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DEVELOPING SUPPLY CHAIN MATURITY

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Abstract

This study introduces an empirical model of supply chain maturity and assesses its impact on performance. Findings suggest that supply chain maturity is multi-dimensional, including the areas of planning, sourcing, making, delivering, new product development, and returning. Valid and reliable measures, scales and supply chain maturity constructs were formulated and significant positive links found with multiple objective performance measures. The supply chain maturity framework is thus concluded to be robust for answering questions relating to *where* a supply chain is in developmental terms and *what* can be done to continue improving on the design. Possible areas for further research and implications for managers are also raised.

Keywords: Supply Chain Design, Supply Chain Coordination.

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DEVELOPING SUPPLY CHAIN MATURITY

Introduction

Competition in many industries is now between supply chains instead of lone companies (Handfield, 2002). Today it is not so much Toyota, Wal-Mart, or Zara competing one-on-one against their competitors, as it is each firm's *entire supply chain* battling it out against those of their rivals. To paraphrase the old saying; "may the best supply chain win." In light of this reality, it is surprising that there are still relatively few frameworks allowing managers to understand *where* their companies are in terms of supply chain evolution and *what* has to occur next in order to keep them maturing. In short, our understanding of inter-firm coordination and cooperation still has gaps, and the field needs a maturity framework in order to help guide supply chain design for academics and practitioners (Bowersox et al., 2000).

Given this gap in our knowledge, the aim of this study is to investigate supply chain maturity as well as assess its impact on performance. In particular, we adopt a definition of "supply chain maturity" consistent with Bowersox et al. (2000) and corresponding to the level of evolution of a company in terms of collaborative knowledge sharing with supply chain partners relating to implementation of up-to-date and appropriate supply chain practices- such as those identified by the widely used Supply Chain Council SCOR model. Thus, the concept of developing maturity coincides with the Bessant et al. (2003) ideal of sustaining continuous organizational learning "using supply chains as a mechanism for upgrading and transferring 'appropriate practice'."

In other words, a "mature" organization is defined as one that engages in extensive collaboration across a wide arc of supply chain partners in order to implement appropriate integrative practices. Conversely, an "immature" organization exhibits a combination of low levels of collaboration, with limited supply chain partners and across a limited range of supply chain integration practices.

Essentially, the underlying proposition of Bowersox et al. (2000) is that companies and sectors can improve their supply chain performance by increasing levels of supply chain maturity. In turn this implies increased levels of collaborative information and knowledge sharing across a range of recognized and appropriate supply chain integration and collaboration practices. Hence high levels of maturity reflect fundamental shifts already "exhibited by leading firms as they transform their supply chain capabilities." Conversely, low maturity levels are likely to be observed in 'laggard' companies or sectors.

For theory and practice to continue advancing, a more complete understanding is needed of the complex dynamics underlying supply chain collaboration and integration (Frohlich and Westbrook, 2001; Narasimhan and Kim, 2002). Coming to terms with such issues is also relevant for practitioners as they struggle with the real-world intricacies of integrating supply chains (Fisher, 1997), given often large practical disparities in relative levels of maturity (Fawcett and Magnan, 2002).

Along these lines, Lamming (1996) emphasized that inter-firm relationships vary between companies and within sectors. Notable examples of disparities in maturity include Lee and Billington (1996), which documented the evolution of Hewlett-Packard's supply chain from high inventory levels and low customer satisfaction into a very mature example. Similarly, the power of mature supply chains is exemplified in the widely-cited example of Dell Computers (Magretta, 1998). Similarly, Fawcett and Magnan (2002) argue that more mature supply chains have discovered that real collaboration goes beyond information exchange and are working diligently to establish other integrative mechanisms to enhance coordination.

Conversely, there are still quite a few companies that have not yet developed sufficient supply chain maturity and suffered resulting failures (Davenport, 1998). A major cause of this relates to a lack of detailed understanding of what constitutes, and needs to be done to attain, supply chain maturity (Bowersox et al., 2000). In essence, academics and practitioners still lack a maturity 'roadmap' guiding collaborative supply chain integration (Fawcett and Magnan, 2002). This represents an important stumbling block on the evolving path of theory and practice, and, in order to begin addressing these issues, this study focuses on developing just such a maturity model. The next section reviews the literature around supply chain maturity and formulates a series of hypotheses. Subsequent sections outline the methodology employed to test these hypotheses and discusses this research's implications for both supply chain academics and managers.

Supply Chain Maturity

Bowersox et al. (2000) define supply chain maturity in terms of the level of adoption or realization of modern collaborative and integrative supply chain practices. They allocated simple subjective scores on a scale of 1 (representing no development) to 10 (being total implementation) to assess differences in supply chain maturity levels across a sample of North American organizations. Other researchers have also investigated different levels of supply chain development between organizations. For example, Harrison and New (2002) identified a spread of relative supply chain sophistication levels, and classified international manufacturing-based companies as: Supply chain leaders; Strong players; Weak players; Lagging players; or Non-players. Yet, while simple score and classification systems represent important first steps in differentiating levels of supply chain maturity, they clearly lack sufficient detail to act as a roadmap for improvements. Towill et al., (2002) state that real world supply chains differ not only in their current performance, but also in the most effective actions required to move each towards world class supply. Thus a more useful formulation of the supply chain maturity concept needs to go beyond a single measure of relative development levels and provide a truly multi-dimensional framework to help guide organizations along this evolutionary continuum.

In terms of identifying the underlying dimensions of supply chain maturity, both the literature and practice suggest that the major categories are planning, sourcing, making, delivering, developing new products, and returning items. In the following paragraphs we use these six overarching dimensions – grounded in the literature – to build a proposed framework of supply chain maturity.

The first element of supply chain maturity is supply chain "Planning". Lee et al., (1997) aptly demonstrated the crucial role of planning in supply chains and its relationship to the well-known "bullwhip effect." Supply chain planning, in turn, is further divisible into downstream (customer facing) and upstream (supplier facing) practices (Frohlich and Westbrook, 2001). A number of downstream customer-oriented collaborative integration practices have been proposed associated with: 1) downstream future demand planning to reduce customer-oriented crises, predict demand, and coordinate delivery dates (Smaros et al., 2003; Finarelli and Johnson, 2004), and 2) downstream customer satisfaction planning to set inventory levels to match customer needs, align the supply chain with sales and marketing activities, and to support customer service and parts systems (see for example Mentzer and Moon, 2004). This leads to the hypothesis that:

H1a: Downstream "planning" maturity is defined by the levels of customer collaboration associated with future demand planning and customer satisfaction planning.

Similarly with upstream planning with suppliers, a number of specific supplier-oriented collaborative integration practices have been proposed associated with: 1) upstream supply planning to reduce supply-related crises, agree supply levels, and coordinate supply dates (Svensson, 2004), and 2) upstream supply satisfaction planning to design supply networks, calculate inventories to match supply needs, and create supply service and parts systems (Wright, 2003). These findings suggest a second hypothesis:

H1b: Upstream "planning" maturity is defined by the levels of supplier collaboration associated with future supply planning and supply satisfaction planning.

In terms of "Sourcing" supply chain maturity, previous work suggests collaborative practices associated with: 1) sourcing knowledge sharing relating to inventory and delivery knowledge along with the formulation of agreements and contracts (Akacum and Dale, 1995), and 2) advanced electronic sourcing techniques (that Disney et al., 2004, call e-Sourcing) which pertain to practices such as online auctions, supplier exchanges, and "next-generation" vendor-managed inventory (eVMI) systems. Thus we hypothesize:

H1c: "Sourcing" maturity is defined by the levels of collaboration with suppliers associated with sourcing knowledge sharing and e-Sourcing.

