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e-Integration in the Supply Chain: Barriers and Performance*

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ABSTRACT

Current opinion holds that Internet-based supply chain integration with upstream suppliers and downstream customers (called "e-integration" in this paper) is superior to traditional ways of doing business. This proposition remains untested, however, and similarly we know little about what are the upstream, internal, and downstream barriers to implementing e-integration. This paper empirically addressed these questions using data from a large single nation study, and found (1) a positive link between e-integration and performance, and (2) that internal barriers impeded e-integration more than either upstream supplier barriers or downstream customer barriers. Findings from this study contribute to our theoretical understanding of implementing change in contemporary supply chains, and have important implications for manufacturers interested in improving their supply chain's performance using the Internet.

Subject Areas: e-Business Implementation, Supply Chain Management, and Survey Research.

INTRODUCTION

The most admired and feared manufacturers today have tightly integrated supply chains. Real-time information travels immediately backwards though these supply chains and inventory flows swiftly forwards. Most importantly, products are delivered quickly and reliably when and where they are needed. This precise coordination with short lead-times helps defeats the bullwhip effect and contributes to the company's overall success (Lee, Padmanabhan, & Whang, 1997).

Although we've know about the theoretical benefits of supply chain integration for years, making it work in practice has been difficult. Pre-Internet, there was no solution to the tradeoffs in supply chain integration between low cost, rich content, and long-distance. Electronic data interchange (EDI) allowed expensive but limited content with a few remote partners, while Kanban provided low cost yet

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rich connections with many nearby customers or suppliers. Only recently has the Internet resolved these tradeoffs, and now all supply chain partners can be effectively integrated.

While Internet-enabled supply chains may be powerful strategic weapons, there are still many questions unanswered about them in practice (Bowersox, Closs, & Stank, 2000). Do Internet-enabled supply chains actually improve performance? If so, what are the barriers that prevent every manufacturer from implementing web-based supply chains? This investigation was especially motivated by the hype surrounding web-based supply chains and lack of confirmatory evidence. In order to implement change, managers need to know (1) what to do and (2) where to start. We can only begin to offer them this type of sound advice once practice is linked to performance and the barriers to change are understood. This research contributes to the literature by being the first to consider these issues. Towards that goal, the paper extends our knowledge about Internet-enabled supply chains and identifies the greatest obstacles to their integration.

E-INTEGRATION

Problems in nonintegrated supply chains are legendary and well documented since Forrester's (1961) pioneering work. Poor integration causes the classic boom-bust bullwhip of materials trickling down the supply chain and alternating excess inventory and stock-outs (Metters, 1997). Conversely, having an integrated supply chain provides significant competitive advantage including the ability to outperform rivals on both price and delivery (Lee & Billington, 1992).

Because planning instability is magnified backwards up the supply chain (Lee, Padmanabhan, & Whang, 1997), controlling error amplification from downstream customers to upstream suppliers is especially crucial (Bhaskaran, 1998). The more integrated the flow of data between customers and suppliers, the easier it is to balance supply and demand across the entire network (Trent & Monczka, 1998). An important new trend, therefore, is coordinating supply chain partners using the Internet (Feeny, 2001). Pre-Internet, real-time demand information and inventory visibility were typically impossible to achieve and most supply and demand "integration" involved a patchwork of telephoning, faxing, and EDI. This has changed in the Internet era, and widely available web-based technologies now permit strong customer and supplier integration for inventory planning, demand forecasting, order scheduling, and customer relationship management. For simplicity, in this paper we call this broad upstream and downstream supply chain integration using the Internet "e-integration."

e-Integration and Performance

There are two relevant types of performance metrics for Internet-enabled supply chains. The first is traditional operational measures like delivery lead-times, transaction costs, and inventory turns. The Internet in theory allows companies to greatly improve these conventional performance metrics and hence managers now talk about "five-day cars," zero-cost or "frictionless" transactions, and days (not months) of inventory in the pipeline. The second metric is e-business performance as measured by the percentage of incoming procurement and outgoing finished goods transacted over the Internet. In 1995, Michael Dell set a famous goal that 50 percent of all business at his company must be done over the web, and in hindsight he thought that they could have easily achieved 70 percent (Margretta, 1998). Other Internet users like Cisco have similarly argued that 50 percent incoming and outgoing transactions over the Internet is a milestone in supply chain evolution at which point e-business truly becomes a decisive competitive weapon.

