

Linking Supply Chain Practices to Operational and Financial Performance



Supply Chain 2020 Project Working Paper

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1. Executive Summary

1.1 Research Approach

The Supply Chain 2020 (SC2020) Project is a multiyear research effort to identify and analyze factors that are critical to the success of future supply chains. Phase I of the project focused on supply chain excellence – researching the evolving business strategies, operating models, practices, and principles that are responsible for driving improved performance in companies today. To this end, we have surveyed twenty-five (25) studies from both industry and academia to identify clear links between supply chain management (SCM) practices and operational and financial performance.

For each of the 8 consulting & analyst studies and 17 academic papers studied, we looked for three types of causal linkages or relationships: the link between SCM practices and financial performance; the link between operational performance and financial performance; and the link between SCM practices and operational performance.

To identify trends across these distinct studies, we classified various factors that could be derived from each of the findings. We first classified the studies' financial performance metrics into three categories: short-term financials, market share, and stock market. In addition, we classified five SCM practice areas: supply chain integration, complexity management, aligning strategy and supply chain, IT with process improvement, and operational innovation. Lastly, we used six types of operational performance metrics: customer service, responsiveness, supply chain cost, asset utilization, product quality, and operational flexibility.

In our analysis, we looked at the number of studies that corroborated any of the targeted causal relationships. We then quantified each study's credibility using a research quality index that assessed the strength of evidence supporting the causal link. This analysis helped provide a comprehensive and synthesized picture of which linkages are credibly tied to a firm's performance.

1.2 SCM Practices that Link to Performance

The studies corroborate that several SCM practices are linked to firm performance. Of the five supply chain practice areas examined in our study, supply chain integration

and complexity management show the most evident link to firm performance, with the strongest link between supply chain integration and financial and operational metrics.

The purpose of supply chain integration is to break down the “silos” across the whole supply chain, allowing the firm to move closer to overall optimized rather than sub-optimized management. Supply chain integration includes supplier-side collaboration such as information sharing, internal integration through cross-functional process teams, and customer-side collaboration through the integrating of customers’ needs and wants into the whole supply chain process. From the product perspective, supply chain integration is reflected in integrated collaborative product development.

Complexity management complements supply chain integration as integration itself expands the scope of the management issues and thus increases complexity. Complexity management could include complexity-reducing methods, such as partnerships, long-term relationships, and the rationalizing of product lines. Other complexity management methods do not reduce complexity but instead manage it through modularity and postponement, which improves the efficiency and effectiveness of supply chains. Advanced information technologies can also enable companies to manage higher levels of supply chain complexity.

The combination of supply chain integration and complexity management is the key enabler for companies to synchronize across customers, products, suppliers, and employees, as well as across supply chain strategies and operations. Effectively applying these two supply chain practices allows firms to move away from sub-optimization and to create a profit cycle: a series of coordinated activities meant to squeeze the greatest profit from each product or product line.

This alignment of strategy and supply chain is becoming an important trend as supply chain management becomes more and more integrated into company strategies. Many practices we found in the literature, such as strategic purchasing or logistics capabilities, confirm such a trend. Our study then confirms the impetus behind this trend by providing evidence that supply chain practices contribute to the financial performance of a company, and therefore decisions regarding these practices should be made on a strategic-level.

Our research also shows that when formulating these strategies, companies must realize that operational innovation is crucial if they want to gain competitive advantage in supply chain management. As Michael Hammer describes, operational innovation is truly deep change, affecting the very essence of a company: how its work is done. The effects ripple outward to all aspects of the enterprise. Breakthrough innovations in operations can help destroy competitors and shake up industries, and ultimately contribute to the financial success of the company.

1.3 Operational Metrics Linked to Financial Performance

To support profitability objectives, companies need to optimize supply chain performance. Companies are challenged to continuously improve their performance indicators and increase their compliances.

Among operational metrics, customer service and responsiveness are the most critical; and through our research, we found these two metrics are also the most directly linked to financial performance. In a world where customers are more demanding and sensitive about what they want, but have an unprecedented number of choices, serving them with superior reliability and responsiveness is crucial to companies' financial success.

Cost management does not rank far behind. As supply chain management extends wider girths of the value chain, cost management encompasses more components, and the effective control of those supply chain costs is critical to a company's bottom line. Supply chain cost includes inventory costs, logistics costs, and any other costs incurred to serve customers.

Other operational metrics linked to financial performance include asset utilization, product quality, and operational flexibility. Asset utilization, such as inventory turns, measures how effective assets are being utilized and how they contribute to the financial status of a company. While product quality is a traditional measure, it is also critical to a company's long term survival and growth, and evidence shows it is directly linked to financial performance. Finally, operational flexibility measures a company's agility to cope with the uncertainties and therefore improves the company's ability to win financially in a highly-uncertain and super-competitive environment.

1.4 SCM Practices Linked to Operational Performance

We also find that the supply chain practices we identified contribute significantly to the above operational metrics, suggesting an indirect path from supply chain practices to financial performances.

Our study suggests that in a world with growing complexity -- but abundant opportunities accelerated by globalization and information technologies -- companies need to closely integrate themselves into the supply network, carefully manage the complexity that ensues, align their business strategy with supply chain operations, leverage information technology with process improvement, and pioneer operational innovation for superior firm performance. Companies also need to rigorously execute against critical operational performance metrics, such as customer service, responsiveness, supply chain cost, asset utilization, product quality and operational flexibility, in order to achieve overall business success.

1.5 Summary

Overall, the 25 studies generally paint a picture of the supply chain challenge as a continuously growing network of supply chain partners with incredible complexity, driven by product variety and globalization, and competing in a fast-changing and super-competitive environment. Under these conditions supply chain management practices are shown as driving improvements to financial and operational performance. A supply chain has to be not only lean and efficient but also responsive and dynamic. Through our research, we found the focus of SCM for most companies has shifted from cost reduction to the overall business impact and shareholder value. Therefore, new supply chain business models and process innovation are required for continual improvements to profitability and performance.

2. Introduction

Long viewed as an operational function, supply chain management has become more strategic to companies along with the trend of globalization and the growth of information technology. During the 1990s, it moved from a logistics-focus dealing primarily with warehousing, inventory, and transportation management to an integrated approach that considers the management of goods flows and conversions from raw material suppliers to consumers and product users. Leading companies such as Dell and Wal-Mart are widely considered to have developed and leveraged integrated SCM concepts to gain competitive advantage during this time period.

The more strategic role of supply chain management could be manifested by its stronger impact on companies' operational and financial performance. This paper intends to find such evidence by surveying both industry studies and academic literature to identify the linkage from supply chain practice to operational and financial performance.

This research is part of the ongoing MIT Supply Chain 2020 (SC2020) research initiative, which is predicated on the belief that the fast pace of change in outsourcing, product introduction, and customer expectations will only increase the importance of supply chain designs and operations. It is a multi-year research effort to identify and analyze the factors that are critical to the success of future supply chains, and the Phase I research is focused on understanding excellent supply chains. For any supply chain, the ultimate measurements of excellence should include the operational and financial success driven by the appropriate supply chain practices. Thus our study is an integral part of the SC2020 research initiative.

The industry studies we surveyed were primarily conducted by leading consulting firms such as Accenture, Deloitte, McKinsey, and PRTM, and research analysis companies such as AMR Research. Some of them were collaborative research efforts either among companies or with universities. Here we refer to them as consulting and analyst studies. These studies identified key success factors, either supply chain practices or operational performance metrics, through extensive surveys and data from public databases. They also took a broad view and present a practical approach on how to achieve operational and financial success by integrating these factors. Most of the consulting and analyst studies were conducted in 2003-2004.

Table 1-1: Consulting and Analyst Study Background

No	Sponsor	Theme	Sample size and demographics	Data Source	Analysis Method
C1	Accenture/Stanford /INSEAD	A global study of supply chain leadership and its impact on business performance	636 global 3000 companies in 24 industries	Survey, Public Database	Tabulation, Multivariate
C2	AMR Research	AMR Benchmark Analytix (Benchmark Study)	About 50 manufacturing companies	Survey	Tabulation
C3	Booz,, Allen Hamilton	Capturing the value of supply chain management	196 manufacturing and industrial companies	Survey	Tabulation
C4	Deloitte	Mastering complexity in global manufacturing	689 companies in manufacturing industries in 26 countries	Survey, Public Database	Tabulation, Multivariate
C5	IBM/Industryweek	2003 IndustryWeek Value Chain Survey	1,416 individual respondents, majority from manufacturing, distribution, and retail industries.	Survey	Tabulation
C6	McKinsey/University of Munster	Supply Chain Champions: What factors can give superior supply chain performance?	58 German companies in manufacturing and retail	Interview, Survey	Tabulation, Multivariate
C7	PRTM/SAP	Supply chain planning benchmark study	Over 60 companies, 75 supply chains of manufacturing industries	Survey,	Tabulation
C8	SAP/Georgia Tech	Quantifying the impact of supply chain glitches on shareholder value	838 supply chain glitches (production delays or shipping delays) of publicly traded companies from 1989 to 2001.	Public Database	Tabulation, Multivariate

In Table 1-1, we outline the sponsor, theme, sample size and demographics, data sources, and analysis method for each study. For data source, “Survey” means either paper or electronic questionnaires are sent to targeted groups to solicit relevant information, and “Database” means objective data is obtained from public sources. For analysis method, “Tabulation” refers to using simple analysis such as taking the statistical average and tabulating, and “Multivariate” refers to using regression and other sophisticated statistical methods to test certain hypotheses or draw conclusions.

Among academic literature, we found 17 publications from 1996 to 2004 through searching the ABI/INFORM global database, which covers worldwide business and management issues selected from more than 1,300 current business journals, professional periodicals, and most of the major academic publications in supply chain management since 1971. As the concept of supply chain management became popular only in the mid-1990s, both the time frame and number of publications seem reasonable as it takes years to accrue the data and evidence on how supply chain management impacts

operational and financial success. As we can see from Figure 1-1, the overall trend of publications on the linkage between supply chain practices to operational and financial performance is rising.

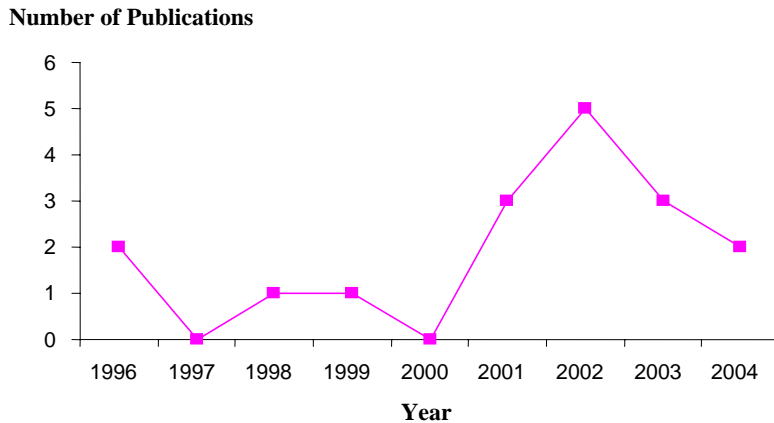


Figure 1: Academic Publications on Supply Chain Management and Firm Performance (1996-2004)

In Table 2-2, we list the backgrounds of the academic studies, including the author(s), year, theme, sample size and industries, data sources, and analysis methods. A common methodology adopted by all 17 academic papers was to conduct a survey and then perform statistical analysis on the data sample to test hypotheses regarding the linkage among supply chain practices, operational metrics, and financial metrics. Regarding the theme, most of the academic studies examine a “snapshot image” of supply chain management compared with consulting and analyst studies.

