UNIVERSITY OF MANNHEIM

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# Enabling Successful Supply Chain Management

## Coordination, Collaboration, and Integration for Competitive Advantage

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# Enabling Successful Supply Chain Management –
## Coordination, Collaboration, and
## Integration for Competitive Advantage

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Submitted by
Dipl.-Kfm. Andreas Hammer
from Pforzheim

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Andreas Hammer

Munich, August 2006

> “Science is facts; just as houses are made of stones, so is science made of facts; but a pile of stones is not a house and a collection of facts is not necessarily science.”
>
> *Henri Poincaré, French mathematician & physicist*

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# Abbreviations

| | | |
|---|---|---|
| 4PL | = | Fourth party logistics service provider |
| ARPA | = | Advanced research projects agency |
| ASCC | = | Automatic Sequence Controlled Calculator |
| ASCII | = | American Standard Code for Information Interchange |
| CAD | = | Computer aided design |
| CERN | = | Conseil Europeen pour la Recherche Nucleaire or European Organization for Nuclear Research |
| CIM | = | Computer integrated manufacturing |
| CPFR | = | Collaborative planning, forecasting and replenishment |
| CSS | = | Cascading style sheets |
| DIKW | = | Data, information, knowledge and wisdom hierarchy |
| EAN | = | European Article Number |
| ECR | = | Efficient consume response |
| EDI | = | Electronic data interchange |
| EPC | = | Electronic product code |
| ERP | = | Enterprise resource planning |
| FTP | = | File transfer protocol |
| GMRG | = | Global Manufacturing Research Group |
| GSM | = | Global system of communication |
| HPM | = | High performance manufacturing |
| HTML | = | Hypertext markup language |
| HTTP | = | Hypertext transfer protocol |
| IETF | = | Internet engineering task group |
| ISO | = | International organization for standardization |
| IT | = | Information technology |
| JIT | = | Just-in-time |
| LISREL | = | Linear structural relation modeling |
| MIT | = | Massachusetts Institute of Technology |
| MPEG | = | Motion pictures expert group |
| MPG3 | = | Motion pictures expert group audio format |
| MRP II | = | Manufacturing resource planning |
| MRP | = | Material requirement planning |

| | | |
|---|---|---|
| NACE | = | Nomenclature Generale des Activites Economiques dans I`Union Europeenne (Classification of economic activities in the European Community) |
| NAICS | = | North American industry classification system |
| NDCF | = | Net Discounted Cash Flows |
| NSF | = | National science foundation |
| OEM | = | Original equipment manufacturer |
| OASIS | = | Organization for the Advancement of Structured Information Standards |
| PC | = | Personal computer |
| PDF | = | Portable document format |
| PIMS | = | Profit Impact on Marketing Strategies |
| PLS | = | Partial least squares |
| PRTM | = | Pittiglio Rabin Todd & McGrath, consulting company |
| RAM | = | Random Access Memory |
| RFID | = | Radio frequency identification |
| SCC | = | Supply chain council |
| SCM | = | Supply chain management |
| SCOR | = | Supply chain operations reference |
| SEM | = | Structural equation model(ing) |
| TCP/IP | = | Transmission control protocol / Internet protocol |
| TQM | = | Total quality management |
| UCC | = | Uniform code council |
| UMTS | = | Universal mobile telecommunications system |
| UPC | = | Universal product code |
| URI | = | Uniform resource identifier |
| URL | = | Uniform resource locator |
| VMI | = | Vendor managed inventory |
| W3C | = | World wide web consortium |
| WLAN | = | Wireless local area network |
| WWW | = | World wide web |
| XML | = | Extensible markup language |

# A. A Shift to Supply Chain Competition – Moving Beyond Management Science

The concept of supply chain management (SCM) is not a new idea. Its meaning has changed considerably, however, over the last decade as researchers have identified potential benefits going along with an expansion of scope of the concept. With this increase in scope, the company vs. company view of competition did not seem to be adequate anymore and the notion of supply chain vs. supply chain competition was adopted by many researchers.[1]

Several macro-economic developments have contributed to this recognition. Significant factors include globalization, a change towards customer-driven markets, acknowledgment of dependencies, a focus on core competencies, increasing cost competition, and advances in information technology. In the following paragraphs, these factors are briefly reviewed:

1. *Globalization*. The political developments of trade policies were and are accompanied by improvements in logistics services and communication technology. This makes global sourcing and partnering more feasible than a few years ago. Managing such global networks on both the supplier as well as the customer side gained in importance as it expanded the opportunities of competition.[2] The enlarged geographical and societal scope now requires companies to manage increased uncertainties.[3]

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1 One of the first references can be traced back to Porter, Michael E.: The competitive advantage of nations, New York 1990, p. 3 in the context of value systems and to Christopher, Martin: Logistics and supply chain management, London 1992, in the context of supply chains. This notion was picked up in the following years by many researchers. Some of the most prominent examples can be found in Lambert, Douglas M., Martha C. Cooper and Janus D. Pagh: Supply chain management: Implementation issues and research opportunities, in: The International Journal of Logistics Management, Vol. 9 (1998), No. 2, p. 1; McCormack, Kevin P. and William C. Johnson: Supply chain networks and business process orientation: Advanced strategies and best practices, Boca Raton 2003, p. 33. The underlying principles of this development, however, were already laid out by Forrester in 1961, see Forrester, Jay W.: Industrial dynamics, Waltham 1961, reprinted in 1999, pp. 4-9. This will be followed up in more detail in section B.I.1.

2 See Christopher, Martin: Logistics and supply chain management: Creating value-adding networks, 3rd ed., Harlow 2005, pp. 32-33.

3 See Lee, Hau L. and Seungjin Whang: Information sharing in a supply chain, in: International Journal of Technology Management, Vol. 20 (2000), No. 3/4, p. 374.

2. *Customer-driven markets*. Customers, especially end customers[4], are more often offered alternatives to existing products and services. This has empowered consumers and leads to advanced requirements concerning all product or service characteristics. Availability of the "right product or service" is considered to be of differentiating importance.[5] Furthermore, basic needs are overly satisfied in the major economies,[6] which has led to a more unpredictable consumer behavior and therefore higher volatility of demand.[7]
3. *Dependency*. Companies realize that they are not operating in a vacuum. They are dependent not only on their customers, but also increasingly on other stakeholders, for example their suppliers, employees, authorities, and shareholders.[8]
4. *Focus on core competencies*. Since the early 1990s, companies have focused more on their core competencies in order to remain competitive.[9] By doing so, they have stripped off activities that do not contribute to these competencies. Consequently, this has led to outsourcing and vertical disintegration.[10]

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4 The terms "end customer" and "consumer" are used in this text interchangeably. There cannot be a "real" end customer before the consumer since all products and services ultimately reach the consumption stage. See also Kuhn, Axel and Bernd Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, Berlin Heidelberg New York 2002, p. 2.

5 See Fulkerson, William: Information-based manufacturing in the informational age, in: The International Journal of Flexible Manufacturing Systems, Vol. 12 (2000), No. 2/3, April, p. 131.

6 See Walther, Johannes: Konzeptionelle Grundlagen des Supply Chain Managements, in: Walther, Johannes (Ed.): Supply Chain Management, Frankfurt am Main 2001, p. 11.

7 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, p. 117.

8 Dependency can be related to the acknowledgement of supply chain vs. supply chain competition, as introduced on the previous page. For an early comment on this issue, see Emery, Frederick E. and Eric L. Trist: The causal texture of organizational environments, in: Human Relations, Vol. 18 (1965), No. 1, January, pp. 21-32.

9 See Wernerfelt, Birger: A resource-based view of the firm, in: Strategic Management Journal, Vol. 5 (1984), No. 2, pp. 171-180; Barney, Jay: Firm resources and sustained competitive advantage, in: Journal of Management, Vol. 17 (1991), No. 1, March, pp. 99-120; and Stalk, George, Philip Evans and Lawrence E. Shulman: Competing on capabilities: The new rules of corporate strategy, in: Harvard Business Review, Vol. 70 (1992), No. 2, March/April, pp. 57-69.

10 See Harland, C. M.: Supply chain management: Relationships, chains and networks, in: British Journal of Management, Vol. 7 (1996), Special Issue, pp. S64-S66.

5. *Cost competition*. Though efficient operating costs have always been considered a qualifying factor of competitiveness,[11] regardless of competitive priorities, the price pressure has increased considerably due to lower trade barriers, excess supply in many industry sectors, and decreasing information asymmetry. Often, companies feel as if their internal cost saving potential is exhausted and seek further cost savings beyond their company boundaries.[12]
6. *Information technology*. The widespread diffusion of the Internet accompanied by digitalization of telecommunication networks, development of broadband transmission and increased performance of distributed computation based on common standards has led to an acceleration of the trends mentioned and impacts customer behavior and spending drastically.[13]

The expanding scope of competitive considerations to the management of entire supply chains appears to make a prophecy come true. Jay W. Forrester foresaw in his seminal work in 1961 the increasing importance of management science and operations research.[14] At the time, management science was in its infancy and management was considered to be more of an art that needed organization in order to understand the foundation on which the art is based on. According to Forrester, "as science develops to explain, organize, and distill experience into a more compact and usable form … [and] … grows, it provides a new basis for further extension of the art."[15] Forrester depicts the development of the perception of management as an art and management science in a graphic illustration. In this illustration, the two converge until the beginning of the 21st century and then, as science builds a solid foundation, diverge again.[16] After decades of solid management science development in functional areas, the focus has now shifted to the management of entire supply chains. This introduces a whole new level of complexity[17], which causes new challenges for management

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11 On "qualifying" factors and "order-winning" factors, see Hill, Terry: Manufacturing strategy, London 1985, p. 44.

12 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 33-37, and Simchi-Levi, David, Philip Kaminsky and Edith Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, 2nd ed., New York 2003, p. 5.

13 Cf. Fulkerson: Information-based manufacturing in the informational age, p. 134.

14 Cf. Forrester: Industrial dynamics, pp. 1-3.

15 Forrester: Industrial dynamics, p. 2.

16 Cf. Forrester: Industrial dynamics, p. 2.

17 Complexity can be defined by the dimensions (1) variety, (2) connectivity, and (3) functionality, cf. Milling, Peter: Systemtheoretische Grundlagen zur Planung der Unternehmenspolitik, Berlin 1981, pp. 91 et sqq., and Milling, Peter: Kybernetische Überlegungen beim Entscheiden in komplexen Systemen, in: Milling, Peter (Ed.): Entscheiden in komplexen Systemen, Berlin 2002, pp. 11 et sqq.

science. However, developments so far build the basis for further extension of the art. Based on existing advances in management sciences, especially the development of advanced and easy to use research and management tools, scientists and practitioners are now better equipped to deal with this "new" complexity.[18] The principles of systems thinking can provide the necessary tools to develop management sciences further and to organize the field in order to explain the art of management. It is one aim of this text to provide such organization in the context of SCM by deriving a new framework for SCM.[19]

Recent developments in information technology, especially the advent of the Internet, play a significant role in this context. In fact, it is the features of the Internet platform, paralleled by breakthroughs in microelectronics, operating systems, and programming languages, that represent the backbone of the above mentioned developments.[20] Kahl and Berquist identify the following key characteristics of the Internet platform and network technology: (1) standardization and common communication protocols, (2) ubiquity and pervasiveness, (3) open, digital many-to-many network configuration and infrastructure, (4) real-time communication, and (5) variety of data structures.[21] By enabling individuals and organizations to communicate and exchange formal information through a widespread, relatively cheap, and fast network, the opportunity costs of such communication and information exchange decreases significantly.

As these opportunity costs are important parameters for decisions on system structures and system designs, such a change must have a profound impact on the economic ecosystem. The current change in the underlying communication and information technology is proceeding faster than ever before. It takes time, however, for the economic ecosystem as well as for society to adjust. Again, not much has changed from 40 years ago. Forrester remarked already in 1961 in context of advances in computing power:

> "Society cannot absorb so big a change in a mere ten years. We have a tremendous untapped backlog of potential devices and applications. It is now to be expected that machine progress will stay ahead of conceptual progress in industrial and economic dynamics."[22]

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18 In line with Milling's definition of complexity, this new complexity is created by expanding the existing scope of management science on all dimensions, i.e. variety, connectivity, and functionality, see Milling: Systemtheoretische Grundlagen zur Planung der Unternehmenspolitik, pp. 91 et sqq.

19 See chapter B.I.3.c.

20 See Fulkerson: Information-based manufacturing in the informational age, p. 134.

21 See Kahl, Steven J. and Thomas P. Berquist: A primer on the internet supply chain, in: Supply Chain Management Review (2000), September/October, pp. 42-43.

22 Forrester: Industrial dynamics, p. 19.

Managers, popular press, and researchers await the latest developments of information technology, especially recently in mobile information and communication technology. Still, most companies are trying to figure out how best to apply existing technology for improving business performance. They attempt to unify separated systems scattered throughout all areas of business and society. With that, they are trying to capture the "untapped backlog" created by the disruptive nature of Internet technology. Though there are further refinements and important developments to come, the underlying characteristics of the Internet, as described above, build the basis as these technological devices and applications develop over time.

Just as information technology keeps inventing and introducing new devices and applications based on technological progress, business research must adjust to the new capabilities provided by Internet technology and the accompanying social impact. Therefore, a need for a persuasive theory in SCM, especially as a foundation for the effective application and implementation of information technology, was identified by researchers.[23]

The aim of the analysis in this text is to contribute to the theory building process in SCM. First, grounding on existing research, a new, comprehensive SCM framework is developed. Then, an in-depth discussion of its elements is presented and core elements of SCM are identified. Based on this thorough foundation, an empirical analysis is conducted in the context of the High Performance Manufacturing (HPM) project. In this context, the analysis focuses on the identified core SCM elements coordination, collaboration, and integration and additionally investigates the role of information technology (IT) and e-business.

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23 See Bechtel, Christian and Jayanth Jayaram: Supply chain management: A strategic perspective, in: The International Journal of Logistics Management, Vol. 8 (1997), No. 1, pp. 25-26; and Chen, Injazz J. and Antony Paulraj: Towards a theory of supply chain management: The constructs and measurements, in: Journal of Operations Management, Vol. 22 (2004), p. 133.

# B. Improving Supply Chain Performance through E-Business Enabled Supply Chain Management

## I. Supply Chain Management as a Strategic Option for Companies

### *1. Emergence of the Concept and Definitions*

The term supply chain management[24] (SCM) seems to have originated from Oliver and Webber in the early 1980s.[25] It started off as a concept that stresses mainly a coordinated, holistic view of the various segments in the chain of supply and demand of functional areas and the strategic importance of this. Emphasis was on the internal supply chain and the broader view of former operational logistics activities. Over time, researchers and practitioners picked up the term and assigned new meanings to it.

The underlying coordinative idea is a rather old one, as several authors have pointed out with examples from centuries ago.[26] The principles of SCM were first systematically identified by Forrester.[27] Even before that, von Bertalanffy and Boulding discussed the concept of general systems theory, which brought up the understanding that the "[…] behaviour of a complex system cannot be understood completely by the segregated analysis of its constituent parts."[28] The notion

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24 Hereafter, the abbreviation SCM is used throughout the text.

25 See Oliver, R. Keith and Michael D. Webber: Supply chain management: Logistics catches up with strategy, in: Christopher, Martin (Ed.): Logistics: The strategic issues, London 1992; and cf. Harland: Supply chain management: Relationships, chains and networks, p. S63.

26 For example, Christopher names the building of the pyramids in ancient Egypt. He also cites the importance of food and equipment supply in the American War of Independence, a major factor in the defeat of the British army. Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 3-4. Geary, Childerhouse and Towill mention the capability of the Venice *arsenalotti* (master ship builders) to deliver warships every 24 hours in 1574 and the just-in-time (JIT) methods used on a large scale during the construction of Crystal Palace in London, cf. Geary, Steve, Paul Childerhouse and Denis R. Towill: Uncertainty and the seamless supply chain, in: Supply Chain Management Review (2002), July/August, p. 53.

27 Cf. Forrester, Jay W.: Industrial dynamics: A major breakthrough for decision makers, in: Harvard Business Review, Vol. 38 (1958), July/August, p. 37. In this article, Forrester relates more to an internal perspective, though it becomes clear that the approach reaches beyond company boundaries.

28 New, Stephen J.: The scope of supply chain management research, in: Supply Chain Management: An International Journal, Vol. 2 (1997), No. 1, p. 16 with reference to

subsequently evolved, mainly driven by the logistics discipline, to arrive at the significance SCM has in today's academic environment and business literature.

The following section gives a brief overview of general, historical developments that are relevant to derivation of the SCM concept from the evolutionary process that occurred. The differences between logistics management and SCM are further examined. Then, the different current perceptions and definitions of SCM are introduced, as there exists a variety of ideas and understandings about SCM.

Before 1975, markets were predominantly controlled by the supplier, which often was an original equipment manufacturer (OEM).[29] Manufacturers focused on their own operations with little or no cooperative supplier relationships. Purchasing and procurement were perceived as a "servant for production". Emphasis was placed on production costs per unit with little product and process flexibility.[30] Chandra and Kumar also tag the year 1975 as the time until which companies had focused on functional optimization and their relationships with suppliers had been mainly adversarial.[31] With the introduction of Material Requirement Planning (MRP) in the 1970s, managers realized the impact of work in process inventory on key performance drivers, such as cost, quality, new product development, and delivery lead time. In the following years of the 1970s, companies began to realize the benefits of coordinating and integrating functions within the corporation. This was followed in the 1980s by more sophisticated and better organized management concepts. This introduced quality initiatives as the total quality management philosophies and ISO certification efforts, Manufacturing Resource Planning (MRP II)[32], Just-in-Time (JIT), and has

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Boulding, Kenneth E: General system theory - the skeleton of science, in: Management Science, Vol. 2 (1956). Roots can be traced back to the ideas of von Bertalanffy in the 1940s, see von Bertalanffy, Ludwig: General system theory: Foundations, development, applications, New York 1968 for an overview.

29 Cf. Schönsleben, Paul: Integrales Logistikmanagement: Planung und Steuerung der umfassenden Supply Chain, 4th ed., Berlin Heidelberg New York 2004, p. 79. He marks the oil crisis as the turning point of this situation as prices rose and demand declined.

