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Arcs of integration: an international study of supply chain strategies

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Abstract

Though there is a wide acceptance of the strategic importance of integrating operations with suppliers and customers in supply chains, many questions remain unanswered about how best to characterize supply chain strategies. Is it more important to link with suppliers, customers, or both? Similarly, we know little about the connections between supplier and customer integration and improved operations performance. This paper investigated supplier and customer integration strategies in a global sample of 322 manufacturers. Scales were developed for measuring supply chain integration and five different strategies were identified in the sample. Each of these strategies is characterized by a different "arc of integration", representing the direction (towards suppliers and/or customers) and degree of integration activity. There was consistent evidence that the widest degree of arc of integration with both suppliers and customers had the strongest association with performance improvement. The implications for our findings on future research and practice in the new millennium are considered.

Keywords: Supply chain management; Operations strategy; Empirical research

1. Introduction

Over the past two decades, there has been a marked shift in the focus of operations strategy. If the 1980s were about *vertically* aligning operations with business strategy (Hayes and Wheelwright, 1984), the 1990s have been about *horizontally* aligning operations across processes (Ghoshal and Bartlett, 1995). In most industries today it is not enough simply to optimize internal structures and infrastructures based upon business strategy. The most successful manufacturers seem to be those that have carefully linked their internal processes to external suppliers and customers in unique supply chains. In short, for the new millennium upstream and downstream integration with suppliers and customers has emerged as an important element of manufacturing strategy.

Though the fundamental importance of supply chains is widely accepted (Saunders, 1997; Gattorna, 1998), important questions remain open about how to characterize them (New, 1996). Our knowledge is relatively weak concerning which forms of integration manufacturers use to link up with suppliers and customers. Moreover, we know little about the connections between upstream and downstream supply chain integration and resulting performance. Which types of integration lead to the greatest overall performance improvements?

This paper empirically analyzed manufacturers' supply chain integration strategies. The paper used evidence from an international study of manufacturing strategy and tested the relationship between supply

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chain integration and performance. As Eloranta and Hameri (1991) noted, inbound and outbound logistics tend to be separated in research with an unbalanced emphasis on the supply or purchasing side. Therefore, an important goal of this paper was simultaneously considering upstream supplier and downstream customer integration during the analysis. In so doing, the paper develops a new way of characterizing the direction and degree of supply chain integration, and thus of defining different supply chain strategies. Finally, some implications of these findings for operations management strategy research and practice in the new millennium are suggested.

2. The strategic importance of supply chain integration

Over the past decade there has been a growing consensus concerning the strategic importance of integrating suppliers, manufacturers, and customers (Reck and Long, 1988; Leender and Blenkhorn, 1988; Bowersox et al., 1989; Freeman and Cavinato, 1990; Syson, 1989; McGinnis and Kohn, 1990, 1993; Morris and Calantone, 1991; Cammish and Keough, 1991; Eloranta and Hameri, 1991; Burt and Doyle, 1992; Clinton and Closs, 1997). As Carothers and Adams (1991), Langley and Holcomb (1992), and Shapiro et al. (1993) convincingly argued, the once narrow subject of logistics has become a comprehensive topic that now spans the entire value system from suppliers to customers. Reinforcing this point, Ragatz et al. (1997) noted that the "effective integration of suppliers into product value/supply chains will be a key factor for some manufacturers in achieving the improvements necessary to remain competitive". For practitioners, the strategic importance of integration is similarly reflected in the Supply Chain Council's popular Supply Chain Operations Reference (SCOR) model that assumes all businesses include sourcing, making, and delivering processes strategically linking suppliers and customers to manufacturers (see www.supply-chain.org.).

Many of the theoretical arguments for closely integrating operations between manufacturers and suppliers and customers come from the process reengineering literature (Hammer and Champy, 1993; Hammer, 1996; Fliedner and Vokurka, 1997; Burgess, 1998). Typically the goal is to create and coordinate manufacturing processes seamlessly across the supply chain in a manner that most competitors cannot very easily match (Anderson and Katz, 1998; Lummus et al., 1998). As Birou et al. (1998) pointed out "the opportunity to use process integration across functional boundaries is now considered a key to competitive success". Davis (1993), Dyer and Ouchi (1993), Eisenhardt and Tabrizi (1994), and Littler et al. (1995) similarly echoed the importance of integrating suppliers and customers into supply chains for developing new products and processes.

2.1. Supply chain integration tactics

At the tactical level, the literature suggests that there are two interrelated forms of integration that manufacturers regularly employ (Fig. 1). The first type of integration involves coordinating and integrating the *forward* physical flow of deliveries between suppliers, manufacturers, and customers (Saunders, 1997; Trent and Monczka, 1998). Many of these proponents of supply chain integration fall under the banner of just-in-time (Chapman and Carter, 1990; Chen and Chen, 1997; Landry et al., 1997; Grout, 1998; Narasimhan and Carter, 1998; Tan et al., 1998; Sakakibara et al., 1997; White et al., 1999). Others have pointed out the importance of delivery integration in terms of implementing product postponement and mass customization in the supply chain (Lee, 1998; Lee and Tang, 1998; Van Hoek et al., 1998; Pagh and Cooper, 1998) or for exploiting third-party logistics (Saunders, 1997; Gattorna, 1998; Marvick and White, 1998).