The higher the level of integrated upstream and downstream coordination the greater the benefits (Narasimhan & Jayaram, 1998; Johnson, 1999; Frohlich & Westbrook, 2001; Ahmad & Schroeder, 2001). In terms of the upstream side of a manufacturer's supply chain, a steady stream of research has noted the importance of close integration with supply partners. One of the biggest barriers to time compression in the supply chain are the long replenishment lead-times often encountered with suppliers (Christopher & Ryals, 1999). Conversely, response is enhanced through coordinating with best-in-class suppliers (Narasimhan & Das, 1999). Supplier integration is especially important in terms of frequent deliveries and reduced buffer inventories (Handfield, 1993), and therefore many manufacturers want strong upstream connections in their supply chains (Ansari & Modarress, 1990; Krause, Handfield, & Scannell, 1998). Other studies have similarly found that strong supply-side integration improves overall supply chain performance and supports competitive advantage (Chapman & Carter, 1990; Akinc, 1993; Lawrence & Hottenstein, 1995; Choi & Hartley, 1996; Germain & Droge, 1998; Tan, Kannan, & Handfield, 1998; Carr & Pearson, 1999; Essig & Arnold, 2001).

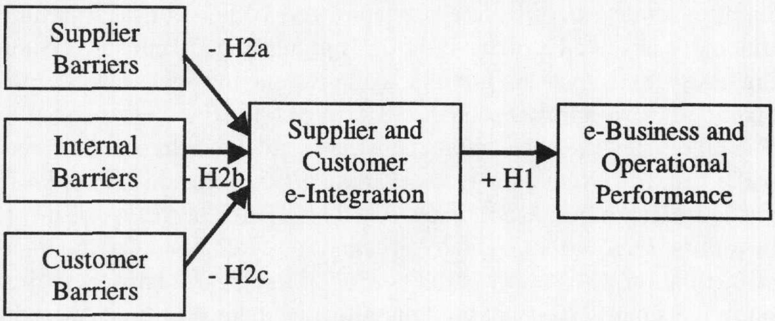
Tight integration is equally important with customers on the downstream side of a supply chain. Recent research shows the importance of strong customer integration in the supply chain (Stock, Greis, & Kasarda, 2000; Reeder & Rowell, 2001) and exploiting virtual connections along with third-party logistics (Bowersox, Closs, & Stank, 1999; Van Hoek, 2000). Evidence suggests that the stronger the downstream integration the greater the potential benefits (Clark & Hammond, 1997; Narasimhan & Jayaram, 1998; Lummus, Vokurka, & Alber, 1998; Gilbert & Ballou, 1999). Daugherty et al. (1999) and Waller et al., (1999) linked integrated distribution programs like automatic replenishment to improved performance. Conversely, there are inherent hazards of not fully coordinating activities in the supply chain with downstream partners (Lee & Billington, 1992; Hammel & Kopczak, 1993; Armistead & Mapes, 1993). By extension, this leads to the first hypothesis:

> **H1**: e-Integration with upstream suppliers and downstream customers is positively related to higher levels of e-business and operational performance.

Resistance to Change and Barriers to e-Integration

We have long known that all organizations suffer from homeostasis or the propensity to resist change and revert to previous ways of doing business (Coch & French, 1948). An organization's status quo is an equilibrium between the barriers to change and the forces driving change (Lewin, 1947; Kwon & Zmud, 1987; Cooper & Zmud, 1990). Some difference in these forces—either a weakening of the barriers to change or a strengthening of the forces driving change—is required to

Figure 1: Conceptual model of e-integration, barriers, and performance.



produce a transformation. Typically, it is more effective to weaken the barriers than to strengthen the drivers (Piderit, 2000).

Since all supply chains involve suppliers, manufacturers, and customers (Stevens, 1989; Davis, 1993), it follows that each of these parties can be a barrier to change. Members of supply chains often compete for the power to control it (Cox, Sanderson, & Watson, 2001). While suppliers often have much to gain from supply chain improvements (Narasimhan & Das, 1999), they may resist change due to the perceived difficulties and necessary costs (Krause, Handfield, & Scannell, 1997; Krause, 1999). Similarly, despite the fact that changing its own internal operations often gives a manufacturer greater competitive advantage (Hayes & Wheelwright, 1984), an organization may nevertheless resist change (Kotter, 1995). Finally, customers can be very skeptical about supply chain improvements (Cachon & Fisher, 1997) and refuse to integrate with upstream supply chain partners due to feared costs, supply disruptions, or confidential data issues (Corbett, Blackburn, & Van Wassenhove, 1999). This leads to the following set of hypotheses:

H2a: Supplier barriers are negatively related to e-integration.

H2b: Internal barriers are negatively related to e-integration.

H2c: Customer barriers are negatively related to e-integration.

In summary, e-integration with upstream suppliers and downstream customers is positively related to greater e-business and operational performance. On the other side of the model, upstream supplier, internal, and downstream customer barriers may potentially decrease a manufacturer's ability to exploit e-integration. These relationships are shown in Figure 1.