Table 2-2: Academic Study Background

No.	Author (Year)	Theme	Sample Size and Industries	Data Source	Analysis Method
A1	Balakrishnan et al (1996)	Financial benefits from JIT adoption: Effects of customer concentration and cost structure	46 manufacturing firms adopted JIT between 1985-1989 through annual report or 10-K	Database	Tabulation, Multivariate
A2	Morash et al (1996)	Strategic logistics capabilities for competitive advantage and firm success	CEO responses from 65 small and large U.S. furniture firms	Survey,	Tabulation, Multivariate
A3	Tan et al (1998)	Supply Chain Management: Supplier performance and firm performance	313 manufacturing firms, who are members of American Society for Quality Control (ASQC)	Survey	Tabulation, Multivariate
A4	Vicknery et al (1999)	Supply chain flexibility: An empirical study	65 responses form firms in the highly competitive office and residential furniture industry.	Survey Database	Tabulation, Multivariate
A5	Frohlich and	Arcs of integration: An international	322 responses in the 1998 International	Survey	Tabulation,

	Westbrook (2001)	study of supply chain strategies	Manufacturing Strategy Survey (IMSS) from 23 countries, focused on manufacture of fabricated metal products, machinery and equipment.		Multivariate
A6	Randall and Ulrich (2001)	Product variety, supply chain structure, and firm performance: Analysis of the U.S. bicycle industry	Total 48 responses from U.S. bicycle manufacturers in 1997.	Survey Database	Tabulation, Multivariate
A7	Tracey and Tan (2001)	Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance	180 senior executives of U.S. manufacturing firms, who are subscribers of <i>IndustryWeek</i> .	Survey	Tabulation, Multivariate
A8	Kannan and Tan (2002) (2003)	Supplier selection and assessment: Their impact on business performance	411 material and purchasing managers, members of Institute for Supply Management (ISM) or American Production and Inventory Control Society (APICS).	Survey	Tabulation, Multivariate
A9	Kaynak (2002)	The relationship between just-in-time purchasing techniques and firm performance	382 firm responses who are the member of the American Society for Quality (ASQ) and ISM.	Survey	Tabulation, Multivariate
A10	Narasimhan and Kim (2002)	Effect of supply chain integration on the relationship between diversification and performance: Evidence from Japanese and Korean firms	623 responses from Korean and Japanese manufacturing companies.	Survey	Tabulation, Multivariate
A11	Tan (2002)	Supply chain management: Practices, concerns, and performance issues	411 supply and materials managers of manufacturing firms, who are members of ISM and APICS.	Survey	Tabulation, Multivariate
A12	Tan et al (2002)	Supply chain management: A strategic perspective	101 senior managers of U.S. manufacturing firms among the members of National Association of Purchasing Management (NAPM)	Survey	Tabulation, Multivariate
A13	Rosenzweig et al (2003)	The influence of an integrated strategy on competitive capabilities and business performance: An exploratory study of consumer products manufacturers	238 responses from consumer products manufacturers of the 1997 VIM (Vision in Manufacturing) survey by Deloitte consulting and Univ. of North Carolina.	Survey, Database	Tabulation, Multivariate
A14	Vickery et al (2003)	The effects of an integrative supply chain strategy on customer service and financial performance: An analysis of direct versus indirect relationships	57 first tier large suppliers to NA automotive OEMs.	Survey, database	Tabulation, Multivariate
A15	Wisner (2003)	A structural equation model of supply chain management strategies and firm performance	556 senior managers in U.S. and European manufacturing and service organizations, who are members of APICS and NAPM	Survey	Tabulation, Multivariate
A16	Chen et al (2004)	Strategic purchasing, supply management, and firm performance	221 purchasing managers, who are members of ISM focusing on the industries of fabricated metals, industrial and commercial machinery, electric and electrical equipment, transportation equipment, instruments and measurements equipment, etc.	Survey	Tabulation, Multivariate

A17	Perona and Miragliotta (2004)	Complexity management and supply chain performance assessment: A field study and a conceptual framework	Case studies with 14 Italian companies in the household appliance industry.	Interview	Tabulation, Modeling
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In section 2, we summarize each of the industry and analyst studies and academic papers. In section 3, we will synthesize the themes in the papers and discuss the insights from our study. A list of key success factors of supply chain management that drive operational financial success will then be presented.

3. Summary of the Survey

In this section, we summarize the content and identify three possible relationships for each study: supply chain practices to financial performance, operational performance to financial performance, and supply chain practices to operational performance.

We classify financial performance matrices into three broad categories: short-term financials, market share, and stock market. Short-term financials include costs, revenue, profit/profitability, return on assets (ROS), return on sales (ROA), etc. Market share metrics include actual market shares and other related measurements, such as growth rate. Stock market metrics include stock price, price change, earning per share (EPS), etc.

For supply chain practices, we classified them into five broad types of practices:

1. Supply Chain Integration includes integration with customers, with suppliers, and across the internal organization. From the functional perspective, we also include integrated collaborative product development.
2. Complexity Management refers to coping with supply chain complexity in a cost-effective way.
3. Aligning Strategy and Supply Chain implies that supply chain management is well-integrated into the strategic planning of a company and thus a CEO-level agenda.
4. Information Technology (IT) with Process Improvement means adoption of advanced supply chain management software combined with process improvement.
5. Operational Innovation means creating and implementing leading-edge practices and technologies in supply chain management.

For operational performance metrics, we use the following six types of definitions:

1. Customer Service includes the measurement of the quality of customer-facing activities, such as on-time delivery and perfect order ratio.
2. Responsiveness refers to the speed of response to customer needs and includes measurements such as lead time, delivery speed, and time-to-market.
3. Supply Chain Cost represents the total cost to serve customers and its components including inventory cost, logistics costs, etc.
4. Asset Utilization refers to metrics such as inventory turn.
5. Product Quality refers to both the quality of the products and the quality of product-based services.
6. Operational Flexibility measures an organization's ability to satisfy customers' changing needs in a timely manner.

3.1 Industry and Analyst Studies

C1: Accenture - A global study of supply chain and its impact on business performance

The Accenture study (Accenture 2003, D'Avanzo et al 2003) aims to understand how companies derive competitive advantage from their supply chains and tries to establish a relationship between supply chain performance and business success. By analyzing corporate disclosure data from 636 Global 3000 companies in 24 industries and measuring three supply chain performance variables (inventory turns, cost of goods sold as a percent of revenue, and return on assets) in the period of 1995-1997 and 1998-2000, the study categorizes companies into four groups: Leaders, Transformers, Decliners, and Laggards -- based on the correlation between their supply chain performance and financial performance.

In this study, compound average growth rate (CAVR) of market capitalization within an industry, a type of market share metric, is used as the key financial performance metric. The result strongly suggests a direct relationship between supply chain and financial performance, especially manifested by the linkage between inventory turns and CAVR. For our study, the linkage of cost of goods sold as a percent of revenue and

return on assets to CAVR are not included, since these two variables are financial metrics by themselves.

The study also shows that virtually all companies that improved their supply chain performance (Transformers) had a higher growth rate in market capitalization in the second period. It confirms that tremendous opportunities for value creation and performance improvement exist in almost all industries and suggests that senior executives at leading companies view supply chain as critical drivers of shareholder value and competitive differentiation. The drivers of operational performance improvements include reducing supply chain cost, improving speed and efficiency, improving service quality and product innovation, expanding channels and markets, and improving product quality and service innovation, which could directly contribute to financial performance improvement. Supply chain capability areas that provide the largest improvement opportunities are also identified in the study.

After gaining an understanding of the value of supply chain operations, the study then goes on to analyze the best practices of Leaders and finds that leading companies incorporate supply chains into their business strategies and devote significant attention to designing integrated operating models. An integrated operating model is often the key to successfully balancing supply and demand across internal operations with supply chain partners. It often incorporates world-class business processes in customer relations, supplier management, new product design, and core logistics operations.

The study also finds that leading supply chain companies build innovation into their operating models, particularly with respect to outsourcing, internal/external integration, and matching supply and demand. Their core operating principle and most critical supply chain process is balancing market needs with available supply. To minimize operating costs and employed assets, they are more likely than most to consider and implement leading-edge operating strategies and technologies. Supply chain leaders also align internal and external organizations to maximize product life cycle revenues from customers. Leading supply chain companies are also found to rigorously execute against their strategies and capabilities, and they constantly adapt them to changing market needs. Best practices in this area include driving end-to-end process excellence across

the operating model; fostering process-oriented, collaborative cultures within and across organizations; and developing corporate-wide, high-level metrics.

C2: AMR Research- The Hierarchy of Supply Chain Metrics

In the AMR Research study (Hofman 2004), the next generation of supply chain is defined as the demand-driven network, which is a system of technologies and processes that senses and responds to real-time signals across a network of customers, suppliers, and employees. The supply chain has to be not only lean and efficient but also responsive and dynamic. New benchmarking studies from AMR Research highlight the importance of excelling in the key capabilities of supply chain management.

The research shows that good demand forecasting yields tangible benefits in operational performance. Across industries, companies that forecast demand more accurately have 15% less inventory, 17% better perfect order ratings, and 35% shorter cash-to-cash cycle times than their peers.

They also demonstrate the relationship between supply chain capabilities and key financial and market indicators. Preliminary findings from the consumer products sector study reveal that companies that do a superior job fulfilling customers' needs, as evidenced by the perfect order, tend to have higher earnings per share (EPS), better return on assets (ROA), and heftier profit margins. The data shows that an improvement of 10 percentage points in a perfect order rating correlates with 50 cents better EPS; a gain of five percentage points in the perfect order rating correlates with 2.5 percent better ROA; and an increase of three percentage points in perfect-order performance adds 1 percent to profit margins. Therefore the key operational-financial-performance relationship in this study is between perfect order (customer service) metrics and short-term financial metrics and stock market performance.

The study then further develops a three-level hierarchy of supply chain metrics to achieve the superior performance mentioned above. The top tier metrics, which allow executives to assess the overall health of the supply chain, include demand forecast accuracy, perfect order, and SCM cost. The mid-tier look at cash-to-cash cycle time, which not only allows a company to see how well it is managing cash flow but also facilitates analysis of the components that tell what's happening deeper in the supply

chain. Ground level metrics enable companies to do analyses which reveal the root causes of high inventories, high costs, or poor customer responsiveness.

C3: Booz Allen Hamilton -Capturing the Value of Supply Chain Management

Although supply chain management (SCM) has officially reached its adulthood since Booz Allen Hamilton coined the term in the early 1980s, it continues to fall short of its great promise of embedded cross-functional capabilities designed to unify and rationalize incongruent parts of a dispersed organization. In this survey conducted by Booz Allen Hamilton (Heckmann, Shorten, and Engel 2003), several reasons why the discipline has under-delivered have been identified through nearly 200 responses from manufacturing and industrial companies in North America, Europe, Asia, and Latin America, many with annual sales of more than \$1 billion. The primary measure the study uses is the annual savings in the “cost to serve customers,” which is a broad measure of manufacturing costs including all aspects of the supply chain from procurement to distribution.

In organizations where SCM is part of the overall business strategy and therefore a CEO-level agenda item, the savings in the “cost to serve customers” are 8.0% compared with 4.4% for companies where SCM responsibilities reside lower in the organization. For companies willing to take a broad approach to SCM, tying together numerous functions across the entire organization to the point where the overall structure of the supply chain is visible and can be reevaluated when necessary, cost savings are greater. The cost to serve savings is 7.6% for constraint breakers and 5.6% for local optimizers, 35% higher. The survey also shows that, although business worldwide invests more than \$19 billion annually on information technology system solutions to improve their supply chain performance, 45% of the companies in the study are disappointed with the results. Technology is simply an enabler not a silver bullet, and SCM managers need more than IT solutions to improve their supply chain performance.

Therefore this study broadly draws the linkage from supply chain integration, complexity management, aligning strategy and supply chain, and IT with process improvement to supply chain cost metrics.