The other prevalent type of integration involves the *backward* coordination of information technologies and the flow of data from customers to suppliers (Martin, 1992; Trent and Monczka, 1998). Information technologies allow "multiple organizations to

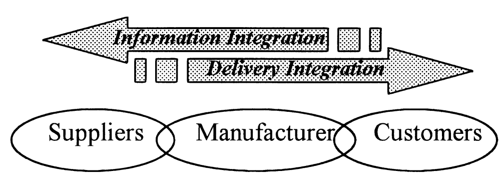


Fig. 1. Integration in the supply chain.

coordinate their activities in an effort to truly manage a supply chain" (Handfield and Nichols, 1999). Integration using information technologies includes electronic data interchange (EDI) (Sheombar, 1992; Walton and Marucheck, 1998; Jayaram and Vickery, 1998; Narasimhan and Carter, 1998) as well as sharing data from traditional planning and control systems (Bowersox and Daugherty, 1995; Lewis and Talalayevsky, 1997; Van Hoek et al., 1998).

2.2. The arc of integration

If this need to develop shared operational activities is accepted, then the strategic issue becomes one of direction and degree — in which direction (towards customers and/or towards suppliers) and to what extent (degree of integration) should such shared activity be developed? Taking this pair of decisions as the key dimensions for representing a strategic position we can illustrate them graphically as an arc, with the direction of the segment showing whether the firm is supplier or customer leaning, and the degree of arc indicating the extent of the integration. This has more visual immediacy than a plot on a line graph for this type of investigation. Hence, in this paper we characterize the strategic position of each respondent with respect to supply chain development as that firm's "arc of integration".

As suggested by Fig. 2, all manufacturers implicitly make strategic decisions concerning the extent of upstream and downstream integration that they want to undertake. Some manufacturers decide to engage in relatively little integration with suppliers or customers and thus have a relatively narrow arc of integration. Other manufacturers extensively integrate their organizations with upstream suppliers and downstream customers by pursuing a strategy with a broad arc of integration.

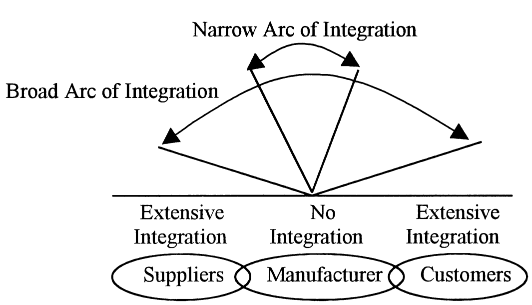


Fig. 2. Arcs of integration.

Growing evidence suggests that the higher the level of integration with suppliers and customers in the supply chain the greater the potential benefits (Stevens, 1989; Lee et al., 1997; Metters, 1997; Narasimhan and Jayaram, 1998; Lummus et al., 1998; Anderson and Katz, 1998; Hines et al., 1998; Johnson, 1999). Tan et al., (1998) noted that when companies "integrate and act as a single entity, performance is enhanced throughout the chain". Others have pointed out the inherent hazards of not fully integrating with upstream suppliers and downstream customers (Lee and Billington, 1992; Hammel and Kopczak, 1993; Armistead and Mapes, 1993). Fisher et al. (1994) highlighted the critical role of balancing supply and demand across the supply chain. Handfield and Nichols (1999) argued that now manufacturers must not only manage their own organizations but also be involved in the management of the network of upstream and downstream firms. Hale (1999) similarly pointed out that those firms "who have traditionally been structured as independent businesses will increasingly have to configure operations on a shared basis". By extension, manufacturers with the broadest arcs of supply chain integration should have the highest levels of performance improvements. This leads to the hypothesis that we wish to examine in this paper:

Hypothesis 1. Companies with the greatest arcs of supplier and customer integration will have the largest rates of performance improvement.

3. Research methods

3.1. Sample

Data from the 1998 round of the International Manufacturing Strategy Survey (IMSS) were used to test the arc of integration hypothesis. The IMSS was founded in 1992 to gather data about the practice and performance related to manufacturing strategy in a global setting (see Voss and Blackmon (1998) and Ettlie (1998) for more details on the IMSS study). The survey focused on the ISIC Division 38: manufacture of fabricated metal products, machinery and equipment. Pending future research, the results of this study should, therefore, be carefully generalized to other sectors such as consumer goods manufacturers. It may be more difficult for consumer goods manufacturers to integrate with customers — especially ones that sell directly to end-users. In addition, such manufacturers tend to have broader customer bases that complicate integration.

For 1998, research coordinators in 23 countries administered the survey on a country by country basis. In nations where English was not a prevalent language the surveys were translated by full-time OM professors familiar with manufacturing strategy. Dillman's (1978) total design method for mail survey research was followed and data were collected from 703 companies in the 23 countries. The response rate for the total sample was approximately 20%.

It is important to note that for this paper only 322 of the 703 total responses were included in the analysis. The excluded cases had relatively incomplete reported performance data. The subset included in this paper and the total sample are summarized by region in Table 1, and the deleted responses were proportional around the world. As an additional test, ANOVA and the Scheffé method were used to check for significant demographic differences between the subset used in this study and the total sample. There were no significant differences ($p < 0.05$) between the total sample and sub-sample for country ($p = 0.7041$), size ($p = 0.6065$), or SIC code ($p = 0.6469$) which suggested that examining only those cases with complete performance data did not bias the analysis.

Table 1
Sample by region

Region	Subset used in this paper		Total sample	
	Count	%	Count	%
Asia/Pacific	85	26.4	210	29.9
Europe	157	48.8	306	43.5
North America	46	14.3	111	15.8
South America	34	10.6	76	10.8
Total	322[a]	100.0	703	100.0

[a] 381 case deleted from the 703 total sample due to incomplete performance data.