For the "Making" dimension of supply chain maturity, the literature notes the following associated practices: 1) lean manufacturing methods including pull production (e.g., reducing batch size/set-up, Kanban systems) and reengineering from functional to process-orientation (e.g., plant-within-a-plant restructuring, cellular manufacturing) (Shah and Ward, 2003), and 2) production knowledge sharing relating to practices such as communication systems, enterprise resource planning (ERP) systems and programs for quality improvement, as well as the presence of leaders/champions within manufacturing (Hines et al., 2004). We therefore hypothesize:

H1d: "Making" maturity is defined by the levels of collaboration associated with lean manufacturing and production knowledge sharing.

As with sourcing, for the "Delivering" dimension of supply chain maturity the literature notes specific collaborative practices associated with: 1) delivery knowledge sharing relating to delivery and downstream inventory information and the nurturing of long-term downstream relationships (Steckel et al., 2004), and 2) e-Delivery relating to up-to-date practices such as participation in online auctions, use of customer exchanges and portals, e-procurement/automated transactions and "next-generation" vendor managed inventory (eVMI) systems (Disney et al., 2004). We accordingly hypothesize:

H1e: "Delivering" maturity is defined by the levels of collaboration with the customer associated with delivery knowledge sharing and e-Delivery.

Emerging evidence suggests that "New Product Development" (NPD) is an important dimension of supply chain maturity (Petersen et al., 2003; Joglekar and Rosenthal, 2003). Practices associated with NPD include collaboration to design and improve products, configuration control via engineering change order systems, coordinated purchasing for prototypes, and collaborative design for effective supply chain management. This suggests the following hypothesis:

H1f: "NPD" maturity is defined by the levels of collaboration associated with the new product development process.

For the "Returns" dimension of supply chain maturity there are both downstream and upstream practices noted in the literature leading to two final hypotheses. Collaboration associated with returns from the downstream customer include: 1) downstream *product* returns, such as coordinating product returns from the customer and end users and maintaining customer confidence in the product returns process (Morton, 2003), and 2) downstream *packaging* returns, such as reusable Kanban containers, empty boxes, dispensers, pallets, etc., from customers and end users (Rogers and Tibben-Lembke, 1999). Thus we hypothesize:

H1g: Downstream "returns" maturity is defined by the levels of collaboration with the customer associated with downstream product returns and downstream packaging returns.

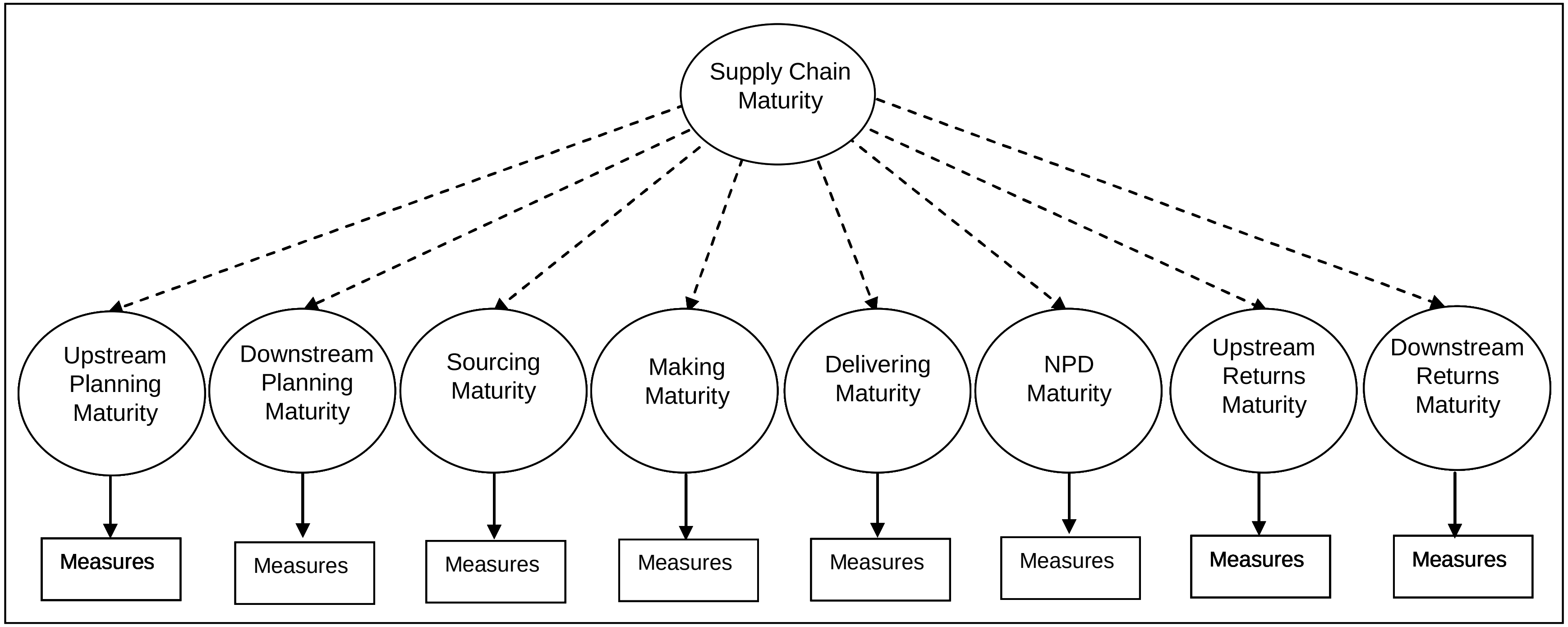
Similarly, the literature notes returns associated with upstream suppliers that also fall into two broad types: 1) upstream *product* returns, such as coordinating product returns from customers to suppliers (Tibben-Lembke, 2002), and 2) upstream *packaging* returns practices, such as reusable Kanban containers, empty boxes, dispensers, pallets, etc., as well as reducing package return cycle times (Rogers and Tibben-Lembke, 1999). This leads to the final hypothesis:

H1h: Upstream "returns" maturity can be defined by the levels of collaboration with the suppliers associated with upstream product returns and upstream packaging returns.

Figure 1 consolidates these eight hypotheses into a proposed supply chain maturity model encompassing "Upstream Planning," "Downstream Planning," "Sourcing," "Making," "Delivering," "NPD," "Upstream Returns" and "Downstream Returns." It is important to note that this proposed model is not applicable to all companies in its full form: only certain parts might apply in some contexts. For example, the downstream planning and delivering dimensions are not applicable to end customers that do not have any further downstream supply chain partners. Similarly, for raw suppliers at the very beginning of supply chains (i.e., ones that do not depend on further upstream supply chain partners), the upstream planning and sourcing dimensions are often not applicable. Also, practices associated with "Making," "Returns" and "NPD" are only relevant to companies that engage in these supply chain operations. Such context-related appropriateness is indicated in Figure 1 by the dotted lines linking the endogenous maturity dimensions.