METHODS

Research Instrument

The survey was developed in three stages. In the first stage, we identified relevant measures of customer and supplier Internet integration, barriers, and e-business and operational performance in the literature and then drafted the instrument. We held a series of meetings with managers in the second stage to gauge the content and face validity of the instrument. In the final stage, we pre-tested the survey with 30 companies to further gauge its validity and overall readability. These 30 pre-test companies were set aside for the final data analysis.

Data were collected from a stratified random sample of companies from across the U.K. The research design proportionally represented large and small companies, and we sampled from all 13 regions of the U.K. including Ireland, Scotland, and Wales. In terms of external validity, the U.K. is the world's fourth largest economy (behind the U.S., Japan, and Germany) and the nation's e-business adoption rate generalizes well to North America and Western Europe. By sampling an entire country, the research design also controlled for many confounding factors like existing telecommunication infrastructure, technology costs, government/laws, and the overall economy.

Typical respondents were VPs of operations or general managers and therefore the data were collected from managers with enough seniority to know about their company's' upstream and downstream Internet-enabled integration, barriers, and e-business and operational performance. The data collection was completed in early 2001 and followed Dillman's (1978) total design method. The sample's demographic breakdown is shown in Table 1. In total, 486 usable surveys from manufacturers were returned and the survey response rate was 20 percent. Although this response rate is typical for lengthy paper-based questionnaires, given the e-business nature of our study we might have improved participation if we had used an Internet survey more in keeping with the spirit of our study into e-integration.

Three months after the original sample was collected 150 of the 486 responding companies were re-contacted and asked to complete a second survey with a different respondent to help test response accuracy. Thirty-seven companies participated, there were no differences ($p < 0.05$) on selected measures, and the inter-rater reliability was satisfactory per Boyer and Verma's (2000) guidelines. We also compared a matched random sample of 60 responding and 60 non-responding companies to assess non-response bias and found no differences ($p < 0.05$) in terms of size, age, location, or industry. Since a single respondent rated barriers, e-integration, and performance, this may have led to common method bias that we checked for using Harmon's one factor test (Podsakoff & Organ, 1986). Six factors with eigenvalues greater than one were extracted from *all* the measures in this study and in total accounted for 68% of the variance. The first factor accounted for 29% of the variance. Since a single factor did not emerge, and one factor did not account for most of the variance, this suggested that the results were not due to common-method bias.

Mediating e-Integration Construct Measurement

The conceptual framework (Figure 1) was operationalized using the structural equation model (SEM) shown in Figure 2. Following basic descriptive analyses of the data, including examination for incorrect coding, item normality, skewness, kurtosis, means, standard deviations, and outliers, the items were grouped into a priori conceptualizations of appropriate sub-scales for barriers, e-integration, and

Table 1: Sample demographic data.

Companies Contacted: 2400		Usable Surveys: 486	
Full-time Employees	Percent (%)	Company Age	Percent (%)
< 100	22	< 5 years	7
101-500	23	6-10 years	7
501-2000	21	11-20 years	23
> 2000	34	> 20 years	63
	100		100

Sector	Percent (%)
Aerospace	8
Automotive	13
Chemicals	8
Computers/Hi-tech	9
Consumer Appliances	6
Food/Beverages	14
Furniture/Household	2
Industrial Products	12
Medical Products	3
Other Manufacturing	14
Mixed Industries	12
	100

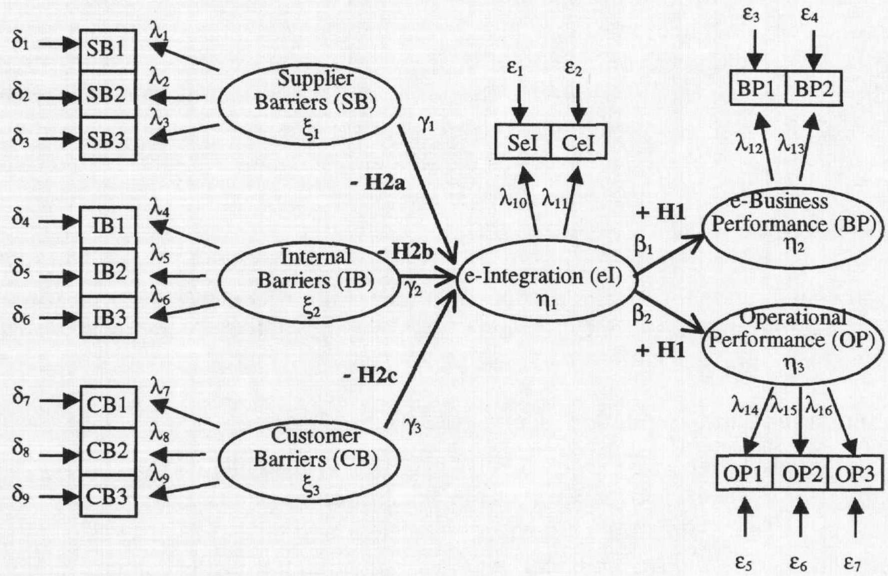
Note: Based on the company's primary product lines.

performance. There were no skewed measures except for online auctions, exchanges/e-marketplaces, e-crime/fraud, and security/privacy concerns discussed below.