3.2. Independent construct measurement

Content validity represents the sufficiency with which a specific domain of content (i.e. construct) was sampled (Nunnally, 1978). As Flynn et al. (1995) highlighted, *content validity* is subjective and judgmental but is often based on two standards put forward by Nunnally: does the instrument contain a representative set of measures, and were sensible methods of scale construction used? In this study integration was operationalized based upon eight different kinds of activities that manufacturers commonly employ to integrate their operations with suppliers and customers (see Appendix A). The literature and diverse experience of researchers from the various schools that participated in the IMSS study played a key part in grounding these integration measures in the field. Comments from the survey pre-testers also helped shape the measures used for this study. All types of integration were measured on 1–5 Likert-type scales from none (1) to extensive (5). The summary statistics for supplier and customer integration variables are shown in Table 2.

Table 2
Summary statistics for integrative activities

Suppliers		Integrative activity	Customers		Paired samples *t*-test	
Mean	S.D.		Mean	S.D.	*t*	Significance
2.22	1.17	Access to planning systems	2.01	1.18	−2.82	0.005
2.67	1.29	Sharing production plans	2.05	1.25	−7.73	0.000
1.97	1.18	Joint EDI access/networks	1.96	1.23	−0.09	0.927
2.48	1.18	Knowledge of inventory mix/levels	2.16	1.16	−4.14	0.000
2.67	1.22	Packaging customization	2.89	1.39	2.80	0.005
3.52	1.16	Delivery frequencies	3.47	1.26	−0.72	0.473
2.49	1.27	Common logistical equipment/containers	2.18	1.29	−4.38	0.000
2.20	1.18	Common use of third-party logistics	2.07	1.19	−2.04	0.042

Table 3
Factor analysis of integrative activities and reliabilities

Suppliers factor 1	Integrative activity	Customers factor 1
Factor loadings		
0.67198	Access to planning systems	0.72540
0.73195	Sharing production plans	0.70770
0.58757	Joint EDI access/networks	0.70037
0.69329	Knowledge of inventory mix/levels	0.64154
0.73187	Packaging customization	0.64262
0.71132	Delivery frequencies	0.66373
0.74822	Common logistical equipment/containers	0.72905
0.74310	Common use of third-party logistics	0.62291
Factor analytic and reliability statistics		
0.87311	Kaiser–Meyer–Olkin adequacy	0.84859
799.4	Bartlett test of sphericity	678.6
0.00000	Significance	0.00000
3.96683	Eigenvalue	3.70216
49.6	Percent of variation	46.3
0.8536	Cronbach's alpha	0.8333

Multi-item scales were developed for each construct in this study. Before creating the final scales, the data were checked for normality and outliers. As shown in the bottom half of Table 3, the Kaiser–Meyer–Olkin measures of sampling adequacy were 0.87311 (suppliers) and 0.84859 (customers). A minimum Kaiser–Meyer–Olkin score of 0.50 is considered necessary to reliably use factor analysis for data analysis. Scores over 0.80 are considered very good. Similarly, the Bartlett test of sphericity (the higher the better) was 799.4 (suppliers) and 678.6 (customers) with significance levels of $p < 0.00000$.

Confirmatory factor analysis (Kim and Mueller, 1978) was employed to help ensure reliable scales (Flynn et al., 1990; O'Leary-Kelly and Vokurka, 1998). SPSS's principal components procedure was used to check that the eight integration measurements were uni-dimensional (see the top half of Table 3). A single factor loaded for the eight integration measurements based on the manufacturer's answer for integrating with suppliers. Similarly, the eight measures loaded on a single factor for the customers. Factor scores were saved from the principal component analysis for supplier and customer integration using the regression method. Factor scores are the weighted averages of values on all the original variables using factor loadings as weightings. Using factor scores in this manner creates a more accurate measure than simply computing a mean, which assigns equal weights to items (Lastovicka and Thamodaram, 1991).

An internal consistency analysis was done for each factor using the SPSS reliability procedure (Saraph et al., 1989; Flynn et al., 1995). As seen at the bottom of Table 3, the reliability of each scale was satisfactory according to accepted guidelines for newly developed scales with Cronbach's alphas of at least 70% (Nunnally, 1978; Flynn et al., 1995).

Table 4 shows the zero-order Pearson correlation coefficients for the supplier and customer integration scales. As might be expected, because many forms of upstream and downstream integration are often undertaken at the same time, the scales were positively correlated with each other.

The reliability and validity of each scale was further analyzed following Flynn et al.'s (1995) example. *Construct validity* is supported if the items in a scale all load on a common factor when within-scale factor analysis is run. Table 3 shows that the eigenvalues for both the supplier and customer integration scales exceeded the minimum threshold of 1.0 and helped confirm the dimensionality of each construct. *Divergent* or *discriminant validity* was tested by analyzing bivariate correlations between each of the scales and other potentially confounding demographic variables included in the study such as country responding, company size, market focus, product focus, and geographical focus

Table 4
Correlations among integration scales and demographic variables

	1	2	Correlations between scale and other demographic variables					
			Country	Size[a]	SIC code	Market focus[b]	Product focus[c]	Geographical focus[d]
Supplier integration (1)	1.00		−0.06	−0.01	−0.03	0.04	−0.01	0.03
Customer integration (2)	0.54[e]	1.00	0.11	−0.01	−0.09	−0.04	−0.01	−0.02

[a] Size = number of employees.
[b] Market focus = 1–5 Likert, 1 = few markets, 5 = manymarkets.
[c] Product focus = 1–5 Likert, 1 = physical attributes, 5 = service emphasis.
[d] Geographical focus = 1–5 Likert, 1 = national attributes, 5 = international.
[e] Significant at $p < 0.01$.