Figure 1

Conceptual Model of the Dimensions of Supply Chain Maturity



Supply Chain Maturity and Performance

Evidence suggests that companies can improve their supply chain performance through the evolution and development of supply chain maturity. Conversely, low supply chain maturity levels are observed in lagging organizations. According to Bowersox et al. (2000) high levels of maturity reflect fundamental shifts already exhibited by leading firms as they transform their supply chain capabilities. For example, collaborative planning reduces bullwhip effects (Lee et al., 1997) while e-Sourcing practices potentially have beneficial impacts on inventory turns (Disney et al., 2004). Along the same lines, implementing practices to align operations, sales and marketing with downstream demand have a positive impact on percentage demand forecast accuracy (Mentzer and Moon, 2004). Collaboration with customers associated with downstream future demand planning often reduces the stock levels necessary to cope with uncertain demand fluctuations. These practices are particularly beneficial in reducing levels of days finished goods (Smaros et al., 2003; Finarelli and Johnson, 2004). Similarly, practices associated with the "make" dimension of maturity (i.e., the use of lean manufacturing and ERP) potentially improve stock keeping operations and inventory performance (Hines et al., 2004). At the same time, collaborative practices associated with sourcing (i.e., sharing inventory and delivery knowledge) frequently have beneficial impacts on operational efficiency (Akacum and Dale, 1995). Comparable downstream collaboration associated with delivery maturity commonly improves inventory level efficiency and provides insight in terms of when customers want to purchase finished products (Steckel et al., 2004). In aggregate, these previous studies lead to the hypothesis that:

H2: Supply chain maturity has a positive impact on supply chain performance.

Research Methods

Survey Design

In order to capture the multi-dimensional nature of supply chain maturity, an innovative survey instrument was devised to go beyond the limitations of static, paper-based surveys. A web-based survey instrument was developed, programmed, and pre-tested over 12 months in 2004-2005. The measures included in the survey were grounded in the literature on planning, sourcing, delivering, making, new product development, and returning, as described above. Academics and practitioners were involved in the survey development to ensure its relevance and validity. Two key features of the adaptive instrument included: 1) respondents being able to diagram online their own specific supply chain for a major product line and responding to survey items for that particular configuration, and 2) respondents selecting optional survey sections (e.g., making, new product development, returning, etc.) according to those practices appropriate to their own specific operations. After several software development phases to ensure functionality, a full pilot test confirmed both high usability for practitioners as well as the ability to generate reliable academic data.

Sample

The development of a supply chain maturity framework is best done by controlling for industry while at the same time collecting data from an industrial sector with a wide variety of possible maturity levels. Healthcare represents one such industry. A comprehensive listing of 957 first-tier product suppliers was obtained from the major United Kingdom healthcare service providers (NHS, BUPA and BMI-General). This list constituted the majority of the respective United Kingdom supplier population across the healthcare industry, including Diagnostic and Medical Equipment, Medical and Surgical Equipment, Pharmaceuticals, Food and Nutrition, Textiles and Domestics, and IT Equipment. A random stratified sample of 596 Supply Chain Directors was invited to participate in the study and given access to the online survey. In total, 154 complete responses were received for a response rate of 25.8%. Mean sales for the sample was $704 million and the average number of employees was 3,035. Perhaps most importantly, these 154 respondents represented the full range of practices across the planning, sourcing, making, delivering, NPD, and returning dimensions of supply chain maturity.

Table 1 gives a detailed breakdown of the responses obtained for each of the survey's planning, sourcing, making, delivering, NPD, and returning sections. As seen in Table 1, the downstream planning and delivering sections were completed by all 154 companies. Of the total sample of 154 companies, 60 responded to survey questions relating to the downstream customers but not for upstream suppliers. Accordingly, these respondents were excluded from analyses relating to upstream planning and sourcing practices in subsequent data analyses. On the other hand, 94 managers responded to survey sections relating to both downstream customers and upstream suppliers (55 for one upstream supplier level, 28 for two upstream supplier levels, and 11 for 3 upstream supplier levels). These respondents were included in all ensuing analyses of upstream planning and sourcing. Similarly, a total of 65 of respondents were involved in manufacturing products, 69 in new product development, and 86 in returns of products and/or packaging. These respondents were correspondingly included in later analyses around supply chain making, NPD and returning maturity.

Table 1

Analysis of Sample and Responses to Optional Survey Sections

Supply Chain Configuration					Total in Sample	Plan	Source	Make	Deliver	NPD	Returns
S4	S3	S2	S1	C							
			●	○	60	60	-	21	60	26	33
		○	●	○	55	55	55	29	55	30	32
	○	○	●	○	28	28	28	8	28	8	14
○	○	○	●	○	11	11	11	7	11	5	7
Total					154	154	94	65	154	69	86

C- Customer, S1- Surveyed Company (1st Tier Supplier), S2- 2nd Tier Supplier, S3- 3rd Tier Supplier, S4- 4th Tier Supplier.

Dependent and Independent Measures

We used objective measures of performance in this study. The overall dependent measure of "inventory days of supply" was subdivided into separate items for days of raw materials, work-in-progress, and finished goods. The means of these responses were: 29.5 days raw materials, 13.7 days WIP, and 29.9 days finished goods. Other objective measures included inventory turns per year (mean 61.7), percent of orders fulfilled by suppliers (mean 88.9%), percent of customer orders fulfilled (mean 91.3%), days lead-time (mean 12.9 days), and percentage demand forecast accuracy (mean 81.1%).

In terms of independent variables, the survey instrument measured levels of collaboration using 1 to 7 Likert scales. For the plan dimension, respondents were asked how frequently their company communicated with respective supply chain partners in order to execute each planning related practice item (1- Never, 2- Annually, 3- Quarterly, 4- Monthly, 5- Weekly, 6- Daily, 7- Hourly). For the sourcing, delivering, NPD, and returning dimensions respondents were asked to what degree their company collaboratively shared knowledge with respective supply chain partners for each of the associated practices (1- Not at all, 2- Very little, 3- Little, 4- Average, 5- Quite a lot, 6- A lot, 7- Completely). On a similar 1-7 Likert scale, respondents were asked to what extent their company implemented "make"-related practices. For those companies with more than one upstream supplier, the upstream planning, sourcing, and returns responses were summed to give a total level of upstream collaboration.

As noted above, respondents could choose whether sections relating to making, NPD or returns were applicable to their respective company supply chain operations and accordingly skip these sections. Thus, while the sample sizes for certain sections were reduced, this skip function with explanatory pop-up windows actually helped us control for missing data. Missing data was further reduced by requiring respondents to complete each chosen section before being able to proceed to the next section. The sub-sample sizes and missing data analysis are presented in Table 2.

Table 2

Sub-sample Sizes and Missing Data Analysis for Optional Survey Sections

Survey Section	Case Responses Per Section	Total Survey Items	Missing Items	% Missing Items	Incomplete Cases	% Incomplete Cases
Performance	154	1232	0	0%	-	0%
Upstream Planning	94	940	118	12.6%	13	13.8%
Downstream Planning	154	1540	163	10.6%	17	11.0%
Sourcing	94	1128	334	29.6%	28	29.8%
Delivering	154	1848	507	27.4%	44	28.6%
Making	65	390	0	0%	0	0%
Upstream NPD	43	301	6	2.0%	1	2.3%
Internal NPD	69	483	20	4.1%	2	2.9%
Downstream NPD	69	483	13	2.7%	3	4.3%
Upstream Returns	53	530	130	24.5%	15	28.3%
Downstream Returns	86	860	210	24.4%	21	24.4%
Total	**1035**	**9735**	**1501**	**15.4%**	**144**	**13.9%**

Boomsma (1985) advocated a sample size of at least 100 for full structural equation modeling and MacCallum et al. (1992) suggested at least 5 responses per parameter. The maximum likelihood estimation procedure we used in this study has also been shown to produce valid results with sample sizes of at least n = 50 (Hair et al., 1998). These minimum thresholds were considerably exceeded and our sample of n = 154 was sufficiently large for the purposes of identifying an underlying factor structure of supply chain maturity and interpreting results. In summary, the sample sizes attained were adequate for our intended analyses.

Results and Discussion

The data analysis followed a three-step process:

1. The creation of valid and reliable scales for supply chain maturity using confirmatory factor analysis in order to test hypotheses H1a-H1h.

2. The validation of an appropriate second-order supply chain maturity model using hierarchical structural equation modeling.