30 Cf. Tan, Keah Choon: A framework of supply chain management literature, in: European Journal of Purchasing & Supply Management, Vol. 7 (2001), No. 1, pp. 40-41.

31 Cf. Chandra, Charu and Sameer Kumar: Supply chain management in theory and practice: A passing fad or a fundamental change? in: Industrial Management & Data Systems, Vol. 100 (2000), No. 3, p. 100.

32 MRP II is an extension of MRP, including all kinds of resources and providing more sophisticated feedback to other enterprise planning systems, including operations, marketing, and finance, see for example Hill, Terry: Operations management, 2nd ed., New York 2005, p. 358.

included immediate suppliers, and transportation and distribution specialists.[33] With increasingly global competition from the 1990s on, the management of outside links to the organization gained attention in the form of strategic alliances. At the same time, information technology picked up speed and enterprise resource planning (ERP), product data management, and computer integrated manufacturing (CIM) became available.[34] Suppliers were included pragmatically in order to reduce costs and improve quality by working with fewer suppliers more strategically, aiming to eliminate redundant tasks. This view has now been extended and broadened, including not only suppliers, but also service providers, and customers.[35]

A similar, though more "aggregated", outline is drawn by Weber, Bacher, and Groll with regard to logistics. They have identified the following four development steps in logistics. First, the functional view of logistics was predominant. The second step focused on the inter-functional coordination and attempted to influence customer needs. In the third step, entire value creation structures have been questioned and a flow-oriented design of processes with the entire company has been emphasized in order to accomplish competitive advantages. The fourth step now reaches beyond company boundaries and extends the flow-oriented process view across supply chains, i.e. from "source of supply" to "point of consumption".[36]

According to a study conducted by Deloitte, this evolutionary process can also be observed in the product development process of leading manufacturers. From a purely functional approach in the 1960s and concurrent product and process engineering in the 1970s, a cross functional emphasis was also used within product development in the 1980s. Starting in the 1990s, customers and suppliers

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33 Cf. Tan: A framework of supply chain management literature, p. 41, and Chandra and Kumar: Supply chain management in theory and practice: A passing fad or a fundamental change?, p. 100.

34 In fact, CIM became available in the 1980s. For an overview at the time see Milling, Peter: Informationstechnologie als Wettbewerbsfaktor industrieller Unternehmen, Beiträge des Fachbereichs Wirtschaftswissenschaften der Universität Osnabrück (No. 8614) 1986, Osnabrück, and a status report in the 1990s, see Milling, Peter: Die 'Fabrik der Zukunft' in strategischer Perspektive, in: Milling, Peter and Günther Zäpfel (Eds.): Betriebswirtschaftliche Grundlagen moderner Produktionsstrukturen, Berlin 1993.

35 Cf. Tan, Gek Woo, Michael J. Shaw and William Fulkerson: Web-based supply chain management, in: Information Systems Frontier, Vol. 2 (2000), No. 1, January, p. 41, and Chandra and Kumar: Supply chain management in theory and practice: A passing fad or a fundamental change?, pp. 100-101.

36 See Weber, Jürgen, Andreas Bacher and Marcus Groll: Supply Chain Controlling, in: Busch, Axel and Wilhelm Dangelmaier (Eds.): Integriertes Supply Chain Management: Theorie und Praxis effektiver unternehmensübergreifender Geschäftsprozesse (2nd ed.), Wiesbaden 2004, pp. 150-151.

have been increasingly involved in the product development process. Deloitte Research reports from 2000 onwards a further shift to a seamless integration across the extended supply chain, allowing real-time development in a dynamic partnering environment.[37]

Besides these more general developments, supply chain management and logistics as related subjects developed quite differently in the Continental European region and the Anglo-American area.[38] The underlying basis of logistics is the same in both regions. Originally, logistics encompassed the "physical transfer activities, thus comprising all structures and processes which served the purpose of transferring objects through space and time."[39] From there, its meaning has been expanded in scope and has brought up an entire concept of logistics in the Continental European area.

According to Göpfert, the development of the logistics discipline happened in three phases. In the first phase, logistics was considered as a functional area with an emphasis on goods transformation, including transportation problems. The second phase extended this view with a more holistic coordination of material and product flows within a system. Finally, the third and current phase refers to logistics as a leadership concept and emphasizes the application of logistics as a management paradigm.[40]

This development resulted in "a three level differentiation of the logistics term, which can be regarded as generally accepted."[41] These levels are defined as follows.

– *1st level: Logistics systems* relate to the original logistics domain, encompassing for example transportation, warehousing, and inventory management (locally).
– *2nd level: Logistics management* is imposed on the first level with the purpose of planning, controlling, and implementing logistics systems. Mellios emphasizes the importance of logistics management to coordinate

37 Cf. Deloitte Research, n.a.: Creating unique customer experiences: The next stage of integrated product development 2000, p. 8.
38 Cf. Delfmann, Werner and Sascha Albers: Supply chain management in the global context, Working Paper Series of the Seminar für allgemeine Betriebswirtschaftslehre, betriebswirtschaftliche Planung und Logistik (No. 102) 2000, Cologne, p. 6.
39 Delfmann and Albers: Supply chain management in the global context, p. 6.
40 Cf. Göpfert, Ingrid: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements, in: Busch, Axel and Wilhelm Dangelmaier (Eds.): Integriertes Supply Chain Management: Theorie und Praxis effektiver unternehmensüber-greifender Geschäftsprozesse (2nd ed.), Wiesbaden 2004, pp. 30-31.
41 Delfmann and Albers: Supply chain management in the global context, p. 6.

different functions of the company.[42] This view especially pointed out the total cost view and the organizational impact of a cross-functional approach, without using this terminology at the time. The logistics management view builds the foundation for the subsequent ERP movement.

– *3rd level: Logistics philosophy* is the most far reaching level of the Continental European logistics view and includes the following principles: (1) systemic perspective and total cost approach, (2) flow-orientation, i.e. process-oriented flow beyond functional and organizational boundaries, and (3) customer- and service orientation, i.e. companies of a supply chain are responsible and accountable for customer satisfaction.[43]

In the Anglo-American region, the Council of Logistics Management as the leading association in the field provided a widely accepted definition of logistics in 1986:

> "Logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements."[44]

This definition clearly encompassed the first two levels of the Continental European interpretation of logistics.[45] However, in contrast to the Continental European understanding, logistics was intended to stop at the organizational boundaries.

Cooper, Lambert, and Pagh have concluded that "there is definitely a need for the integration of business operations in the supply chain that goes beyond logistics."[46] Consequently, they have stated: "The integration of business processes across the supply chain is what we are calling supply chain

42 See Mellios, George G.: Logistics management: What, why, how, in: Journal of Business Logistics, Vol. 5 (1984), No. 2, pp. 106-122.

43 Cf. Delfmann and Albers: Supply chain management in the global context, p. 7, and Göpfert: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements , pp. 25-45 for a similar view.

44 Cf. Cooper, Martha C., Douglas M. Lambert and Janus D. Pagh: Supply chain management: More than a new name for logistics, in: The International Journal of Logistics Management, Vol. 8 (1997), No. 1, p. 1.

45 Cf. Delfmann and Albers: Supply chain management in the global context, p. 8.

46 Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, p. 1.

management."[47] This notion reflects the evolutionary path logistics took after Oliver and Webber's introduction of the term SCM. Instead of further refining the logistics discipline, SCM has evolved and disengaged from it.

Based on this discussion and development, the Council of Logistics Management revised its definition of logistics in 1998 to better distinguish logistics from supply chain management and explicitly included the supply chain prcoess:[48]

> "Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point-of-origin to the point-of-consumption in order to meet customers' requirements."[49]

Delfmann and Albers have concluded that the Anglo-American SCM concept can be seen as a pragmatic representation of the theoretically more sophisticated logistics philosophy.[50] Though the logistics philosophy may be regarded as a meta-concept and vision, it fails to specify its meaning well enough. This might be the reason SCM has become the dominant term that relates to the holistic, systemic, and inter-company organization view of management. In recognition of this development, the Council of Supply Chain Management Professionals (CSCMP), formerly known as the Council of Logistics Management,[51] updated its definition of the management of logistics:

> "Logistics Management is that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements."[52]

The key difference between these last two definitions can be seen in the fact that the supply chain was previously perceived as a phenomenon. In the latter definition from 2005, SCM has been acknowledged as a concept. In line with this

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47 Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, p. 2.

48 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 1-3.

49 Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 3.

50 See Delfmann and Albers: Supply chain management in the global context, p. 9.

51 The Council of Logistics Management changed its name to the Council of Supply Chain Management Professionals (CSCMP). In 1985, the organization had already changed its name from Council of Physical Distribution Management to Council of Logistics Management, recognizing the growing field of logistics.

52 n.a.: Council of Supply Chain Management Professionals: http://www.cscmp.org, 2005, retrieved on: February 15, 2006, see also its definition of SCM on page 20.

perception, Lambert, Cooper, and Pagh attribute the early confusion between logistics and SCM to the fact that the concept of logistics can be seen as a functional silo within a company as well as a bigger concept that deals with the management of material and information flows across the supply chain.[53] They have observed parallels to marketing, which can be seen as a functional discipline as well as an overall company philosophy, for example the well-known customer focus philosophy. They have concluded: "The understanding of SCM has been re-conceptualized from integrating logistics across the supply chain to the current understanding of integrating and managing key business processes across the supply chain."[54] *Figure B-1* illustrates this along the dimensions of theoretical scope and practical applicability.

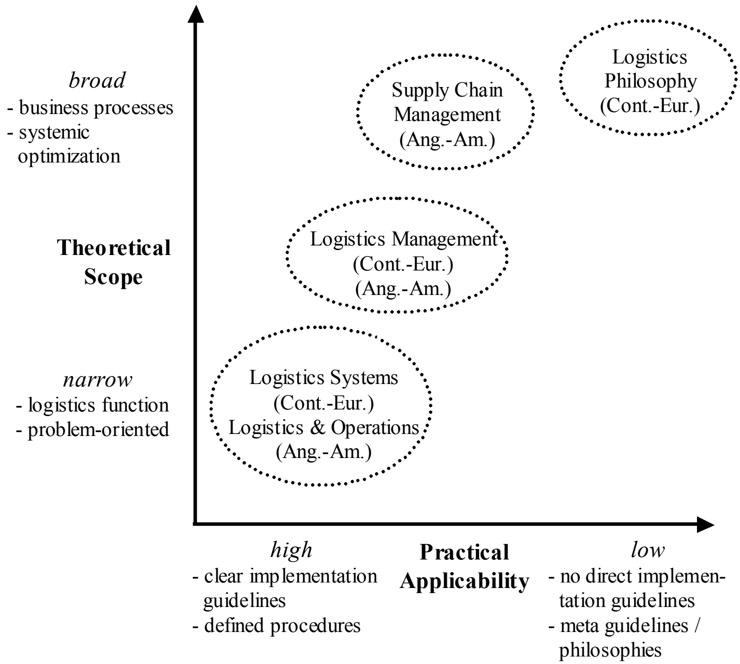


*Figure B-1: Anglo-American vs. Continental-European understanding of logistics and SCM*

It can be argued that the concept of SCM has developed in line with these observations. This has stimulated many authors and researchers to come up with a

53 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 2.

54 Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 2-3.

variety of interpretations and understandings of SCM and logistics and it has been accompanied by countless definitions. Other authors have made great efforts to synthesize all these different views in order to organize the field and to develop a theory of SCM. The remainder of this section provides a meta-analysis of some streams of thought and definitions and presents some synthesized views.[55]

Several definitions have been already introduced above. Definitions are an important and necessary part of theory building for two reasons. First, definitions communicate a picture of a phenomenon. Second, they avoid misunderstandings that are caused by different personal or organizational perceptions of terms.[56] Thus, definitions fulfill an important role. Providing definitions is not to be mistaken with terminological discussions conducted in a way that they do not contribute to the increase in the body of knowledge. Obviously, such discussions should be avoided.[57]

In an attempt to summarize existing SCM literature at the time, Bechtel and Jayaram have identified four generic schools of thought:[58]

1. The *functional awareness school*. Authors representing this school recognize the existence of a chain of functional areas. They agree that the supply chain covers material flow from channel members or suppliers through end users. Emphasis is placed on including all chain members from beginning to end.
2. The *linkage/logistics school*. The linkage and logistics school reaches beyond the functional awareness school and begins to address the material flows through this chain. It identifies the linkages among functional areas that generally includes suppliers, production, and distribution. Whereas the functional awareness school merely recognizes the existence of linkages, the linkage/logistics school investigates how linkages among the functional areas can be exploited for competitive advantage, especially in the area of logistics and transportation.
3. The *information school*. Here, authors emphasize the bidirectional flow of information between supply chain members and identify it as the backbone of effective SCM. According to this school, companies that are prospering

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55 The following meta-analysis is not intended to elaborate on the different SCM concepts in detail. That will be provided in subsequent chapters.

56 See Schönsleben: Integrales Logistikmanagement: Planung und Steuerung der umfassenden Supply Chain, p. 4. Schönsleben mentions a third reason, namely that definitions simply belong to a scientific book.

57 For further reference, see for example Popper, Karl R.: The open society and its enemies - Band 2: The high tide of prophecy: Hegel, Marx and the aftermath, 5th ed., London 1966, reprinted in 1973, p. 15.

58 Cf. Bechtel and Jayaram: Supply chain management: A strategic perspective, pp. 16-18.

appear to be those taking advantage of information technology on several levels.

4. The *integration/process school*. Under this school of thought, supply chain areas are integrated into "a system defined as a set of processes that strive for the best overall system, which adds value."[59] In contrast to the linkage school that assumes functional areas appear in a fixed sequence that cannot be changed, the integration/process school suggests that the emphasis is on customer satisfaction and the configuration of the functional areas in the supply chain can be changed if necessary.

Though there is not an intended hierarchy of the four generic schools of thought, one can clearly observe that the schools differ in scope with the integration school being the most far reaching. What becomes clear in their analysis is that SCM includes issues of cooperative relations with supply chain members.[60]

Harland has come to a similar conclusion but has identified four different uses of the term SCM. In his analysis, the relational aspects of SCM have been emphasized even more. Again, a clear hierarchy can be observed:[61]

1. *Internal view* use. This view relates closely to preexisting concepts of materials management and the value chain. SCM under this understanding is limited to integrating business functions involved in the flow of materials and information from inbound logistics to outbound distribution.
2. *Dyadic relationship* use. Advocates of SCM in a dyadic relationship context focus only on the management of two party relationships with immediate suppliers.
3. *Chain of business* use. Considering a chain of business, the perspective extends beyond suppliers and customers to suppliers' suppliers and customers' customers.
4. *Network* use. Adopting a network view encompasses the management of an entire network that is involved in the supply of a product or service to end customers.

Göpfert has identified a dichotomy of definition groups. In definition group one, Göpfert has summarized those definitions that show a direct connection to business logistics. It emphasizes the logistics flow and the coordination of this between companies and across supply chains. Definition group two, in contrast, does not establish a direct link to logistics, instead emphasizing an inter-organizational management of business processes. It relates more to cooperation

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59 Bechtel and Jayaram: Supply chain management: A strategic perspective, p. 18.
60 See Bechtel and Jayaram: Supply chain management: A strategic perspective, p. 18.
61 Cf. Harland: Supply chain management: Relationships, chains and networks, p. S64.

management or relationship management.[62] Cooper, Lambert and Pagh have been cited as a prominent example of this group: "The integration of key business processes across the supply chain is what we are calling supply chain management."[63]

Another way to categorize existing SCM definitions has been provided by Mentzer et al. Though their analysis has added substantially to the development of a common understanding of the term SCM, the categories seem to be more a mixture of levels of detail and emphasis than emphasis alone. In their view, the most far reaching definitions see SCM as a management philosophy.[64] This can be compared to the integration/process school suggested by Bechtel and Jayaram and the second definition group from Göpfert. In particular, SCM as a philosophy "extends the concept of partnerships into a multiform effort to manage the total flow of goods from the supplier to the ultimate customer."[65] The following elements characterize the management philosophy view: (1) systems approach, i.e. considering the supply chain as one entity, (2) strategic, cooperative orientation, and (3) customer focus.

In another category, Mentzer et al. see SCM as a set of activities that implement a management philosophy. In contrast to SCM as a management philosophy, specific activities are identified to integrate a SCM philosophy. These are: (1) integrating behavior, (2) sharing information mutually, (3) sharing risks and rewards mutually, (4) cooperation, (5) having the same goal and the same focus on serving customers, (6) integrating processes, and (7) building and maintaining long-term relationships with partners.[66]

Those authors who focus on SCM as a set of management processes constitute another group summarized by Mentzer et al.[67] In contrast to the activities view, processes are considered to be "a structured and measured set of activities designed to produce specific output for a particular customer or market."[68] The key difference from the activities view is that companies are to be organized around processes with the objective of meeting the end customers needs best.

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[62] Cf. Göpfert: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements, pp. 28-32.

[63] Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, p. 2.

[64] Cf. Mentzer, John T. *et al.*: Defining supply chain management, in: Journal of Business Logistics, Vol. 22 (2001), No. 2, p. 7.

[65] Mentzer *et al.*: Defining supply chain management, p.7.

[66] See Mentzer *et al.*: Defining supply chain management, pp. 7-10.

[67] Cf. Mentzer *et al.*: Defining supply chain management, pp. 10-11.

[68] Cf. Mentzer *et al.*: Defining supply chain management, p. 10; based on Davenport, Thomas H.: Process innovation, Boston 1993, see also section B.III.2.a.

Whereas some authors have a broad understanding of such a process view of SCM, others have identified a set of specific processes that must be managed across company boundaries. For example, Cooper, Lambert, and Pagh have identified the following eight key SCM processes that have to be managed across company boundaries: (1) customer relationship management, (2) customer service management, (3) demand management, (4) order fulfillment, (5) manufacturing flow management, (6) procurement, (7) product development and commercialization, and (8) returns/reverse logistics.[69] Chopra and Meindl have identified three macro processes that all companies participating in a supply chain have in common:[70] (1) supplier relationship management, (2) internal supply chain management,[71] and (3) customer relationship management.

Discussions on SCM became more structured over the years. *Table B-1* provides some recent definitions provided by selected, renowned authors. In light of the discussions described above, they give a broad overview of the individual views of the authors.