C4: Deloitte - Mastering complexity in global manufacturing

The Deloitte study (Deloitte 2003a, b) first presents the challenges of complexity and the paradoxes in managing supply chain complexity in global manufacturing. Three drivers of supply chain complexity are identified: cost, pursuit of new markets, and innovation. A cost-focus dominates manufacturers' supply chain agendas. Pursuit of new markets stretches their supply chain capabilities. Product innovation continues to be the No. 1 factor to drive future revenue growth, however, companies often face discrepancies between their goals and actions. Therefore, the five paradoxes of complexity are:

1. The optimization paradox: Despite the potentially huge economies from designing supply chains from a global view, most manufacturers optimize locally.
2. The customer collaboration paradox: Despite the need to be much more responsive to customers, few manufacturers are collaborating closely with them.
3. The innovation paradox: Product innovation is continuing to accelerate, yet few manufacturers are preparing their supply chains for faster new product introductions.
4. The flexibility paradox: Flexibility is a key priority, but it is being sacrificed in the drive to cut unit costs.
5. The risk paradox: Keeping supply chain quality high is critical, yet manufacturers' risk of supply chain failures keeps growing.

The paradoxical behavior comes at a cost for many companies, but the complexity masters (defined below) are being rewarded handsomely. Their superior ability to synchronize their value chains, including customer, product, and supply chain-related strategies and operations, and to leverage their strengths in collaboration, flexibility, visibility, and technology has helped them generate profit margins up to 73 percent greater than those of other manufacturers. And they outperform the rest in revenue increases, market share growth, and shareholder returns, corresponding to all three types of financial metrics defined.

In the study, complexity is defined by the degree to which companies' value chain operations were dispersed around the world. The capabilities of those value chains are measured as key capabilities in product innovation, time to market, product quality, and customer service levels. A universal measure is used by taking a composite score of each respondent's ratings in ten areas: product innovation, time to market, sourcing

effectiveness, product quality, manufacturing flexibility, manufacturing productivity and cost-effectiveness, manufacturing lead time, logistics effectiveness, customer service, and supply chain cost structure.

By looking at the performances of more than 300 companies with annual revenue of at least US\$200 million, the study identifies the complexity masters, who are the manufacturers with highly complex global networks but strong value chain capabilities. The complexity masters' profit margins are 73 percent greater than those with weaker value chain capabilities and less complex environments. They also enjoy greater competitive advantage and higher shareholder value.

The study then goes further to identify the key success factors of the complexity masters, who are further ahead in synchronizing key activities both within and across their customer, product and supply chain operations and building the capabilities needed to sustain those advantages. Compared with most other companies surveyed, complexity masters have developed superior capabilities in customer-related, product-related, and supply chain-related operations. Complexity masters synchronize across customer, product, and supply chain strategies and operations, moving from sub-optimization to create what we call a profit cycle: a series of coordinated activities meant to squeeze the greatest profit from each product or product line. Underlying complexity masters' ability to synchronize customer, product, and supply chain operations is excellence (exceeding that of most other companies studied) in collaboration, flexibility, visibility, and technology. Another finding is that while complexity masters are far superior to other manufacturers in many key areas, such as outsourcing of manufacturing, distribution, logistics functions, and workforce reduction, they are no better in others.

This study draws comprehensive linkages from the practices of supply chain integration and complexity management to all financial metrics and from customer service, responsiveness, supply chain cost, product quality, and process flexibility to all three financial metrics defined by the study.

C5: IBM/IndustryWeek -2003 IndustryWeek Value Chain Survey

IBM Business Consulting Services conducted the 2003 IndustryWeek Value Chain Survey in conjunction with IndustryWeek magazine. The survey (IBM 2004) identifies

current practices, captures significant trends, and establishes operational performance benchmarks in five key areas of supply chain management (SCM): new product development, supply chain planning, customer order management, procurement, and logistics. The study sample includes a total of 1,461 respondents, the majority of which are from the consumer products and industrial products industries with limited representation from distribution and transportation, high technology, energy, services, retail, and wholesale industries.

Regarding the new trends in SCM, the study finds that new supply chain business models are required to meet the expected levels of profitability, performance, and partnership. In the past, SCM's focus for most companies has been fixed primarily on cost reduction, while now supply chain performance is centered more and more on the overall business impact and shareholder value. To deliver higher profits, companies need to reduce the fixed costs and capital requirements of supply chain operations and move to a more variable cost structure that can be controlled and managed in a direct relationship to customer demand. The quest for profitability is also demonstrated through supply chain initiatives that can deliver a rapid return-on-investment.

To support profitability objectives, companies need to optimize supply chain performance effectiveness. Companies are challenged to continuously improve their performance indicators (i.e., reduced time-to-market, reduced lead times, and on-time delivery) and increasing their compliances (i.e., adherence to plan and perfect order). They are broadening the reach of their key performance indicators to measure the extended value chain network that includes customers, suppliers, service providers, and other partners. The survey shows that supply chain performance is being monitored for: “perfect order” attainment (on-time, right product, right price, and damage free); cycle time reduction in new product time-to-market; and customer product delivery. Productivity initiatives and performance score-carding continue to target improvements in customer fill rates, retention, stock-outs, supplier order fill rates, lead times, and inventory turns.

To optimize efficiency and enable effective and responsive customer value delivery across the extended enterprise, collaboration, process and information integration, and visibility with strategic supply chain partners is imperative. According to the survey

results, many companies are continuing to focus efforts on partner collaboration and the need to coordinate/integrate supply chain event management to reduce latency and end-to-end supply chain cycle time. Extended enterprise partnerships are required to develop new products and services, produce hybrid and cost-effective products and services, and deliver them into multiple channels.

The survey reveals that supply chain executives are concentrating on operational excellence while meeting profitability and other business performance objectives in five major process areas:

1. In new product development, cost and time is king. Companies are developing strategies for cost reduction, such as commonality of components, platforms, and assets for reuse and revenue growth; and improving speed to market, which is a type of complexity management as we have defined. Many are also implementing integrated collaborative processes with partners to manage product change and new, derivative product launches.
2. In supply chain planning, it is all about sensing and responding. Advanced planning systems and leading supply chain practices have been implemented or piloted to increase the responsiveness to customer needs. Such leading practices include rapid responses to changing market conditions, maximizing variable supply chain costs to be aligned with revenues, “real-time” information transparency inside and outside the enterprise, and risk-sharing across the supply network.
3. For customer order management, real-time processing leads to superior customer experience. Late delivery/shipment and inability to fulfill sales orders due to out-of-stock continue to be challenges in meeting customer responsiveness and satisfaction targets. Companies are still slow to embrace leading customer order management practices of self-service, automated cross and up-selling, and demand conditioning.
4. In procurement, the key is to leverage global sourcing to go to the next level of advantage. Global sourcing is on the rise with a growth rate of 6 to 8 percent from three years ago. Attainment of perfect order delivery is growing rapidly but supplier lead times remain static, averaging 20-plus days for more than 30 percent of the respondents. The information technology focus is on integration of internal

procurement and supplier management, as well as external integration with trading partners.

5. For logistics, the focus is on differentiating competencies through outsourcing. Specifically in transportation, warehousing/distribution and freight bill audit, and payment outsourcing is a theme for 70 percent of the respondents. Companies are implementing flow-through strategies (i.e. cross-docking and merge-in-transit) to provide specialized logistics services by customer segment. New technologies such as radio frequency identification (RFID) are creating significant change in logistics performance and inventory control.

C6: McKinsey/University of Munster -Supply Chain Champions: What factors can give superior supply chain performance?

The study of the Institute for Supply Chain Management at the University of Munster with the support from McKinsey & Co. (Thonemann and Grobpietsch 2004) addresses two questions: Which concepts and instruments of SCM really affect supply chain performance through statistical analysis of high and low performers?; What are the key success factors for implementation (via examples and best examples from interviews)?

The data sample includes 58 interviews with German companies and supporting questionnaires with quantitative questions on SC practices, qualitative aspects of SC strategy, and data on performance and structure. The 58 companies are categorized as 40 industry companies and 18 retail companies.

The supply chain performance metrics used for the industry section include resource metrics: logistics cost and finished goods (FG) inventory; and service metrics: service level and delivery time. The study shows that all four measures have impact on return on sales (ROS), which is a measure of a company's profitability equal to a fiscal year's pre-tax income divided by total sales. For industry sections, logistics cost's impact on ROS is 1.8%, FG inventory has 1.0 to 1.5%, and service level has 0.5 to 1.0%. The leaders in the industry sections have: 4.1% logistics cost versus the industry average of 5.0%; 11 days of finished goods inventory versus an industry average of 31 days; more than 99% service level versus a 97.5% industry average; and less than 2.5 days delivery time

compared with a 3.5 days industry average. These show the linkage from customer service, responsiveness, and supply chain costs to short-term financials

The metrics used for the retail section include total inventory, subjective cost, shelf availability, and internal delivery time. The study shows that total inventory has 0.5 to 1.0% impact on ROS, and shelf availability has an impact of 1.0 to 3.0%. The leaders in the retail sections have 27 days of total inventory versus an average of 34 days, subjective costs of 27 versus 36, more than 97.5% shelf availability versus 96.4%, and less than 1 day internal delivery time compared with an average of 1.8 days.

The study provides statistical evidence of the correlation between certain supply chain practices and performances. The following table gives the correlation and key messages from the study.

Table 2-1: Correlation between Supply Chain Practices and Performances

Supply Chain Practices	Correlation with SCM success	Key messages
SCM cooperation - Operative cooperation - Trust/partnership - VMI	0.4	Clear strategy and personal relationships beat pure IT
Production flexibility	0.35	Major shift in mind-set of production
Integrated SCM organization	0.3	Proves value of organization setup
Complexity management	0.3	Not only low complexity is important, but how complexity is managed
Planning processes - Overall planning - Demand forecasting	0.27	Often large conceptual gaps; Process matters, not IT only
SCM controlling/systems	0.22	Proves old wisdom: you get what you measure

Key success factors in supply chain management are elaborated in the study. First, it shows that champions often focus on operative cooperation. They extensively involve their clients in day-to-day operations with immediate benefits, such as informal operative contacts in logistics and joint capacity planning. Regarding trust/partnership, champions are not necessarily easy partners, but they focus on their individual results. Very few leaders adopt VMI at this stage, showing that champions are not necessarily involved in high-cost cooperation projects. For production flexibility, champions focus on optimization of production. The efficiency in production process often outweighs the potential impact of stock reduction and logistics optimization. The top two priorities in

production flexibilities include increasing flexibility by changes in infrastructure, line optimization, etc. and managing remaining inflexibility by clear, rule-based planning processes. Data shows that champions integrate their supply chain organization, adopting integrated operating models. As wide variety of products and customers with different characteristics and requirements create tremendous complexity, champions focus on actively managing complexity. The three identified priorities include creating transparency by fair and detailed allocation of cost and benefit to every product and customer; reducing complexity by fact-based evaluation of SKU proliferation and elimination of unprofitable SKUs without strategic importance; and improving management of remaining complexity by segmentation of products, customers, and other demand criteria. Champions also emphasize clear end-to-end planning processes. For overall planning, champions have clearly defined planning processes that are coordinated by fixed rules. While for demand forecasting, champions achieve high accuracy as a basis for stability along other planning processes. Champions often adopt impact-driven SC controlling, where SC controlling must support SC strategy but does not have to be expensive and IT-intensive. Selection of useful KPI's is as important as data quality, frequent data collection, and proper use of data for controlling purposes.

This study shows the wide range of implications from supply chain integration, complexity management, and operational flexibility to short-term financials through statistical analysis. Similarly, operational metrics such as customer service, responsiveness, and supply chain cost are also linked to short term financials.