In the survey, web-based supplier e-integration (SeI) and customer e-integration (CeI) were gauged based upon various initiatives that manufacturers commonly use to coordinate supply chains using the Internet (see Appendix). The literature, company visits, and manager's comments during survey development helped ground these measures in the field. The extent of implemented web-based supplier and customer integration for each manufacturer was measured on 1-5 Likert-type scales (1 = *not at all* to 5 = *fully*).

The most appropriate approach for scale purification when theory drives a study is confirmatory factor analyses (CFA) (Kim & Mueller, 1978). Items were selectively deleted through repeated CFA runs (LISREL 8) and each time we identified a measure for deletion based upon standardized residuals, observed improvements in comparative goodness of fit index (CFI), normed fit index (NFI), magnitude of modification indices, chi-square with corresponding degrees of freedom, and overall interpretability. Four weak/redundant measures were eventually dropped to form the parsimonious and reliable four-item scales for web-based supplier and customer integration shown in the Appendix. One of the dropped SeI measures, e-procurement of services, overlapped with e-procurement of materials.

Figure 2: Structural equation model operationalizing conceptual framework.



SB1: Technology costs/benefits not demonstrated
SB2: Existing business model/current practice
SB3: Lack of technical/e-business skills
IB1: Technology costs/benefits not demonstrated
IB2: Existing business model/current practice
IB3: Lack of technical/e-business skills
CB1: Technology costs/benefits not demonstrated
CB2: Existing business model/current practice
CB3: Lack of technical/e-business skills
SeI: e-Integration with suppliers
CeI: e-Integration with customers
BP1: Annual % of procurement using Internet
BP2: Annual % of sales/turnover using Internet
OP1: Faster delivery times
OP2: Reduced transaction costs
OP3: Enhanced inventory turnover

Note: Major barriers inhibiting the implementation of e-business 1-5 Likert (1 = *insignificant*; 5 = *highly significant*).
See appendix for supplier and customer e-integration scales.
Actual annual percentage rate for BP1 and BP2.
Benefits from web-based integration OP1, OP2, OP3: 1-5 Likert (1 = *none*; 5 = *extensive*).

While online auctions and exchanges/e-marketplaces are interesting ideas and much talked about in the popular press, only 7 of the 486 companies in the sample used them so they were dropped from the analysis. One CeI measure, electronic payments, was redundant with on-line order taking and eventually excluded.

The modification indices suggested that some of the constraints on the error terms for the manifest variables should be relaxed in order to get a better fit of the model. For example, since web-based procurement of materials is likely to improve integrated inventory planning and vice versa, an error covariance between the two indicators was included and the measurement model modified accordingly. Where indicated by modification indices, the error terms for other pairs of indicators such as integrated order scheduling with integrated demand/forecasting and targeted marketing with on-line order taking were also relaxed. The modification indices, however, should be used with caution. A parameter/link should only be relaxed if it can be interpreted substantively (Joreskog & Sorbom, 1993) regarding both the direction of impact as well as the sign of the parameter. For this study, all the links added were appropriate to the analysis.

Together SeI and CeI operationalized e-integration (eI) in the overall conceptual model shown in Figure 2. The four measures for SeI were summed together and run in the overall conceptual model (Figure 2) as a single scale. Similarly, the four measures for CeI were summed together into the construct for customer integration used in Figure 2's SEM.

Independent and Dependent Construct Measurement

The supplier barriers (SB), internal barriers (IB), and customer barriers (CB) to e-integration were likewise grounded in the literature per O'Leary-Kelly and Vokurka's (1998) guidelines. Barriers were measured on 1-5 Likert scales (1 = *insignificant*; 5 = *highly significant*) in terms of their inhibiting the implementation of e-integration. Multiple iterations of CFA were again used for scale purification and to help ensure reliable measures of supplier, internal, and customer barriers. Four items were dropped to form the resulting three-item scales for barriers shown in Figure 2. Two of the dropped barriers were constraints of technology and lack of awareness of potential. These overlapped with technology costs/benefits not demonstrated and existing business model/current practice. The other two measures dropped were e-crime/fraud and security/privacy concerns, which were issues with only roughly 30 of the 486 companies in the sample in contrast to the popular perception that these are major barriers to most e-business.