69 Cf. Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, p. 10.

70 Cf. Chopra, Sunil and Peter Meindl: Supply chain management: Strategy, planning, and operation, 2nd ed., Upper Saddle River 2004, p. 17.

71 For the internal supply chain management process, Porter provides the well-known framework of the value chain, see Porter, Michael E.: Competitive advantage, New York 1985, pp. 33-61.

*Table B-1: Selected, recent SCM definitions, sorted by year*

| *Author(s)* | *Definition* |
|---|---|
| Lambert et al. (1998), p. 1 | "SCM is the integration of business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders." |
| Mentzer et al. (2001), p. 18. | "SCM is the systemic, strategic coordination of the traditional business functions and the tactics across [these] business functions within a particular company and across businesses with the supply chain, for the purpose of improving the long-term performance of the individual companies and the supply chain as a whole." |
| McCormack & Johnson (2001), p. 34 | "SCM is the process of developing decisions and taking actions to direct the activities of people within the supply chain toward common objectives." |
| Vakharia (2002), p. 496 | "SCM is the art and science of creating and accentuating synergistic relationships among the trading partners in supply and distribution channels with the common shared objective of delivering products and services to the 'right customer', in the 'right quantity', and at the 'right time'. |
| Stadtler (2002), p. 9 | "SCM is the task of integrating organizational units along a supply chain and coordinating material, information, and financial flows in order to fulfill (ultimate) customer demands with the aim of improving competitiveness of a supply chain as a whole." |
| Kuhn & Hellingrath (2002), p. 10 | "SCM is the integrated, process-oriented planning and management of material, information and financial flows along the entire value chain; from the customer to the supplier of raw material […]." |
| Swaminathan & Tayur (2003), pp. 1387-1388 | "SCM is the efficient management of the end-to-end process, which starts with the design of the product or service and ends with the time when it has been sold, consumed, and finally, discarded by the consumer. This complete process includes product design, procurement, planning and forecasting, production, distribution, fulfillment, after-sales support, and end-of-life disposal." |
| Simchi-Levi et al. (2003), p. 2 | "SCM is the process of planning, implementing and controlling the efficient, cost effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements." |

| | |
|---|---|
| Chen & Paulraj (2004), p. 147 | "SCM, as we envision, is a novel management philosophy that recognizes that individual businesses no longer compete as solely autonomous units, but rather as supply chains. Therefore, it is an integrated approach to the planning and control of materials, services and information flows that adds value for customers through collaborative relationships among supply chain members." |
| Göpfert (2004), p. 32 | "SCM is a modern concept of company networks to exploit inter-company success potentials by means of R&D, design and steering of effective and efficient material, information and financial flows." |
| Busch & Dangelmaier (2004)[72] | "SCM is the inter-company coordination of material and information flows among the entire value creation process – from raw material over the individual processing steps to the end consumer – with the goal to optimize the entire process in terms of time and cost aspects." |
| CSCMO (2005)[73] | "SCM encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies." |
| Christopher (2005), p. 5 | "SCM is the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole." |

The variety of definitions supports the view that, in spite of the achievements so far and the commonalities the most important representatives of definitions share, there still exists a need for developing a theory on SCM, which serves as a

[72] Busch, Axel and Wilhelm Dangelmaier: Integriertes Supply Chain Management - ein koordinationsorientierter Überblick, in: Busch, Axel and Wilhelm Dangelmaier (Eds.): Integriertes Supply Chain Management: Theorie und Praxis effektiver unternehmensübergreifender Geschäftsprozesse (2nd ed.), Wiesbaden 2004, p. 5. They claim that this definition – adopted from Scholz-Reiter and Jakobza, SCM – Überblick und Konzeption, in HMD, No. 207 (1999), pp. 7-15 – represents the "bottom line" definition of SCM in German-speaking countries, although they add that other authors do alter it. This is well justified as firstly, it leaves many aspects out, which other authors might consider as important, for example integration and quality aspects. And secondly, it does not make sense to claim a "bottom line" definition for a subject like SCM on a regional basis.

[73] Cf. n.a.: Council of Supply Chain Management Professionals.

framework for researchers and practitioners. This will be addressed in chapter B.I.3. The next chapter discusses some controversial issues that have emerged around the SCM evolution.

### *2. Supply Chain Management as a Perspective for Inter-Company Management*

Most views on SCM aim at the most comprehensive perception of the concept, i.e. the consideration of an entire supply chain in the decision making process. With such an understanding, Delfmann and Albers remarked that the proponents of this view "run into the omnipotence trap, as then, SCM is just synonymous for management."[74] Whereas this does not seem to be too much of a concern in the Anglo-American SCM literature, Göpfert also favors definition group one, which is closer to the original logistics domain.[75] Therefore, the questions to be addressed must be the following.

– To what extent should SCM involve participants of a specific supply chain?
– What is meant by "a specific supply chain"?
– Who actually "manages" the supply chain?

Some attempts to answer these questions in more detail are provided in subsequent chapters, especially in chapter B.III.2. In short, the answers depend on the specific circumstances of a given supply chain. However, developing a general framework provides support for this process. Additionally, the underlying theory of SCM must be developed so that the concept can be grounded on solid support from empirical data.

Another discussion has emerged around the term SCM, reflecting the concerns of many. It centers on the comparison of the terms supply chain, demand chain, distribution chain, supply network, supply web, and value system.

Several authors have argued in favor of the term "demand chain management" in order to emphasize that all upstream activities in a supply chain are demand-driven, triggered by the ultimate demand, and therefore "causing" the chain to exist.[76] However, emphasizing the importance and role of the ultimate demand for a supply chain, all upstream activities represent supply relative to the ultimate

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74 Cf. Delfmann and Albers: Supply chain management in the global context, p. 5.

75 See Göpfert: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements, p. 32 and section B.I.1., p. 16 in this text.

76 See, for example, Christopher: Logistics and supply chain management: Creating value-adding networks, p. 5, or Frohlich, Markham T. and Roy Westbrook: Demand chain management in manufacturing and services: Web-based integration, drivers and performance, in: Journal of Operations Management, Vol. 20 (2002).

demand. Therefore, both views accept the importance of demand and there is no solid ground for a terminological change because of this. SCM does not rule out customer focus *per se* and a distinction or even replacement of the term supply is rejected.[77] As Horvath remarked: "[…] the distinction between supply and demand chains seems increasingly arbitrary."[78]

Other authors have noted that the terms "network", "web", or "system" are more accurate descriptions for what is known as a "chain" since companies normally transform inputs from many suppliers into one or more outputs often for many different customers.[79] However, especially when adopting a process view, as described in detail in chapter B.III.2., it can be argued that it indeed does fit the description of a chain. Although there might be many suppliers of raw materials and components throughout the supply process, in the end it is all merged into one product or service. This entire process can therefore be seen as a chain from a consumer's perspective. Additionally, the physical flow of a supply chain routes through the system in only one sequential direction. Accompanying information and financial flows, however, can go both ways supporting a network view. Based on this, the term supply chain network can be used as a synonym to supply chain when writing about supply chains.[80] The term "supply chain" does recognize the most common supply chain structures without ruling out inherent branch structures in supply chains. For that reason and for the sake of continuity, there is no fundamental need to replace the term supply chain and SCM should not be renamed on the basis of this argumentation.[81]

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77 Cf. Vakharia, Asoo J.: E-business and supply chain management, in: Decision Sciences, Vol. 33 (2002), No. 4, Fall, pp. 495-496.

78 Horvath, Laura: Collaboration: The key to value creation in supply chain management, in: Supply Chain Management: An International Journal, Vol. 6 (2001), No. 5, p. 206.

79 Most authors who challenge the traditional terminology propose these variations, such as Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 5; Christopher: Logistics and supply chain management: Creating value-adding networks, p. 5; McCormack and Johnson: Supply chain networks and business process orientation: Advanced strategies and best practices; or Delfmann and Albers: Supply chain management in the global context, p. 5.

80 Cf. Hertz, Susanne: Dynamics of alliances in highly integrated supply chain networks, in: International Journal of Logistics: Research and Applications, Vol. 4 (2001), No. 2, p. 239; and McCormack and Johnson: Supply chain networks and business process orientation: Advanced strategies and best practices, pp. 2-4.

81 This is in line with the opinion of several authors, such as Werner, Hartmut: Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling, 2nd ed., Wiesbaden 2002, p. 14; Delfmann and Albers: Supply chain management in the global context, p. 5; or Knolmayer, Gerhard, Peter Mertens and Alexander Zeier: Supply chain management based on SAP systems, Berlin Heidelberg New York 2002, p. 3.

Porter has introduced the terms “value chain” and “value system” when referring to internal operations and industries.[82] This puts emphasis on the value creation process of supply chains. Ultimately, all activities and processes aim to bring value to the consumer, be it as a product or a service. The entire process is therefore a value creation process. In the end, value is expressed by the willingness of consumers to pay a certain price for the product or service. From a business process perspective, activities that do not add value are waste and should be eliminated. Waste has been defined as “[…] anything other than the minimum amount of equipment, materials, parts, space, and time which are absolutely essential to add value to the product.”[83] This is especially important in highly competitive markets. Though the term “value” better describes the processes within the value creation process, there are also arguments that support the traditional and established terminology. In accordance with the explanations given above, from a consumer perspective all activities are supply activities and therefore all preceding activities and processes of the total value created can also be seen as supply that contributes to this value.

Weighing the arguments described, it can be concluded that the term SCM should be used in the future as the sole reference for contributions in the field. It should be accepted that it covers also all aspects and variations described above. Introducing different terms without a solid, scientific foundation causes confusion and does not provide any contribution. Nonetheless, the terms supply chain and supply chain network may be used alternatively as they represent a description and do not describe an entire field of research.

## *3. Concepts of Supply Chain Management*

### 3.a. Supply Chain Management Objectives and Strategic Relevance

As definitions and understandings of SCM vary, so do objectives related to SCM. In order to structure the stated goals, a three level hierarchy can be identified: (1) strategic objectives, (2) tactical objectives, and (3) operational objectives.[84]

Many goals in literature are phrased in a way that disregards strategic trade-offs. For example, Knolmayer, Mertens, and Zeier have noted the strategic SCM objective of maximizing customer and business value at the lowest total cost.[85] Porter remarked, however, that strategy always involves trade-offs and decisions

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82 See Porter: Competitive advantage, pp. 34-35.

83 Suzaki, Kiyoshi: The new manufacturing challenge, New York 1987, p. 250.

84 See Stevens, Graham C.: Integrating the supply chain, in: International Journal of Physical Distribution & Materials Management, Vol. 19 (1989), No. 8, p. 4. This classification is an appropriate framework to classify SCM objectives.

85 Cf. Knolmayer, Mertens and Zeier: Supply Chain Management Based on SAP Systems, p. 7.

on what to do and what not to do.[86] Therefore, statements like the one mentioned above have to be placed in perspective. In the field of Operations Management, the theory of performance frontiers provides explanation for this.[87] In variations also known as 'production frontier' or 'trade-off curve', it is mainly based on economic theory. According to this, a production frontier describes the maximum output that can be produced from any input combination, given existing technology.[88] Thus, before elaborating on the previously mentioned three objective categories, a note on performance frontiers seems to be appropriate.

Schmenner and Swink have expanded the scope of this definition in two ways. Firstly, instead of merely encompassing a production output, performance encompasses multidimensional elements, including all kinds of possible performance elements, such as quality, product variety, or flexibility.[89] Secondly, the performance frontier itself encompasses two elements. (1) The operating frontier consists of a set of operating practices and policies on an aggregate level, such as quality management, process reengineering, just-in-time (JIT) and so on. Theoretically, applying all available management practices and tools to the fullest extent limits the performance at any given cost level, subject to the asset frontier, which is described next. (2) The asset frontier limits the achievable performance at any given cost level due to physical or technological restrictions. Either one, the operating frontier or the asset frontier, can restrict overall performance at a given cost level. The restrictive frontier will be the one whose graph lies below the other, see *Figure B-2*.[90] The absolute performance limit, then, defines maximum achievable performance independently from cost. This restricts therefore achievable performance. Up to the absolute performance limit, the marginal performance gains tend to decrease. Besides the simple monotonic shape depicted in *Figure B-2*, the efficient performance frontier could also take an S-shape course.

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[86] See Porter, Michael E.: What is strategy? in: Harvard Business Review, Vol. 74 (1996), No. 6, pp. 68-70.

[87] Cf. Schmenner, Roger W. and Morgan L. Swink: On theory in operations management, in: Journal of Operations Management, Vol. 17 (1998), pp. 107-110.

[88] See Samuelson, Paul: Foundations of economic analysis, Cambridge, MA 1947, chapter 4, taken from Schmenner and Swink: On theory in operations management, p. 107. On production frontiers, any introductory business textbook provides assistance, especially see Gutenberg, Erich: Grundlagen der Betriebswirtschaftslehre. Band I: Die Produktion, 24th ed., Berlin Heidelberg New York 1983, pp. 303-327.

[89] Schmenner and Swink include costs as a possible performance element. As this is the counterpart on the vertical axis, this seems inappropriate.

[90] Cf. Schmenner and Swink: On theory in operations management, pp. 107-109.

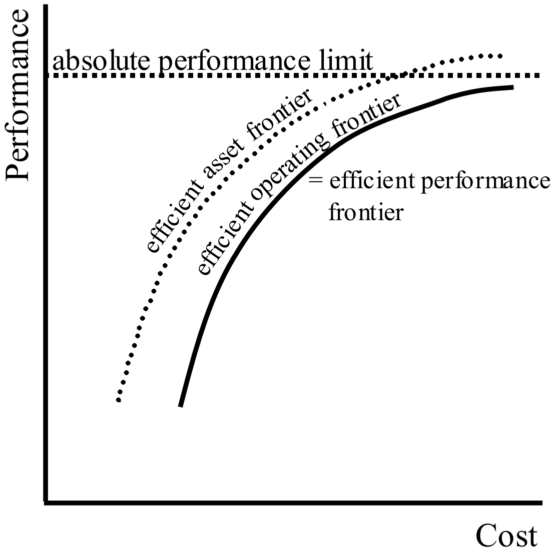


*Figure B-2: Efficient asset and operating frontiers*[91]

A distinction between asset frontiers and operating frontiers has been also elucidated. The asset frontier limits performance mainly due to technological restrictions. In contrast, the operating frontier limits performance mainly because of managerial and organizational limitations. Usually, one of the two limits overall performance, though they can be considered to be considerably interdependent. For example, in *Figure B-2*, the operating frontier is considered to be the limiting factor. The introduction of new management practices and concepts, such as SCM, can lead to a betterment of the efficient performance frontier, i.e. a shift to the left/upper left. SCM as a set of management practices affects mainly the operating frontier. If this betterment exceeds the asset frontier, the asset frontier becomes the new limiting factor. Technological improvements, such as with e-business capabilities, tend to affect the asset frontier.

What is termed betterment in this context is in contrast to improvement. Whereas the term improvement refers to the improvement of performance within a

[91] In contrast to the original illustration, performance frontiers are differentiated. The absolute limit of performance mainly due to technological limitations, no matter the cost, limits possible absolute performance. The efficient performance frontier depicts the most efficient realization of any performance level, utilizing best practice management practices and most efficient technology. This is reflected by efficient asset and operating frontiers.

given efficient performance frontier, betterment refers to a shift of the efficient performance frontier all together, as illustrated in *Figure B-3*.[92]

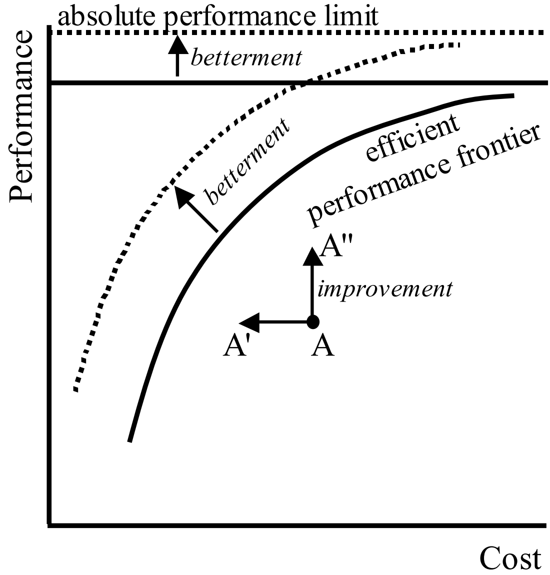


*Figure B-3: Effect of improvement and betterment on the efficient performance frontier*

A company in position *A* can improve its performance to *A'* and *A''*, doing the same at less cost or doing better at the same cost. A company also can witness a shift in the efficient performance frontier without embracing its benefits. Hence, betterment only addresses the potential for improvement by shifting the performance frontier. If a company fails to adopt operating practices or technological advances made available by an advancing frontier, no improvement takes place for that company. In fact, the advanced frontier places that company at a greater competitive disadvantage than before the advance occurred.

As an extension of this view, there is an additional aspect to consider. Due to differentiation strategies and individual customer perceptions, it is rather impossible to define efficient performance frontiers as if they relate to many products or even product groups. A superior performance to one may only be marginal to someone else even in the case of homogeneous products. Thus, a differentiated view should be reflected as well. *Figure B-4* accounts for this by adding a third dimension: *differentiation*. Adding this categorical dimension allows rotation around the performance dimension and therefore defines different

92 See Schmenner and Swink: On theory in operations management, pp. 109-110.

efficient performance frontiers along the way. *Figure B-4* shows one such "performance frontier slice" for a specific, differentiated product or product group. For each dotted line in the differentiation circle, such a "performance frontier slice" exists. Thus, efficient performance frontiers are highly situational and product-specific. The differentiated products, however, are still interdependent, depending on demand elasticity or more precisely product-specific demand elasticity. According to the underlying economic theory, however, a trade-off is inevitable and this is of high relevance in the context of objective definitions in SCM.