(right side of Table 4). There were no significant correlations ($p < 0.05$) between the two scales and other demographic variables, and thus the scales were not measuring other unintended constructs.

3.3. Operationalizing arcs of integration

Arcs of integration were operationalized as shown in Fig. 3. Five mutually exclusive groups were defined that conceptually represented the major different integration strategies that manufacturers could undertake in relation to suppliers and customers (see Fig. 3). The factor score for supplier integration was used to classify each manufacturer into either the upper, middle, or lower quartiles. Similarly, each manufacturer's customer integration score was used to classify the case into the correct quartile. Although the selection of cut-off points in any statistical analysis is somewhat arbitrary, dividing samples into quartiles is commonly done in applications ranging from student graduation rankings to benchmarking studies for identifying best-in-class (75th percentile), median (50th percentile), and worst-in-class (25th percentile) group membership (McClave and Benson, 1985). Relying on quartiles for data grouping, instead of other data classification method such as cluster analysis, also means that future researchers using identical cut-off points can readily replicate this study.

Quartiles were then used to sort the 322 cases into the five different integration strategies. For example, respondents that were in the bottom quartiles of integration with *both* suppliers and customers were classified as “inward-facing”. Manufacturers who reported integration levels above the lower quartiles in *at least one* direction (upstream with suppliers or downstream with customers) but that fell below the upper quartiles for suppliers and customers were categorized as “periphery-facing”. Respondents that reported extensive integration with suppliers (in the upper quartile), but that had customer integration below the upper quartile were categorized as “supplier-facing”. In a similar manner, manufacturers that reported extensive integration with customers (in the upper quartile) but remained below the upper quartile for suppliers were categorized as “customer-facing”. Finally, companies that reported high levels of integration in the upper quartiles for *both* customers and suppliers were labeled “outward-facing”.

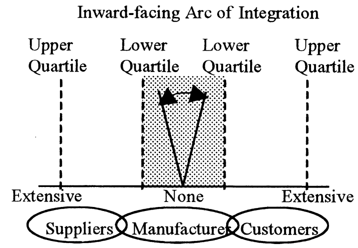
We analyzed supply chain integration based upon the above operationalization for arcs of integration. As shown in Table 5, the sample of 322 manufacturers was sorted into the five different integration groups outlined above and in Fig. 3. For example, 44 of the 322 respondents were in the bottom quartiles for integrating with suppliers and customers. We therefore classified them as “inward-facing”. Conversely, 29 of the 322 respondents indicated extensive (upper quartile) upstream and downstream integration with sup-

Table 5
Arc of integration group membership

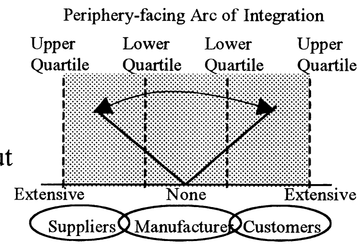
Integration type	Number	%
Inward-facing (1)	44	13.7
Periphery-facing (2)	137	42.5
Supplier-facing (3)	39	12.1
Customer-facing (4)	42	13.0
Outward-facing (5)	29	9.0
Missing	31	9.6
Total	322	100.0

To what extent do you organizationally integrate activities with your customers and suppliers?

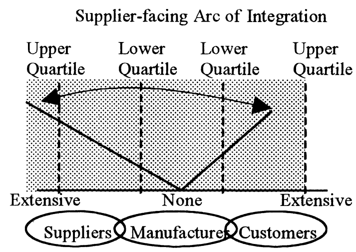
1. Inward-facing
   Classified as inward-facing if response was:
   a. In lower quartile for suppliers, and
   b. In lower quartile for customer



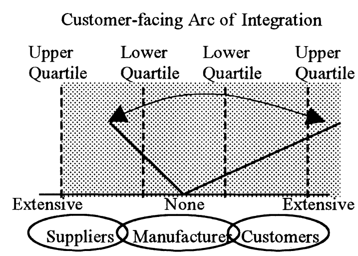
2. Periphery-facing
   Classified as periphery-facing if response was:
   a. Above lower quartile for suppliers *or* customers, but
   b. Below upper quartile for suppliers *and* customers



3. Supplier-facing
   Classified as supplier-facing if response was:
   a. In upper quartile for suppliers, and
   b. Below upper quartile for customers



4. Customer-facing
   Classified as customer-facing if response was:
   a. In upper quartile for customers, and
   b. Below upper quartile for suppliers



5. Outward-facing
   Classified as outward-facing if response was:
   a. In upper quartile for suppliers, and
   b. In upper quartile for customers

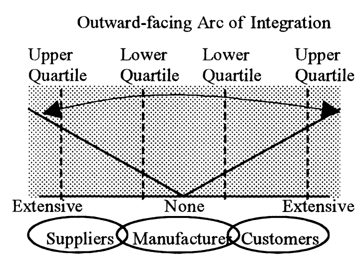


Fig. 3. Operationalization of arcs of integration.

pliers and customers. These 29 manufacturers were grouped as "outward-facing". Similar procedures were followed for classifying the remaining companies in the sample into the 137 "periphery-facing", 39 "supplier-facing", and 42 "customer-facing" groups. Thirty-one cases had missing data for supply chain integration and were omitted.