3. The investigation of the impact of the underlying supply chain maturity dimensions on performance using set correlation analysis in order to evaluate hypothesis H2.

Reliability Analysis

Diagnostic checks ensured that the data was adequate for creating multi-item maturity scales through principle component factor analysis. Inspection of the full survey data correlation matrices revealed all correlations to be significant and greater than 0.30 (Hair et al., 1998). Partial/anti-image correlations were small, indicating a high degree of suitability for factor analysis. Bartlett's test indicated that correlations were significant at the 0.001 level. Similarly the overall Keiser-Meyer-Olkin (KMO) measures of sampling adequacy of 0.80 corresponded to the "meritorious" level. The measure of sampling adequacy (MSA) for individual variables also indicated high suitability of the data for factor analysis. None of the selected items fell into the unacceptable range for exclusion.

Factor extraction was undertaken in accordance with established practice and determined by a combination of criteria (Cattell, 1966; Hair et al., 1998). Weak or redundant items were selectively dropped to form parsimonious, interpretable, and reliable factors. Varimax orthogonal rotation of factors maximized the sum of variances of required loadings of the factor matrix. Table 3 shows that Cronbach alpha values for all individual factors exceeded the minimal acceptance level of 0.60 (Nunnally, 1979; Robinson et al., 1991). Also the high item-to-total correlations, inter-item correlations exceeding 0.30, good KMO measures, and highly significant Bartlett test values indicated representative, unidimensional, and significant factors. In terms of statistical significance, Cliff (1967) demonstrated that factor loadings should be strictly evaluated according to the effective sample size. All factor loadings for respective survey section sample sizes (n= 53 to 154) exceeded requirements to achieve a statistical power of 80% at the 0.05 significance level.

Table 3

Reliability Analysis of Maturity Scales

Construct	Scale	Items	Item-to-total	1st Item % Variance	KMO	Bartlett's Test X^2	df	p	Cronbach α
Down-stream Planning	**Downstream Future Demand Planning (DFDP)** n=154	DP1: Reduce future crises	.873	72.047	.657	169.537	3	.000	.801
		DP2: Predict future demand	.903						
		DP5: Coordinate delivery dates	.764						
	Downstream Customer Satisfaction Planning (DCSP) n=154	DP8: Inventory to match customer needs	.880	73.012	.670	175.882	3	.000	.811
		DP9: Align SC to sales/marketing	.901						
		DP10: Customer service/parts system	.777						
Upstream Planning	**Upstream Future Supply Planning (UFSP)** n=94	UP1: Reduce future crises	.906	82.483	.747	162.316	3	.000	.888
		UP3: Agree future supply	.899						
		UP5: Coordinate supply dates	.920						
	Upstream Supply Satisfaction Planning (USSP) n=94	UP7: Design supply networks	.788	62.513	.670	48.002	3	.000	.692
		UP8: Calculate supply inventory	.774						
		UP10: Supply service/parts system	.810						
Sourcing	**Sourcing Knowledge Sharing (SKS)** n=94	S4: Share inventory knowledge	.846	73.474	.699	99.668	3	.000	.815
		S5: Share delivery knowledge	.892						
		S7: Formulate agreements/ contracts	.833						
	e-Sourcing (eS) n=94	S8: Participate in on-line auctions	.713	58.050	.618	36.627	3	.000	.605
		S10: Use exchanges/portals	.742						
		S11: Use e-Vendor Managed Inventory (eVMI)	.826						
Delivering	**Delivery Knowledge Sharing (DKS)** n=154	D3: Nurture long-term relationships	.886	75.527	.686	198.621	3	.000	.835
		D4: Share inventory knowledge	.808						
		D5: Share delivery knowledge	.910						
	e-Delivery (eD) n=154	D8: Participate in on-line auctions	.696	51.233	.666	102.369	6	.000	.667
		D9: Use e-procurement/ automated transactions	.804						
		D10: Use exchanges/portals	.653						
		D11: Use e-Vendor Managed Inventory (eVMI)	.701						

Table 3

Reliability Analysis of Maturity Scales (Continued)

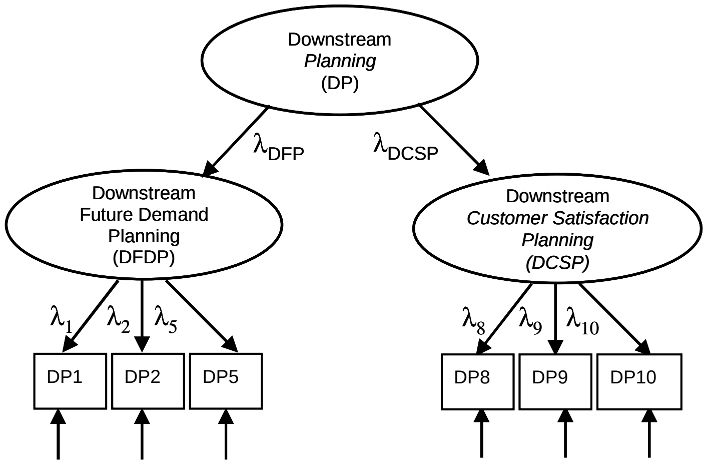
Construct	Scale	Items	Item-to-total	1st Item % Variance	KMO	Bartlett's Test χ^2	df	p	Cronbach α
Making	**Lean Making (LM)** n=65	M2: Implement Pull production	.908	82.463	.500	34.211	1	.000	.787
		M4: From functional to process orientation	.908						
	Production Knowledge Sharing (PKS) n=65	MI: IT communications/ERP	.768	60.945	.629	31.391	3	.000	.676
		M3: Programs for quality and control	.842						
		M6: Dedicated Supply Chain Champions	.727						
NPD	**NPD (NPD)** n=69	INPD1: Product design/ improvement	.691	59.885	.726	76.514	6	.000	.775
		INPD2: Control Engineering Change Order System	.811						
		INPD4: Coordinate Purchasing for Prototypes	.857						
		INPD6: Design "for" effective SCM	.725						
Upstream Returns	**Upstream Product Returns (URP)** n=53	UR1: Coordinate product returns to supplier/s	.867	82.806	.706	99.975	3	.000	.894
		UR2: Coordinate product returns from/to end users	.944						
		UR7: Identify legitimate returns	.917						
	Upstream Packaging Returns (URPK) n=53	UR3: Coordinate packaging returns to supplier/s	.916	82.508	.667	106.658	3	.000	.892
		UR4: Coordinate packaging returns from/to end users	.955						
		UR8: Reduce returns processing cycle time	.851						
Down-stream Returns	**Downstream Product Returns (DRP)** n=86	DR1: Coordinate product returns from customer	.906	72.706	.671	91.035	3	.000	.811
		DR2: Coordinate product returns from end users	.842						
		DR10: Maintain customer confidence in returns process	.810						
	Downstream Packaging Returns (DRPK) n=86	DR3: Coordinate packaging returns from customer	.864	77.332	.726	111.000	3	.000	.853
		DR4: Coordinate packaging returns from end users	.899						
		DR5: Ensure sufficient processing capability	.875						

Maturity Scale Validity

The requirements for validity are twofold. First, a scale must truly measure what it is supposed to measure, and second it must not measure anything else (Flynn et al., 1990). To satisfy these two requirements, several facets of validity were tested. Content or face validity was determined through a non-statistical assessment of the correspondence of the variables in each scale and its conceptual definition. The scales formed were reviewed for face validity with experienced academics and practitioners (Churchill, 1979; Robinson et al., 1991). Further forms of validity were measured empirically through second order confirmatory factor analysis (CFA). Optimally, factor analysis should always be followed by some form of CFA, which is particularly useful in the validation of scales emerging from more exploratory analysis (Kim and Mueller, 1978; Gerbing and Hamilton, 1996). Repeated CFA runs, similar to the example shown for the downstream planning construct in Figure 2, were conducted *for all the maturity dimensions* to assess convergent and discriminant validity.