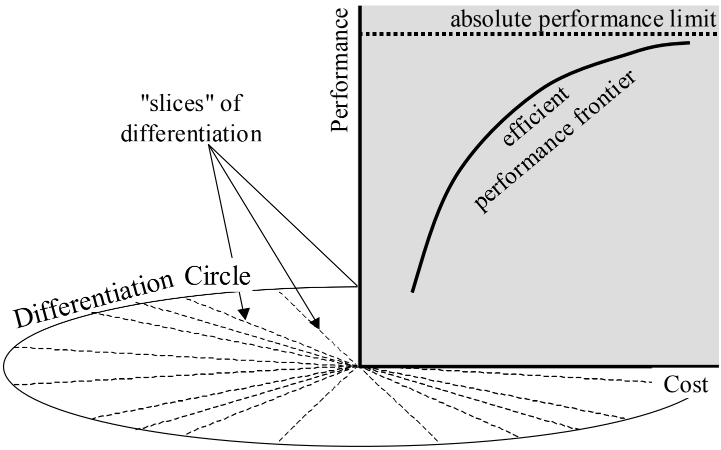


*Figure B-4: A third dimension for performance frontiers*

It should be noted here that the SCM objective of improving cost and performance together would imply the betterment of the efficient performance frontier. Thus, this should better be phrased in a way to state that SCM promises higher customer and business value (performance) at a given cost level or a lower cost level at a given customer and business value proposition. Based on this analysis and the objectives identified in literature, it can be concluded that the availability of the SCM concept promises not only a betterment of performance frontiers, but also that partial adoption can lead to improvements on the individual company level below the efficient performance frontier to approach the efficient performance frontier.

With this in mind, the following objectives are identified. At the strategic level, objectives are related to the strategic orientation of a supply chain.[93] This

[93] See Stevens: Integrating the supply chain, p. 4.

includes first and foremost the definition of competitive priorities with regard to supply chain capabilities. The major dimensions of competitive priorities include cost, quality, time, and flexibility.[94] Only a few proponents can be found that explicitly point out strategic objectives for SCM. Often, authors only mention optimization potentials and by that implicitly reduce SCM effects to rationalization effects.[95] One rather simplistic view has been expressed by New, who compressed the benefits claimed by SCM – namely lower costs, improved quality, more effective technological development, and reduced lead times – into the one dimension "efficiency", i.e. "doing better with the same or less investment or resources."[96] A similar approach has been adopted by Delfmann and Albers, who note that a frequently mentioned objective of SCM is the reduction of cost.[97] They have also acknowledged, however, that building a competitive advantage is an essential goal of SCM. The following strategic objectives and goals can be identified in literature as strategic objectives by means of SCM:

- Maximal customer and business value at the lowest possible total cost.[98]
- Superior speed-to-market by means of agility at the lowest possible costs.[99]
- Fulfillment of a desired level of customer service performance.[100]

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94 Cf. Krajewski, Lee J. and Larry P. Ritzman: Operations management, 7th ed., Upper Saddle River 2005, pp. 62-67. Other textbooks vary these elements, for example Slack, Nigel, Stuart Chambers and Robert Johnston: Operations management, 4th ed., Harlow 2004, pp. 44-57 divide the time dimension up into speed and dependability or Russell, Roberta S. and Bernard W. Taylor III: Operations management, 3rd ed., Upper Saddle River 2000, pp. 32-35 replace time by speed. However, the essence remains the same. Traditionally, three dimensions have been used as strategic success factors, see Kaluza, Bernd and Guido Klenter: Zeit als strategischer Erfolgsfaktor von Industrieunternehmen, Diskussionsbeiträge des Fachbereichs Wirtschaftswissenschaften der Universität - Gesamthochschule - Duisburg (No. 173) 1992, Duisburg, pp. 14-18; and Sommerlatte, Tom and Michael Mollenhauer: Qualität, Kosten, Zeit - Das magische Dreieck, in: Little, Arthur D. (Ed.): Management von Spitzenqualität,Wiesbaden 1992, pp. 26-36.

95 Cf. Göpfert: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements, p. 33.

96 Cf. New: The scope of supply chain management research, p. 20. Here, New mixes performance measures with cost parameters, which increases complexity.

97 Cf. Delfmann and Albers: Supply chain management in the global context, p. 10.

98 See Knolmayer, Mertens and Zeier: Supply Chain Management Based on SAP Systems, p. 7.

99 Cf. Samaranayake, Premaratne: A conceptual framework for supply chain management: a structural integration, in: Supply Chain Management: An International Journal, Vol. 10 (2005), No. 1, p. 48.

– Improvement of competitiveness.[101]

Strategic objectives all relate to the generally accepted aim of a company to achieve a competitive advantage and therefore superior profitability.[102] Alternative objective statements on the strategic level are superior customer service level or business excellence.[103]

Most authors have focused on tactical and operational objectives. Tactical objectives can be considered to link operating objectives to strategic objectives. In this role, they represent a more abstract aggregation of operating objectives. Thus, they can hardly be measured directly. Operational objectives, in contrast, are directly measurable and have mostly an obvious, immediate effect. Usually, they are then linked directly or through mediating performance measures to strategic objectives. As with other management concepts, like Total Quality Management (TQM), authors hardly leave out any performance measure that could be positively affected by the SCM concept. In order to provide an overview of the most commonly identified objectives, *Table B-2* summarizes tactical SCM objectives and *Table B-3* shows operational SCM objectives. Arrows in the table indicate the direction of change in order to achieve improvements.

In order to organize goal items mentioned in literature, the individual goal items can be summarized as follows. On the tactical level, four goal categories can be identified:

– *Communication*, i.e. better communication.
– *Collaboration*, i.e. improved synchronization and management control, joint optimization, better external integration, a reduction of complexity and strengthening relationships. Also, lower transaction costs can be considered as a collaboration related objective.
– *Customer orientation*, i.e. higher customer satisfaction and service and more customer orientation.

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100 This objective definition is rather unspecific, see Stevens: Integrating the supply chain, p. 3.

101 Cf. Stadtler, Hartmut: Supply chain management - an overview, in: Stadtler, Hartmut and Christoph Kilger (Eds.): Supply chain management and advanced planning: concepts, models, software and case studies (2nd ed.), Berlin Heidelberg New York 2002, p. 8.

102 For example, see Mentzer *et al.*: Defining supply chain management, pp. 12-19; and Porter: Competitive advantage, p. 3.

103 See Kanji, Gopal K. and Alfred Wong: Business excellence model for supply chain management, in: Total Quality Management, Vol. 10 (1999), No. 8, pp. 1150-1152; and Delfmann and Albers: Supply chain management in the global context, p. 10.

– *Flexibility*, i.e. more resource flexibility, better availability, better adaptability and faster time-to-market.

*Table B-2: Identified tactical SCM objective items*

| *Tactical Objectives* | *Knolmayer, Mertens and Zeier (2002), p.7* | *Nicolai (2001), p. 2* | *Busch and Dangelmaier (2004), pp. 8-9* | *Göpfert (2004), pp. 33-35* | *Schönsleben (2004), pp. 35-37* | *Mentzer et al. (2001), p. 15* | *Stank, Keller and Daughertyt (2001), p. 29* | *Croom (2005), p. 60* | *Deloitte study (1999)*[104] | *Simchi-Levi, Kaminsky and Simchi-Levi (2003), p. 255* |
|---|---|---|---|---|---|---|---|---|---|---|
| ↑ customer satisfaction / service | | X | | | | X | X | X | X | |
| ↑ information sharing | X | | X | X | | X | | | | |
| ↑ synchronization/ management control | X | | | X | | X | | | X | |
| ↑ (resource) flexibility | | | | X | X | | | | | X |
| ↑ availability | | | | X | X | | | | | X |
| ↑ joint optimization | X | | | | | | | | X | |
| ↑ external integration | X | | | X | | | | | | |
| ↓ complexity | | | X | X | | | | | | |
| ↑ customer orientation | | | | X | | | | | | |
| ↑ adaptability | | | | | X | | | | | |
| ↓ time-to-market | | | X | | | | | | | |
| ↑ strength of relationships | | | | | | | | | X | |
| ↑ indicates higher values for improvement and ↓ indicates a lower value for improvement | | | | | | | | | | |

On the operational level, three goal categories can be identified:

– *Fulfillment*, i.e. faster delivery times, better on-time delivery, shorter lead times and faster order fulfillment times.

104 Cf. Deloitte Consulting, n.a.: Energizing the supply chain: Trends and issues in supply chain management 1999, p. 21.

- *Efficiency*, i.e. lower cost per unit (inventory, procurement, production, distribution and administration), higher utilization, reduction of waste and non-added value activities, seamless processes and reduction of redundant work.
- *Quality*, i.e. improved product quality, higher process quality.

Since many authors have referred to SCM as a concept assumed of improving operational performance, improvements in competitiveness are to diffuse through this better operational performance, giving SCM strategic relevance. Despite this lack of precision, SCM is still considered to be a strategic management concept; though, according to Schönsleben, it is one that focuses as no other on delivery and processes.[105] Furthermore, decisions made in SCM are also of a strategic nature that is to say they have long-term implications in order to achieve objectives.

The strategic relevance of SCM can be justified by means of the resource-based view of competitive advantage. Initially, the resource-based view of the firm has focused on internal resources rather than products as sources of competitive advantage.[106] Prahalad and Hamel have referred to such resources as core competencies of a company that, in order to attain strategic relevance, should be applicable to a wide variety of markets, be of significant value to the end customer, and be hard to imitate. They point out that such competencies are most likely to occur as "[…] a complex harmonization of individual technologies and production skills."[107]

Barney has distinguished between competitive advantage and sustained competitive advantage. Whereas competitive advantage is a "[…] value creating strategy not simultaneously being implemented by any current or potential competitor", a sustained competitive advantage implies that current and potential competitors are unable to duplicate that strategy.[108] According to Barney, firm resources must possess four attributes in order to be a source of sustained competitive advantage: (1) they have to be valuable for a company and its environment, (2) they have to be rare, (3) they have to be imperfectly imitable,

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105 Cf. Schönsleben: Integrales Logistikmanagement: Planung und Steuerung der umfassenden Supply Chain, p. 35.

106 Cf. Wernerfelt: A resource-based view of the firm, pp. 171-180.

107 Prahalad, C.K. and Gary Hamel: The core competence of the corporation, in: Harvard Business Review, Vol. 68 (1990), May/June, pp. 83-84.

108 Cf. Barney: Firm resources and sustained competitive advantage, pp. 102-103. In addition, Barney points out that this does not mean that a sustained competitive advantage necessarily lasts forever. Changes in the economic structure of industries may nullify the advantage, which in turn indicates that these unique capabilities are not of value anymore in the new structure.

and (4) no substitutes for an otherwise valuable, rare, and imperfectly imitable resource are available.[109]

*Table B-3: Identified operational SCM objectives*

| *Operational Objectives* | *Wannenwetsch (2005), p. 4* | *Knolmayer, Mertens and Zeier (2002), p. 7* | *Nicolai (2001), p. 2* | *Busch and Dangelmaier (2004), pp. 8-9* | *Göpfert (2004), pp. 33-35* | *Schönsleben (2004), pp. 35-37* | *Zadek (2001), p. 329* | *Mentzer et al. (2001), p. 15* | *Stank, Keller and Daughertyt (2001), p. 29* | *Croom (2005), p. 60* | *Frohlich and Westbrook (2001), p. 194* | *Deloitte study (1999)[110]* | *Simchi-Levi, Kaminsky and Simchi-Levi (2003), p. 255* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ↓ inventories | X | | X | X | X | X | | | | X | | X | |
| ↓ procurement costs | X | | X | | X | | | X | | X | | X | X |
| ↓ production costs | | | X | | X | | | X | | X | | X | X |
| ↓ distribution costs | | | X | X | | | | X | | X | | X | X |
| ↑ on-time delivery | | | X | | | X | X | | | X | | X | X |
| ↓ lead times | X | | X | X | | X | | | | | | X | |
| ↑ process quality/ seamless processes | | | X | X | | X | X | | | | | | X |
| ↓ order fulfillment time | | | X | | | | | | | X | | X | X |
| ↑ utilization | X | | | | X | X | | | | | | X | |
| ↓ waste[111]/ non-value added activities | | X | | | | | | X | | | X | | |
| ↓ administration costs/ redundancies | | | | | | X | | X | X | X | | | |
| ↑ product quality | | | X | X | | X | | | | | | | |
| ↓ delivery times | X | | | | | X | | | | | X | | |
| ↑ indicates higher values for improvement and ↓ indicates a lower value for improvement | | | | | | | | | | | | | |

[109] Cf. Barney: Firm resources and sustained competitive advantage, pp. 105-112.

[110] Cf. n.a.: Energizing the supply chain: Trends and issues in supply chain management, p. 21.

[111] If not explicitly stated as an operational objective item in itself, this refers to the seven classic wastes, introduced by Shigeo Shingo: overproduction, waiting, transportation, unnecessary processing steps, stocks, motion, and defects, see Slack, Chambers and Johnston: Operations management, pp. 524-525.

The resource-based view builds the foundation for the relational view. The relational view has expanded the unit of analysis to dyadic and network firm relationships and thereby implicitly to supply chain networks. The sources of sustained competitive advantage are no longer seen within a firm's boundaries but in resources that attain relevance only by combining two or more independent firms. Dyer and Singh have defined benefits based on and grounded in relationships as relational rents. They have stated that "[…] relational rents are possible when alliance partners combine, exchange, or invest in idiosyncratic assets, knowledge, and resources/capabilities, and/or they employ effective governance mechanisms that lower transaction costs or permit the realization of rents through the synergistic combination of assets, knowledge, or capabilities."[112] Relational rents are preserved because it is almost impossible to replicate such a distinctive, socially complex institutional environment with its formal and informal rules controlling opportunism and/or encouraging cooperative behavior. More precisely, such an advantageous constellation implies that the source of advantage cannot be traced by competitors because

- competitors are unable to replicate the resources due to causal ambiguity,
- time delays of beneficial successive relational investments cause prohibitively high costs of replication,
- no partners possessing the necessary complementary resources or relational capability are available, and
- capabilities have grown indivisible due to coevolution with the partnering firm.[113]

Consequently, relational rents based on resources developed within supply chains are harder to imitate than company-specific resources because of their higher complexity. They are also, however, more difficult to establish and require more resources and strategic consideration. In conclusion, relational rents materialize in a variety of operational and tactical objectives as identified in this section. Strategic relevance is achieved through the relational view, which essentially is an expansion of the resource-based view of the firm, and its implications for sustained competitive advantage.

The level of objectives – strategic, tactical, and operational – is independent from the view of SCM and authors representing the holistic, systemic perspective as well as the ones proposing a more narrow, limited perspective, argue for the

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112 Dyer, Jeffrey H. and Harbir Singh: The relational view: Cooperative strategy and sources of interorganizational competitive advantage, in: Academy of Management Review, Vol. 23 (1998), No. 4, p. 662.

113 Cf. Dyer and Singh: The relational view: Cooperative strategy and sources of interorganizational competitive advantage, pp. 671-674.

above stated goals. The relational view, however, emphasizes that strategic importance increases with a more holistic approach because constellations are more likely to carry a sustained competitive advantage as complexity increases. Many diverse concepts and models of SCM have been suggested with an aim to apply the concept in a way that improves performance and achieves the previously discussed objectives and sustained competitive advantage. To give an overview of the different perspectives on SCM, these approaches are introduced in the following section. Following this discussion, a comprehensive third generation model of SCM is introduced.

### 3.b. Elements of Supply Chain Management and Underlying Theories

Stevens, as one of the early proponents of the total integration approach, has identified four stages of progression towards an integrated supply chain. In the first stage, called “baseline”, companies operate with separate departments that carry their own responsibility. There are no integrative efforts visible even within functions. The second stage, “functional integration”, integrates the activities within the functions. This aggregation is reflected in common organizational structures where business units are organized through functional departments. Stage three leads to “internal integration”. Here, functional boundaries are overcome in order to manage material and information flows smoothly within a company or a business unit. Stevens remarked that internal integration is still reactive to customer demand rather than managing of demand together with customers. Therefore, Stevens has introduced stage four, “external integration”. Key changes within the organization that accompany external integration include a customer-oriented focus and a change in attitude towards non-adversarial relationships with suppliers along the supply chain, characterized by mutual support and cooperation.[114]

The following concepts have picked up these key characteristics and have expanded the idea further. Bechtel and Jayaram not only brought together definitions of SCM, leading to the four schools of thought described earlier, but also have analyzed elements of SCM. Based on this analysis, they have submitted two areas of SCM elements: content elements and process elements. As content elements, they have identified the importance of designing the product and the information flow around the customer. This spans from the design stage, over procurement, storage, manufacturing, warehousing, distribution to recycling. Thus, on the content side, they have emphasized the holistic approach.[115]

As process elements, five process areas have been identified that are relevant for SCM: (1) planning, (2) implementation, (3) inter-organizational structure, (4) measurement, and (5) IT. The planning process consists of TQM practices,

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[114] Cf. Stevens: Integrating the supply chain, pp. 6-8.
[115] Cf. Bechtel and Jayaram: Supply chain management: A strategic perspective, p. 20.

systems thinking, cost analysis modeling, and (process) reengineering. Implementation is concerned with the implementation sequence of SCM. Inter-organizational structures are mainly concerned with cooperative relationships and partnerships. The measurement process points out that measurement systems are mainly directed to individual companies instead of entire supply chains. The IT process deals with issues if data and information exchange, data storage, and data usage. In conclusion, Bechtel and Jayaram have identified areas of interest for SCM and have illustrated the importance of a systemic and expanded view. This includes also the key elements identified by Stevens, namely customer focus and cooperative relationships. As a third, major block for SCM, Bechtel and Jayaram have put IT in the overall context of SCM.[116]

The scope of a supply chain to be managed involves first and foremost the number of firms involved and their functions and activities.[117] In their literature review, Cooper, Lambert, and Pagh have come to the conclusion that the functions and activities mostly agreed on are the integration of information systems, joint planning and control activities, and cooperative efforts in the process areas.[118] The integrated supply chain is characterized by a change towards customer orientation and cooperative relationships, just as envisioned by Stevens.[119] Their framework for SCM identifies the following eight processes that are connected by information flows and have to be managed across supply chain partners: (1) customer relationship management, (2) customer service management, (3) demand management, (4) order fulfillment, (5) manufacturing flow management, (6) procurement, (7) product development and commercialization, and (8) returns/reverse logistics. These processes are then to be managed by means of the management components depicted in *Figure B-5*.

[116] Cf. Bechtel and Jayaram: Supply chain management: A strategic perspective, pp. 20-25.

[117] Cf. Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, p. 8.