C7: PRTM/SAP - Supply chain planning benchmark study

Many companies install the latest software for supply chain planning without rethinking their underlying processes and expect it to solve their problems. As a result, these investments rarely deliver the intended benefits, since technology is only an enabler of supply chain excellence. The study (Cohen and Roussel 2004), jointly conducted by PRTM and SAP, aims to examine how supply chain planning and systems affect business performance.

The survey uncovered a solid linkage between supply chain planning and systems, and business performance. Well-developed supply chain planning processes are critical

to achieving a competitive advantage. Companies with mature planning practices are 38% more profitable, have 22% lower levels of inventory, and provide 10% greater delivery performance than average companies. Companies that combine mature planning processes with advanced planning systems gain added performance improvements, including 27% greater profitability and as much as 40% advantage in supply chain performance metrics across the board. Mature planning processes are critical to a successful planning system. Companies that operate state-of-the-art planning software without solid processes in place risk hurting their planning performance overall.

In the survey, participating companies provided quantitative data on supply chain and financial performance, and qualitative data on their level of planning process capability based on PRTM's Supply Chain Maturity Model consisting of four stages: functional focus, internal integration, external integration, and cross-enterprise collaboration. Adapted for this survey, this four-stage model evaluates an organization's level operational and IT maturity in each of the planning areas defined by the Supply chain Council's SCOR model: plan supply chain, plan source, plan make, and plan deliver. (www.supply-chain.org)

The supply chain planning benchmarking study demonstrates the critical role of planning maturity in driving supply chain and financial performance. Although planning systems can lead to best-in-class performance, they must be applied with the right processes in place to deliver results.

C8: SAP/Georgia Tech - Quantifying the Impact of Supply Chain Glitches on Shareholder Value

Instead of focusing on the positive effects of supply chain on financial performance, the SAP study attempts to estimate the economic impact of supply chain malfunction, mainly production delays and shipping delays, on shareholder value.

The evidence collected from 838 supply chain glitches from 1989 to 2001 shows there is a direct linkage between supply chain performance and shareholder value. On average, the initial news report of a production or shipping delay is associated with nearly 11% decrease in stock price. The stock market reaction is negative for 75% of the announcements, providing additional support that glitches have a negative impact on

shareholder value. The average destruction in shareholder value ranges from \$129 million to \$145 million per major glitch. The total loss in shareholder value for companies experiencing the 838 glitches is estimated to be between \$107 billion and \$120 billion. All these are adjusted for industry and market movements.

The study also discusses potential long-term consequences of glitches on economic performance. For instance, the steep drop in stock price associated with supply chain glitches can easily derail or slow down the long-term growth of companies whose strategy is to use their stock as currency in acquisition. Glitches can also adversely impact the long-term reputation of a company in the minds of investors, lead to loss of revenue from service contracts, and result in negative publicity.

The study goes on further to see how the impact differs among different industries. It shows that the stock prices of high technology companies drop 12.3% on the day of announcement, while companies in the aerospace and defense industry experienced a 2.5% drop in share price. It seems industries with longer production and delivery lead-time are less vulnerable to stock price drop although supply chain problems have an across-the-board negative impact on shareholder value. Another interesting finding of the study is that the reactions to glitches are higher in recent years. For instance, between 1989 and 1993, the average loss in shareholder value was 8% compared with 13% between 2000 and 2001. The higher penalty associated with the more recent supply chain glitches could be due to the fact that effective supply chain management is becoming more crucial to success in the current competitive environment.

The study also uncovers that supply chain glitches caused by external sources, either suppliers or customers, brought higher penalties than glitches caused internally, suggesting that these problems are perceived to be more expensive and time-consuming for a company to fix. This finding highlights the importance of effective supplier relationship management and customer relationship management to increase the efficiency, reliability, and responsiveness of their supply chains. Regarding the root causes of glitches, changes by customers and ramp-up/roll out problems receive higher penalties than parts shortages, production problems, development problems, and quality problems.

Another finding is that the impact of supply chain glitches on shareholder value is modulated by company size and growth prospects. Both small and large companies experience a significant drop in share price when they suffer a glitch. However, a glitch has more devastating impact on smaller companies than on larger companies, since smaller companies are more likely to focus on a limited set of products and have limited capital to invest in technologies and solutions for recovery. The smaller the company, the more negative the stock market reaction could be. Companies with high-growth prospects suffer more from glitches than their low-growth counterparts. The more negative economic impact could be due to the fact that companies with high-growth prospects generally have shorter life cycles, carry higher contribution margins, and require shorter delivery times; and they often have a new but less loyal customer base and face stiff competition. The data also shows that after problems are made public, the stock price of a company does not recover in the short term, leading to long-term loss of shareholder value.

The study then goes on to discuss how to deal with supply chain glitches. The key is to develop adaptive supply chain capabilities, including better forecasting and planning and real-time visibility, to reduce the likelihood of glitches, develop the ability to predict glitches, reduce the lag between the occurrence and detection of glitches, and reduce the time it takes to resolve glitches. The highlighted linkage in this study is from customer service to stock market performance.

In the next sub-section, we review the 17 academic papers with similar approaches in analyzing the three types of SCM versus performance relationships.

3.2 Academic Studies

A1: Financial benefits from JIT Adoption: Effects of customer concentration and cost structure

Balakrishnan et al (1996) examines whether firms exhibiting improved inventory utilization subsequent to JIT adoption achieve a corresponding increase in their Return on Assets (ROA) and whether firm-specific characteristics affect such ROA responses.

The authors first test the hypothesis that firms that adopt JIT have higher ROA than a controlled sample that does not adopt JIT. The results show that this test fails. The evidence shows, on average, superior inventory management does not improve ROA. The authors then partition the sample into two groups to investigate whether differences in customer concentration and cost structure affect firms' responses to JIT adoption. If a firm disclosed the presence of a major customer under SFAS 14, it is considered to have a highly concentrated customer base, Otherwise, the firm is considered to be "free". Results show that "free" firms have positive responses to JIT adoption via less ROA decline during the same period.

JIT is a type of supplier collaboration on production. This paper shows that under the condition of a more diversified customer base, JIT could have a positive impact on ROA, one of the short term financial measures.

A2: Strategic logistics capabilities for competitive advantage and firm success

Morash et al (1996) explores the importance of strategic logistics capabilities to firm performance and competitive advantages. The primary focus of this research is whether strategic logistics capabilities contribute significantly to superior company performance and sustainable competitive advantages. The authors first define demand-oriented and supply-oriented logistics capabilities. Table 2-2 provides a listing of the major logistics capabilities under these two categories. To measure how logistics capabilities are implemented compared with their perceived importance, the research also evaluated implementation of logistics capabilities relative to competitors.

Table 2-2: Major Strategic Logistics Capabilities

Demand-oriented capabilities	<ul style="list-style-type: none"> • Pre-sales customer service • Post-sale customer service • Delivery speed • Delivery reliability • Responsiveness to target markets
Supply-oriented capabilities	<ul style="list-style-type: none"> • Widespread distribution coverage (availability) • Selective distribution coverage • Low total cost distribution

The measurement for firm performance includes Return on Assets (ROA), Return on Investment (ROI), Return on Sales (ROS), ROI Growth, ROS Growth, and Sales Growth.

The authors also measure the above profitability and growth metrics relative to major competitors through a subjective rating. All these measures belong to short-term financials.

The data shows that the demand-oriented capabilities consistently display higher mean important scores than the supply-oriented capabilities, and delivery reliability scores the highest. The implementation levels of these capabilities are mostly consistent with the perceived importance. The authors discover significant correlation among demand-oriented capabilities. Not only are customers more likely to receive both speed and reliability simultaneously, but they can also expect to receive both pre-sale and post-sale customer service as well.

The study identifies four strategic logistics capabilities that are significantly correlated to firm performance: delivery speed, reliability, responsiveness, and low cost distribution. The other four capabilities were not significantly related to performance, possibly representing order qualifiers, not order winners. Responsiveness to target markets dominates the statistical models and is identified as an especially important logistics capability for firm success and competitive advantage. Delivery speed and reliability are especially important for growth opportunities in profits or sales, relative to competitors. Low total distribution cost was the most important variable for the competitor-oriented performance measures related to operating margins, such as ROS.

The study also finds that although managers do recognize demand-side capabilities as more important than supply-side capabilities, their subjective ranking of the detailed capabilities are not consistent with the relative performance findings. Therefore, the authors suggest that capabilities should be based or grounded on objective firm performance measures. Otherwise, there is the danger that management time, effort, and resources will be spent on doing the wrong things or doing the right things wrong. Another managerial implication is the necessity of developing different logistics capabilities for multiple firm objectives. For example, competing on time dimensions such as speed and reliability is especially important for growth in sales and profits. Low total distribution cost has margin-oriented advantages for operating performance by likely reducing per unit costs and increasing sales through lower prices. The findings also imply that in the current competitive environment, customers, no longer satisfied with speed or

reliability tradeoff, often demand total excellence. Therefore, companies must develop creativity and excellence in all capabilities that matters to customers.

A3: Supply Chain Management: Supplier performance and firm performance

Tan et al (1998) examines the relationship between supply chain management practices, supplier performance, and company performance. It provides empirical evidence that selected purchasing practices and customer relation practices are strongly associated with the perceived financial and market success.

The financial metrics used are market share, ROA, market share growth, ROA growth, and sales growth, which are included in short-term financials and market share. Operational metrics include production costs (supply chain cost), customer service, product quality, and competitive position. Competitive position is relatively vaguely defined, therefore we do not include it in our comparison. Relevant purchasing and customer relation practices that have correlation with financial and operational performance are tabulated in Table 2-3.

Table 2-3: Purchasing and Customer Relation Practices

Purchasing Practices	Customer Relation Practices
Commodity teams set supplier goals	Predict customer’s future expectations
Supplier certification - product	Predict key factors affecting customer relationships
Supplier certification - process	Enhance customer support
Use suppliers’ technical support	Evaluate customer complaints
Visit supplier facilities regularly	Follow-up with customers for feedback
Share confidential information	Interact with customers to set standards
Annual price negotiation on key items	Measure customer satisfaction

Purchasing practices that take advantage of supplier capabilities correlate positively and significantly with most firm performance measures, which strongly supports the relationship between supplier collaboration and financial success. With the exception of production costs, the performance measures show significant correlation with each of the seven customer relation practices. The only practice to correlate significantly with production cost was enhancing customer support. This is likely due to increased after-sale service, participation in customers’ product design and development, or other forms of early supplier involvement.

A4: Supply chain flexibility: An empirical study

Vickery et al (1999) investigates different dimensions of supply chain flexibilities and how they impact firm performance. Both the importance and performance of the following five supply chain flexibilities are rated by the respondents.

1. Product flexibility (customization): The ability to handle difficult, nonstandard orders; to meet special customer specifications; and to produce products characterized by numerous features, options, sizes or colors.
2. Volume flexibility: The ability to rapidly adjust capacity so as to accelerate or decelerate production in response to changes in customer demand.
3. New product introduction (i.e., launch flexibility): The ability to rapidly introduce large numbers of product improvements/variations or completely new products.
4. Widespread distribution (i.e., access flexibility): The ability to effectively provide widespread and/or intensive distribution coverage.
5. Responsiveness to target market(s): The ability to respond to the needs and wants of the firm's target market(s).

The authors study the flexibilities under the environment uncertainties of volatility in marketing practices, product obsolescence rate, unpredictability of competitors, unpredictability of demand and tastes, and change in production or service modes. Financial performance is measured by ROI, ROI Growth, Market Share, Market Share Growth, Return on Sales (ROS) and ROS Growth, which are part of short-term financials and market share measures.