The measures for e-business and operational performance were similarly grounded in the literature. The degree of e-business performance was based on the actual percentage of procurement and sales revenue/turnover conducted using the Internet. Operational performance was based on faster delivery times, reduced transaction costs, and enhanced inventory turnover related to web-based integration (1-5 Likert: 1 = *none*; 5 = *extensive*). During the pre-test we attempted to collect profit margin financial data related to e-business, but it was not available from any of the 30 pre-testers either because it was considered too confidential or was unknown, so we did not attempt to collect this type of performance measure in the final study.

Reliability and Validity Checks

The reliability of each scale (see Table 2) was satisfactory with Cronbach alphas of at least 70 percent (Nunnally, 1978). The validity of each scale was analyzed following Flynn, Sakakibara, and Schroeder's (1995) example. *Construct validity* was established by testing whether the items in a scale all loaded on a common factor when within-scale factor analysis was run—the eigenvalues all exceeded the minimum threshold of 1.0 and helped confirm the dimensionality of each construct.

Table 2: Measurement analysis: Barriers, e-integration, and performance.

Measure	Cronbach's Alphas	Average Interscale Correlate	Average Item Total Correlations: Non-scale Items	Average Item Total Correlations: Scale Items
1. Supplier Barriers	.84	.23	.21	.76
2. Internal Barriers	.70	.29	.24	.61
3. Customer Barriers	.81	.22	.21	.72
4. Supplier e-Integration	.79	.19	.20	.60
5. Customer e-Integration	.83	.18	.19	.65
6. e-Business Performance	.73	.20	.20	.78
7. Operational Performance	.84	.19	.20	.75

Divergent or *discriminant validity* was tested two ways. First, we compared the average interscale correlations in Table 2 to the Cronbach alphas. Acceptable *divergent validity* is shown when the alphas are greater than the average interscale correlations and this was found true for each of the scales. Second, the average correlations between scale and nonscale items were lower than between scale and scale items and that helped support *discriminant validity.*

RESULTS AND DISCUSSION

Traditional regression ignores that many constructs (such as barriers and supplier and customer integration) are interrelated and its use potentially biases results by excluding important interdependencies from the analysis (Asher, 1983; Bollen, 1989; Chin, 1998). This study therefore used structural equation modeling (LISREL 8) to test the hypotheses. Because LISREL is sensitive to violations of normality, and the statistical tests conducted with the analysis (e.g., the model chi-square test and significance tests for path coefficients) assume a multivariate normal distribution, the Q-plot of the standardized residuals was checked and suggested that this condition was not violated (Hayduk, 1987). Likewise, the sample size ($n = 486$) used in this analysis is acceptable. Boomsma (1985) and Hayduk (1987) argued that a sample size of 100 generally provides stable estimates. MacCallum, Roznowski, and Necowitz (1992) recommended in general five observations per parameter be estimated for SEM analyses (this study estimated 35 parameters).

Table 3 summarizes the goodness of fit for Figure 2's SEM. The model's fit was acceptable based upon suggested criteria (Bollen, 1989; Hoyle, 1995; Marcoulides & Schumacker, 1996). Table 4 contains the independent latent variable loadings. All loadings were significant ($p < 0.01$), and existing business models/current practices at upstream suppliers (standardized estimate = 0.90, t = 24.46) and downstream customers (standardized estimate = 0.90, t = 23.45) were the biggest external barriers to e-integration. Interestingly, the technology's cost/lack of demonstrated benefits for Internet-enabled supply chain integration was the single largest loading for internal barriers (standardized estimate = 0.88, t = 15.03).

Table 3: Goodness-of-fit for structural equation model.

Goodness-of-Fit Statistic	(df = 84)
χ^2	72.44 ($p < 0.81$)
χ^2 /df	0.86 ($\leq$ 2.00)[a]
GFI	0.99 (> 0.90)[a]
AGFI	0.97 (> 0.90)[a]
RMSR	0.04 (< 0.10)[a]
NNFI	1.00 (~1.00)[a]
NFI	0.98 (> 0.90)[a]
Hotelling's Critical N	785 (> 200)[a]

Note: Critical values for concluding "good" fit of model to data (Bollen, 1989; Hoyle, 1995; Marcoulides & Schumacker, 1996).

Also worth noting is that the lack of technical/e-business skills were the weakest of the three barriers for suppliers (standardized estimate = 0.73, t = 19.13), manufacturers (standardized estimate = 0.71, t = 11.70), and customers (standardized estimate = 0.71, t = 18.11) which suggested that it was not really the Internet technology that most held-back e-integration. Table 4 also contains the mediating and dependent latent variable loadings for e-integration, e-business performance, and operational performance.