[118] Cf. Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, pp. 8-9.

[119] Cf. Stevens: Integrating the supply chain, p. 8.

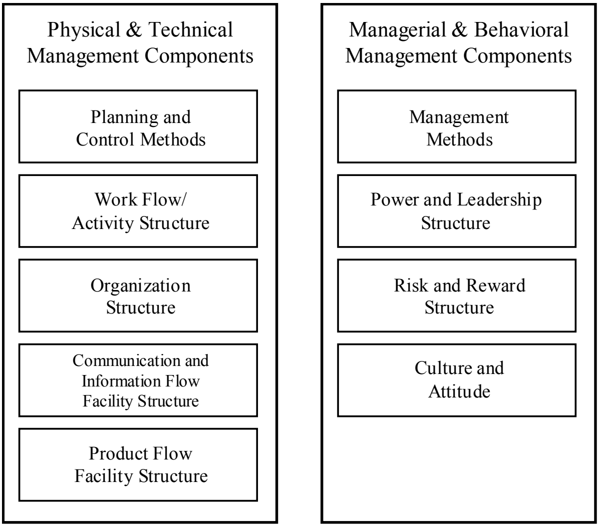


*Figure B-5: Fundamental operational SCM components*[120]

The supply chain business processes noted by Cooper, Lambert, and Pagh match well with the elements identified by Bechtel and Jayaram. Nevertheless, Cooper, Lambert, and Pagh's SCM components are more detailed and better illustrate the influence the SCM concept has on nearly all management elements than the related process elements provided by Bechtel and Jayaram do. Both, however, have especially emphasized the importance of the information flow in their models.[121]

Business processes are also central to the view Chopra and Meindl have taken on SCM. They have summarized three SCM macro processes that have to be well integrated and mirrored along the supply chain. These are: (1) customer relationship management, (2) internal supply chain management, and (3) supplier relationship management. As key characteristics for successful management of these macro processes, they identify communication and coordination between the process owners.[122]

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120 Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 12.

121 See Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, pp. 5-6; and Bechtel and Jayaram: Supply chain management: A strategic perspective, pp. 19-25.

122 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 17.

Cross has placed special emphasis on the role of IT in the context of future supply chains. Though less well grounded in literature, the outlined characteristics fit well into the stream of the developing SCM. Cross has envisioned future supply chains as transparent, timely, and tuned. Transparency refers to extensive information sharing on capabilities, capacities, inventories, and plans between systems. In this view, humans should be freed as much as possible from repetitive tasks. With timeliness, Cross has also emphasized customer orientation. Tuning aims at collaborative relationships, which includes the sharing of knowledge in order to better meet customer requirements.[123]

Kanji and Wong have derived a business excellence model that hypothesizes that leadership positively influences customer focus, cooperative relationships, management by fact, and continuous improvement.[124] These four factors are supposed to lead to SCM excellence. They have tested this model with structural equation modeling. As a result, leadership was shown to have a positive influence on all four factors. More importantly, only customer focus and cooperative relationships had a significant relationship with SCM excellence. These two factors can also be found in other models and this underlines their importance.

A similar view is supported by Stank, Keller, and Daugherty. They have emphasized the three elements integration, coordination, and collaboration across organizations, incorporating a customer focus.[125] This spans all major business processes.[126] They have not differentiated well, however, between the three elements and have combined the elements into the factors internal collaboration and external collaboration. According to this analysis, they have tested the effect of these two factors on logistical service performance. External collaboration seemed to be a necessary, but not sufficient condition for increased logistical service performance. Internal collaboration was found to mediate the relationship between external collaboration and logistical service performance.[127] Bask and Juga's view of SCM can be seen in a similar way. They have named only

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[123] Cf. Cross, Gary J.: How e-business is transforming supply chain management, in: Journal of Business Strategy (2000), March/April, p. 39.

[124] Cf. Kanji and Wong: Business excellence model for supply chain management.

[125] Cf. Stank, Theodore P., Scott B. Keller and Patricia J. Daugherty: Supply chain collaboration and logistical service performance, in: Journal of Business Logistics, Vol. 22 (2001), No. 1, p. 30.

[126] In essence, this refers to processes as outlined by Cooper, Lambert and Pagh: Supply chain management: More than a new name for logistics, p. 10; Bechtel and Jayaram: Supply chain management: A strategic perspective, p. 20; or Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 17.

[127] Cf. Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, p. 40.

integration and collaboration as the "dominant logic in SCM" while combining coordination with collaboration.[128]

Based on an extensive literature review and a joint research effort, Mentzer et al. have developed a supply chain model that aims to merge existing understanding into one joint model.[129] Their model has been suggested as the basis for further research in the field. Mentzer et al. have differentiated between a SCM philosophy and SCM itself. The supply chain philosophy is referred to as supply chain orientation and comprises a systemic view of supply chains as a whole, a strategic orientation towards collaborative relationships, and a customer focus.[130] Supply chain orientation is seen as a prerequisite to SCM. It is important to note that it is not sufficient if only one company in a supply chain adopts a supply chain orientation and not the other supply chain partners. SCM then transfers the philosophy into practice. Willingness to address the following factors has been identified as an antecedent to supply chain orientation:[131] (1) trust, (2) commitment, (3) interdependence, (4) organizational compatibility, (5) vision, (6) key processes, (7) necessity of a leading firm, and (8) top management support. Based on supply chain orientation, SCM then is characterized by inter-company management elements. Mentzer et al. have identified the following: (1) information sharing, (2) shared risks and rewards, (3) cooperation, (4) similar customer service goals and focus, (5) integration of key processes, (6) long-term relationships, and (7) interfunctional coordination. Though also based on the previously identified key characteristics of SCM – namely cooperation between supply chain partners, systemic process integration, and customer focus – Mentzer et al.'s model provides a greater level of detail than other models. It does not, however, explicitly address the role of IT in SCM.[132] In a follow-up study, Min and Mentzer conceptualized their model by developing and testing corresponding constructs and found support for their hypothesized relationship between supply chain orientation, SCM, and performance.[133]

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128 Cf. Bask, Anu H. and Jari Juga: Semi-integrated supply chains: Towards the new era of supply chain management, in: International Journal of Logistics: Research and Applications, Vol. 4 (2001), No. 2, pp. 137-139.

129 See Mentzer *et al.*: Defining supply chain management, pp. 1-25.

130 Cf. Mentzer *et al.*: Defining supply chain management, p. 7.

131 Cf. Mentzer *et al.*: Defining supply chain management, pp. 12-15.

132 For example, Tan provides a related description of effective SCM but uses only some elements of Mentzer et al.'s model. Tan's model does provide indications on the usefulness of IT in SCM, see Tan: A framework of supply chain management literature, pp. 44-45.

133 Cf. Min, Soonhong and John T. Mentzer: Developing and measuring supply chain management concepts, in: Journal of Business Logistics, Vol. 25 (2004), No. 1, pp. 63-99.

The principle of SCM as a more outcome-driven description has been defined by Christopher along the following “4Rs”: (1) responsiveness, (2) reliability, (3) resilience, and (4) relationships. Responsiveness refers to demand-driven operations in contrast to forecast-driven operations. Reliability aims at visibility and process control. Resilience addresses the ability to deal with unexpected disturbances. Relationships are expected to seek win-win situations and process integration. Thus, Christopher, too, has captured the major SCM blocks of customer focus, process orientation, process integration, and cooperation. With the element of resilience, Christopher has pointed out an increasing importance of flexibility, or at least the need to be prepared for flexibility in addition to other views.[134]

Packaging SCM in different terms, Lee has posited the “triple-A supply chain” based on case studies and consulting projects conducted.[135] According to Lee, successful supply chains are characterized by agility, alignment, and adaptability. The essence of the three “A”s fits well with principles and elements identified by other researchers. Agility promotes the information flow with business partners, the development of collaborative relationships, and a design for postponement in order to combine efficient production processes without “pushing” expensive finished good inventories down the supply chain.[136] Therefore, it emphasizes cooperative relationships and process integration across the supply chain. Alignment is achieved by open information and knowledge exchange, the assignment of clear roles and responsibilities across the supply chain, and the equal sharing of risks, costs, and rewards for improvements. Again, cooperative relationships are indicated. Adaptability refers to the readiness to adapt to changes in the environment. In order to adapt in a timely way, companies should monitor the environment, technology cycles, the product life cycle and ultimate customers need, be able to develop new suppliers, and have a flexible product design. Here, a customer focus in the form of a broader market view is suggested. All in all, Lee has suggested an even more flexible setup than, for example, Christopher did with the element resilience.[137]

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[134] Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 38-40.

[135] See Lee, Hau L.: The triple-a supply chain, in: Harvard Business Review, Vol. 82 (2004), October, p. 105.

[136] For a brief description on push and pull processes, see e.g. Chopra, Sunil and Jan A. Van Mieghem: Which e-business is right for your supply chain? in: Supply Chain Management Review (2000), July/August, p. 35.

[137] See Lee: The triple-a supply chain and Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 39-40.

A more recent framework of SCM has been provided by Chen and Paulraj.[138] They have defined an "outside" model that influences an "inside" model. This "inside" model consists of practices in buyer-supplier relationships.[139] Though they have explicitly focused on this dyad, they claim that their model is still targeted at SCM as supply chains consist of many such dyadic relationships within the network. The "outside" model consists of environmental uncertainty, customer focus, top management support, competitive priorities, IT, and strategic purchasing. These factors are seen as determinants of the "inside" SCM model, which consists of practices for supply management, i.e. the buyer-supplier relationship, the supply network structure, and logistics integration. Non-power based, cooperative relationships are defined as beneficial supply network structures for supply management. High logistics integration is based on logistics-related communication and coordination between companies. The supply management domain itself is characterized by the following practices: (1) communication, (2) supplier base reduction, (3) long-term relationships, (4) supplier selection, (5) supplier certification, (6) supplier involvement, (7) cross-functional teams, and (8) trust and commitment. This "inside" model is then hypothesized to have a positive effect on supplier performance and buyer performance. Based on an empirical study, they have concluded "that the theoretical constructs developed have an acceptable criterion-related validity."[140] Unfortunately, they only tested their constructs against buyer operational performance by means of a Pearson's correlation. Thus, only limited empirical support can be construed from their study.

Comparing Chen and Paulraj's model with others provides some additional insights. Most importantly, though the model covers all the factors others derived as well, it lacks a sound structure. For example, whereas environmental uncertainty represents an exogenous condition, customer focus, and top management support represent policies and attitudes. Furthermore, in the "inside"

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138 Chen and Paulraj describe their SCM model in two different publications and slightly differently in each. The one mainly referred to here is Chen and Paulraj: Towards a theory of supply chain management: The constructs and measurements, pp. 119-150. The other one can be found in Chen, Injazz J. and Antony Paulraj: Understanding supply chain management: Critical research and a theoretical framework, in: International Journal of Production Research, Vol. 42 (2004), No. 1, pp. 131-163.

139 The terms "outside" and "inside" are used because Chen and Paulraj depict their model in such a way that some parameters and elements influence supply network structure, buyer-supplier relationships, and logistics integration in a unidirectional way. The nature of this influence, however, is unclear at this point. The "inside" elements could be determinants of the "outside" model. More specifically, do they determine, affect, or support the "ouside" model or are they determined by them?

140 Chen and Paulraj: Towards a theory of supply chain management: The constructs and measurements, p. 134.

model, practices are also mixed with characteristics, such as cross-functional activities, trust, and commitment. Consequently, the approach of Mentzer et al. to differentiate between supply chain antecedents, supply chain orientation, and SCM appears much more appropriate. Flexibility, indicated by environmental uncertainty and the role of IT, in SCM could be added to the set of supply chain antecedents and the supply chain model respectively, since they are also seen as important factors by others as pointed out above.[141]

Although English can be considered to be the *lingua franca* in the field of Operations Management and SCM, some interesting views on SCM have been provided by the German language literature. The principles of SCM according to Werner are: (1) compression, i.e. a reduction in nodes and participants, (2) cooperation, (3) integration, (4) virtualization, i.e. little legal or formal connection within the supply chain, (5) customer orientation, (6) standardization, and (7) optimization, i.e. analytical and operations research methods for inter-company optimization models.[142] A more aggregated view has been adopted by Busch and Dangelmaier. Although they do not elaborate, they have categorized SCM along the following four dimensions: (1) developments in IT, such as Computer Integrated Manufacturing (CIM), Electronic Data Interchange (EDI), and Enterprise Resource Planning (ERP), (2) industry specific initiatives, such as Efficient Consumer Response (ECR), and Collaborative Planning, Forecasting and Replenishment (CPFR), (3) partnerships, i.e. business partnering, collaboration, and vertical integration, and (4) functional concepts, such as logistics, value chain management, or logistics management.[143]

Kuhn and Hellingrath have rested SCM on three pillars: integration, process redesign, and application of IT systems. The main prerequisites for achieving close cooperation or integration of all partners are partnerships characterized by trust and a common, process-oriented understanding of the supply chain. The redesign of core business processes should lead to the effective design of material and information flows that eliminate non-added value activities and improve existing processes across companies. The application of IT systems has been seen to perform two fundamental functions: coordination and communication. Its main

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141 For flexibility considerations, see Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 39-40; and Lee: The triple-a supply chain, pp. 107-110. For the consideration of IT in SCM, cf. Lee: The triple-a supply chain, pp. 44-45.

142 Cf. Werner: Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling, p. 12.

143 Cf. Busch and Dangelmaier: Integriertes Supply Chain Management - ein koordinationsorientierter Überblick, pp. 7-8.

problem within the SCM conceptualization has been seen to be the reluctance to share information, due to lack of trust or misuse of trust.[144]

A similarly strong emphasis on long-term cooperation has been expressed by Schönsleben. Three elements of SCM have been identified: (1) supply chain structure, which includes the network configuration, an agreement of leadership in the collaboration, and trust building, (2) supply chain organization, which encompasses a sense of supply chain responsibility, process design, performance evaluation, and information and communication, and (3) IT, which refers to state-of-the art IT technology, such as supply chain software, e-marketplaces, or XML and the Internet.[145]

Though all previously mentioned interpretations of SCM in the German language literature have captured important aspects of SCM also identified by international authors, their content is still fragmented. In an attempt to better organize SCM elements, Stadtler has proposed the "House of SCM".[146] As the foundations of SCM, Stadtler has identified functional areas such as logistics, marketing, and operations. The framework then consists of the two major blocks integration and coordination. The integration block comprises the choice of partners, network organization and inter-organizational collaboration, and leadership. Coordination, on the other side, is realized by the use of information and communication technology, a process orientation, and advanced planning capabilities. Special emphasis has been placed on process orientation as it aims at coordinating all activities involved in the customer order fulfillment process and this in turn promises the most significant impact on costs, quality, and time performance measures.[147] Customer service as a means to the ultimate goal of competitiveness is placed on top of the two building blocks and aims to provide guidance to all elements of the "House of SCM".

### 3.c. A Third Generation Model for Supply Chain Management

The previously described models and interpretations of SCM are of relevance for SCM theory development and have been prominently positioned in literature. A closer analysis of these models shows that some SCM approaches are focusing on principles, while others try to break the notion down to a more detailed level. Most of the models described can be labeled "second generation" models of SCM, as they build on a previously more scattered and vague understanding of SCM and aim at bringing it together.

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144 Cf. Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, pp. 22-31.

145 Cf. Schönsleben: Integrales Logistikmanagement: Planung und Steuerung der umfassenden Supply Chain, p. 85.

146 Cf. Stadtler: Supply chain management - an overview, pp. 9-10.

147 Cf. Stadtler: Supply chain management - an overview, p. 16.

Though these second generation models of SCM are better organized and more well-grounded on existing literature than "first generation" models, it still appears that there is currently no single model that offers an overall sound and convincing structure. In order to derive such a model, researchers have suggested structuring the research of the SCM field differently. Most propose a three-level structure. Giannakis and Croom have suggested the three categories synthesis, synergy, and synchronization.[148] Stevens has considered a strategic perspective, a tactical perspective, and an operational perspective.[149] Göpfert has used the terms normative SCM, strategic SCM, and operative SCM.[150] Though all three share a similar content in their categories, Göpfert's terminology seems to be the most appropriate one. According to Göpfert, the normative level represents a meta-level of SCM. It fulfills the function of giving identity, motivation, direction, and focus to the SCM concept. The strategic level includes the structure of the supply chain network. On the operational level, the execution of the supply chain strategy is described.

Based on the second generation SCM models and the research structure proposed by Göpfert, the core SCM concept should be positioned on the strategic level. Based on the previously reviewed models, a "third generation" SCM framework is developed. *Figure B-6* provides an overview. Its main contribution is that it covers all SCM aspects identified so far and combines them in one sound model. It is intended to avoid incompleteness and inconsistencies on different levels. Whereas completeness is hard to claim, the basic structure is believed to be sound and consistent and prepared for extensions if appropriate.

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148 Cf. Giannakis, Mihalis and Simon R. Croom: Toward the development of a supply chain management paradigm: A conceptual framework, in: Journal of Supply Chain Management, Vol. 40 (2004), No. 2, Spring, p. 32.