Figure 2

Example of Second Order CFA- Downstream Planning Maturity



Downstream Future Demand Planning (DFDP):

How frequently does your company communicate with supply chain partners to:

(1-7 Likert scale: 1- Never, 2- Annually, 3- Quarterly, 4- Monthly, 5- Weekly, 6- Daily, 7- Hourly)

DP1: optimize the supply chain to reduce future crisis situations?	1	2	3	4	5	6	7
DP2: predict future demand?	1	2	3	4	5	6	7
DP5: coordinate delivery dates?	1	2	3	4	5	6	7

Downstream Customer Satisfaction Planning (DCSP):

How frequently does your company communicate with supply chain partners to:

(1-7 Likert scale: 1- Never, 2- Annually, 3- Quarterly, 4- Monthly, 5- Weekly, 6- Daily, 7- Hourly)

DP8: calculate inventory levels to meet customer requirements?	1	2	3	4	5	6	7
DP9: align the supply chain with sales/ marketing activities?	1	2	3	4	5	6	7
DP10: create service and parts systems to sustain customer satisfaction?	1	2	3	4	5	6	7

Convergent validity refers to the extent to which varying approaches to construct measurement yield the same results (Churchill, 1979). By treating each item in a scale as a different approach to measuring the same construct, convergent validity is assessed by verifying whether each indicator's estimated pattern coefficient on its hypothesized underlying construct factor is significant (Anderson and Gerbing, 1988). The survey items relating to each of the maturity dimensions were subjected to second-order CFA using the maximum likelihood method of estimation (Joreskog and Sorbom, 1989). In the second-order factor model, it was hypothesized that the second-order maturity construct explains the association among the first-order dimensions, thereby avoiding the problem of correlated measurement errors. The results of the CFA are shown in Tables 4 and 5.

Table 4

Confirmatory Factor Analysis (CFA): Summary Statistics

CFA Model	SMC range		Max MI	X^2	df	p	X^2/ df	NFI ~.90	CFI >.90	RFI >.90	IFI >.90	TLI ~.95	RMSEA <.05
	1st Order	2nd Order											
Downstream Planning	.325-.912	.552-.991	-	10.010	8	.264	1.25	.975	.995	.953	.995	.990	.043
Upstream Planning	.290-.768	.352-1.921	4.25	11.597	8	.170	1.45	.956	.985	.917	.973	.973	.075
Sourcing	.306- .731	.143- 1.188	9.09	12.168	8	.144	1.52	.896	.959	.805	.923	.923	.090
Delivering	.242-.828	.401-.543	-	17.146	13	.193	1.32	.931	.982	.888	.982	.970	.054
Making	.241-.815	.338-1.004	-	5.763	4	.218	1.44	.936	.978	.839	.979	.945	.083
NPD	.331-748	-	-	2.382	2	.304	1.19	.970	.995	.910	.995	.984	.054
Downstream Returns	.472-.761	.301-2.713	-	10.708	8	.219	1.34	.955	.988	.916	.988	.977	.072
Upstream Returns	.571-.936	.122-3.008	-	10.630	8	.224	1.33	.945	.985	.897	.986	.972	.092

Criteria for Good Fit indicated for appropriate statistics. (Bollen, 1989; Hoyle, 1995; Marcoulides and Schumacker, 1996).

Table 5

CFA Loadings for Underlying Dimensions of Supply Chain Maturity

Construct	Construct/ Indicator	Factor Loading	t-Value	
Downstream Planning				
Second-Order Results				
Downstream Planning	Downstream Future Demand Planning (DFDP)	.990	4.195	***
Downstream Planning	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
First-Order Results				
	DP1: Reduce future crises	1.410	6.714	***
Downstream Future Demand	DP2: Predict future demand	1.559	7.059	***
Planning (DFDP)	DP5: Coordinate delivery dates	1.000	n.a.	
	DP8: Inventory to match customer needs	1.738	7.116	***
Downstream Customer	DP9: Align SC to sales/marketing	1.455	7.105	***
Satisfaction Planning (DCSP)	DP10: Customer service/parts system	1.000	n.a.	
Upstream Planning				
Second-Order Results				
Upstream Planning	Upstream Future Supply Planning (UFSP)	3.654	4.7050	***
Upstream Planning	Upstream Supply Satisfaction Planning (USSP)	1.000	n.a.	
First-Order Results				
	UP1: Reduce future crises	.917	11.196	***
Upstream Future Supply	UP3: Agree future supply	.708	9.958	***
Planning (UFSP)	UP5: Coordinate supply dates	1.000	n.a.	
	UP7: Design supply networks	.485	4.409	***
Upstream Supply Satisfaction	UP8: Calculate supply inventory	.599	4.920	***
Planning (USSP)	UP10: Supply service/parts system	1.000	n.a.	
Sourcing				
Second-Order Results				
Sourcing	Sourcing Knowledge Sharing (SKS)	.969	2.045	*
Sourcing	e-Sourcing (eS)	1.000	n.a.	
First-Order Results				
	S4: Share inventory knowledge	.784	5.741	***
Sourcing Knowledge Sharing	S5: Share delivery knowledge	1.000	n.a.	
(SKS)	S7: Formulate agreements/contracts	.935	5.615	***
	S8: Participate in on-line auctions	.461	2.914	***
e-Sourcing	S10: Use exchanges/portals	1.000	n.a.	
(eS)	S11: Use e-Vendor Managed Inventory (eVMI)	1.239	2.893	***
Delivering				
Second-Order Results				
Delivering	Delivery Knowledge Sharing (DKS)	1.158	3.249	***
Delivering	e-Delivery (eD)	1.000	n.a.	
First-Order Results				
	D3: Nurture long-term relationships	1.632	7.316	***
Delivery Knowledge Sharing	D4: Share inventory knowledge	1.000	n.a.	
(DKS)	D5: Share delivery knowledge	1.631	7.339	***
	D8: Participate in on-line auctions	.378	4.470	***
	D9: Use e-procurement/automated transactions	1.000	n.a.	
	D10: Use exchanges/portals	.519	4.045	***
	D11: Use e-Vendor Managed Inventory (eVMI)	.565	4.435	***
e-Delivery	DR4: Coordinate packaging returns from end users	1.069	7.309	***
(eD)	DR5: Ensure sufficient processing capability	1.074	7.304	***

*** p<0.001. 2) ** p<0.01. 3) * p<0.05. 4) To define scales, one link has to = 1. These t-values are marked "not applicable" (n.a.).

Table 5

CFA Loadings for Underlying Dimensions of Supply Chain Maturity (Cont.)