Once again, the modification indices suggested that some of the constraints on the error terms for the manifest variables should be relaxed in order to get a better fit of the model. For example, reduced transaction costs negatively correlated with annual percent of sales/turnover using Internet while technology costs/benefits not demonstrated inversely varied with lack of technical/e-business skills. In such cases, an error covariance between the two indicators was included and the measurement model modified accordingly. As before, modification indices were cautiously used and a parameter/link was only relaxed if it could be interpreted substantively (Joreskog & Sorbom, 1993) regarding both the direction of impact as well as the sign of the parameter.

Table 6 shows the direct and indirect effects between the independent, mediating, and dependent constructs for the model (GAMMA and BETA in LISREL notation), and Figure 3 maps the direct effects against the conceptual model. Overall, there was strong support for the hypothesized relationships between e-integration and performance. As predicted, e-integration (H1) had strong direct effects on e-business and operational performance.

To further test this conclusion, we used cluster analysis to isolate the cases that had the least e-integration (n = 269) from those with the highest levels (n = 26). Manufacturers with the lowest mean levels of e-integration (based on ANOVA and the Scheffe test) had significantly lower e-business performance (p = 0.001) and operational performance (p = 0.001) in comparison with companies that had successfully e-integrated.

As expected, high supplier (H2a), internal (H2b), and customer barriers (H2c) all had significant negative effects on the degree of e-integration. Findings in particular suggest that internal barriers are the single most important factor

Table 4: Independent (Lambda-X) latent variable loadings.

Item	Supplier Barriers (SB)	Internal Barriers (IB)	Customer Barriers (CB)
λ_1	0.85 $t = 22.25$		
λ_2	0.90 $t = 24.46$		
λ_3	0.73 $t = 19.13$		
λ_4		0.88 $t = 15.03$	
λ_5		0.60 $t = 12.30$	
λ_6		0.71 $t = 11.70$	
λ_7			0.78 $t = 19.03$
λ_8			0.90 $t = 23.45$
λ_9			0.71 $t = 18.11$

Note: Standardized estimates shown. All values indicate statistically significant at the $p < 0.01$ level.

Table 5: Mediating and dependent (Lambda-Y) latent variable loadings.

Item	e-Integration (eI)	e-Business Performance (BP)	Operational Performance (OP)
λ_{10}	0.77 $t = 4.36$		
λ_{11}	0.78 $t = 4.31$		
λ_{12}		0.79 $t = 5.58$	
λ_{13}		0.73 $t = 5.69$	
λ_{14}			0.86 $t = 6.98$
λ_{15}			0.88 $t = 7.00$
λ_{16}			0.80 $t = 6.93$

Note: Standardized estimates shown. All values indicate statistically significant at the $p < 0.01$ level.

Table 6: Direct and indirect effects (GAMMA and BETA) of SEM.

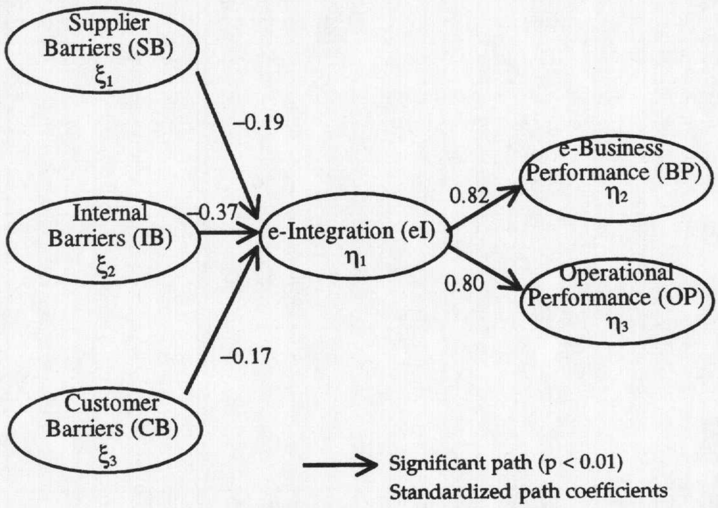
	Hypothesis 2a Supplier Barriers (SB) on	Hypothesis 2b Internal Barriers (IB) on	Hypothesis 2c Customer Barriers (CB) on
GAMMA Direct Effects			
e-Integration (eI)	–0.19 $t = -2.71$	–0.37 $t = -5.12$	–0.17 $t = -2.36$
GAMMA Indirect Effects			
e-Business Performance (BP)	–0.15 $t = -2.41$	–0.30 $t = -3.67$	–0.14 $t = -2.15$
Operational Performance (OP)	–0.15 $t = -2.28$	–0.31 $t = -3.25$	–0.14 $t = -2.06$

BETA Direct Effects

	Hypothesis 1 e-Integration (eI) on
e-Business Performance (BP)	0.82 $t = 4.06$
Operational Performance (OP)	0.80 $t = 4.55$

Note: Standardized estimates shown. All values indicate statistically significant at the $p <$ 0.05 level.

