of the three first level integration constructs were between .83 and .84 indicating strong internal consistency among measured variables within each construct.

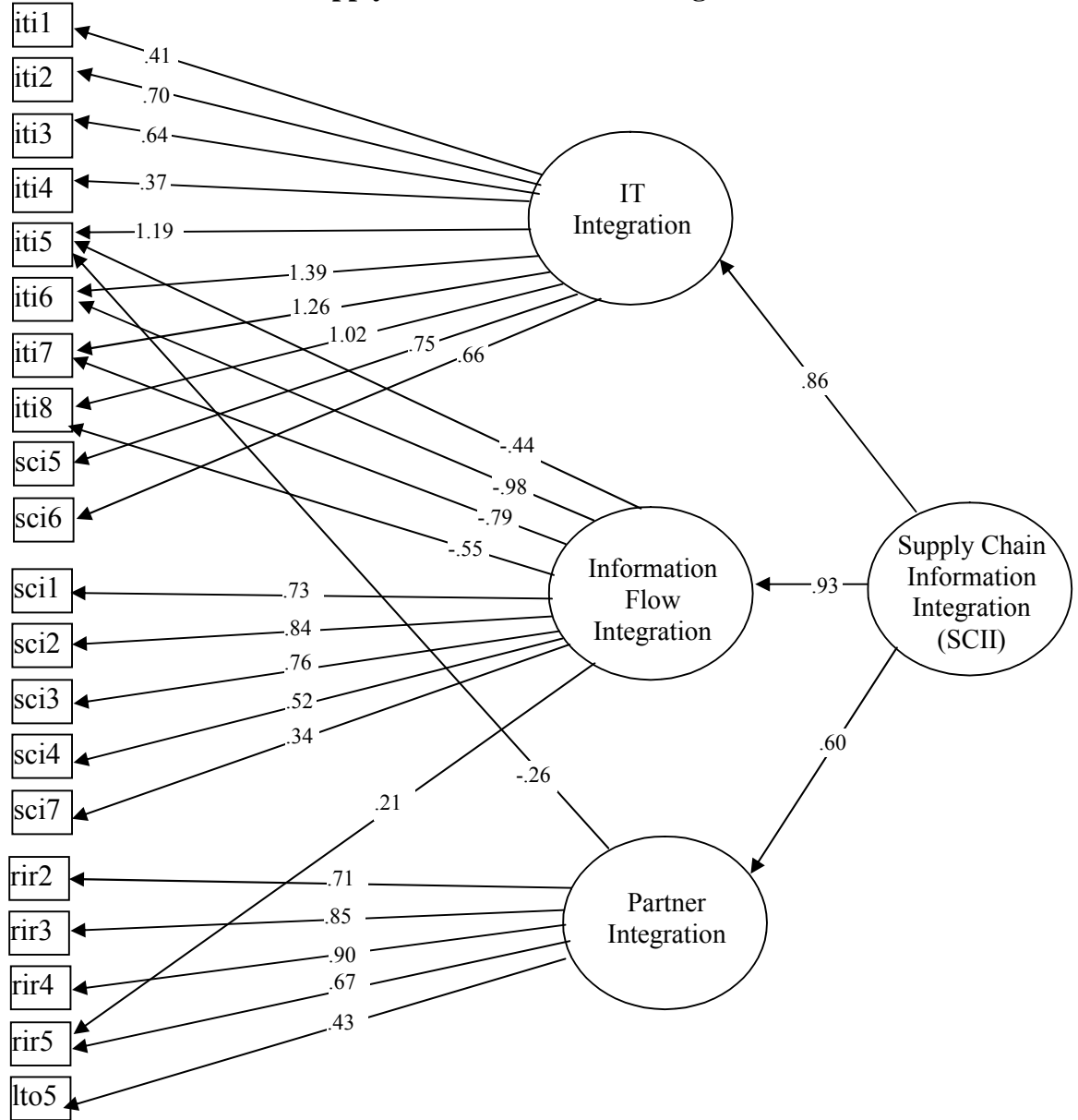
The data were imported into EQS where further analysis was performed. The Mardia coefficient showed evidence of non-normality so the Satorra-Bentler scaled chi-square test was used to reject the independence model at  $p=.01$ . Fit indices showed acceptable RMSEA (.078), but NNFI and CFI (.853 and .871, respectively) below acceptable levels (Schermelleh-Engel, Moosbrugger, & Müller, 2003). The single congeneric model was run to rule out the possibility that this model was a better representation of the relationships among variables. This model's Satorra-Bentler scaled chi-square (452.37) was larger than that of the 3 factor model (269.01) providing support for the latter structure.