Construct	Construct/ Indicator	Factor Loading	t-Value	
Making				
Second-Order Results				
Making	Lean Making (LM)	1.067	2.517	**
Making	Production Knowledge Sharing (PKS)	1.000	n.a.	
First-Order Results				
Lean Making (LM)	M2: Implement Pull production	.862	4.051	***
	M4: From functional to process orientation	1.000	n.a.	
Make Communications (MC)	MI: IT communications/ERP	1.000	n.a.	
	M3: Programs for quality and control	1.680	3.405	***
	M6: Dedicated Supply Chain Champions	.965	3.105	***
NPD				
First-Order Results				
NPD (NPD)	INPD1: Product design/improvement	.474	4.113	***
	INPD2: Control Engineering Change Order System	1.000	n.a.	
	INPD4: Coordinate Purchasing for Prototypes	1.086	5.490	***
	INPD6: Design 'for' effective SCM	.598	4.333	***
Upstream Returns				
Second-Order Results				
Upstream Returns	Upstream Product Returns (URP)	4.392	2.936	***
Upstream Returns	Upstream Packaging Returns (URPK)	1.000	n.a.	
First-Order Results				
Upstream Product Returns (URP)	UR1: Coordinate product returns to supplier	.883	6.253	***
	UR2: Coordinate product returns from/ to end users	1.198	8.490	***
	UR7: Identify legitimate returns	1.000	n.a.	
Upstream Packaging Returns (URPK)	UR3: Coordinate packaging returns to supplier	1.000	n.a.	
	UR4: Coordinate packaging returns from/to end users	1.019	9.288	***
	UR8: Reduce returns processing cycle time	.814	6.121	***
Downstream Returns				
Second-Order Results				
Downstream Returns	Downstream Product Returns (DRP)	2.610	3.916	***
Downstream Returns	Downstream Packaging Returns (DRPK)	1.000	n.a.	
First-Order Results				
Downstream Product Returns (DRP)	DR1: Coordinate product returns from customer	1.250	6.143	***
	DR2: Coordinate product returns from end users	1.135	5.698	***
	DR10: Maintain customer confidence in returns process	1.000	n.a.	
Downstream Packaging Returns (DRPK)	DR3: Coordinate packaging returns from customer	1.000	n.a.	
	DR4: Coordinate packaging returns from end users	1.069	7.309	***
	DR5: Ensure sufficient processing capability	1.074	7.304	***

1) *** p<0.001. 2) ** p<0.01. 3) * p<0.05. 4) To define scales, one link has to = 1. These t-values are marked "not applicable" (n.a.).

The overall validities of the CFA models were tested using multiple fit criteria in Table 4 (Bollen, 1989; Hoyle, 1995; Marcoulides and Schumacker, 1996). The highly insignificant p-values associated with chi-square and degrees of freedom indicated a failure to reject the null hypothesis that the CFA models represented a good fit to the data. Further to the chi-square value, analysis of the subjective fit criteria Normed Fit Index (NFI), Comparative Fit Index (CFI), Relative Fit Index (RFI), Incremental Index of Fit (IFI), Tucker-Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA) all indicated highly valid CFA models for the maturity dimensions.

In addition, Table 5 indicates a high degree of convergent validity in both first- and second-order constructs for all of the maturity dimensions. Notably, all of the first- and second-order factor loadings were statistically significant and positive, and the squared multiple correlations for the indicators were within acceptable ranges. Discriminant validity, which measures the extent to which the constituent items of a scale measure only one distinct construct (Campbell and Fiske, 1959; Robinson et al., 1991), was ascertained by examining modification indices. These results are seen in Table 4 and reveal a high degree of divergence across factors, as indicated by the lack of cross-loadings. The rule of thumb for evidence of lack of discriminant validity is modification indices higher than 10. As the largest modification index encountered was 9.1, with most models lacking any cross-loadings, there was a high degree of discriminant validity among all supply chain maturity dimension constructs and measures.

To summarize, the results of the second-order CFA therefore indicate high levels of validity, and provide strong statistical support for the hypotheses H1a to H1h. Thus the underlying maturity dimensions of upstream/downstream planning, sourcing, making, delivering, NPD and upstream/downstream returning can be defined in terms of collaborative knowledge sharing across associated practices.

Validating the Supply Chain Maturity Construct

Structural equation modeling (SEM) is an appropriate technique for validating a latent higher-order construct such as supply chain maturity (Bollen, 1989). A hierarchical SEM procedure was followed to establish the validity of appropriate supply chain maturity constructs for different supply chain configurations and operations. Second-order hierarchical models using the previously defined maturity scale factor scores were subjected to the maximum likelihood method of estimation (Joreskog and Sorbom, 1989). A baseline supply chain maturity model comprising downstream planning and delivering factor scores was first validated on the whole sample of 154. The validity of adding appropriate upstream planning, sourcing, making, NPD, downstream and upstream returning factor scores in turn to this baseline model was assessed on the reduced sample sizes of companies engaged in such operations. As with the CFA analysis above, the problem of correlated measurement errors was avoided by the second-order supply chain maturity construct explaining association among first-order dimensions. The results of the hierarchical SEMs are shown in Tables 6 and 7.

Table 6

Supply Chain Maturity Structural Equation Models: Summary Statistics

SEM Model	n	SMC range 1st	SMC range 2nd	Max MI	X^2	df	p	X^2/ df	NFI ~.90	CFI >.90	RFI >.90	IFI >.90	TLI ~.95	RMSEA <.05
1. Baseline: Downstream Plan and Deliver	154	.222-.748	.460-2.08	-	1.02	1	.313	1.02	.995	1.00	.969	1.00	.999	.011
2. Baseline + Upstream Plan	94	.162-2.50	.054-.375	-	7.16	7	.412	1.02	.944	.999	.833	.999	.996	.017
3. Baseline + Sourcing	94	.006-27.3	.000-2.14	-	7.71	6	.260	1.29	.966	.992	.916	.992	.980	.055
4. Baseline + Making	65	.379-.792	.109-1.70	-	10.6	7	.155	1.52	.925	.970	.774	.973	.909	.090
5. Baseline + NPD	69	.212-.755	.000-4.51	-	31.0	18	.029	1.72	.898	.951	.796	.955	.903	.069
6. Baseline + Downstream Returns	86	.398-.922	.379-1.32	7.30	20.5	7	.005	2.93	.920	.944	.828	.946	.880	.150
7. Baseline + Upstream Returns	53	.288-1.25	.129-.998	-	8.43	7	.296	1.21	.942	.989	.875	.990	.976	.063

Criteria for Good Fit indicated for appropriate statistics. (Bollen, 1989; Hoyle, 1995; Marcoulides and Schumacker, 1996).

Table 7

SEM Loadings for Appropriate Supply Chain Maturity Constructs

'Appropriate' Supply Chain Maturity Construct	Construct/ Indicator	Factor Loading	t-Value	
Model 1: Downstream Planning + Delivering (n=154)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	1.000	n.a.	
Supply Chain Maturity	Delivering (D)	.319	4.318	***
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFDP)	1.243	8.233	***
	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	1.657	5.308	***
	e-Delivery (eD)	1.000	n.a.	
Model 2: Downstream Planning + Delivering + Upstream Planning (n=94)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	1.000	n.a.	
Supply Chain Maturity	Delivering (D)	.227	2.530	**
Supply Chain Maturity	Upstream Planning (UP)	.366	3.840	***
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFDP)	.840	5.391	***
	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	1.023	2.345	**
	e-Delivery (eD)	1.000	n.a.	
Upstream Planning (UP)	Upstream Future Supply Planning (UFSP)	.253	1.309	
	Upstream Supply Satisfaction Planning (USSP)	1.000	n.a.	
Model 3: Downstream Planning + Delivering + Sourcing (n=94)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	.439	4.385	***
Supply Chain Maturity	Delivering (D)	1.000	n.a.	
Supply Chain Maturity	Sourcing (S)	.060	.878	
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFDP)	1.418	7.147	***
	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	1.505	7.841	***
	e-Delivery (eD) [a]	1.000	n.a.	
Sourcing (S)	Sourcing Knowledge Sharing (SKS)	1.000	n.a.	
	e-Sourcing (eS) [a]	.015	.013	
Model 4: Downstream Planning + Delivering + Making (n=65)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	.636	4.081	***
Supply Chain Maturity	Delivering (D)	1.000	n.a.	
Supply Chain Maturity	Making (M)	.218	1.850	*
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFP)	1.372	6.503	***
	Downstream Customer Satisfaction Planning (DCP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	1.247	6.455	***
	e-Delivery (eD)	1.000	n.a.	
Making (M)	Lean Making (LM)	.924	1.771	*
	Production Knowledge Sharing (MKS)	1.000	n.a.	