Figure 3: Results of testing the model.



when it comes to implementing Internet-enabled supply chains (standardized estimate = –0.37, $t = -5.12$). Although the conclusion that companies can be their own "worse enemy" is itself hardly novel, it is an important finding when taken in the overall context of the two other crucial issues of upstream supplier and downstream customer barriers. In other words, internal barriers most prevent Internet-enabled integration from occurring. Conversely, if internal barriers are weak in a manufacturer's supply chain then achieving e-integration is potentially much simplified.

Based on these findings, we are now able to pinpoint what manufacturers should focus on first when implementing e-integration. Reducing internal barriers are the necessary initial step for any company that wants to integrate its supply chain using the latest web-based techniques. As a further test of this conclusion, we used cluster analysis to isolate from the rest of the sample the cases that had the lowest internal barriers ($n = 68$) from those with the highest ($n = 81$). Manufacturers with the lowest mean levels of internal barriers (based on ANOVA and the Scheffe test) had significantly higher e-business performance ($p = 0.003$) and operational performance ($p = 0.033$) in comparison with companies that had the highest internal barriers.

High upstream supplier barriers (standardized estimate = –0.19, $t = -2.71$) and downstream customer barriers (standardized estimate = –0.17, $t = -2.35$) had similar negative effects when it comes to implementing e-integration. Evidence suggests that while supplier and customer barriers are not as crucial as internal barriers, they must nevertheless be reduced before a manufacturer can truly achieve an integrated supply chain using the Internet. Should supplier or customer barriers be addressed first? To answer this question we again used cluster analysis to isolate 78 cases that had much higher supplier barriers than customer obstacles and conversely 147 manufacturers where customer resistance greatly exceeded supplier hurdles. There was no significance difference in the t-tests for equality of means between these two groups on e-business performance ($p = 0.206$) and operational performance ($p = 0.921$). This suggests that there is no preferred sequence to addressing either supplier or customer barriers—resistance in both areas must simultaneously be overcome before high levels of e-integration are possible.

CONCLUSIONS

The findings support the arguments that e-integration improves performance, and clarifies the most crucial barriers to web-based supply chains. In terms of contributions to our field, this is the first such study (empirical or modeling) to do so. There was consistent evidence that external supplier, customer, and internal barriers were to varying degrees all obstacles to e-integration. In particular, the key to implementing e-integration is overcoming internal barriers. By their very nature the supply chain must be tightly interwoven and coordinated, and manufacturers neglecting their own internal obstacles stand a very small chance of successfully implementing e-integration outwards to their suppliers and customers. Moreover, companies also need to consider resistance in their upstream supply base and with downstream customers when trying to achieve e-integration. Following the analogy of a pipeline, upstream bottlenecks are just as important as downstream blockages when it comes to implementing e-integration.

Findings in this study lead to some tentative prescriptions for implementing supply chain improvements using e-integration. The results in particular suggest that managers interesting in improving their company's supply chain using e-integration should first focus on internal barriers. Lewin's (1947) pioneering work and subsequent studies such as Cooper and Zmud (1990) theorized that there were three steps to successful implementation: (1) "unfreezing" of the initial steady state, (2) a period of trial and change, and (3) consolidation with a "refreezing" in a new steady state. During the initial unfreezing phase, the supposed benefits of e-integration need to be thoroughly investigated and demonstrated as part of the implementation process. Since e-integrated supply chains involve information sharing, joint planning, channel-wide management of inventory, and customer relationship management, all of these areas should be considered in the analysis to help build broad consensus for the proposed improvements. Once internal support for e-integration is built, the company can then move on to reducing supplier and customer resistance. Many companies today are interested in Collaborative Planning, Forecasting and Replenishment (CPFR) that uses Internet connectivity between supply chain partners to share information and coordinate operations (Bowersox, Closs, & Stank, 2000; Holweg & Pil, 2001). Results from this study suggest that CPFR will likely remain elusive to companies until they have removed the internal, supplier, and customer barriers that prevent true supply chain collaboration.

As noted above, although the literature suggests the relevance of e-integration and many practitioners have speculated on its importance, this hypothesis was previously untested. Results from this study indicate that achieving strong upstream and downstream e-integration is the correct goal for companies to work towards. E-integration had important links to both e-business and operational performance, and the relatively few companies in the sample that have so far achieved it significantly outperformed the others. These forms of integration include order scheduling and tracking, inventory planning, integrated demand/forecasting, targeted marketing, and after-sales services. Even if some of these improvements may have been started in companies over the past few years due more to the hype surrounding the Internet than any real formal strategy, results suggest that manufacturers should continue improving e-integration whenever possible.