Two checks were done to help ensure that the five groups were correctly classified for supply chain integration in Table 5. First, SPSS's *K*-means cluster analysis was used to group the 322 cases into five groups based upon the scales for supplier and customer integration. The *K*-means procedure identifies relatively homogeneous groups of cases for selected variables. Cluster memberships for each of the five groups was saved and then compared using SPSS's Crosstabs procedure to the five groups in Table 5. Crosstabs was used to count the number of cases that were in common (and different) between the two classifications and to calculate bivariate statistics. The Pearson's correlation between group membership for the two classification procedures was 0.2919 ($p < 0.00000$). This strong correlation between the data-driven cluster analysis and our quartile procedure supported the way we operationalized arcs of integration.

Second, discriminant analysis was run to ensure that the five groups were correctly classified for supply chain integration. The 16 integrative activities (eight for suppliers and eight for customers) listed in the Appendix A and Table 2 were entered as independent variables along with group membership from Table 5 (inward-, periphery-, supplier-, customer-, and outward-facing) as the dependent variable. As seen in Table 6, the discriminant analysis confirmed that 81.8% of the respondents were classified correctly, indicating extremely good differentiation among the five groups and substantially above the 20% correct classification that would be expected by chance. This relatively high percentage of correctly classified cases likewise supported the validity of the groups into which usable respondents were placed.

The operationalization of arcs of integration in Fig. 3 was least exact at classifying the periphery-facing group (70.8%) as shown in Table 6. This was to be expected since the more inclusive, less discriminating definition (integration levels above the lower quartiles in at least one direction for suppliers or customers, but below the upper quartile for both) classified the periphery-facing group. A manufacturer just *above* the lower quartiles for suppliers or customers was classified as periphery-facing whereas a respondent just *below* the lower quartiles for suppliers and customers was grouped as inward-facing. The supplier-facing (89.7%) and customer-facing (90.5%) groups were very accurately classified. The polar extremes of inward-facing (90.9%) versus outward-facing (96.6%) were the two most accurate classifications.

3.4. Dependent construct measurement

Prior work has identified many types of potential performance improvements that are commonly associated with supply chains (see for example, Martin, 1992; Saunders, 1997; Gattorna, 1998; Handfield and Nichols, 1999). Voss (1988) divided manufacturing success into three levels: marketplace competitive advantage, productivity increases, and non-productivity benefits. Marketplace success involved longer-term competitive gains including increased market share and greater profitability. Productivity gains came

Table 6
Classification results for discriminant analysis test for arcs of integration[a]

Group	No. of cases	Predicted group membership				
		Inward-facing (1)	Periphery-facing (2)	Supplier-facing (3)	Customer-facing (4)	Outward-facing (5)
Inward-facing (1)	44	40 (90.9%)	4 (9.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Periphery-facing (2)	137	18 (13.1%)	97 (70.8%)	14 (10.2%)	8 (5.8%)	0 (0.0%)
Supplier-facing (3)	39	0 (0.0%)	1 (2.6%)	35 (89.7%)	2 (5.1%)	1 (2.6%)
Customer-facing (4)	42	0 (0.0%)	0 (0%)	2 (4.8%)	38 (90.5%)	2 (4.8%)
Outward-facing (5)	29	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (3.4%)	28 (96.6%)
Missing cases	31	0 (0.0%)	18 (58.1%)	6 (19.4%)	5 (16.1%)	2 (6.5%)

[a] Overall percent of grouped cases correctly classified: 81.8%.

from decreased labor costs and increased throughput. Non-productivity benefits included quality improvements and lead-time reductions. In order to capture the multi-dimensional nature of supply chain performance this study included 19 diverse measures of marketplace, productivity, and non-productivity success. All metrics were based on reported changes in business unit performance on a percentage improvement basis per year.

4. Results and discussion

The five arcs of integration representing inward-, periphery-, supplier-, customer-, and outward-facing groups were evaluated using ANOVA and the Scheffé method to test for significant differences between their mean levels of improvements for the 19 performance measures. Table 7 shows that there were numerous significant ($p < 0.05$) differences between the five different arcs of supply chain integration.

Hypothesis 1 that companies with the greatest arcs of supplier and customer integration will have the largest rates of performance improvement was strongly supported. The subset of outward-facing manufacturers clearly recorded greater rates of performance improvements in comparison to the inward-facing group. The outward-facing supply chain strategy also consistently outperformed the periphery-, supplier-, and customer-facing strategies. While our analysis does not prove a causal relationship between arcs of integration and performance, these findings provide more evidence to the growing consensus in the literature that coordinated upstream and downstream integration in the supply chain differentiates performance (Stevens, 1989; Lee and Billington, 1992; Hammel and Kopczak, 1993; Armistead and Mapes, 1993; Lee et al., 1997; Metters, 1997; Narasimhan and Jayaram, 1998; Lummus, 1998; Anderson and Katz, 1998; Hines et al., 1998; Tan et al., 1998; Johnson, 1999).