Statistics show that target market responsiveness is rated significantly higher than the next in rank in both importance and performance. On the other side, product flexibility is rated significantly lower than others. Product and demand/tastes uncertainties are rated higher than marketing, which is followed by competitors and production. Regarding whether supply chain flexibilities are responses to uncertainty, the study finds that marketing uncertainties are correlated with volume flexibilities, and product uncertainties are correlated with launch flexibilities. Among the flexibilities, access flexibility is significantly correlated with target market responsiveness suggesting that access flexibility is a facilitator of target market responsiveness. This suggests that the critical aspects of target market responsiveness are (1) having the appropriate number of supply chain interfaces for customers and (2) having the ability to provide the

appropriate volume at these interface nodes. Data also supports that importance and performance are highly correlated. The top performers in product flexibility assign more responsibility for product flexibility to manufacturing.

The most important results are: volume flexibility is significantly correlated to every firm performance indicator; launch flexibility and target market responsiveness are significantly correlated with ROI, ROI Growth, Market Share Growth, and ROS Growth; product flexibility is correlated only with ROI; and access flexibility is correlated only with market share. Overall, excellent performers on supply chain flexibility are rewarded at the bottom line. In our measurements, these flexibilities can be broadly categorized into customer service metrics, responsiveness, and operational flexibility. They are all positively linked to short-term financials and market share.

A5: Arcs of integration: an international study of supply chain strategies

In the new millennium, upstream and downstream integration with suppliers and customers has emerged as an important element of manufacturing strategy. Frohlick and Westbrook (2001) use evidence from an international manufacturing study and test the relationship between supply chain integration and performance.

The authors first define two types of integration. The first type involves coordinating and integrating the forward physical flow of deliveries between suppliers, manufacturers, and customers; and the second type involves the backward coordination of information technologies and the flow of data from customers to suppliers. Combining the direction and degree of integration, the authors define arcs of integration and propose the hypothesis that companies with the greatest arcs of supplier and customer integration will have the largest rates of performance improvement.

Supply chain integration is operationalized based upon eight different kinds of activities that manufacturers commonly employ to integrate their operations with suppliers and customers: access to planning systems, sharing production plans, joint EDI access/networks, knowledge of inventory mix/levels, packaging customization, delivery frequencies, common logistics equipment/containers, and common use of third party logistics.

By using quartiles to sort the 322 cases, the authors develop five different integration strategies: inward-facing, periphery-facing, supplier-facing, customer-facing, and outward-facing. Voss (1988) divides manufacturing success into three levels: marketplace competitive advantage, productivity increases, and non-productivity benefits. This study includes 19 diverse measures of market place, productivity, and non-productivity success (Table 2-4).

Table 2-4: Measures of Market Place, Productivity, and Non-productivity Success

Marketplace	Productivity	Non-productivity
<ul style="list-style-type: none"> • Market share • Profitability • Return on investment (ROI) 	<ul style="list-style-type: none"> • Average unit manufacturing cost • Materials and overhead total costs • Manufacturing lead time • Equipment changeover time • Delivery lead time • Inventory turnover (sales/inventory) • Worker/direct labor productivity 	<ul style="list-style-type: none"> • Customer service • Customer satisfaction • Conformance quality • Product variety • Speed of product development • Number of new products developed • On-time delivery • Supplier quality

Statistical analysis strongly supports the hypothesis that companies with the greatest arcs of suppliers and customer integration, that is the highest degree of integration, will have the largest rates of performance improvement. The subset of outward-facing manufacturers records greater rates of performance improvements in comparison to all the other groups. Why is the outward-facing supply chain strategy associated with the largest rates of significant performance improvements? The authors suggest that better coordination in the supply chain reduces uncertainty throughout manufacturing networks, which in turn leads to greater efficiency along with faster delivery of finished goods. 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.

Although the assumption that the greatest degree of supply chain integration was strongly associated with higher levels of performance is behind much of the supply chain literature, this study is probably the first to demonstrate it empirically with a large international group of companies. This paper provides linkage from supply chain integration (customer and supplier integration) to short term financials; market share

metrics; and the broad measures of customer service, responsiveness, supply chain costs, and product quality.

A6: Product variety, supply chain structure, and firm performance: analysis of the U.S. bicycle industry.

Randall and Ulrich (2001) examine two research questions: 1) how does product variety relate to supply chain structure?; and 2) how does matching product variety to supply chain structure affect firm performance?

The presence of variety increases two basic categories of costs within supply chains: production costs and market mediation costs. Product costs include direct materials, labor, costs for design and tooling, and manufacturing overhead. Market mediation costs include inventory costs and product mark-down costs occurring when supply exceeds demand, and the costs of lost sales when demand exceeds supply.

The authors distinguish between two types of product variety: production-dominated variety and mediation-dominated variety. They postulate that firms using scale-efficient production processes will have higher levels of production-dominant variety than firms using scale-inefficient processes. On the other hand, firms with plants located within target markets will have higher levels of market mediation-dominated variety than firms located away from the target market. Then they make the hypothesis that firms matching production-dominant variety with scale-efficient production and mediation-dominant variety with local production outperform firms which fail to make such matches. The financial metrics include ROA and ROS, which belong to short-term financials.

Statistical results show that production-dominant variety is positively associated with scale-efficient/distant production, while market-mediation dominant variety is positively associated with scale-inefficient/local production. There is also evidence that firm performance is positively associated with correctly matching supply chain strategies to product variety strategy. This paper presents two linkages from practices to short-term financials: effective complexity (variety) management and aligning (product) strategy with supply chain structure.

A7: Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance

Tracey and Tan (2001) examine the relationship among supplier selection criteria (quality, delivery reliability, product performance, and unit price), supplier involvement on design teams and in continuous improvement programs, four dimensions of customer satisfaction (competitive pricing, product quality, product variety, and delivery service), and overall firm performance.

The authors test the hypothesis that selecting suppliers based on unit price will have a positive total effect on at least one of the four dimensions of customer satisfaction and on firm performance. Similarly, the second hypothesis is that selecting suppliers based on product quality, deliver reliability, and product performance will have a significant positive total effect on at least one of the four dimensions of customer satisfaction and on firm performance. The last hypothesis is that involving suppliers in product design and in continuous improvement programs will have a significant positive total effect on at least one of the four dimensions of customer satisfaction and on firm performance. The firm performance is a combined construct of growth in sales, ROA, market share gain, and competitive position. We categorize firm performance into short-term financials and market share.

The first hypothesis is rejected. The second is supported, showing that selecting suppliers based on product quality, deliver reliability, and product performance has significant positive total effect on all four dimensions of customer satisfaction and on firm performance. The last hypothesis is also not rejected, so the authors conclude that involving suppliers on product design teams and in continuous improvement programs has significant positive impacts on delivery service and financial performance. Selecting suppliers based on product quality, deliver reliability, and product performance instead of unit price implies closer interaction with suppliers, as does involving suppliers on product design teams and continuous improvement teams. Therefore, the linkage is from supplier chain integration to short term financials, market share, customer service, responsiveness, supply chain cost, and product quality.

A8: Supplier selection and assessment: Their impact on business performance

Increasingly firms are allocating more resources to their core competencies and encouraging the outsourcing of non-core activities, which increases their reliance and dependence on suppliers. This increases the importance of effective supplier selection and assessment. Kannan and Tan (2002) describe an empirical study of the supplier selection and assessment criteria used by American manufacturing companies for items to be used in products already in production. It identifies relationships between criteria and a buying firm's business performance. Results indicate that soft, non-quantifiable selection criteria, such as a supplier's strategic commitment to a buyer, have a greater impact on performance yet are considered less important than hard, more quantifiable criteria, such as supplier capability,.

The survey of senior materials and purchasing managers in the United States, who are either members of the Institute for Supply Management (ISM) or APICS –The Educational Society for Resource Management, generates 411 usable data sets. Responses come from a variety of industries, including raw material and component manufacturers, final product manufacturers, wholesalers, and retailers.

Not surprisingly, due date performance and quality rank as the most important supplier selection criteria. Price and capabilities also rank among the more important selection criteria. Soft selection criteria did not rank among the more important selection criteria. Quality, on-time delivery, response time, and service rank as the most important supplier assessment criteria. To provide more insights, the authors then group the individual selection criteria into five groups: strategic commitment of supplier to buyer, ability to meet buyer needs, capability, buyer-supplier fit, and honesty and integrity. The assessment criteria are grouped into three groups: delivery and service quality, responsiveness, and information sharing.

Correlation analysis reveals that the ability to meet buyer needs, supposedly the most important factor, correlates positively only with product quality, while strategic commitment correlates positively with all measures of business performance. Improving long-term performance requires not only a buying firm's strategic commitment to improve supply chain performance, but also a corresponding commitment from its partners. As the results indicate, market share correlates only with a supplier's strategic

commitment to the buyer, and return on asset correlates only with the supplier's strategic commitment to the buyer and its honesty and integrity.

For the supplier assessment criteria, not surprisingly, delivery and service quality correlate positively with product quality and competitive position. However, since high-performing suppliers also supply other companies (some might be the buying firm's competitors), delivery and service quality might not impact broader measures of market performance, such as ROA and market share. Responsiveness correlates positively with product quality and return on assets. Not only does it suggest that supplier responsiveness enables a buying firm to respond more rapidly to market forces, but also that it allows buying firms to use their own resources more effectively. Information sharing, which is deemed to be the least important dimension of supplier assessment, correlates positively with all performance measures. Information sharing is believed to be a critical factor in improving supply chain performance by facilitating planning and scheduling, reducing the need to carry inventory, and improving the nature and speed of communication between buyers and suppliers. The results validate this important relationship between information flow and performance. Kannal et al (2003) describes similar results of American and European companies and their impact on business performance.

In this paper, strategic commitment, information sharing, and other soft criteria can be categorized as supplier collaboration in supply chain integration; and they correlate with ROA, market share, and product quality. The assessment criteria of delivery and service (customer service) and responsiveness are both correlated with short-term financials.

A9: The relationship between just-in-time purchasing techniques and firm performance

Just-in-time purchasing (JITP) is a process technology that involves procurement of materials that have specific quality attributes required by the buying firm delivered frequently in small quantities. In recent years, companies have adopted JITP to coordinate and integrate their inventory management activities in the supply chain, synchronizing the flow of inventory throughout the supply chain and reducing channel

inventories. Kaynak (2002) investigates the relationships among JITP techniques and a firm's performance.

Two broad divisions of JITP techniques are defined: external and internal. Implementation of external JITP techniques and supplier value-added practices requires a purchasing department to change its approaches in its procurement activities. Supplier value-added practices include establishing long-term cooperative relations with suppliers in order to obtain quality supplied materials and/or services on time. Internal JITP techniques include top management commitment, training, and employee relations.

The author uses three levels of performance metrics. Financial and market performance indicators include Return on Investment (ROI), sales growth, profit growth, market share, and market share growth. Time-based quality performance indicators include product/service quality, productivity, cost of scrap and rework, delivery lead-time of purchased materials, and delivery lead-time of finished products/service to the customer. The inventory management performance indicators include purchased material turnover and total inventory turnover.

The study shows that improved relationships with suppliers and enhanced supplier quality result in small lot deliveries with increased frequency. Well-managed supplier relations will improve a buyer firm's product/service quality, increase productivity, reduce scrap and rework, and shorten delivery lead-time of finished product/service to its customers. JITP also has a positive impact on the financial and market performance via the time-based quality performance.

This paper presents the relationship between supplier integration (JITP) and short-term financials (ROI, sales growth, and profit growth) and market share (growth). On the dimension of practices-to-operational-performance, it finds that supplier integration positively influences customer service, responsiveness, supply chain cost, and product quality. The intermediate relationship includes the correlation from customer service, responsiveness, and product quality to short-term financials and market share.