These findings also have some important implications for the theory and research of contemporary supply chains—especially those relying on e-integration. First, this study provides reliable and valid scales for measuring upstream supplier and downstream customer e-integration. These scales can facilitate future work in this area and should prove valuable to other supply chain researchers.

Second, this study contributes to our theoretical understanding about implementing change in the supply chain. Findings suggest that an "inside-out" strategy of first removing internal barriers and then bringing upstream suppliers and downstream customers onboard is the best way to change the supply chain. This is the same strategy that Taiichi Ohno used in the 1950s to diffuse the now famous Toyota Production System outwards to suppliers, and the one that Michael Dell followed in the 1990s to revolutionize his supply chain. The alternative "outside-in" strategy of first pressuring suppliers and/or customers into changing their supply chain practice is likely doomed to failure if a manufacturer has not already addressed its own internal barriers. Indeed, many of the anecdotal stories about supply chain failures seem to fit the "outside-in" model. Companies that try to force their suppliers or customers into changing without first making their own internal improvements always seem to end up with few supply chain improvements.

Finally, this study raises the possibility that improvement strategies should actually span across supply chains. For example, what happens in a particular supply chain if one company is focusing on either supplier or customer's barriers while its upstream and/or downstream partners are concentrating on their internal barriers? The optimal sequence for removing the barriers to e-integration across supply chains needs to be investigated in future research. Should various supply chain members all simultaneously remove their internal barriers first? Conversely, what happens in a supply chain if members randomly improve various barriers? Finally, what is the optimal combination or sequence of improvement strategies in a supply chain? This paper provides some of the basic building blocks for answering these questions, but the very nature of the cross-firm analysis presents an extra layer of difficulty to whichever research method is employed. In the case of empirical studies, it means that the next generation of e-integration research will likely involve data collection from more than one unit along the supply chain to provide the multiple perspectives that helps us address these issues. [Received: September 29, 2001. Accepted: September 9, 2002.]

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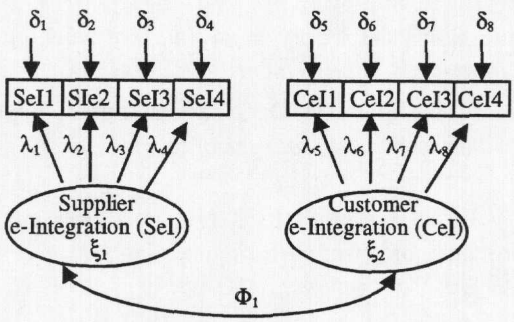
Appendix: A two-factor oblique measurement model for e-integration.



ξ_1 **Supplier e-Integration (SeI):** To what extent have you implemented *web-based* processes for any of the following with suppliers?

	No at all				Fully	Loading	t-score
SeI1: Procurement for materials	1	2	3	4	5	$\lambda_1 = .56$	13.06
SeI2: Integrated order scheduling and tracking	1	2	3	4	5	$\lambda_2 = .93$	24.32
SeI3: Integrated inventory planning	1	2	3	4	5	$\lambda_3 = .85$	21.96
SeI4: Integrated demand/forecasting	1	2	3	4	5	$\lambda_4 = .84$	20.70

ξ_2 **Customer e-Integration (CeI):** To what extent have you implemented *web-based* processes for any of the following with customers?

	No at all				Fully	Loading	t-score
CeI1: Targeted marketing/customer profiling	1	2	3	4	5	$\lambda_5 = .78$	18.43
CeI2: On-line order taking/receipt	1	2	3	4	5	$\lambda_6 = .91$	21.59
CeI3: After-sales service/support	1	2	3	4	5	$\lambda_7 = .84$	20.25
CeI4: Integrated demand/forecasting	1	2	3	4	5	$\lambda_8 = .75$	18.84

Goodness of Fit Statistic	2-Factor Model (df = 9)
χ^2	10.50 ($p < 0.31$)
χ^2/df	1.17 (≤ 2.00)
GFI	0.99 (> 0.90)
AGFI	0.98 (> 0.90)
RMSR	0.01 (< 0.10)
NNFI	1.00 (~ 1.00)
NFI	1.00 (> 0.90)
Hotelling's Critical N	1002 (> 200)

Covariance between supplier and customer e-integration
$\Phi_1 = .68$
t-score = 24.92

Note: Standardized estimates shown for loadings, all *t*-scores significant at $p < 0.001$. Critical values for concluding "good" fit of model to data (Bollen, 1989; Hoyle, 1995; Marcoulides & Schumacker, 1996).

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