Table 7
ANOVA results for performance measures by arc of integration

Performance indicator[a]	Inward-facing (1)	Periphery-facing (2)	Supplier-facing (3)	Customer-facing (4)	Outward-facing (5)	Significance
Marketplace						
Market share	8.7%$^{(5)}$	11.6%$^{(5)}$	10.3%$^{(5)}$	8.7%$^{(5)}$	26.5%$^{(1,2,3,4)}$	0.0001
Profitability	12.3$^{(5)}$	14.9$^{(5)}$	12.2$^{(5)}$	9.1$^{(5)}$	31.5$^{(1,2,3,4)}$	0.0003
Return on investment	7.5	16.5	12.4	8.0	21.8	0.2146
Productivity						
Average unit manufacturing cost	11.0	11.6	10.3	8.3	21.9	0.0298
Materials and overhead total costs	13.6	12.3	8.9	9.5	20.8	0.0519
Manufacturing lead time	11.3$^{(5)}$	14.5	13.5	10.9$^{(5)}$	25.1$^{(1,4)}$	0.0269
Equipment changeover time	9.1	14.7	10.5	10.0	23.1	0.0320
Procurement lead time	9.1$^{(5)}$	12.9	10.4$^{(5)}$	7.3$^{(5)}$	22.4$^{(1,3,4)}$	0.0043
Delivery lead time	8.3$^{(5)}$	13.7	13.0	6.6$^{(5)}$	22.8$^{(1,4)}$	0.0038
Inventory turnover (sales/inventory)	11.7	15.3	12.4	9.6	23.6	0.0750
Worker/direct labor productivity	12.7	15.1	10.4$^{(5)}$	9.0$^{(5)}$	23.0$^{(3,4)}$	0.0092
Non-productivity						
Customer service	9.7$^{(5)}$	15.4	10.8$^{(5)}$	9.1$^{(5)}$	24.6$^{(1,3,4)}$	0.0019
Customer satisfaction	10.3$^{(5)}$	14.9	10.9$^{(5)}$	9.4$^{(5)}$	23.3$^{(1,3,4)}$	0.0025
Conformance quality	10.4$^{(5)}$	14.1	12.4$^{(5)}$	14.0	25.5$^{(1,3)}$	0.0067
Product variety	9.7$^{(5)}$	14.8	10.7$^{(5)}$	9.5$^{(5)}$	25.8$^{(1,3,4)}$	0.0062
Speed of product development	12.9	18.2	13.9	9.9$^{(5)}$	24.2$^{(4)}$	0.0034
Number of new products developed	12.1	15.6	18.8	10.0	22.7	0.0954
On-time delivery	11.9$^{(5)}$	15.0	10.5$^{(5)}$	10.7$^{(5)}$	22.6$^{(1,3,4)}$	0.0207
Supplier quality	9.4$^{(5)}$	14.2$^{(5)}$	10.3$^{(5)}$	7.5$^{(5)}$	28.1$^{(1,2,3,4)}$	0.0001

[a] Percentages shown are percentage improvement in each measure reported per year. Numbers in parentheses indicate group number from which the group is different (Scheffé pairwise test with significance level 0.05).

Table 7 leads to four tentative conclusions. First, the outward-facing supply chain strategy is associated with the largest rates of significant performance improvements. Why was this so? The answer possibly lies in the fact that better coordination in the supply chain reduces uncertainty throughout manufacturing networks (Davis, 1993; Lee et al., 1997). Tighter coordination helps eliminate many non-value-adding activities from *internal* and *external* production processes including the seven classic wastes of Shigeo Shingo: overproduction, waiting, transportation, unnecessary processing steps, stocks, motion, and defects (Hall, 1987). In terms of supply chains, better coordination directly translates into reduced variability (Metters, 1997; Lee and Tang, 1998; Grout, 1998) which in turn leads to greater efficiency along with faster delivery of finished goods.

Second, manufacturers may be seriously jeopardizing performance by continuing to follow the inward-facing strategy. Schmenner and Swink's (1998) theory of swift, even flows postulated that the most successful operations smoothly move raw materials and subassemblies through processes and into finished goods. Raw materials, work-in-process, and finished goods only move swiftly if there are no flow impediments in the way, and productivity rises proportionally to the speed that materials move through processes (Schmenner and Swink, 1998). By extension, manufacturers failing to integrate upstream and downstream in their supply chain have little hope of ever completely achieving swift, even flows. Theory thus predicts that performance for relatively isolated operations will suffer, as was the case for the inward-facing manufacturers in this study.

Third, results for the supplier- and customer-facing strategies suggested that focusing on only the inbound or the outbound sides of the supply chain gained little more for manufacturers than adopting the periphery- or inward-facing strategies. Inbound and outbound logistics is often separated in practice with a disproportional emphasis on the supply side (Eloranta and Hameri, 1991). Lee and Billington (1992) and Hammel and Kopczak (1993) reached similar conclusions concerning the dangers of fragmented supply chains. Lee and Billington (1992) in particular argued that common pitfalls of supply chain management included incomplete supply chains, poor coordination, inaccurate delivery status data, inefficient information systems, and ignoring the impact of uncertainties. Conversely, "going beyond the internal supply chain by including external suppliers and customers often exposes new opportunities for improving internal operations" (Lee and Billington, 1992).

Once again, Schmenner and Swink's (1998) work on operational theory gives us insight into why the supplier- and customer-facing supply chain strategies had lower performance improvement rates than the outward-facing group. Their theory of "Performance Frontiers" holds that every manufacturer has an *operating frontier* based on a unit's current performance and an *asset frontier* defined as the maximum performance that can be achieved. The more completely a manufacturer aligns their operating policies with the theoretical capabilities of its assets the greater the eventual performance (Schmenner and Swink, 1998). Findings in this study suggest that supplier and customer-facing manufacturers were not making full use of their potential by focusing on only one side of their supply chains. If theory is correct, and performance improvements come from altering manufacturing policies in ways that move or change the shape of operating frontiers, then broad upstream and downstream supply chain integration appears to be the optimal strategy to follow. Similarly, supplier- and customer-facing manufacturers are unlikely to achieve their theoretical levels of performance improvement until they take the final step and evolve into the outward-facing supply chain strategy.