149 Cf. Stevens: Integrating the supply chain, pp. 4-5.

150 Cf. Göpfert: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements, pp. 39-43.

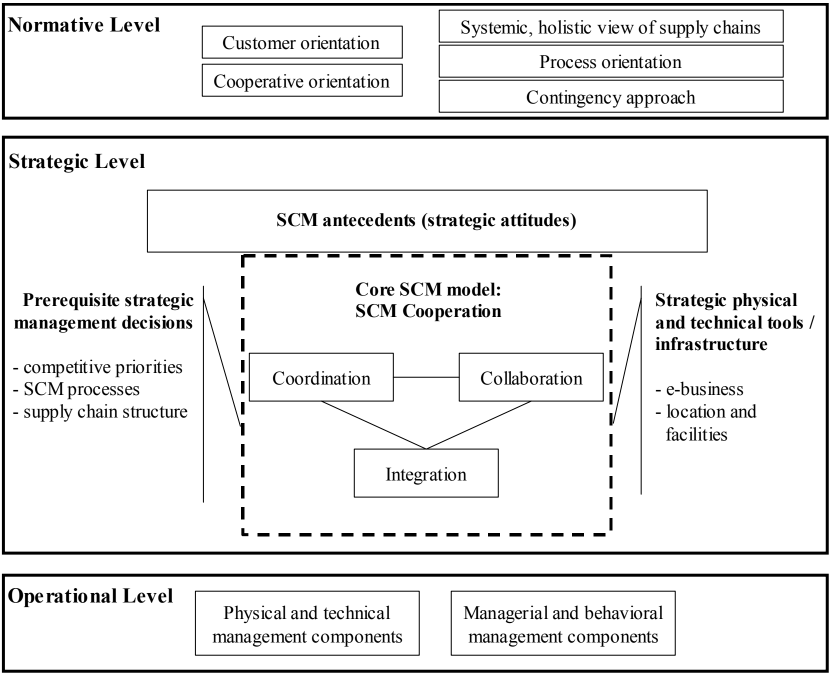


*Figure B-6: A holistic third generation SCM framework*[151]

The model follows a top-down approach. Five meta-policies are placed on the normative level, since these policies provide the umbrella for the strategic as well as the operational levels. Four of them can be derived directly from the previous discussion. These are customer orientation, cooperative orientation, process orientation, and a systemic view of supply chains. Without these four elements, no viable SCM application is possible. The fifth element – contingency – has not been discussed to a great extent in the SCM literature. It calls for "appropriateness" in the way supply chains are designed and managed.[152] In that light it reflects the fact that not all relationships within a supply chain require the same level of cooperation. Thus, the SCM model defined on the strategic level represents the dimensions from which to choose in implementing SCM. It is,

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151 A more detailed graphic can be found in *Appendix 1*.

152 See Cox, Andrew: Power, value and supply chain management, in: Supply Chain Management: An International Journal, Vol. 4 (1999), No. 4, pp. 171-173; Cox, Andrew: The power perspective in procurement and supply management, in: The Journal of Supply Chain Management, Vol. 37 (2001), No. 2, Spring, pp. 4-5; and section B.IV. in this text, where challenges for SCM are discussed.

however, assumed that especially these dimensions hold hidden opportunities to improve supply chain performance in existing non-transactional supply chain relationships. In the context of high performance manufacturing practices, Schroeder and Flynn refer to this concept of appropriateness as a contingency approach.[153] This term has been adopted in the SCM framework depicted in *Figure B-6*. On the normative level, no direct rules are implied. For example, it is not being claimed that only cooperative policies are successful, but rather that there should exist an overall organizational direction towards cooperative behavior. The same holds true for the other three elements, i.e. customer orientation, process orientation, and systemic view of supply chains.

Since SCM is considered to be a strategic concept, the core model is placed on the strategic level. In order to avoid inconsistencies, the elements are carefully separated. Though of crucial importance, competitive priorities, supply chain structure, and SCM processes are not included in the core SCM model. They are considered to be interdependent with the core model but, based on the focus of SCM, are external to it, as illustrated in *Figure B-6*. Competitive priorities focus on the strategic position of a company and supply chain structure takes into account the structural interrelations. SCM processes are supplier relationship processes, internal supply chain processes and customer relationship processes[154] or more specifically the ones Lambert, Cooper, and Pagh have defined.[155] SCM processes also include industry-specific process packages such as Efficient Consumer Response (ECR) or Collaborative Planning, Forecasting and Replenishment (CPFR).

The essence of the framework is SCM cooperation. This comprises the elements coordination, collaboration, and integration. Because of their relevance, these elements are discussed in greater detail in section B.II. In short, coordination is mainly concerned with communication and information sharing functions. Collaboration requires a greater level of interaction and involvement and includes joint activities and teamwork. Integration aims at reducing frictions between interacting and communicating entities. Details are shown in a more precise illustration in *Appendix 1*.

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153 Cf. Schroeder, Roger G. and Barbara B. Flynn: High performance manufacturing: Just another fad?, in: Schroeder, Roger G. and Barbara B. Flynn (Eds.): High performance manufacturing - global perspectives, New York 2001, pp. 4-5.

154 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 17.

155 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 8-9, i.e. customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, procurement, product development and commercialization, and returns and reverse logistics.

Excluded from the core model are strategic physical and technical tools and infrastructure. They are available to design and shape coordination, collaboration, and integration, but are not considered to be means in themselves. As the core SCM model consists of managing elements, e-business is seen as a set of tools supporting, advancing and enabling the practices of the core model. They are discussed in greater detail in section B.III.3. as they are seen to be of great importance for SCM. Other more traditional elements are location and facility considerations.

Another category identified on the strategic level is strategic attitudes. Mentzer et al. have used the term SCM antecedents.[156] These are attributes that make SCM more effective if present or hinder the effectiveness if absent. The existing literature especially emphasizes the importance of trust, and commitment.[157] Other antecedents are top management support, common supply chain understanding, acknowledgment of interdependencies, risk and reward sharing, accountability and responsibility, and willingness of supply chain alignment.

On the operational level, the categories suggested by Lambert, Cooper, and Pagh are proposed to structure operational management components.[158] In essence, the operational level is concerned with the execution of the strategic level. Suggestions made by other authors fit in well with the components identified by Lambert, Cooper, and Pagh. Therefore, their components can be adopted without the need to add many specific suggestions made by other authors.[159] Some elements here can be considered to be more strategic in nature, as for example culture and attitude. The components identified on the operational level, however, refer to the operational implementations of these. Otherwise, adjusted versions are considered separately on the strategic and normative levels. A common supply chain understanding or a customer orientation would be specific instances of cultural considerations.

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156 Cf. Mentzer *et al.*: Defining supply chain management, pp. 12-15.

157 See for example Mentzer *et al.*: Defining supply chain management, pp. 12-13; Spekman, Robert E., John W. Kamauff Jr. and Niklas Myhr: An empirical investigation into supply chain management: A perspective on partnerships, in: Supply Chain Management: An International Journal, Vol. 3 (1998), No. 2, pp. 55-56; Chandra and Kumar: Supply chain management in theory and practice: A passing fad or a fundamental change?, pp. 101-103; and Chen and Paulraj: Towards a theory of supply chain management: The constructs and measurements, pp. 149-150.

158 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 11-12.

159 For example Kanji and Wong: Business excellence model for supply chain management, pp. 1153-1155 especially point out management by fact and continuous improvement practices. As these represent management methods, they can be listed as such as managerial management components under Lambert, Cooper, and Pagh's categories. For an overview of these categories, see *Appendix 1*.

In a slightly different approach, Trent has related SCM to the principles of TQM. Trent has argued that, although many companies claim to apply TQM, they do not actually live by and practice them.[160] This view has also been taken by Hayes and Pisano, who remarked that instead of focusing on the form of organizational methods such as TQM, it is necessary to focus on the substance, i.e. the underlying skills and capabilities, promoted by these concepts.[161] Reviewing the principles of TQM reveals the proximity to SCM. Trent has identified the following eight principles of TQM.[162] (1) Define quality in terms of customers and their requirements. (2) Pursue quality at the source. (3) Stress objective rather than subjective analysis. (4) Emphasize prevention rather than detection of defects. (5) Focus on process rather than output. (6) Strive for zero defects. (7) Establish continuous improvement as a way of life. (8) Make quality everyone's responsibility.

Viewing the third generation SCM framework derived in this text with these principles indeed shows the complementary nature of the TQM concept and SCM. The first principle directly relates to the customer orientation of SCM. The second one is reflected by the systemic and holistic view of supply chains. This view also covers the fourth and eighth principle of TQM. Management by objective rather than subjective justifications is incorporated as strategic attitude and as the operational management component. Process focus is another major component of SCM. Striving for zero defects is quite specific to TQM, but can be related to the aim of maximal efficiency under the conditions determined by strategic decisions. Establishing continuous improvement can be seen as central to collaboration,

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160 Cf. Trent, Robert J.: Applying TQM to SCM, in: Supply Chain Management Review (2001), May/June, p. 71; and Bragg, Wayne: Executive commentary on Liedtka's article: Collaboration across lines of business for competitive advantage, in: Academy of Management Executive, Vol. 10 (1996), No. 2, pp. 35-36.

161 Cf. Hayes, Robert H. and Gary P. Pisano: Beyond world-class: The new manufacturing strategy, in: Harvard Business Review, Vol. 72 (1994), January/February, p. 78.

162 Cf. Trent: Applying TQM to SCM, p. 71. Trent's eight principles differ slightly from the eight principles of quality management that underlie the ISO 9000 standards, see n.a.: International Organization of Standardization: http://www.iso.org, 2005, retrieved on: February 15, 2006. These, as well, are based on the previous work of quality management authors like Ishikawa, Feigenbaum, Deming, Juran, Crosby, Imai, Ohno and Taguchi. The ISO 9000 quality principles comprise customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making and mutually beneficial supplier relationships. Leadership and a system approach to management are not reflected in Trent's principles. Instead, Trent adds a prevention emphasis and the aim for zero defects.

because this is in fact why companies do collaborate.[163] The last principle, establishing a holistic attitude of responsibility and accountability, is part of the SCM antecedents.

Since the SCM framework depicted in *Figure B-6* and illustrated in more detail in *Appendix 1* is sound, consistent, and comprehensive in light of the previous SCM concept expositions, it will be pursued in the following as the relevant SCM foundation. *Figure B-7* illustrates the organization of the discussion in this text.

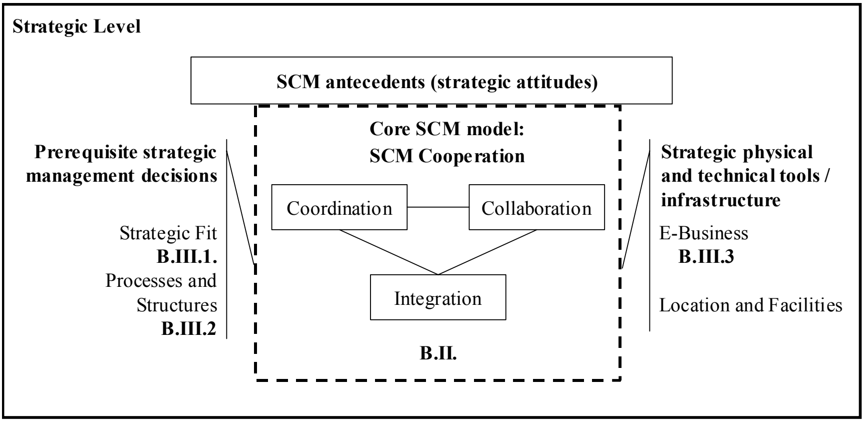


*Figure B-7: Overview of SCM theory discussion structure*

Section B.II. discusses the core SCM model, i.e. the elements of SCM cooperation: coordination, collaboration and integration. In sections B.III.1 and B.III.2., the necessary prerequisite strategic management decisions in the context of SCM are addressed. More concretely, the often noted strategic fit and how this is reflected in the newly developed framework is discussed. Related to structural aspects of SCM, then the process view of SCM is emphasized. Because of its increasing importance and acceptance, the Supply Chain Operations Reference (SCOR) model is next reviewed and placed in perspective relative to the SCM framework. Based on this discussion of supply chain structures and processes, a formal framework is developed. Such a formal representation is believed to better support the analytical analysis of supply chains. Finally, in section B.III.3., e-business aspects are considered. Due to their rapid diffusion and potential, they are of special importance and therefore are discussed in a broader perspective.

[163] Therefore, this is added as part of the managerial and behavioral management components based on the TQM concept.

## II. Cooperation as Success Factor for Supply Chain Management

### *1. The Bullwhip Effect as a Result of Uncoordinated Decision Making*

Forrester has been the first to identify the phenomenon of oscillating and amplifying order behavior upstream of supply chains and its effects on inventories, capacity utilization and other operational parameters.[164] This Forrester effect has become known as the bullwhip effect and can be considered to be the best-known phenomenon of supply chain inefficiencies. According to Lee, the first time the bullwhip effect was evident in an industrial company was in the supply chain of Procter & Gamble's diaper products. Though diaper sales were relatively stable, fluctuations of distributor orders were much higher and so were material orders of Procter & Gamble's suppliers.[165] After this discovery, the same effect has been observed in other supply chains as well and is still evident.[166] The bullwhip effect is evidence of the consequences of uncoordinated decision making, i.e. that members of supply chains make decisions without having knowledge about the decisions in other parts of the supply chain. The resulting order fluctuations have a variety of consequences for the supply chain. These fluctuations increase manufacturing costs, inventory costs, replenishment lead times, transportation costs, and labor costs for shipping and receiving. Additionally, the level of product availability decreases and relationships across supply chains are affected negatively.[167]

The structure of a system is of great importance for explaining system behavior. This bullwhip effect is a consequence of this structure.[168] Structure influences the behavior of a system to a great extent. More precisely, feedback structures and inherent delays unavoidably cause distortions that then become

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164 Cf. Forrester: Industrial dynamics: A major breakthrough for decision makers, pp. 37-66.

165 Cf. Lee, Hau L., V. Padmanabhan and Seungjin Whang: The bullwhip effect in supply chains, in: Sloan Management Review, Vol. 38 (1997), No. 3, Spring, pp. 93-94.

166 Cf. McCullen, Peter and Denis R. Towill: Diagnosis and reduction of bullwhip in supply chains, in: Supply Chain Management: An International Journal, Vol. 7 (2002), No. 3, p. 164; and Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, p. 93 who report about similar effects in HP's printer supply chain.

167 Cf. Andraski, Joseph C.: Leadership and the realization of supply chain collaboration, in: Journal of Business Logistics, Vol. 19 (1998), No. 2, p. 10; and Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 480-481.

168 Cf. Forrester, Jay W.: Industrial dynamics - after the first decade, in: Management Science, Vol. 14 (1968), No. 7, p. 406.

evident through oscillations in key system parameters, such as inventory levels or utilization rates.[169]

Based on a more detailed analysis of given industry supply chain structures, Lee, Padmanabhan, and Whang have identified four factors that cause the bullwhip effect: (1) demand forecast updating, (2) order batching, (3) price fluctuation, and (4) the rationing and shortage game. These will be described briefly in the following:

- *Demand forecast updating*. When performing demand forecasts, companies interpret historical order information and update them regularly. This order information from customers, however, does not directly reflect actual demand. This information is used to determine supply requirements as a function of historical demand information, service level policies, and lead times in order to satisfy future demand and safety stocks. The further upstream in the supply chain these forecasts are conducted the more their variability increases.[170] Because longer lead times require higher safety stocks under otherwise identical conditions, worsening the bullwhip effect, some authors mention long lead times as a separate reason for the bullwhip effect.[171]
- *Order batching*. Two forms of order batching are identified by Lee, Padmanabhan, and Whang: periodic ordering and push ordering. Most frequently, periodic orders are used. Many companies run their MRP systems or inventory status periodically and therefore, orders occur periodically as well. Additionally, fixed order costs, such as order processing costs and transportation costs, contribute to larger orders in order to reduce per unit order costs. Push ordering refers to behavioral order distortions. It occurs in cases of budget spending related end-of-year or end-of-period surges or forward ordering by sales agents in order to meet incentive related goals.[172] It also contributes to erroneous demand signaling and therefore less reliable forecasts upstream in the supply chain.
- *Price fluctuation*. Temporary price discounts, promotions, and payment term benefits offered by manufacturers, wholesalers, or distributors to downstream supply chain members encourages forward buying behavior.

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169 Cf. Maier, Frank: Die Integration wissens- und modellbasierter Konzepte zur Entscheidungsunterstützung im Innovationsmanagement, Berlin 1995, pp. 177-178.

170 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, p. 95.

171 Cf. for example Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 103-104 who add long lead times as a fifth reason for the bullwhip effect.

172 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, pp. 95-96.

In order to benefit from these price reductions, companies buy larger amounts than immediately needed. Depending on inventory holding costs, this might be beneficial for really large amounts. In any case, for upstream supply chain members it is impossible to derive real customer demand because of this forward buying behavior. Higher direct costs might occur because of over-utilization of resources and resulting negative long-term consequences of varying capacity utilization.[173]

– *Rationing and shortage game*. If supply is limited due to a temporary surge in demand and orders are only partly filled due to this shortage, customers might react by overstating their real demands in order to receive a larger share of the limited supply. When demand returns to normal levels, orders are cancelled or, because of previous more-than-demanded deliveries, simply disappear. This is especially a problem when customers only anticipate a shortage and place multiple orders with multiple suppliers. Then, after the first order is fulfilled, all redundant orders are cancelled. The problem is that it is almost impossible for a manufacturer to tell real orders from fake ones.[174] As Sterman remarked: "Even a perfect forecast will not prevent a manager who ignores the supply line from overordering."[175]

If one common denominator can be derived as counter-measure for the bullwhip effect, it would be coordination. Based on simulation results, Towill has concluded that the improvements gained from information integration and therefore information sharing and information exchange are relatively high.[176] Operational and economic factors, such as lead times and ordering costs, also play a role but the lack of coordination seems to explain most of the bullwhip effect. Though coordination can significantly reduce the bullwhip effect, it may not completely eliminate it.[177] The magnitude of the bullwhip effect is highly dependent on the specific problem situation and therefore hard to pin down in general terms. The major causes and counter-measures, however, are well known

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173 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, p. 97.

174 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, pp. 97-98.

175 Sterman, John D.: Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment, in: Management Science, Vol. 35 (1989), No. 3, p. 336.

176 Cf. Towill, Denis R.: The seamless supply chain - the predator's strategic advantage, in: International Journal of Technology Management, Vol. 17 (1997), No. 1, p. 50.

177 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, p. 109.

and grounded on the foundations laid out by Forrester as well as Lee, Padmanabhan, and Whang.[178]

Counter-measures to weaken or even eliminate the bullwhip effect have been analyzed and suggested by several authors. They can be summarized as follows:

– *Information sharing*. In order to avoid the problem of multiple demand forecasts based on indirect demand data, it is suggested that end consumer demand information be shared with upstream members of the supply chain. Still, differences in the forecasts might occur due to different forecasting methods and assumptions. The concept of Vendor Managed Inventory (VMI) builds on information sharing but goes one step further. With VMI, suppliers or manufacturers manage inventory directly at the retailer's site. Inventory information is shared in addition to demand information. Improvements in automation and information technology have been important for efficiently managing such a system. Operationally, shorter lead times reduce uncertainty.[179] Consequently, safety stock inventory and capacity cushions can be reduced. Information sharing can also include capacity information sharing with downstream supply chain partners. Fundamentally, information sharing influences all causes for the bullwhip effect positively.[180]

– *Smaller order batches*. The effects of large order batches contribute not only to wrong demand signaling but also to increase in workload fluctuations. Besides more frequent MRP runs and policy adjustments to avoid push ordering, operational improvements are important to keep per unit costs low even with small order batches.[181] This can be achieved by transportation aggregation through third party logistics providers or arrangements with *cosuppliers*[182] and by reduction of order processing costs through automation and ERP systems.