A10: Effect of supply chain integration on the relationship between diversification and performance: evidence from Japanese and Korean firms

Supply chain strategies and practices depend on not only the nature of the business, the competitive environment, and technology intensity of the product, but also on product and market characteristics. Consequently, supply chain integration (SCI) strategies should be evaluated in the light of a company's market and product strategies.

Narasimhan and Kim (2002) examine the effect of SCI in the relationship between diversification and a firm's competitive performance. The principal research questions that they address include: what SCI strategies are compatible with what product/IMD (International Market Diversification) strategies? And are there synergies that a firm could/must exploit to achieve higher levels of performance?

The variables include supply chain integration, diversification, and firm performance. There are three aspects of SCI: company's integration with suppliers, internal integration across the supply chain, and company's integration with customers. Diversification includes both international market diversification and product diversification. Firm performance metrics include sales growth, market share growth, profitability, etc., which all belong to the categories of short-term financials and market share metrics.

The study shows that internal integration across the supply chain and external integration with suppliers and customers positively moderate the curvilinear relationship between product development and performance, and between IMD and performance, respectively. This implies that for successful product and international market diversifications, internal integration across the supply chain and external integration with suppliers and customers should be prerequisites. Thus, supply chain integration is correlated with both short-term financials and market share metrics. Another message from the paper is the linkage from aligning supply chain and strategy to short-term financial and market share.

A11: Supply chain management: practices, concerns, and performance issues

The advent of information technology and intense global competition has enticed many world-class manufacturers and service providers into adopting an integrated strategic approach to supply chain management. Although many supply chain management efforts have failed to achieve the desired results, it has become a significant strategic tool for firms striving to achieve competitive success. Tan (2002) investigates

the contemporary practices and concerns of supply chain management and relates the practices and concerns to firms' performance.

The author identifies 25 SCM practices and then reduces them to six underlying factors (Table 2-5); and the nine SCM concerns are reduced to three underlying factors (Table 2-6). Performance metrics include overall product quality, competitive position, and customer service level.

Table 2-5: Supply Chain Management Practices and Underlying Factors

Factors	Scale Items
Supply Chain Integration	<ul style="list-style-type: none"> - Searching for new ways to integrate SCM activities - Improving the integration of activities across your SC - Reducing responses time across the supply chain - Establishing more frequent contact with SC members - Involving SC in your product/service/marketing plans
Supply Chain Characteristics	<ul style="list-style-type: none"> - Communicating your firm's future strategic needs - Creating a greater level of trust among SC members - Identifying additional SC - Communicating customers' future strategic needs - Creating a compatible information system - Extending SC beyond immediate suppliers/customers - Creating SCM teams to include different companies
Information Sharing	<ul style="list-style-type: none"> - Use of informal information sharing - Use of formal information sharing agreements - Participating in the marketing efforts of customers - Determining customers' future needs
Strategic Location	<ul style="list-style-type: none"> - Locating closer to your customers - Requiring suppliers to locate closer to your firm - Use of a third-party SCM specialist
Customer Service Management	<ul style="list-style-type: none"> - On-time delivery directly to customers' points of use - On-time delivery directly to your firm's points of use - Contacting the end users to get feedback
JIT Capability	<ul style="list-style-type: none"> - Increasing your firm's JIT capability - Aiding suppliers to increase their JIT capability - Participating in the sourcing decisions of suppliers

Table 2-6: Supply Chain Management Concerns and Underlying Factors

Factors	Scale Items
Supply Chain Coherence	<ul style="list-style-type: none"> - Lack of trust among SC members - Lack of cooperation among SC members - Competition from other SC
Information Capability	<ul style="list-style-type: none"> - Lack of sophisticated information system - Lack of ability in managing SC inventories - Lack of interest among your suppliers or customers - Your firm's lack of leverage within your supply chain
Geographical Proximity	<ul style="list-style-type: none"> - Your customers' geographical distance - Your suppliers' geographical distance

Regression analysis shows that JIT capability correlates with product quality, while concerns for information capability adversely affect the overall product quality. Supply chain integration, information sharing, and JIT capability have a positive impact on competitive position, while lack of information capability adversely affects the overall competitive position. The supply chain characteristics affect overall customer service level, while the lack of information capability and supply chain coherence adversely affect the ability to provide customer service. These relationships corroborate the linkage from supply chain integration to customer service and product quality.

A12: Supply chain management: a strategic perspective

Tan et al (2002) surveys senior managers in various industries to study the prevalent supply chain management and supplier evaluation practices. The results show that many of the practices and metrics are correlated with firm performance and some could adversely affect performance.

For the purpose of the study, 25 supply chain management practices and 13 supplier evaluation practices are identified. Six performance measures operationalized by senior management’s perceptions include market share, return on assets, average selling price, overall product quality, overall competitive position, and overall customer service levels. The authors aggregate the supply chain management practices, and the three relevant to performance are shown and defined in Table 2-7.

Table 2-7: Supply Chain Management Practices

Factors	Scale items
Supply chain characteristics	<ol style="list-style-type: none"> 1. Identifying additional SC 2. Suppliers’ on-time delivery directly to your points of use 3. Communicating your future strategic needs to your suppliers 4. Creating a greater level of trust among SC members
Geographical proximity	<ol style="list-style-type: none"> 1. Locating closer to your customers 2. Requiring suppliers to locate closer to your firm 3. Participating in the marketing efforts of your customer
JIT capability	<ol style="list-style-type: none"> 1. Aiding your suppliers to increase their JIT capabilities 2. Increasing your firm’s JIT capabilities

Table 2-8 lists the supplier evaluation practices.

Table 2-8: Supplier Evaluation Practices

Factors	Scale items
Product and delivery assessment	<ol style="list-style-type: none"> 1. Quality level 2. On-time delivery 3. Correct quantity 4. Service level 5. Price/cost of product
Capacity assessment	<ol style="list-style-type: none"> 1. Willingness to change products/services to meet changing needs 2. Quick response time 3. The flexibility to respond to unexpected demand changes 4. Communication skills/systems
Information assessment	<ol style="list-style-type: none"> 1. Willingness to share sensitive information 2. Use of electronic data interchange (EDI) 3. Willingness to participate in new product development and VA

Results show that geographical proximity is positively correlated with market share. For instance, local suppliers can compete effectively by emphasizing quick delivery and small lot sizes. JIT capability and supply chain characteristics have a positive relationship with overall product quality. Interestingly, supply chain characteristics also have a significant inverse relationship with average selling price, implying that supply chain cost could be reduced. Firms that try to create a greater level of trust among supply chain members, communicate future needs to suppliers, emphasize suppliers' on-time delivery, and identify additional supply chains to reduce can reduce their average selling price compared to competitors.

For the supplier assessment, product and delivery assessment is positively related to overall customer service levels. Capacity assessment shows an inverse relationship to market share, suggesting that if firms emphasize capacity assessment in evaluating supplier performance, they are likely to sacrifice market share performance. While capacity assessment is important, the result shows that it should not be the primary focus of supplier evaluation. Finally, information assessment has the greatest impact on return on assets.

In summary, this paper presents the linkage from supply chain integration to product quality, supply chain cost, customer service, and short-term financials (i.e., ROA).

A13: The influence of an integrated strategy on competitive capabilities and business performance: An exploratory study of consumer products manufacturers

Expanding on the research by Frohlick and Westbrook (2001), Rosenzweig et al (2003) investigate the ways that manufacturing-based competitive capabilities mediate the relationship between supply chain integration and business performance. The authors introduce supply chain integration intensity as a reasonable proxy for the outward-facing supply chain strategy in Frohlick and Westbrook (2001). The model developed in this paper draws upon the strategic management literature, including information processing theory, knowledge-based views of the firm, and transaction cost economics. In a hypercompetitive environment, highly integrated organizations are posited to obtain competitive advantages relative to more independent firms in two main ways. First, with increased information visibility and operational knowledge, integrated supply chain partners can be more responsive to volatile demand resulting from frequent changes in competition, technology, regulation, etc. Second, firms with highly integrated supply chains have the potential to lower the net costs of conducting business and the total delivered costs to customers.

The integration intensity construct reflects the linkages among the various supply chain elements. First, the departments, functions, or business units within the firm that “source,” “make,” and “deliver” products represent the enterprise entities in which internal integration occurs. Second, integration intensity also spans externally to the linkages with entities outside the enterprise, including the network of direct suppliers and their suppliers, and direct customers and their customers. This study defines competitive capabilities to include product quality, delivery reliability, process flexibility, and cost leadership; and proposes the hypothesis that high integration intensity directly influences all four capabilities. The paper also tests whether the four competitive capabilities directly influence business performance, and whether high integration intensity leads directly to better business performance.

The database used in this research is part of the Vision in Manufacturing (VIM) project, which has been conducted biennially by Deloitte Consulting and researchers at the Kenan-Flagler Business School at the University of North Carolina since 1989. This

study employs the 1997 survey with 238 respondents of consumer products manufacturers.

Integration intensity is operationalized through the statistical average of four integration items in the survey. Competitive capabilities are measured through a rating relative to primary competitors in the same markets. Financial performance measurements include return on assets (ROA), the percentage of revenues from new products, and sales growth and customer service.

The empirical results demonstrate that high integration intensity leads directly to superior product quality, delivery reliability (customer service), process flexibility, and cost leadership (supply chain cost). The direct effect of competitive capabilities on the percentage of revenues derived from new products is also significant. While the overall empirical results indicate that enhanced competitive capabilities lead directly to better business performance, their individual effects vary with different performance metrics. Analysis shows that integration intensity has a positive and direct effect on percentage of revenues from new products and ROA, but no direct significant effect on customer service and sales growth.

Testing of the sequence of hypotheses provides empirical evidence that integration intensity influences competitive capabilities, which in turn lead to superior business performance. The relationship between integration intensity and percentage of revenue from new products is partially mediated by cost leadership. The influence of integration intensity on ROA is partially mediated by the delivery reliability. Delivery reliability and process flexibility fully mediate the relationship between integration intensity and customer satisfaction. Product quality, delivery reliability, and cost leadership influence the indirect effect of integration intensity on sales growth.

Besides testing the direct relationship between integration intensity and performance, this study also shows that consumer products manufacturers with high integration intensity also achieve superior product quality, delivery reliability, process flexibility, and cost leadership. When embedded within the organization's operating processes, these capabilities are inherently difficult to imitate, thus providing a competitive advantage over less highly integrated firms in the industry.

A14: The effects of an integrative supply chain strategy on customer service and financial performance

Vickery et al (2003) examines the performance implications of an integrated supply chain strategy, with customer service performance followed by financial performance as a performance construct. Two major components of an integrated supply chain strategy are integrated information technologies and supply chain integration. The study tested four sets of positive relationships: integrative IT and supply chain integration, supply chain integration and customer service, customer service and financial performance, and supply chain integration and financial performance. Table 2-9 gives the definition of the factors.

Table 2-9: Definition of Factors

Construct	Detailed items
Integrative information technologies	<ul style="list-style-type: none"> • Integrated electronic data interchange • Integrated information systems • Computerized productions systems
Supply chain integration	<ul style="list-style-type: none"> • Supplier partnering • Closer customer relationships • Cross-functional teams
Customer service	<ul style="list-style-type: none"> • Pre-sales customer service • Product support • Responsiveness to customers • Delivery speed • Delivery dependability
Financial performance	<ul style="list-style-type: none"> • Pre-tax return on assets (ROA) • Return on investment (ROI) • Return on sales (ROS)

From the above definitions, supply chain integration includes all three types: customer, supplier, and internal integration. Customer service corresponds to our definition of customer service and responsiveness. All the financial performance metrics belong to short-term financials.