Finally, over 40% of the sample was in the periphery-facing group. This suggests that periphery-facing may be the supply chain's natural "equilibrium point" in terms of integration. Many manufacturers have no doubt recognized the dangers of adopting an inward-facing strategy and have evolved into the broader periphery-facing perspective. From there, manufacturers may or may not continue evolving into the supplier, customer, or outward-facing strategies.

5. Theoretical conclusions and managerial implications

This study leads to two main conclusions. First, evidence suggested that there were different supply chain integration strategies that manufacturers followed. Around the world these different supply chain strategies can be empirically classified into at least five valid types, defined by the direction (towards suppliers and/or customers) and degree of integration. These five groups — inward-, periphery-, supplier-, customer-, and outward-facing — have both intuitive appeal and statistical validity in a reasonably large international database. They can be defined, in terms of the direction and degree of their similar supply chain activities, by their quite different arcs of integration. This classification could be of potential value to future researchers and is capable of further refinement (e.g. the periphery-facing group — the largest in our study — might yield further subclassifications).

Second, the greatest degree (or broadest arc) of supply chain integration was strongly associated with higher levels of performance. Although this has been an assumption behind much of the supply chain literature, this is the first time (to the best of our knowledge) that it has been demonstrated empirically with a large international group of companies. The outward-facing group had the highest level of performance improvements while the inward-facing manufacturers recorded some of the lowest. Only the outward-facing manufacturers chose to act upon the powerful benefits of supply chain integration. Perhaps surprisingly, adopting either a supplier- or a customer-facing supply chain strategy had few apparent advantages over the inward-facing strategy. This finding helps to validate the metaphor of a supply "chain", since weak links between suppliers and customers actually appeared to hurt performance.

These findings have some important implications for theory and managerial practice. In terms of theory, it may no longer be enough to consider only the vertical alignment of a manufacturing function with business strategy. Future research should also consider the horizontal degree of upstream and downstream integration as part of operations strategy. This study raises the interesting prospect that manufacturing strategy needs to be aligned *across* the supply chain not just inside organizations. What happens in a supply chain if one or more manufacturers adopt the inward-facing strategy? Without an over-arching operations strategy, just one isolated manufacturer will likely keep other firms in the supply chain from achieving their utmost performance.

Similarly, why did the five groups end up with very different supply chain integration strategies? It is too simplistic to say that some groups like the supplier- and customer-facing groups unluckily crafted relatively poor manufacturing strategies, but somehow the outward-facing group seemed to have wisely grasped the importance of supply chain integration and incorporated it into their operations. This raises the importance of the process of formulating and implementing manufacturing strategy. Not only is the content of manufacturing strategy critical, but evidently so is the process through which manufacturers develop a greater appreciation for supply chain integration, synthesize their plans and strategies, and ultimately implement upstream and downstream changes.

The study also has several important implications for managers. First, the outward-facing supply chain strategy appeared to be the best overall approach to follow. The relatively few manufacturers that are already following this approach should therefore continue holding the course and even perhaps increase integration with suppliers and customers wherever possible. Second, manufacturers in the other four groups should begin moving towards more extensive supply chain integration. It is not too difficult to imagine what will happen in many industries if and when a series of suppliers, manufacturers, and customers link together into seamlessly integrated supply chains. Their greater rates of cumulative performance improvements will let them steadily pull away from their more isolated competitors.

In many ways, the supplier- and customer-facing manufacturers have the easiest next steps. These two groups now need to take the final leap and begin integrating the upstream or downstream sides of their supply chains that they have neglected in the past. The periphery- and inward-facing groups, on the other hand, have perhaps a harder task ahead of them. They need to simultaneously begin implementing the supplier and customer supply chain integration that promises to unlock their performance potential. Although this may appear to be a daunting task, the alternative of remaining isolated in their respective supply chains is probably of greater concern since these manufacturers' long-term competitiveness may ultimately be at stake.

6. Supply chain integration and the new millennium

The history of operations management in the 20th century can in some ways be seen as leading to the current emphasis on supply chain integration as the way to compete, since that history has been largely been concerned with ever-increasing spans of control. From Taylor's pioneering work of 1911 to the IMVP's lean production study in the 1980's — the era of "Taylor to Toyota" (Voss, 1995) — has seen the unit of investigation expand from the task of an individual to the activities of a network of firms. Scientific management was concerned primarily with direct labor productivity and thus the study of work methods. Lean production was similarly concerned with productivity, but now involved all the resources of a firm including time itself. It also looked beyond the firm to its suppliers and customers. But in all this long history of development, there is a perennial concern for control, which has required the firm increasingly to look beyond its own boundaries. For example, controlling product quality requires manufacturers to work with suppliers, just as controlling demand patterns requires them to work with their customers. In this millennium, enhanced competitiveness not only in control but also in issues such as product design will require that manufacturers increasingly open out their arcs of integration and collaborate within a network of organizations.

New technology is already facilitating such developments. The Internet allows any member of a supply chain to connect to any other organization. In other words, the widest possible arc of integration has rapidly changed from a theoretical concept into an operational reality. Manufacturers can now link to customers using e-commerce on the sell-side of the Internet in what is popularly termed the "Dell direct" model. The more information that manufacturers have concerning end consumer's requirements the simpler supply and demand decisions become (Poirier, 1999) and the lower the risks of stockouts or obsolete inventory (Fisher and Raman, 1996; Metters, 1997).