1) *** p<0.001. 2) ** p<0.01. 3) * p<0.05. 4) To define scales, one link has to = 1. These t-values are marked "not applicable" (n.a.). 5) a Indicates residual error correlation between items.

Table 7

SEM Loadings for Appropriate Supply Chain Maturity Constructs (Cont.)

'Appropriate' Supply Chain Maturity Construct	Construct/ Indicator	Factor Loading	t-Value	
Model 5: Downstream Planning + Delivering + NPD (n=69)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	.319	4.324	***
Supply Chain Maturity	Delivering (D)	1.000	n.a.	
Supply Chain Maturity	NPD (NPD)	.032	.267	
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFDP)	1.246	8.222	***
	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	1.651	5.323	***
	e-Delivery (eD)	1.000	n.a.	
NPD (NPD)	INPD1: Product design/improvement	.434	3.965	***
	INPD2: Control Engineering Change Order System	.915	5.482	***
	INPD4: Coordinate Purchasing for Prototypes	1.000	n.a.	
	INPD6: Design "for" effective SCM	.546	4.412	***
Model 6: Downstream Planning + Delivering + Downstream Returns (n=86)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	.893	7.309	***
Supply Chain Maturity	Delivering (D)	1.000	n.a.	
Supply Chain Maturity	Downstream Returns (DR)	.507	4.607	***
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFDP)	.863	10.456	***
	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	.969	8.209	***
	e-Delivery (eD)	1.000	n.a.	
Downstream Returns (DR)	Downstream Product Returns (DRP)	1.203	6.781	***
	Downstream Packaging Returns (DRPK)	1.000	n.a.	
Model 7: Downstream Planning + Delivering + Upstream Returns (n=53)				
Second-Order Results				
Supply Chain Maturity	Downstream Planning (DP)	1.220	6.332	***
Supply Chain Maturity	Delivering (D)	1.000	n.a.	
Supply Chain Maturity	Upstream Returns (UR)	.402	2.950	***
First-Order Results				
Downstream Planning (DP)	Downstream Future Demand Planning (DFDP)	.785	8.696	***
	Downstream Customer Satisfaction Planning (DCSP)	1.000	n.a.	
Delivering (D)	Delivery Knowledge Sharing (DKS)	.967	6.299	***
	e-Delivery (eD)	1.000	n.a.	
Upstream Returns (UR)	Upstream Product Returns (URP)	.475	1.667	*
	Upstream Packaging Returns (URPK)	1.000	n.a.	

1) *** p<0.001. 2) ** p<0.01. 3) * p<0.05. 4) To define scales, one of links has to = 1. These t-values are marked "not applicable" (n.a.) 5) a Indicates residual error correlation between items.

For the baseline Model 1 in Table 6 – incorporating downstream planning and delivering – the highly insignificant chi-square p-value failed to reject the null hypothesis of the model being a good fit to the data. Further analysis of subjective fit criteria NFI, CFI, RFI, IFI, TLI and RMSEA also indicated high validity of this model. This baseline model indicated high degrees of convergent validity, given that first and second-order factor loadings were statistically significant and positive (see Table 7). Squared multiple correlations were within acceptable ranges. Discriminant validity for the baseline model was established by a lack of modification indices. The results for the baseline model therefore provided strong statistical support that downstream planning and delivering represent appropriate dimensions of supply chain maturity.

Similarly, Models 2 to 7 in Table 6 indicated the validity of adding appropriate upstream planning, sourcing, making, NPD, downstream and upstream returning dimensions to the baseline Model 1 for the respectively reduced sample sizes. In all cases, subjective fit criteria, SMC values, and modification indices all demonstrated valid models fitting the data. Chi-square values are sensitive to small sample sizes and, therefore, for these models more emphasis was placed on subjective fit criteria (Byrne, 2001). Nevertheless, with the exception of NPD and downstream returning, the insignificant chi-square values further confirm well-fitting models.

Significant factor loadings for Models 2 to 7 in Table 7 further confirm convergent validity of the appropriate planning, delivering, making, and returns dimensions.

Impact of Supply Chain Maturity on Performance (Hypothesis H2)

The relationships between the underlying supply chain maturity dimensions and multiple performance measures were simultaneously investigated using set correlation (SC) analysis. SC analysis is a sophisticated technique that permits a set of dependent variables to be simultaneously related to a set of independent variables (Cohen et al., 2003). It is a truly multivariate method that addresses shortcomings of more common methods by providing a single measure of association between data sets and a single framework for variable association, parameter estimation, hypothesis testing, and statistical power analysis. We conducted the SC analyses in line with the examples of Cohen et al. (2003) and Vastag and Montabon (2001).

Two separate SC analyses were undertaken:

1. A full consideration of all 15 underlying dimensions against all 8 performance measures, on the reduced sub-sample of 33 companies for whom all dimensions were appropriate.

2. A reduced consideration of only the "baseline" practice dimensions relating to Downstream Plan and Deliver against a reduced set of performance measures on the full sample of 154 companies.

Table 8 shows the results for the first SC analysis. The multivariate $R^2_{Y,X}$ quoted for SC is a generalization of the simple bivariate r^2 and multiple R^2 (Rozeboom, 1965; Van den Burg and Lewis, 1988). It represents the proportion of generalized variance of the dependent variable set accounted for by the independent variable set. The obtained $R^2_{Y,X}$ value of 99.9% and 'shrinkage' $\tilde{R}^2_{Y,X}$ value of 97.4% indicate an extremely high degree of multivariate association between the independent supply chain maturity dimensions and dependent performance measures. Rao's F value of 2.14 rejects the null hypothesis of no association between the independent and dependent sets at the $p<.001$ level (Rao, 1975).

Table 8

Set Correlation Analysis 1: All Supply Chain Maturity Dimensions and Performance Measures

A. Correlations among basic variables

	Set Y_B								Set X_B													
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
Y1: Inventory Turns	1.00																					
Y2: % Orders Fulfilled by Supplier	.25	1.00																				
Y3: % Customer Orders Fulfilled	.26	.94	1.00																			
Y4: Lead-Time	-.08	.23	.07	1.00																		
Y5: % Demand Forecast Accuracy	.24	.94	.92	.21	1.00																	
Y6: Days Raw Material Inventory	-.13	.45	.45	.14	.47	1.00																
Y7: Days Work in Progress Inventory	-.05	.40	.40	-.09	.32	.43	1.00															
Y8: Days Finished Goods Inventory	-.05	.44	.31	.10	.42	.40	.10	1.00														
X1: Downstream Future Demand Plan (DFP)	.01	.10	-.02	.25	.02	-.35	-.22	.16	1.00													
X2: Downstream Customer Satisf. Plan (DCP)	.21	-.02	-.04	.08	.03	-.39	-.33	.02	.64	1.00												
X3: Upstream Future Demand Planning (	-.08	-.10	.02	.16	.03	.36	-.15	-.02	.08	.31	1.00											
X4: Upstream Customer Satisfaction Planning	.01	-.01	.07	-.04	.08	-.01	-.30	-.14	.30	.60	.71	1.00										
X5: Sourcing Knowledge Sharing	.05	-.11	-.01	-.07	-.10	-.16	-.19	-.41	.27	.46	.51	.77	1.00									
X6: e-Sourcing	.48	.01	.03	.12	.11	.09	-.16	-.12	.00	.30	.48	.38	.28	1.00								
X7: Delivery Knowledge Sharing	-.23	.01	.04	-.02	-.11	-.33	.16	-.25	.31	.26	.01	.10	.40	-.01	1.00							
X8: e-Delivery	.45	.10	.05	-.15	.07	-.22	.08	-.08	.12	.30	-.12	-.07	.04	.55	.24	1.00						
X9: Lean Making	.38	.23	.30	.10	.25	-.14	-.12	-.03	.14	.35	.14	.19	.25	.38	.22	.15	1.00					
X10: Make Knowledge Sharing	.39	.20	.25	-.00	.17	-.57	-.02	-.14	.35	.58	-.23	.09	.17	.08	.36	.53	.36	1.00				
X11: NPD	.37	.08	.11	-.12	.07	-.07	-.02	-.02	-.07	.31	.01	.21	.32	.28	-.01	.19	.45	.26	1.00			
X12: Upstream Product Returns	.02	-.10	-.03	.15	.04	.05	-.22	-.17	.05	.43	.68	.79	.65	.56	.07	.08	.07	.06	.34	1.00		
X13: Upstream Packaging Returns	.14	.09	.11	-.02	.13	-.07	-.04	-.06	.29	.56	.45	.76	.68	.41	.2	.29	.12	.38	.41	.77	1.00	
X14: Downstream Product Returns	-.00	.17	.08	.03	.16	-.17	.02	.19	.42	.36	.07	.26	.37	.30	.39	.43	.17	.28	.42	.41	.56	1.00
X15: Downstream Packaging Returns	.11	.09	.02	-.06	.09	-.03	-.06	.17	.55	.56	.38	.51	.45	.37	.21	.47	.12	.25	.31	.45	.73	.69