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178 Cf. Sahin, Funda and E. Powell Robinson Jr.: Flow coordination and information sharing in supply chains: Review, implications, and directions for future research, in: Decision Sciences, Vol. 33 (2002), No. 4, Fall, pp. 511-514.

179 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, pp. 98-100.

180 Cf. Lee, Hau L., V. Padmanabhan and Seungjin Whang: Information distortion in a supply chain: The bullwhip effect, in: Management Science, Vol. 43 (1997), No. 4, April, p. 558.

181 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, pp. 100-101; and Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 490-492.

182 For the term *cosupplier* as suppliers who deliver to the same customer, cf. Hammer, Michael: The superefficient company, in: Harvard Business Review, Vol. 79 (2001), September, pp. 88-89.

- *Price stability*. Instead of providing irregular price discounts, an every day low price policy can avoid forward buying or purchase postponement in anticipation of price discounts or promotions.[183] Another alternative is to move from lot size-based discounts to volume-based quantity discounts.[184]
- *Reducing delays*. Material flow delays, information flow delays, and information distortion can be reduced by eliminating entire tiers from the supply chain or by time compression of the processes.[185] Changing the supply chain structure, however, is a difficult task. Therefore, time compression is the more common and more feasible approach for counterbalancing the bullwhip effect.

As pointed out before, the bullwhip effect can be mainly attributed to a lack of coordinated decision making. This includes structural deficits with regard to coordinated decision making. In the context of SCM, the terms cooperation, collaboration, and integration appear frequently together with or instead of coordination. Therefore, the next section takes a closer look at those terms and examines how they correspond, interrelate, and most importantly, differ.

## *2. Supply Chain Management Cooperation: Coordination, Collaboration, and Integration at the Core*

Generally, coordination and coordinated decision making refers to separated entities that work together for decision alignment in order to improve overall performance. This has been a major issue of early economic theory that differentiated between the firm and its hierarchies and price mechanisms as forms of coordination.[186] If separate companies coordinate, Coase has referred to that as combination or integration.[187] In the context of management research and in particular SCM research, the related terms cooperation, coordination, and collaboration are often used interchangeably without clearly distinguishing them from each other. This can cause confusion and ambiguity.

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183 Cf. Lee, Padmanabhan and Whang: The bullwhip effect in supply chains, p. 101.

184 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 487-493.

185 Cf. Towill: The seamless supply chain - the predator's strategic advantage, p. 51.

186 Cf. Coase, Ronald H.: The nature of the firm, in: Economica, Vol. 4 (1937), No. 13-16, pp. 7-11; and Williamson, Oliver E.: Economic organizations: Firms, markets and policy control, Bodmin 1986, pp. 32-36.

187 Cf. Coase: The nature of the firm, pp. 14-15.

Cooperation is defined as acting or working together for a shared purpose,[188] working or acting together toward a common end or purpose, being compliant,[189] or as working with someone toward a common goal.[190] In the context of SCM, Quiett has interpreted cooperation as "little more than toleration of each other."[191] While this view might be a bit too drastic, the other definitions imply that cooperation emphasizes mainly the alignment towards a common goal and a shared purpose. The notion of "working together" in the context of cooperation does not suggest a close operational working relationship, but rather a positive attitude towards each other.

Coordination refers to a more direct, active cooperation. It is defined as "the act of making arrangements for a purpose," the "harmony of various elements,"[192] "harmonious adjustment or interaction,"[193] and making separate things working together.[194] Compared to cooperation, coordination indicates an interactive, joint decision making process, where separate entities influence each others' decisions more directly. Besides horizontal coordination, i.e. coordination within a supply chain tier, and vertical coordination, i.e. coordination across supply chain tiers, for example between supplier and customer, coordination can also be distinguished according to the mechanism of coordination. The fundamental mechanisms are markets and hierarchies. Both mechanisms can reflect different degrees of coordination. Market structures refer mainly to incentive-driven coordination between separate, legally independent companies whereas hierarchical structures indicate either a high unilateral dependency or that companies are not legally independent and equity is shared.[195] High degrees of coordination are subject to antitrust actions because they are believed to impede competition and reduce

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188 Cf. Cambridge Dictionaries Online, http://dictionary.cambridge.org/, Cambridge University Press,retrieved on: February 15, 2006.

189 Cf. The American Heritage Dictionary of the English Language, http://www.bartleby.com/61/, Houghton Mifflin Company,retrieved on: February 15, 2006.

190 Cf. Heinle's Newbury House Dictionary of American English, http://nhd.heinle.com, Thomson Heinle,retrieved on: February 15, 2006.

191 Cf. Quiett, William Frank: Embracing supply chain management, in: Supply Chain Management Review (2002), September/October, p. 45.

192 Heinle's Newbury House Dictionary of American English.

193 The American Heritage Dictionary of the English Language.

194 Cf. Cambridge Dictionaries Online.

195 Williamson introduces the hybrid form as another governance structure, positioned between markets and hierarchies, see Williamson, Oliver E.: Comparative economic organization: The analysis of discrete structural alternatives, in: Administrative Science Quarterly, Vol. 36 (1991), No. 2, pp. 269-296.

welfare. Whether or not this belief is true has been the subject of discussions among economists and has been doubted especially for vertical coordination.[196]

Collaboration is defined as "[working] together or with someone else for a special purpose,"[197] "[working] together, especially in a joint intellectual effort,"[198] or simply as working with someone.[199] In the last instance, collaboration is simply defined as a synonym for working together. The other two definitions point out common objectives and efforts. Therefore, they put the activity in a context. Whereas coordination is mainly conducted by sending the right signals or sharing the right information and the same policies, collaboration indicates a joint, interactive process that results in joint decisions and activities. By that, it also indicates a higher degree of joint implementation and can be thought of as a teamwork effort. According to this interpretation, coordination alone excludes joint implementation and operational efforts.

Within the SCM framework, the core SCM model is labeled SCM cooperation.[200] It is seen as a strategic directive that subsumes coordination and collaboration. The distinction between these two is necessary in order to distinguish different types of cooperation that are relevant to SCM. Cooperation can be divided into intra-company cooperation, bilateral cooperation, and multilateral cooperation, depending on the scope of the cooperation under consideration.[201]

In terms of cooperative intensity, collaboration can be seen as more intensive than coordination because most of the time it subsumes all characteristics of coordination as well. Therefore, in a hierarchy of different levels of cooperation, collaboration would be positioned above coordination. This is not to say that coordination is less important or relevant; it is just not as intensive.

In the context of SCM, coordination aims at achieving global optimization within a defined supply chain network. Interactive, joint collaborative efforts aim to exploit hidden potential and consequently expand the optimization potential, i.e. shifting the efficient performance frontier upwards. This view is also supported by Shaw, who has differentiated between three types of coordination in terms of level

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196 For a review of antitrust, see Williamson: Economic organizations: Firms, markets and policy control, pp. 250-257; and Boarman, Patrick M.: Antitrust laws in a global market, in: Challenge (1993), January/February, pp. 30-36. Negative welfare effects have been already doubted by Spengler, Joseph J.: Vertical integration and antitrust policy, in: Journal of Political Economy (1950), p. 352.

197 Cambridge Dictionaries Online.

198 The American Heritage Dictionary of the English Language.

199 Cf. Heinle's Newbury House Dictionary of American English.

200 See *Figure B-6*, p. 45 and *Appendix 1*.

201 Cf. Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, pp. 38-39.

of involvement, in ascending order: (1) simple information exchange, (2) formulated information sharing, and (3) modeled collaboration. Simple information exchange is straightforward in its meaning. It refers to information exchange without additional interpretation or rules. In formulated information sharing, such policies as restocking policies are shared together with operational information. In modeled collaboration, operational models are also shared, together with capabilities, factory load, inventories, and orders.[202] This understanding can be directly linked to the three levels of collaboration that Quiett has identified, which are data exchange, cooperative collaboration and cognitive collaboration.[203] These views, however, indicate a more extensive information sharing scheme on the highest level instead of a close, teamwork-like working relationship.

As also suggested in the context of the bullwhip effect, supply chain profitability as a whole can only be maximized when all stages are coordinated.[204] Consequently, this must lead to concerted decisions.[205] The significance of coordination has been confirmed by a study conducted by Thonemann among manufacturing companies. There, supply chain coordination has been identified as the top success factor by manufacturing companies.[206] Sahin and Robinson have stated that "a supply chain is fully coordinated when all decisions are aligned to accomplish global system objectives."[207] Information sharing is of central importance for coordination. It allows for coordinated forecasts and forecasts based on richer information.[208]

Thus, a "lack of coordination occurs when decision makers have incomplete information or incentives that are not compatible with system-wide objectives."[209] As also shown in the context of the bullwhip effect, even full information

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202 Cf. Shaw, Michael J.: Information-based manufacturing with the Web, in: The International Journal of Flexible Manufacturing Systems, Vol. 12 (2000), No. 2,3, April, p. 123.

203 Cf. Quiett: Embracing supply chain management, p. 45.

204 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 46-47.

205 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, p. 258.

206 Cf. Thonemann, Ulrich *et al.*: Supply chain champions, Wiesbaden 2003, p. 30. Thonemann et al. refer to cooperation in their study, but in fact mean coordination, i.e. sharing of information.

207 Sahin and Robinson Jr.: Flow coordination and information sharing in supply chains: Review, implications, and directions for future research, p. 507.

208 Cf. Swaminathan, Jayashankar M. and Sridhar R. Tayur: Models for supply chains in e-business, in: Management Science, Vol. 49 (2003), No. 10, p. 1397.

209 Sahin and Robinson Jr.: Flow coordination and information sharing in supply chains: Review, implications, and directions for future research, p. 507.

availability does not guarantee optimal supply chain performance. Nevertheless, full information availability can have a significant, positive impact on supply chain performance.[210] But the problem of conflicting objective functions may remain and cause forecasts to be distorted.[211]

Complementary to the counter-measures identified by Lee, Padmanabhan, and Whang in the context of the bullwhip-effect, Chopra and Meindl have considered five categories of obstacles to coordination. These comprise factors that lead to local optimization, an increase in information delay, distortion, and variability within the supply chain. These categories are:[212]

– *Incentive obstacles*. These are obstacles that are caused by wrong incentives provided to supply chain members in order to influence their decisions to support global optimization instead of pareto-efficient solutions.
– *Information processing obstacles*. They consist of orders based on forecasts instead of customer demand, and a lack of information sharing.
– *Operational obstacles*. Large ordering lot requirements, rationing and shortage gaming, and large replenishment lead times can be summarized as operational obstacles. The effect of lead times was pointed out by Stalk and Hout, who note that halving lead times can result in the halving of forecast errors.[213]
– *Pricing obstacles*. Lot sizes based on quantity discounts and price fluctuations contribute largely to the variability within supply chains.
– *Behavioral obstacles.* Policies and management practices, such as frequency of MRP runs, limited company perspective and local optimization characterize this category.

When examining coordination, one can distinguish between two types, horizontal coordination and vertical coordination. Horizontal coordination refers to coordination issues within one tier, whereas vertical coordination involves different tiers, such as a customer and supplier. Horizontal coordination problems are for instance location decisions and centralization decisions. Location decisions

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210 Cf. Chen, Frank *et al.*: Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times, and information, in: Management Science, Vol. 46 (2000), No. 3, March, p. 442. Information and its value is discussed in more detail in section B.II.3.

211 Cf. Swaminathan and Tayur: Models for supply chains in e-business, p. 1396.

212 For the following, see Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 482-487.

213 Cf. Stalk, George and Thomas M. Hout: Competing against time, London 1990, pp. 31-34.

can be analyzed within the Hotelling model, where it is implicitly assumed that firms solve such coordination problem of their decision to the extent that they correctly anticipate the behavior of other parties.[214] Vertical coordination problems include the well-known newsvendor problem,[215] issues of risk pooling, coordinated demand forecasting, coordinated pricing, and coordinated lot sizing. Some of these were discussed earlier. The bullwhip effect, for example, can be considered to be a consequence of uncoordinated demand forecasts.

Centralization, also known as risk pooling, is referred to as a horizontal coordination mechanism. Risk pooling reduces demand variability if demand is aggregated across locations. It is a means by which safety stock and average inventory can be reduced in a system. Of course, some costs might increase, such as transportation costs or customer lead time and therefore this has to be weighed against the benefits.[216] To illustrate this beneficial effect, Christopher has described the “square root rule”. According to this, system inventory can be reduced proportionally to the square root of the number of stock locations before and after centralization, under certain assumptions. For example, a reduction from 25 locations to four would correspond to the relation $\sqrt{25}$ : $\sqrt{4}$, which leads to 5:2 and therefore a 60% reduction.[217]

Munson, Hu, and Rosenblatt have provided examples for horizontal and vertical coordination problems. It has been shown that in these straightforward examples, better solutions can be derived by coordinated decision making. They have developed several numerical examples in the areas of location decisions, centralization, lot sizing, demand forecasting, pricing, and newsvendor lot sizing to illustrate this.[218] Often, such coordination problems refer to specific situations on the operational level. In the context of SCM, however, the strategic dimension of coordination is of paramount interest.

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214 See Gabszewicz, Jean J. and Jacques-Francois Thisse: Location, in: Aumann, Robert J. and Sergiu Hart (Eds.): Handbook of game theory with economic applications volume 2,Amsterdam 1994, chapter 9.

215 For example, see Eppen, Gary D.: Effects of centralization on expected costs in a multi-location newsboy problem, in: Management Science, Vol. 25 (1979), No. 5, pp. 408-501.

216 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 66-67.

217 For more details, see Christopher: Logistics and supply chain management: Creating value-adding networks, p. 215.

218 See Munson, Charles L., Jianli Hu and Meir J. Rosenblatt: Teaching the costs of uncoordinated supply chains, in: Interfaces, Vol. 33 (2003), No. 3, May/June, pp. 24-36 for simple mathematical examples that clearly prove this. A detailed explanation would exceed the scope of this text.

Sahin and Robinson Jr. have summarized the major strategic and tactical coordination mechanisms according to the following categories:[219]

- *Price coordination using quantity discounts*. System optimization is sought through the alignment of a manufacturer's pricing structure with a retailer's purchasing incentives under a variety of conditions, such as capacity restrictions and different information availability.
- *Non-price coordination*. This includes mechanisms such as service territories, quantity forcing, and service differentiation.
- *Buy-back and returns policy*. Such strategies aim to increase stocking incentives for retailers, especially for perishable products.
- *Quantity flexibility*. Contracts including flexible quantities – such as a guaranteed amount of minimum purchases by a buyer and maximum amount of products made available through a supplier – aim at sharing the risks of forecast deviations.
- *Allocation rules*. Due to scarce capacity resources, retailers might distort their orders, which in turn leads to supply chain inefficiencies. Cachon and Lariviere have shown that under certain conditions, a supply chain is better off not providing truthful information about actual order requirements but also note that this might change if conditions change, such as marginal cost for capacity or marginal retailer costs.[220] In conclusion, Cachon and Lariviere state "[…] that truth telling provides some advantages to the supply chain that should be weighed against the costs of inducing truth telling."[221]

In collaboration, two or more entities work together, share resources, and seek to achieve collective goals. It depends on the ability to trust each other, and to appreciate one another's knowledge and emphasizes the building of meaningful relationships.[222]

An understanding in line with this interpretation of collaboration is provided by Liedtka, who has defined collaboration "as a process of decision making

[219] Cf. Sahin and Robinson Jr.: Flow coordination and information sharing in supply chains: Review, implications, and directions for future research, pp. 508-509.

[220] Cf. Cachon, Gérard P. and Martin A. Lariviere: Capacity choice and allocation: Strategic behavior and supply chain performance, in: Management Science, Vol. 45 (1999), No. 8, pp. 1091-1107.

[221] Cachon and Lariviere: Capacity choice and allocation: Strategic behavior and supply chain performance, p. 1104.

[222] Cf. Stank, Theodore P., Patricia J. Daugherty and Alexander E. Ellinger: Marketing/logistics integration and firm performance, in: The International Journal of Logistics Management, Vol. 10 (1999), No. 1, p. 12.

among interdependent parties; it involves joint ownership of decisions and collective responsibility for outcomes."[223] Liedtka has emphasized the cross-functional teamwork aspect of collaboration with a clear focus on processes instead of functions. Because processes rarely stop at company boundaries, this includes external organizations as well. Therefore, the term partnership is also used to include external collaboration. Success factors identified in Liedtka's study are quite independent from legal forms of partnerships. The components of successful partnering comprise a partnering mindset, a partnering skillset, and a supporting organizational architecture.[224]

In a Deloitte study conducted in 2003, collaboration has been characterized by internal and external teamwork in the context of manufacturing companies, i.e. with customers and suppliers. As differentiating factors, strong cross-functional teams, stronger commitments to these teams, design for quality, and design for manufacturability techniques have been identified. Necessary elements were cited to be joint working with suppliers and customers on production planning, inventory management, replenishment, forecasting, and demand planning.[225]

Barratt has identified yet another, however closely related, set of elements that define collaboration. These are (1) cross-functional activities, (2) process alignment, (3) joint decision making, and (4) supply chain metrics. The elements that support a collaborative culture are trust, mutuality, information exchange, openness, and communication, which in turn is necessary for successful collaboration.[226] It is important to note that a rather close proximity to team working exists. As Christopher remarked: "The closer the relationship between buyer and supplier the more likely it is that the expertise of both parties can be applied to mutual benefit."[227] Consequently, higher levels of internal and external collaboration are expected to improve performances in the areas of collaboration.[228] As such, these capabilities also underlie previous management concepts, such as Total Quality Management (TQM) and, very closely related,

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223 Liedtka, Jeanne M.: Collaborating across lines of business for competitive advantage, in: Academy of Management Executive, Vol. 10 (1996), No. 2, p. 21.