Based on EQS output, additional analyses were run in an attempt to improve model fit, while not straying from theoretical bases for relationships. The final single stage model, with NNFI of .95, CFI of .958, and RMSEA of .045 is shown in Figure 2.

According to this model, the observed variable “Supply chain planning applications communicate in real time” is a function of all three integration factors. The other variables indicating whether applications communicate in real time load on both IT integration and information flow integration while “Learning about new technologies and markets from our partners” loads on both information flow and partner integration. All of these are reasonable given the nature of the questions asked and the overlap between constructs. For example, the ability for an application to communicate in real time necessitates not only robust integration of intercompany information technology infrastructures, but implies that information flows are well integrated across companies. If supply chain planning applications such as demand planning and transportation planning communicate in real time this itself implies a tight integration with a supply chain partner. Learning about new technologies from partners is in itself a flow of information, while showing a strong link with supply chain partners.

Next, a two level model was run, including the relationships shown in Figure 3, with the addition of a second level factor representing the SC Information Integration construct. With no additional modifications, this model was shown to fit the data adequately with CFI=.953 and RMSEA of .048, although the NNFI was just shy of adequate at .945.

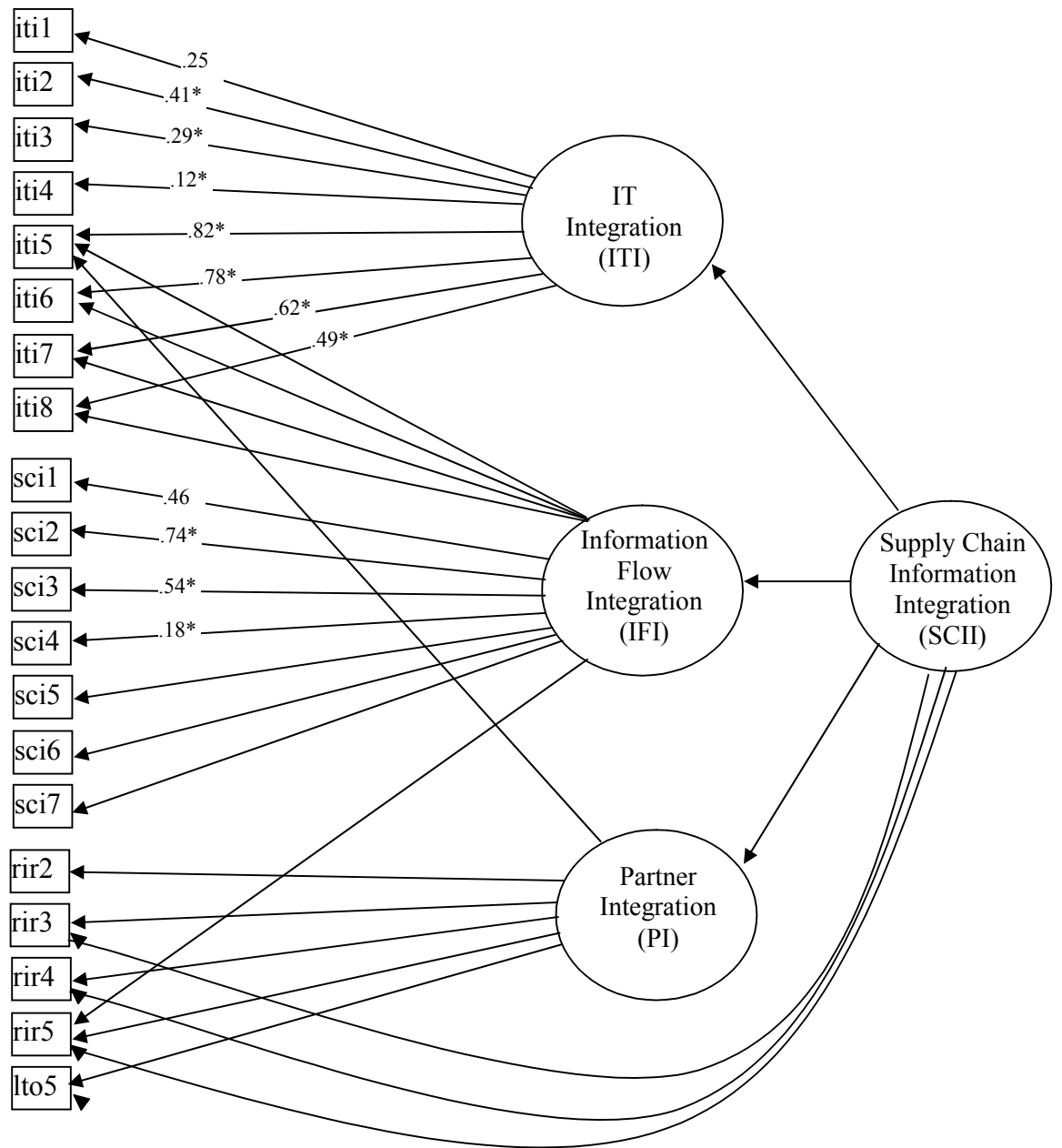
**Figure 3**  
**Structural Model of Supply Chain Information Integration**