B. Set Correlation Analysis findings for simultaneous multiple dependent variables

Model $R^2_{Y,X}$ = .999 ; $\tilde{R}^2_{Y,X}$ = .974; Rao *F* = 2.140; (*df: u* = 83.4, *v* = 120.0); *p* < .001

Variable	r^2 (Set X toY)
Y1: Inventory Turns	**0.68****
Y2: % Orders Fulfilled by Supplier	0.31
Y3: % Customer Orders Fulfilled	0.38
Y4: Lead-Time	0.53
Y5: % Demand Forecast Accuracy	0.30
Y6: Days Raw Materials	0.58
Y7: Days WIP Inventory	**0.60***
Y8: Days Finished Goods	0.38

*** p< .001. ** p< .05. * p< .1. Number of Cases = 33.

The r^2 (set X to Y) values in Table 8 gives the equivalent measure of association to that of a multivariate regression R^2, and is significant for Inventory Turns and Days WIP. A very high proportion of the variance for Inventory Turns (68%) and Days WIP (60%) was explained by the supply chain maturity dimensions. Thus, the hypothesis (H2) that supply chain maturity has a significant positive impact on supply chain performance measures was supported.

Table 9 shows the results for the second SC analysis. The multivariate $R^2_{Y,X}$ value of 30.6% and 'shrinkage' $\tilde{R}^2_{Y,X}$ value of 15.3% indicate acceptable degrees of multivariate association between performance measures and downstream planning and delivering related maturity. Rao's F value of 1.88 rejected the null hypothesis of no association between the independent and dependent sets of measures at the $p<.008$ level. Several r^2 (set X to Y) values were significant and indicated acceptable levels of explained variance for Inventory Turns (8.8%), Percentage Customer Order Fulfillment (5.2%), Percentage Demand Forecast Accuracy (10.6%), Days WIP Inventory (4.8%) and Days Finished Goods Inventory (5.7%). Thus the hypothesis (H2) that the dimensions underlying supply chain maturity have a significant positive impact on supply chain performance measures was further supported by this second SC analysis.

Table 9

Set Correlation Analysis 2: Downstream Planning and Delivering Maturity Dimensions and Performance Measures

A. Correlations among basic variables

	Set Y_B						Set X_B			
	Y1	Y2	Y3	Y4	Y5	Y6	X1	X2	X3	X4
Y1: Inventory Turns	1.00									
Y2: % Customer Orders Fulfilled	-.05	1.00								
Y3: % Demand Forecast Accuracy	-.02	.46	1.00							
Y4: Days Raw Material Inventory	-.09	.01	.04	1.00						
Y5: Days Work in Progress Inventory	.02	-.18	.07	.44	1.00					
Y6: Days Finished Goods Inventory	-.09	-.02	-.09	.20	.07	1.00				
X1: Downstream Future Demand Plan (DFP)	.13	-.04	-.02	-.08	.04	-.16	1.00			
X2: Downstream Customer Satisf. Plan (DCP)	.28	.13	.24	-.04	.02	-.14	.59	1.00		
X3: Delivery Knowledge Sharing	.10	.07	.05	-.16	-.09	-.01	.67	.51	1.00	
X4: e-Delivery	.18	.03	-.01	.05	.11	.03	.44	.44	.48	1.00

B. Set Correlation Analysis findings for simultaneous multiple dependent variables

Model $R^2_{Y,X}$ = .306 ; $\tilde{R}^2_{Y,X}$ = .153; Rao F = 1.880; (*df: u* = 24.0, *v* = 409.4); *p* < .008

Variable	r^2 (Set X toY)
Y1: Inventory Turns	**.088****
Y2: % Customer Orders Fulfilled	**.052***
Y3: % Demand Forecast Accuracy	**.106*****
Y4: Days Raw Materials	.047
Y5: Days WIP Inventory	**.048***
Y6: Days Finished Goods	**.057***

*** p< .001. ** p< .05. * p< .1. Number of Cases = 154.

Conclusions and Managerial Implications

This study contributes to the supply chain design literature by developing a model of maturity. Valid and reliable maturity measures, scales and constructs were formulated and their impact on performance was assessed. In developing a supply chain maturity framework this study goes beyond previous research, which relied on single measures of maturity, to include multi-item scales of collaboration and integration. To do this, the conceptual framework draws on both the supply chain management and operations management streams of literature. In terms of the final result, this supply chain maturity framework is a robust model suitable for use across both academic and practitioner communities in answering questions relating to *where* a supply chain is in developmental terms and *what* might be done to keep improving the design.

While recognizing the limitations of survey research (and emphasizing that care be exercised not to over-generalize our findings) the results of this study indicate three broad theoretical conclusions. First, that this proposed framework constitutes an appropriate model on which to base the concept of supply chain maturity. Through confirmatory factor analysis (CFA) techniques, valid and reliable scales were formulated for each of the planning, sourcing, making, delivering, NPD and returning dimensions of supply chain maturity. All related hypotheses relating to these scales were supported by substantiating analyses.

Second, the downstream planning and delivering dimensions constitute a baseline supply chain maturity framework for supply companies. Furthermore, the validity of adding appropriate upstream planning, sourcing, making, NPD, and upstream/downstream returning maturity dimensions to relevant supply chain operational contexts was empirically supported. While hierarchical structural equation modeling indicates that their inclusion creates a valid supply chain maturity framework, the NPD and sourcing dimensions were not found to be significant components of the model despite their apparent appropriateness to many suppliers. In addition to the possible effects of reduced sample sizes or insufficient levels of NPD and sourcing practices in the sample, possible explanations for such insignificance could include: i) further complexities relating to the extensive internal and external nature of NPD that were not picked up in this study, or ii) confounding effects of differing upstream supply chain configurations. These uncertainties warrant further investigation.

Finally, the results from this investigation indicate strong statistical support regarding the significant impact of supply chain maturity dimensions on multiple objective performance measures. Findings suggest supply chain maturity ranges from underdeveloped to fully developed. Perhaps most importantly, results indicate that supply chain maturity has a significant *positive* impact on a broad range of performance measures. By extension, these conclusions suggest that managers should seek to develop higher levels of supply chain maturity across those dimensions appropriate to their own supply chains in order to achieve superior performance.

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