Statistical analysis shows that there is a positive relationship between integrative information technologies and supply chain integration. The positive relationship between supply chain integration and customer service is also supported. However, the link between integrative information technologies and customer service is indirect. The relationship of customer service to financial performance is also supported. The results

also show that indeed the direct relationship between supply chain integration to performance is non-significant, and that customer service fully mediates the relationship of supply chain integration to performance. Therefore, the linkages supported in this paper are from supply chain integration to customer service and responsiveness, and from customer service and responsiveness to short-term financials.

A15: A Structural Equation Model of Supply Chain Management Strategies and firm performance

Wiser (2003) investigates whether there are positive linkages between supplier management strategy, customer relationship strategy, supply chain management strategy, and firm performance. The research contends that all firms can benefit from some form or at least limited use of supply chain integrative practices. The author tested the following hypotheses:

1. Inbound logistics strategy positively affects firm performance.
2. Outbound logistics strategy positively affects firm performance.
3. Supplier management strategy positively affects supply chain management strategy.
4. Customer relationship strategy positively affects supply chain management strategy.
5. Supply chain management strategy positively affects firm performance.
6. Supplier management and customer relationship strategies impact each other.

The data and analysis support hypotheses 3 to 6, namely that the supplier management and customer relationship strategies significantly impact supply chain management strategy, supply chain management strategy significantly influences firm performance, and supplier management and customer relationship strategies significantly impact each other.

Firm performance includes the financial metrics of market share and ROA and operational metrics of product quality, customer service, and competitive position. Supply chain management strategy includes numerous measurements of different aspects of supply chain integration (Wisner 2003). Supplier management and customer relationship are integral parts of supply chain integration and are therefore positively

correlated. Therefore the primary relationships we are interested in are from supply chain integration to short-term financials and market share metrics and from supply chain integration to product quality and customer service.

A16: Strategic purchasing, supply management, and firm performance

Chen et al (2004) investigates the relationships among strategic purchasing, supply management capabilities (communication, limited number of suppliers, and long-term relationship orientations), customer responsiveness, and buyer firm financial performance.

The authors hypothesize that strategic purchasing will have a positive effect in fostering buyer-supplier communication, close relationships with a limited number of suppliers, and long-term buyer-supplier relationships. On the other hand, these three factors will have a positive effect on customer responsiveness, and customer responsiveness is positively related to financial performance. Customer responsiveness describes a firm's ability to respond in a timely manner to customers' needs and wants. It is a key building block of competitive advantage (Hill and Jones 2001).

The construct "Strategic Purchasing" includes the extent to which: a) purchasing is included in the firm's strategic planning process; b) purchasing performance is measured in terms of its contributions to the firm's success; c) purchasing professionals have a good knowledge of the firm's strategic goals; and d) purchasing professionals' development focuses on elements of the competitive strategy. Therefore, strategic purchasing is one practice of integrating strategy and supply chain as we defined.

The construct "Limited Number of Suppliers" is operationalized by indicators reflecting the extent to which firms increasingly emphasize close relational contracting with a smaller number of dedicated suppliers. "Long-term Orientation" is operationalized by items reflecting the extent to which the buying firm: a) expects its relationship with key suppliers to last a long time; b) works closely with key suppliers to improve product quality; c) views the suppliers as an extension of the company; and in turn, d) gets suppliers to see their relationship as a long-term alliance. The construct "communication" is operationalized to include the extent to which the firm and its key suppliers: a) share critical, sensitive information related to operational and strategic

issues; b) exchange such information frequently; c) maintain frequent face-to-face meetings; and d) closely monitor and stay abreast of events or changes that may affect both parties. Most of these indicators are part of supply chain integration.

The construct of “Customer Responsiveness” is measured by indicators reflecting the firm’s ability to respond in a timely manner to the needs and wants of its customers through: a) rapid confirmation of orders and b) rapid handling of customer complaints. We consider it to include both customer service and responsiveness measures, as we defined. Finally, “Financial Performance” is operationalized by items indicating the extent of changes in: a) return on investment; b) profits as a percent of sales; and c) net income before tax over the past 3 years, all of which belong to short-term financials.

Statistical results show that strategic purchasing is significantly linked to limited number of suppliers, long-term orientation, and communication. The relationship between long-term orientation and customer responsiveness is significant. The path linking communication and customer responsiveness is marginally significant. However, the path between limited number of supplier and customer responsiveness is not statistically significant. Finally, the path linking customer responsiveness to financial performance is found to be significant. Through direct and indirect relationships, we find that strategic purchasing (linking supply chain with strategy) and supply chain integration are linked to customer service and responsiveness; and customer service and responsiveness are linked to short-term financials.

A17: Complexity management and supply chain performance assessment: A field study and a conceptual framework

With the trends of innovation, globalization of markets and increasingly demanding customers, manufacturing companies are supplying a growing mix of products with features more tailored to customers’ individual needs, both in terms of product characteristics and support services. This relentless effort has caused a ballooning in the complexity of supply chains: wider product variety, smaller production lot sizes, and more tiers and different actors to coordinate within each supply chain. Perona and Miragloitta (2004) investigate the relationship between complexity and business

performances and find that both complexity reduction and management levers can improve business performance.

Results show that partnership or integration with key suppliers can reduce complexity (all complexity indexes are defined in the paper), reduce time in managing commercial transaction, increase transaction reliability, decrease defect rates in delivered goods, and reduce inventory. Long term relationships can also reduce complexity, which results in lower inventory and shorter delivery lead time. Both partnership and long-term relationship are complexity reduction levers that produce remarkable benefits in both efficiency and effectiveness. These relationships suggest that reducing complexity through supply chain integration can improve customer service, responsiveness, product quality, supply chain cost, and asset utilization.

The study also looks at the impact of product modularization in improving new product development performances. Although modular design itself does not shift complexity in a considerable way, it is connected to a sharp increase of efficiency performances, represented by the average R&D man-hours devoted to each new model. A noteworthy improvement in the design effectiveness was found to be connected to modular design as shown by a reduced number of interventions on existing models. Product modularization turns out to be a powerful lever to manage complexity. Therefore, complexity management can contribute to savings in supply chain cost.

Information systems for production planning and control (PP&C) are also a powerful lever to manage complexity. Not only can it reduce the number of employees involved in production planning, but it also increases production readiness by reducing the frozen period.

Empirical findings show that the level of complexity of an operative system is connected to both efficiency and effectiveness. By reducing complexity of one operative system, it is possible to jointly improve its efficiency and effectiveness. Two different kinds of levers can help managers cope with complexity. Complexity reduction levers reduce complexity at a physical level, and complexity management levers reduce the impact of a certain amount of physical complexity on a system's performances. The authors also develop a normative model of using complexity reduction levers to first

reduce the complexity of a system and then manage the actual complexity using management levers to reduce the perceived complexity and improve performance.

In the next section, we will summarize the reviews in tables and synthesize the themes reflected.

4. Opinion

In this section, we synthesize the results from the literature review and present several insights from our findings. We first summarize the three types of relationships for consulting and academic studies, respectively.

4.1 Summary of the Linkages

In describing the practice-financial relationship, we define the following rule of coding: A, B, C represents a relationship from either a supply chain practice or an operational metrics to short-term financials, market share, and stock market performance respectively. Lower case a, b, c represent a sub-relationship.

Table 3-1: Supply Chain Practices and Financial Performance Linkage (Consulting Studies)

	C1	C2	C3	C4	C5	C6	C7	C8	Short-term Financials (A)	Market Share (B)	Stock Mkt. Perform. (C)
Supply chain integration	B			ABC	A	A	A		4	2	1
- Customer collaboration	b				a	a	a		3	1	
- Internal integration	b				a		a		2	1	
- Supplier integration	b				a		a		2	1	
- Integrated collaborative product development					a				1		
Complexity management				ABC	A	A			3	1	1
Aligning strategy & SC	B									1	
Information technology with process improvement							A		1		
Operational innovation	B									1	

On the relationship from supply chain practices to financial performance, consulting studies show that supply chain integration has the highest correlation to financial performance, especially the short-term financials and market share (Table 3-1).

Customer, supplier, and internal integration seem to have significant impact on short-term financials. Complexity management, aligning strategy and supply chain, IT with

process Improvement, and operational innovation also have significant correlation with performance metrics. On the other side, short-term financials and market share metrics are correlated with almost all of the supply chain practices we studied.

Table 3-2: Operational and Financial Performance Linkage (Consulting Studies)

	C1	C2	C3	C4	C5	C6	C7	C8	Short-term Financials (A)	Market Share (B)	Stock Mkt. Perform. (C)
Customer service		A, C		ABC	A	A		C	4	1	3
- On-time delivery					a	a		c	2		1
- Perfect order		a,c			a			c	2		2
Responsiveness				ABC	A	A			3	1	1
- Lead time					a	a			2		
- Delivery speed						a			1		
- Time-to-market					a				1		
Supply chain cost				ABC	A	A			3	1	1
- Inventory cost					a	a			2		
- Logistics cost					a	a			2		
Asset utilization	B									1	
-Inventory turn	b									1	
Product quality				ABC		A			2	1	1
Operational flexibility				ABC					1	1	1

Regarding the relationship between operational and financial performance metrics (Table 3-2), customer service, responsiveness, and supply chain cost are most relevant to financial performance. Here the measures are broadly defined. For example, customer service includes many more aspects than just on-time delivery and perfect order. All these financial metrics are correlated with almost all types of operational metrics.

Table 3-3 presents the relationship between supply chain practices and operational performance. The total number of linkages and respective studies are tabulated. As we can see, supply chain integration can improve customer service, responsiveness, and reduce supply chain costs. Combining advanced information technology with process improvement also contributes to all three metrics. Complexity management and aligning strategy with supply chain have a positive impact on supply chain cost.

Table 3-3: Supply Chain Practices and Operational Performance Linkage (Consulting Studies)

	Customer Service	Responsiveness	Supply Chain Cost
Supply chain integration	1 (C7)	1 (C7)	2 (C3, C7)
Complexity management			1 (C3)

Aligning strategy & SC			1 (C3)
Information technology with process Improvement	1 (C7)	1 (C7)	2 (C3, C7)

The 17 academic studies corroborate the consulting studies in most of the relationships we identified. Only short-term financials and market share metrics are used, since no study measured stock market performance. The academic studies seem to focus more on supply chain integration. Ten studies (60%) find supply chain integration positively impacts financial metrics. Among the four types of supply chain integration, supplier collaboration seems to be the most influential factor for both short-term financials and market share, while integrated collaborative product development only has marginal evidence. Complexity management and aligning strategy and supply chain are also found to be linked to financial metrics.

Table 3-4: Supply Chain Practices and Financial Performance Linkage (Academic Papers)

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	Short-term Financials(A)	Market Share (B)
Supply chain integration	A		AB		AB		A	AB	AB	AB		B	A		AB			9	7
- Customer collaboration			ab		ab					ab			a		ab			5	4
- Internal integration							a			ab			a		ab			4	2
- Supplier collaboration	a		ab		ab			ab	ab	ab		b	a		ab			8	7
- Integrated collaborative product development												b							1
Complexity management						A												1	
Aligning strategy & SC						A				AB								2	1

In the operational and financial performance linkage (Table 3-5), we find that customer service and responsiveness continue to be the most influential performance metrics to impact both short-term financials and market share. On the other hand, their impacts on short-term financials are much higher than on market share. The correlation between customer service metrics and short-term financials is the highest among others. Supply chain cost, product quality, and operational flexibility all have modest impact on the financial metrics.

Table 3-5: Operational and Financial Performance Linkage (Academic Papers)

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	Short-term Financials (A)	Market Share (B)
Customer service		A		AB				A	AB				A	A		A		7	2
- On-time delivery		a						a	ab					a				4	1
- Perfect order																			
Responsiveness		A		AB				A	AB					A		A		6	2
- Lead time									Ab									1	1
- Delivery speed		a												a				2	
- Time-to-market		a																1	
Supply chain cost		A											A					2	
- Inventory cost																			
- Logistics cost		a																1	
Product quality									AB				A					2	1
Operational flexibility				AB									A					2	1

The linkages between supply chain practices and operational metrics in academic studies are also concentrated on supply chain integration (Table 3-6). SCI seems to have the highest impact on customer service and product quality, followed by supply chain cost and responsiveness. There is some evidence that supports that complexity management could reduce supply chain cost, and aligning strategy and supply chain can improve customer service and responsiveness.