The Schmid-Leiman approach was implemented next. This approach enables separation of variance into that due to the second order construct (SCII) and that due to the three first order constructs. Loadings on a first order construct represent the variance explained by that factor once the variance due to the higher-order factor has been removed. Small

loadings on lower-order factors indicate these items were saturated with variance from the SCII construct not that an inappropriate number of factors was extracted during factor analysis (Taylor, McKay, & Abramowitz, 2005).

With no additional modifications, this model was shown to fit the data adequately with NNFI= .96, CFI=.969 and RMSEA of .041. This final model is shown in Figure 3 (THIS DRAWING IS INCOMPLETE).



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# Appendix 1 Questionnaire<sup>1</sup>

## Part II: Supply Chain IT Infrastructure

For the primary products or product lines you have chosen, this part refers to the IT infrastructure (hardware, software, networks and operating systems) that interfaces with suppliers and customers.

### B. Integration of IT infrastructure

1. Automatic data capture systems are used (e.g. bar code) across the supply chain.
2. Definitions of key data elements (e.g. customer, order, part number) are common across the supply chain.
3. Same data (e.g. order status) stored in different databases across the supply chain is consistent.
4. Same data needs to be reentered in the computer at each step in the supply chain.
5. The following applications communicate in real-time:
  - Supply chain planning applications (e.g. Demand planning, transportation planning, manufacturing planning).
  - Supply chain transaction applications (Order management, procurement, manufacturing and distribution).
  - Supply chain applications with internal applications of our organization (such as enterprise resource planning).
  - Customer relationship applications with internal applications of our organization.

### C. Integration of Information Flows

1. Production and delivery schedules are shared across the supply chain.
2. Performance metrics are shared across the supply chain
3. Supply chain members collaborate in arriving at demand forecasts.
4. Actual sales data is shared by our downstream partners (e.g. distributors, wholesalers, retailers).
5. Inventory data are visible at all steps across the supply chain. SA A AS N DS D SD
6. Order fulfillment and shipment status are tracked at each step across the supply chain.
7. Information about the product moves faster than the product in our supply chain.

## Part V: Relationships with Supply Chain Partners

This part refers to your organizations relationship with suppliers and other partners involved in logistics, distribution, warehousing etc.

### B. Interaction

2. We have created formal and informal arrangements for information exchange with our partners.
3. Partners are involved in quality and improvement initiatives.
4. We share best practices with our partners.
5. We learn about new technologies and markets from our partners.

### C. Trust and Partnerships

5. With our key partners, procedures and cost structures are transparent to each other

<sup>1</sup> Rai, A., Patnayakuni, R., & Seth, N. 2006. Firm performance impacts of digitally enabled supply chain integration capabilities. *MIS Quarterly*, 30(2).