Conversely, on the buy-side of the Internet extensive electronic supply base management is increasingly feasible. For many years now cost and delivery information has been shared between manufacturers and a few major suppliers using electronic data interchange (EDI). But these EDI systems, unlike the Internet, are generally incompatible with each other and expensive to develop and install. Internet technology, with its world-wide interconnectivity and ease of access, is far less costly and permits many more suppliers, even quite small ones, to be integrated electronically into a supply chain (Evans and Wurster, 1999).

One consequence for supply chain integration of this cheaper, easier Internet communication may be to extend the types of information exchanged. Not only the delivery schedules and billing data of an EDI system, but also new product ideas, on-line product support material, training aids, and technical knowledge can be transferred. Thus, the nature of collaboration may increase in range and intensity, and a broad arc of integration will be defined in terms of more or different variables.

A second consequence of Internet use for supply chain integration, related to the closeness of the relationship between firms, is harder to predict. By making collaboration easier and cheaper, the new technology means companies can integrate aspects of their operations more swiftly and collaborate more closely than before. But the open architecture of the Internet means that many more potential suppliers can bid for business, and new collaborations, beyond the circle of favored "partners", are easily formed. EDI ties companies together with a proprietary link representing substantial investment, but the Internet makes such communications available to everyone. Supply requirements can even be posted on an electronic bulletin board or supplier network and rival bids easily compared, permitting new rivals to compete in the electronic marketplace. Thus, vendor switching may be as likely as partnership, for the Internet enables both approaches.

But assuming that the ultimate arc of integration is a web-enabled supply chain, then the challenge is to get there first. In many ways, the new millennium is shaping up as a race between the outward-facing companies and their less integrated rivals. It probably took the outward-facing companies in our sample many years to achieve their high degrees of integration, and today they still have the advantage. New Internet technologies, however, such as e-procurement software and advanced supply chain planning systems can greatly simplify implementation, so that manufacturers with traditionally narrow arcs of integration now have an opportunity to quickly catch up.

7. Further research

This section makes six suggestions for further research, and concludes with a general observation on the significance of the increasing importance of supply chain research for the field of operations management. Our findings suggests that the following topics may be fruitful ones for investigation in further studies.

1. This study draws on data from fabricated metal products, machinery, and equipment manufacturers. There may be particular characteristics to these supply chains that do not apply to other sectors. Sector specific studies of arcs of integration and their relation to performance improvement will potentially yield different insights.
2. Since this study primarily focused on manufacturing, future research might also include data from purchasing and marketing representatives to better gauge the degree of supplier and customer integration.
3. Our study takes a snapshot in time of the arc of integration of each firm in the sample, but says nothing about the route taken. What are the necessary steps towards a broad arc of integration?
4. Over 40% of the sample was in the periphery-facing group. Is this the natural point of equilibrium in terms of supply chain development? If so what are the forces of inertia that inhibit onward development into an outward-facing arc of integration, and how can they be overcome?
5. Similarly, it appears that a balanced up- and down-stream approach, like that taken by the periphery and outward facing groups, is associated with higher performance than strategies biased towards customers and suppliers. Should supply chain integration follow specific evolutionary patterns?
6. As discussed above in Section 6, the role of the Internet and supply chain integration seems potentially profound. How can the new media best be deployed to broaden arcs of integration more swiftly and at less cost than hitherto?

It is to be hoped that other researchers will be attracted to such issues. Supply chain management has only relatively recently been recognized as a core topic in OM. Indeed, Pannirselvam et al. (1999) compared OM journal topics in the 1980s and 1990s, but had no category for supply chain management in a list of 17 topics. Nevertheless we believe that the growing evidence linking supply chain integration to performance improvement, such as we have presented here, will encourage more OM academics to investigate an area which now so much concerns practitioners themselves.

Finally, what might increased research activity into supply chain management mean for the field of operations management in the new millennium? Such a development could have at least two potential consequences. First, the unit of investigation will increasingly not be the firm but the network of collaborating companies (Fisher, 1997). This will surely present an extra layer of difficulty to whichever research method is employed. In the case of empirical studies, it means that the next generation of research will likely involve data collection from more than one unit along the supply chain to provide the multiple perspectives that bring us closer to scientific validity. Second, if supply chain management continues to be, as this and other studies suggest, a key source of competitive excellence, then the prospect is for operations management practice (and study) to be seen as an even more crucial and decisive business discipline than perhaps was the case in the past. Many of us in the field would happily accept the first of these suggested consequences in return for the second. That is, we will take on the burden of an increasingly complex research task, encouraged by the prospect of our subject playing an even more central role in business during the 21st century.

Appendix A. Integration measures

To what extent do you organizationally *integrate activities* with your suppliers and customers?

	With suppliers					With customers				
	None		Extensive			None		Extensive		
Access to planning systems	1	2	3	4	5	1	2	3	4	5
Sharing production plans	1	2	3	4	5	1	2	3	4	5
Joint EDI access/networks	1	2	3	4	5	1	2	3	4	5
Knowledge of inventory mix/levels	1	2	3	4	5	1	2	3	4	5
Packaging customization	1	2	3	4	5	1	2	3	4	5
Delivery frequencies	1	2	3	4	5	1	2	3	4	5
Common use of logistical equipment/containers	1	2	3	4	5	1	2	3	4	5
Common use of third-party logistical services	1	2	3	4	5	1	2	3	4	5

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