Table 3-6

Supply Chain Practices and Operational Performance Linkage (Academic Papers)

	Customer Service (1, 2)	Responsiveness (1, 2, 3)	Supply Chain Cost (1, 2, 3)	Product Quality	Process Flexibility
Supply chain integration	11 (A3, A5, A7, A9, A11, A12, A13, A 14, A15, A16, A17)	6 (A5, A7, A9, A 14, A16, A17)	7 (A3, A5, A7, A9, A12, A13, A17)	10 (A3, A5, A7, A8, A9, A11, A12, A13, A15, A17)	1 (A13)
Complexity management			1 (A17)		
Aligning strategy & SC	1 (A16)	1 (A16)			

Since the data sample, collection, and analysis methods vary significantly from study to study, we define a Research Quality Index, which is the sum of the scores of Sample Size, Data Source, and Analysis Method to reflect and measure the credibility of each conclusion. The definition of each measure is in Table 3-7.

Table 3-7: Definition of Research Quality Index Measures

Measures	Definition
Sample Size	1: < 100, 1.5: 100~500, 2: 500+
Data Source	1: Survey or Public database, 2: Survey AND Public database
Analysis Method	1: Tabulation, 2: Tabulation AND Multivariate analysis

For consulting and analyst studies, the Accenture and Deloitte studies have the highest research quality index with their large data sample size, subjective and objective data sources, and comprehensive analysis approach.

Table 3-8: Consulting and Analyst Study Research Quality Indexes

	C1	C2	C3	C4	C5	C6	C7	C8
Sample size	2	1	1.5	2	2	1	1	2
Data source	2	1	1	2	1	1	1	1
Analysis method	2	1	1	2	1	2	1	2
Index	6	3	3.5	6	4	4	3	5

For academic studies, the multivariate analysis methods adopted by all studies increase the average scores compared with the consulting and analyst studies. On the other hand, since all academic studies use mail surveys that usually have a relatively low response rate (10-20%), their sample sizes are often smaller compared with consulting and analyst studies.

Table 3-9: Academic Study Research Quality Indexes

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
Sample size	1	1	1.5	1	1.5	1	1.5	1.5	1.5	2	1.5	1.5	1.5	1	2	1.5	1
Data source	2	1	1	2	1	2	1	1	2	1	1	1	2	2	1	1	1
Analysis method	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Index	5	4	4.5	5	4.5	5	4.5	4.5	4.5	5	4.5	4.5	4.5	5	5	4.5	4

We use the Research Quality Indexes to evaluate the credibility of the linkages by obtaining the average quality index for each linkage. Tables 3-10 shows the total number and average quality of the relationship from supply chain practices to financial performances in the consulting studies. We find that linkages with Market Share and Stock Market Performance have relatively less numbers but the highest quality index. This suggests that more studies could be conducted to uncover high quality linkages to these measures.

Overall, the linkages from supply chain integration and complexity management to financial performances have the highest total numbers. The average quality of the linkages from supply chain integration and complexity management to short-term financials is relatively low due to the larger number of linkages and the diverse research methods of each study. For relationships with only one identified study (IT with process improvement and operational innovation), the average quality is subject to the quality of that single study.

Table 3-10

Total Number and Average Quality of SC Practice-Financial Linkage (Consulting)

	Short-term Financial		Market Share		Stock Market Perform.	
	Total Number	Average Quality	Total Number	Average Quality	Total Number	Average Quality
Supply chain integration	4	4.4	2	6	1	6
Complexity management	3	4.5	1	6	1	6
Aligning strategy & SC			1	6		
Information technology with process improvement	1	3				
Operational innovation			1	6		

Table 3-11 shows the total number and average quality of the linkage from operational metrics to financial metrics. Similar to Table 3-10, linkages with Market Share and Stock Market Performance have relatively less numbers but the highest quality index. The linkages from customer service, responsiveness, and supply chain cost have the highest total numbers. The overall average quality is high. Likewise, linkages with higher total numbers could have a relatively low average quality due to the larger number of linkages and the diverse research methods of each study.

Table 3-11

Total Number and Average Quality of Operational-Financial Linkage (Consulting)

	Short-term Financial		Market Share		Stock Market Perform.	
	Total Number	Average Quality	Total Number	Average Quality	Total Number	Average Quality
Customer Service	4	4.3	2	6	1	6
Responsiveness	3	4.7	1	6	1	6
Supply Chain Cost	3	4.7	1	6	1	6
Asset Utilization					1	6
Product Quality	2	5			1	6
Operational Flexibility	1	6	1	6	1	6

Table 3-12 shows the average content quality of the linkage from supply chain practices to operational performances in consulting studies. The total numbers are in the corresponding Table 3-13. The relatively low quality indexes are due to the smaller sample size and less comprehensive data collection and analysis methods of the studies.

Table 3-12: Average Content Quality of Practices-Operational Linkage (Consulting)

	Customer Service	Responsiveness	Supply Chain Cost
Supply Chain Integration	3	3	3.25
Complexity management			3
Aligning strategy & SC			3
Information Technology with process Improvement	3	3	3.25

Overall academic studies corroborate the results from consulting studies. In Table 3-13, we find that supply chain integration dominates in the total number of linkages to financial performance, including both short-term financials and market share. Its quality indexes are relatively low since these studies on SCI vary in sample size, data collection and analysis methods. Complexity management and aligning strategy & supply chain have lower total numbers and relatively higher average quality.

Table 3-13

Total Number and Average Quality of SC Practice-Financial Linkage (Academic)

	Short-term Financial		Market Share	
	Total Number	Average Quality	Total Number	Average Quality
Supply chain integration	9	4.7	7	4.6
Complexity management	1	5		
Aligning strategy & SC	2	5	1	5

In Table 3-14, customer service and responsiveness dominate the relationships from operational performance metrics to financial metrics, and their quality indexes are significantly higher, as well. The linkages to market share seem to have higher average quality than those to short-term financials.

Table 3-14

Total Number and Average Quality of Operational-Financial Linkage (Consulting)

	Short-term Financial		Market Share	
	Total Number	Average Quality	Total Number	Average Quality
Customer Service	7	4.6	2	4.8
Responsiveness	6	4.6	2	4.8
Supply Chain Cost	2	4.3		
Product Quality	2	4.5	1	4.5
Operational Flexibility	2	4.8	1	5

Table 3-15 presents the average content quality of the practice-operational performance linkages. As we can see, the overall quality is quite high as most of academic studies use comprehensive analysis methods.

Table 3-15: Average Content Quality of Practices-Operational Linkage (Academic)

	Customer Service (1, 2)	Responsiveness (1, 2, 3)	Supply Chain Cost (1, 2, 3)	Product Quality	Process Flexibility
Supply chain integration	4.6	4.5	4.4	4.5	4.5
Complexity management			4		
Aligning strategy & SC	4.5	4.5			

A comparison of the total number of linkages and average quality gives a more objective picture of the relationship among supply chain practices, operational performance, and financial performance within the scope of our study.

4.2 Insights from the Study

The 25 studies we surveyed reveal the supply chain challenge: a continuously growing network of supply chain partners with incredible complexity caused by product variety and globalization must compete in a fast-changing and super-competitive environment. The supply chain has to not only be lean and efficient but also responsive and dynamic. The focus of SCM for most companies has shifted from cost reduction to the overall business impact and shareholder value. New supply chain business models are required to meet the expected levels of profitability, performance, and partnership.

On the other hand, scholars and practitioners are generating numerous ideas, practices, and metrics on how to succeed in supply chain management, thereby creating another type of complexity. We identify a set of supply chain practices and performance

metrics based on how they contribute to financial metrics, which ultimately determine a company's overall business success. These practices and metrics address the supply chain change, as well as contributing to the bottom line of a company.

First, supply chain integration and complexity management are the most critical supply chain practices that are linked to firm performance. Supply chain integration is characterized by supplier-side collaboration, like information sharing, internal integration through cross-functional teams; and by customer-side collaboration, the integrating of customers' needs and wants into the whole supply chain process. From the product perspective, supply chain integration is reflected in integrated collaborative product development. The underlying reason for integration's linkage to performance is the reduction of "silos" throughout the whole supply chain. Our study finds the strongest support for the link between supply chain integration and both financial and operational metrics.

Complexity management complements supply chain integration, as integration itself expands the scope of the management issues and thus increases complexity. Complexity management could include complexity-reducing methods such as partnership, long-term relationships, and the rationing of product lines. Other methods do not reduce complexity but indeed manage complexity through modularity and postponement to improve the efficiency and effectiveness of supply chains. Advanced information technologies can also enable companies to manage higher levels of supply chain complexity. The combination of supply chain integration and complexity are key enablers, allowing companies to synchronize across customer, product, and supply chain strategies and operations. Moving from sub-optimization the companies can create a profit cycle: a series of coordinated activities meant to squeeze the greatest profit from each product or product line.

Aligning strategy and supply chain is becoming an important trend as supply chain management becomes more and more integrated into the strategic planning of companies. Many practices such as strategic purchasing or strategic logistics capabilities are found in the literature to confirm such a trend. The evidence from our study showing that supply chain practices contribute to the financial growth of a company provides further support for supply chain management to be a strategic-level decision.

Despite the fact that businesses worldwide invest more than \$19 billion annually on information technology systems solutions to improve their supply chain performance, the actual value delivered is less than satisfying, and many companies are disappointed with the results. Information technology is simply an enabler but not a silver bullet. It must be combined with significant process improvement to contribute to the bottom line improvement of companies in this information era.

Operational innovation is crucial to gain competitive advantage in supply chain management. As Michael Hammer describes, operational innovation is truly deep change, affecting the very essence of a company: how its work is done. The effects ripple outward to all aspects of the enterprise. Breakthrough innovations in operations can destroy competitors and shake up industries, and ultimately contribute to the financial success of the company.

To support profitability objectives, companies need to optimize supply chain performance effectiveness. Companies are challenged to continuously improve their performance indicators and increase compliance. Among operational metrics, customer service and responsiveness are the most critical, and we find the most quantitative evidence that they are directly linked to financial metrics. In a world where customers are more and more demanding regarding what they want but have an unprecedented number of choices, serving them with superior reliability and responsiveness is crucial to a company's financial success.

As the supply chain encompasses more of the value chain, supply chain-related costs also include components; and effective control of supply chain cost is critical to a company's bottom line. Supply chain cost could include inventory cost, logistics cost, and other costs to serve the customers. Asset utilization, such as inventory turns, measures how effective assets, such as capital, are being utilized, thereby also contributing to the financial status of a company. Product quality, although a traditional measure, is critical to a company's long term survival and growth, and we found it to be directly linked to financial performance. Operational flexibility measures a company's agility to cope with the uncertainties and therefore improve its ability to win financially in a highly-uncertain and super-competitive environment.

We also find that the supply chain practices we identified contribute significantly to the above operational metrics, suggesting an indirect path from supply chain practices to financial performances.

Our study suggests that in a world with growing complexity but abundant opportunities accelerated by globalization and information technologies, companies need to closely integrate themselves into the supply network, carefully manage the complexity that ensues, align their business strategy with supply chain operation, leverage information technology with process improvement, and pioneer operational innovation for superior firm performance. Companies also need to rigorously execute against critical operational performance metrics, such as customer service, responsiveness, supply chain cost, asset utilization, product quality, and operational flexibility, in order to achieve overall business success.

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