224 Cf. Liedtka: Collaborating across lines of business for competitive advantage, pp. 21-25.

225 Cf. Deloitte & Touche LLP, Koudal, Peter: Mastering complexity in global manufacturing: Powering profits and growth through value chain synchronization 2003, pp. 20-23.

226 Cf. Barratt, Mark: Understanding the meaning of collaboration in the supply chain, in: Supply Chain Management: An International Journal, Vol. 9 (2004), No. 1, pp. 35-37.

227 Christopher: Logistics and supply chain management: Creating value-adding networks, p. 201.

228 Cf. Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, pp. 32-33.

Collaborative Planning, Forecasting and Replenishment (CPFR). In fact, with the emergence of CPFR in the mid-1990s, collaboration has become more recognized in the context of SCM.[229]

Spekman, Kamauff Jr., and Myhr have drawn a similar conclusion. In their view, cooperation refers to rudimentary information exchange with little interaction and is seen as a necessary but not sufficient condition for managing business relationships. The next level would then be coordination. JIT and EDI linkages can reflect such coordinated relationships. Again, though companies cooperate and coordinate, they still might not behave as true partners. In order to achieve collaboration, a level of trust and commitment beyond that found in cooperation and coordination is required. Thus, supply chain partners may cooperate and coordinate, but still not collaborate.[230]

In the context of SCM, trust has been defined as "[…] one's belief that one's supply chain partner will act in a consistent manner and do what he/she says he/she will do."[231] This definition neglects the beneficial nature of trust-based relationships. Robbins has provided a general definition of trust: "Trust is a positive expectation that another will not – through words, actions, or decisions – act opportunistically."[232] As characteristics of a trust-based relationship, Robbins has identified integrity, competence, consistency, loyalty, and openness.[233] Based on a cross-discipline analysis, Rousseau et al. have found that a common understanding of trust among scholars exists. This understaning has been summarized in the following definition: "Trust is a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another."[234] In contrast to trust, commitment refers to the belief that companies are dedicated and willing to invest resources to guard a relationship.[235]

Collaboration mainly materializes on the process level. In this light, it can relate to specific processes, such as procurement, demand, inventory, capacity,

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229 Cf. Barratt: Understanding the meaning of collaboration in the supply chain, pp. 30-39.

230 Cf. Spekman, Kamauff Jr. and Myhr: An empirical investigation into supply chain management: A perspective on partnerships, pp. 55-56.

231 Cf. Spekman, Kamauff Jr. and Myhr: An empirical investigation into supply chain management: A perspective on partnerships, p. 56.

232 Robbins, Stephen P.: Organizational behavior, 11th ed., Upper Saddle River 2005, p. 356.

233 Cf. Robbins: Organizational behavior, p. 356.

234 Rousseau, Denise M. *et al.*: Not so different after all: A cross-discipline view of trust, in: The Academy of Management Review, Vol. 23 (1998), No. 3, July, p. 395.

235 Cf. Spekman, Kamauff Jr. and Myhr: An empirical investigation into supply chain management: A perspective on partnerships, pp. 55-57.

and product development or to general collaboration terms. In the latter case, general collaborative rules and standards are established between supply chain partners.[236] The complementary nature of collaboration and SCM becomes evident when reviewing success factors for collaboration and collaborative relationships. Hammer, for instance, has emphasized process orientation, distributed decision making, and collaborative style as requirements for successful cross-company collaboration.[237] Christopher has pointed out the importance of processes as a series of interactions between the parties involved and generally joint objectives among supply chain partners.[238] Bowersox, Closs, and Stank have mentioned three factors of enhanced collaboration: (1) mutual trust and shared visions and objectives, (2) clear structures based on rules, agreements, and guidelines to encourage risk and benefit sharing, and (3) pre-agreement on exit procedures in case of adversarial behavior of partners or other reasons for ending the collaboration. This view, however, leaves out some important issues seen as critical by other authors, such as information sharing.[239]

A study conducted by Meritus, IBM, and CSR back in 1995 has identified the use of IT for relationship-specific processes, major capital and resource commitments on each side of the relationship, shared information such as costs, point-of-sales data and future plans, and shared efficiencies for enhancing end customer value as characteristics of advanced relationships.[240] This entire understanding of collaboration matches well the SCM framework developed in this text. These arguments help justify the positioning of the notion of collaboration at the core of the SCM framework.

Practice leaders report benefits such as inventory reductions, lower operating costs, and potentially profit gains through coordination and collaboration.[241] Basch has stated that collaboration with channel partners is the most effective strategy

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236 See Kilger, Christoph and Boris Reuter: Collaborative planning, in: Stadtler, Hartmut and Christoph Kilger (Eds.): Supply chain management and advanced planning: Concepts, models, software and case studies (2nd ed.), Berlin Heidelberg New York 2002, pp. 226-231.

237 Cf. Hammer: The superefficient company, p. 90.

238 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, p. 495.

239 Cf. Bowersox, Donald J., David J. Closs and Theodore P. Stank: Ten mega-trends that will revolutionize supply chain logistics, in: Journal of Business Logistics, Vol. 21 (2000), No. 2, p. 5.

240 Cf. Neuman, John and Samuels Christopher: Supply chain integration: vision or reality? in: Supply Chain Management: An International Journal, Vol. 1 (1996), No. 2, pp. 7-10.

241 Cf. Poirer, Charles C.: Achieving supply chain connectivity, in: Supply Chain Management Review (2002), November/December, p. 18.

for manufacturers.[242] Still, many companies are unwilling or unable to share sensitive data that could be beneficial for both parties. They protect information in order to sustain a advantageous position.[243] This behavior can be interpreted as a lack of trust. Therefore, trust is considered to be the most critical element of collaboration. It can be a great enabler but also a powerful barrier for collaboration.[244]

The last ingredient of the core SCM model, indeed that component of SCM cooperation, which supplements coordination and collaboration, is integration. Many authors writing about integration seem to enhance its meaning beyond the one intended in the SCM framework developed in this text. This might be due to linguistic reasons, but it is important to clarify those differences.

Hertz, for example, has developed a broad understanding of integration and has defined it as "a process of coordinating activities, resources, and organizations in order to function in concert."[245] Similarly, Kahn and Mentzer have seen integration as bringing parts together into a cohesive organization.[246] Two elements have been identified that bring about integration: interaction and collaboration. Both elements were introduced as separate philosophies and combined as integration. The interaction philosophy emphasizes exchange of information through meetings, phone calls and similar communications. The collaboration philosophy is seen similar to the relationship marketing philosophy in the marketing discipline. Emphasis is laid on strategic alignment through a shared vision, collective goals, and joint rewards, along with an informal structure of managing relationships. It is considered to be an attitudinal approach that does not focus on establishing information linkages, but rather on building an *esprit de corps*. Combined, integration then is viewed as comprising interaction and collaboration activities.[247] Though Kahn and Mentzer have applied their interpretation to an interdepartmental setting, this understanding has also been transferred by others to inter-company relationships.[248]

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242 Cf. Basch, Michael D.: Harness the power of the Internet: A new model for the 21st century., in: Information Executive, Vol. 4 (2000), No. 10, October, pp. 8-9.

243 Cf. Poirer: Achieving supply chain connectivity, p. 18.

244 See also section B.IV. for an extended discussion of supply chain relationships.

245 Hertz: Dynamics of alliances in highly integrated supply chain networks, p. 239.

246 Cf. Kahn, Kenneth B. and John T. Mentzer: Logistics and interdepartmental integration, in: International Journal of Physical Distribution & Logistics Management, Vol. 26 (1996), No. 8, p. 9.

247 Cf. Kahn and Mentzer: Logistics and interdepartmental integration, pp. 7-9.

248 For another interdepartmental usage, cf. Stank, Daugherty and Ellinger: Marketing/logistics integration and firm performance, p. 12. Authors, who expanded this understanding to inter-company relationships are Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, p. 31; and also Lee, Hau

Integration is perceived differently in this text. Coordination and collaboration includes the interaction and collaboration notions described by Kahn and Mentzer as part of their understanding of integration. In contrast, integration should be considered separately with a distinct meaning. This is also more in line with the following definition of the act of integrating: “To make into a whole by bringing all parts together; unify.”[249] According to this, unification of once separate parts is implied. In the overall SCM context, this may only be desired in some areas, in particular in the material and information flows along supply chain processes. Diversity in contrast to homogeneity may be beneficial especially in collaborative efforts, as defined above.[250] Therefore, integration refers mainly to a seamless material and information flow of all members within a supply chain with the objective to maximize competitive advantage.[251]

Schmenner and Swink have referred to this in the context of manufacturing operations as the Theory of Swift, Even Flow. According to this theory, “[…] the more swift and even the flow of materials through a process, the more productive that process is. Thus, productivity for any process “[…] rises with the speed by which materials flow through the process, and it falls with increases in the variability associated with the flow, be that variability associated with the demand on the process or with steps in the process itself.”[252] Though material flows are of relevance,[253] the information flow is not only of crucial importance for coordination and collaboration, but is also seen as key to a seamless supply chain.[254]

In the context of integration, however, the emphasis is not on what, how, or in what kind of relationship information should be shared. Rather, integration aims at facilitating the agreed upon way of coordination and collaboration in the most effective way. Though operational aspects can be derived directly from it, the

L.: Creating value through supply chain integration, in: Supply Chain Management Review (2000), September/ October, pp. 32-36.

249 The American Heritage Dictionary of the English Language.

250 Cf. also section B.I.3.a. for the context in the SCM framework. Especially teams and team-like relationships rely on bringing diverse parts together in order to create new knowledge, cf. Robbins: Organizational behavior, pp. 281-283.

251 Cf. Mason-Jones, R. and D. R. Towill: Information enrichment: designing the supply chain for competitive advantage, in: Supply Chain Management: An International Journal, Vol. 2 (1997), No. 4, p. 137; and Frohlich, Markham T. and Roy Westbrook: Arcs of integration: An international study of supply chain strategies, in: Journal of Operations Management, Vol. 19 (2001), p. 186.

252 Schmenner and Swink: On theory in operations management, p. 102.

253 With regard to material flow and logistics integration, higher efficiency and productivity has been observed, for example see Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, p. 31.

254 Cf. Towill: The seamless supply chain - the predator's strategic advantage, pp. 52-53.

strategic dimension is of relevance as part of SCM cooperation. Strategic relevance for integration is derived by creating better information, which in turn fuels coordination and collaboration.[255] Therefore, not only does the management of key business processes across the supply chain determine success, but so also their integration.[256]

Balancing supply and demand becomes easier the more integrated information flows between customers and suppliers are. Before the diffusion of the Internet and before common IT infrastructures became available, such high integration was infeasible and was achieved only by using regular mail, telephone, and fax, followed by early forms of EDI.[257] Therefore, integration gained in importance through the proliferation of IT and the Internet because real-time information sharing has become feasible.[258] Hertz has noted that the growing connectedness requires a higher degree of standardization, formalization, homogenization, communication, and simplicity of companies in supply chains.[259] Therefore, it is no surprise that Schönsleben has defined integration as "the ability of a comprehensive information system to exchange information."[260] Consequently, section B.III.3. discusses the importance of standardization, IT systems, and e-business for integration in greater detail.

The synergistic nature of coordination, collaboration, and integration is evident in several focused concepts that have recently been promoted and successfully applied. For example, design for logistics (DFL) as a variation of design for manufacturing aims at designing products and packages in a way that minimizes transportation and storage costs.[261] Tracking and tracing of product orders is another development that can be directly linked to the simultaneous and balanced application of the elements of the core SCM model. More industry-specific packages such as ECR and CPFR, as previously mentioned, provide comprehensive guidelines to implement the SCM idea in the retailing industry

255 See Lewis, Ira and Alexander Talalayevsky: Logistics and information technology: A coordination perspective, in: Journal of Business Logistics, Vol. 18 (1997), No. 1, p. 145. About the importance of information, see next section B.II.3.c.

256 See Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 15.

257 Cf. Frohlich, Markham T.: E-integration in the supply chain: Barriers and performance, in: Decision Sciences, Vol. 33 (2002), No. 4, p. 538.

258 Cf. Frohlich and Westbrook: Demand chain management in manufacturing and services: Web-based integration, drivers and performance, p. 731.

259 Cf. Hertz: Dynamics of alliances in highly integrated supply chain networks, p. 240.

260 Schönsleben: Integrales Logistikmanagement: Planung und Steuerung der umfassenden Supply Chain, p. 425.

261 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 215-216. DFL is especially relevant for the material flow.

environment.[262] The idea of fourth party logistics service providers (4PL) was originated by the consulting firm Accenture and extends the functions of present logistics service providers to include planning, management, and process control of entire supply chains.[263]

### 3. *Importance of Information for Coordination, Collaboration and Integration in Supply Chains*

Information is of crucial importance in SCM cooperation because it is present in all three elements of the core SCM model. It can be seen as the "glue" that holds together business structures, processes, and entire supply chains.[264] Some even see information as an independent production factor, in addition to the traditional production factors of material, capital, and human capital.[265] In general, a distinction can be drawn between the volume of information and the richness of information exchanged. In the case of coordination, the amount of information exchanged is generally larger, whereas the information exchanged in collaborative relationships is richer. Evans and Wurster have differentiated between the reach of information and the richness of information. Reach refers to the number of people or companies exchanging information and therefore to connectivity. Richness is characterized by the dimensions bandwidth, customization, and interactivity. Bandwidth refers to the amount of information that can be moved between sender and receiver. Customization differentiates between mass customization and individual conversation. Interactivity determines whether a monologue or a dialogue type of information exchange is conducted.[266]

When information is defined, the most common reference is the one made to the data, information, knowledge, and wisdom (DIKW) hierarchy.[267] According to

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262 For example, cf. Werner: Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling, pp. 120-124.

263 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 295-297.

264 Cf. Sanders, Nada R. and Robert Premus: IT applications in supply chain organizations: A link between competitive priorities and organizational benefits, in: Journal of Business Logistics, Vol. 23 (2002), No. 1, p. 65.

265 See Fulkerson: Information-based manufacturing in the informational age, pp. 131-132. For traditional production factors, see for example Wöhe, Günter and Ulrich Döring: Einführung in die allgemeine Betriebswirtschaftslehre, 22nd ed., München 2005, p. 46.

266 Cf. Evans, Philip B. and Thomas S. Wurster: Strategy and the new economics of information, in: Harvard Business Review, Vol. 75 (1997), September/October, p. 73.

267 Tracing back the origins of the DIKW hierarchy, Sharma concludes that though the DIKW hierarchy is used in many research fields, these references fail to trace it back to its origins. As the ultimate source, Sharma identified Cleveland, Harland: Information

the DIKW hierarchy, the lowest level of content is represented by data. Information is produced by putting data in context. As Duè remarked: “Data, by itself, has little value. Data must be turned into information by being organized, modeled, formatted, edited, verified, placed in context, and delivered in a timely manner to decision makers before it takes on value.”[268] Davenport and Prusak have suggested the “five Cs” as methods to transform data into information. According to this, data has to be (1) contextualized, (2) categorized, (3) calculated, (4) corrected, and/or (5) condensed in order to become information.[269]

Knowledge represents the next level in the DIKW hierarchy. In order to aquire knowledge, information has to be transformed or applied for a purpose. Knowledge can be seen as a set of justified true beliefs.[270] Nonaka has pointed out the importance of information in the knowledge creation process: “Information is a necessary medium or material for initiating and formalizing knowledge […].”[271] A distinction can be drawn between explicit knowledge and tacit knowledge. Explicit knowledge can be communicated in formal, systematic language whereas tacit knowledge is more personal and is deeply rooted in action, commitment, and involvement in a specific context. Tacit knowledge is thus much harder to share with others. This sharing with others is of crucial importance in order to make knowledge accessible for organizations. Though knowledge cannot be created without individuals, their ability to create new knowledge can be supported and enhanced by organizations.[272] Organizational learning theory is based on this realization and suggests that the result of organizational learning is more than the sum of each member’s knowledge. In addition, it is believed that organizations can learn independently from their members and store this knowledge in

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as resource, in: The Futurist (1982), December, pp. 34-39, who makes reference to a 1934 poem by T.S. Eliot that was then expanded by Cleveland to form the DIKW hierarchy. Expansions of the hierarchy were for example the addition of the level understanding between knowledge and wisdom by Ackoff, R. L.: From data to wisdom, in: Journal of Applied Systems Analysis, Vol. 16 (1989), pp. 3-9 or the addition of enlightenment as sort of a meta-learning level on top of wisdom by Zeleny, M.: Management support systems: Towards integrated knowledge management, in: Human Systems Management, Vol. 7 (1987), No. 1. See Sharma, Nikhil: The origin of the DIKW hierarchy, 2005, http://www-personal.si.umich.edu/~nsharma/dikw_origin.htm, retrieved on: February 15, 2006 for an overview.

268 Cf. Duè, Richard T.: The value of information, in: Information Systems Management, Vol. 13 (1996), No. 1, Winter, p. 68.

269 Cf. Davenport, Thomas H. and Laurence Prusak: Working knowledge: How organizations manage what they know, Boston, MA 1998, p. 4.

270 Cf. Nonaka, Ikujiro: A dynamic theory of organizational knowledge creation, in: Organization Science, Vol. 5 (1994), No. 1, February, p. 15.

271 Nonaka: A dynamic theory of organizational knowledge creation, p. 16.

272 Cf. Nonaka: A dynamic theory of organizational knowledge creation, pp. 16-17.

nonhuman repositories that are evident as strategies, structures, systems, culture, and routines.[273]

On top of knowledge, wisdom refers to the understanding of the underlying principles and theories that explain why the applied knowledge works and completes the DIKW hierarchy. This classic DIKW hierarchy has been altered and expanded by several authors, but the basic principle prevails. The boundaries between the levels are rather vague and the point at which data turns into information can be considered to be a philosophical one.[274]

Information and its use is potentially the most important determinant of successful SCM as it directly influences all aspects of the SCM framework. Moberg et al. have found in their research and literature review that information flow facility structure was the only component to be identified on virtually every occasion of common SCM components.[275] Though information has always been a key aspect of management, developments in information processing and exploration technology increased the importance of information management for SCM.[276] As illustrated before, integrated and coordinated decisions in supply chain networks require a free flow of relevant information.[277]

Acknowledging the importance of information for SCM raises the question of how important it is. Many researchers have tried to capture the value of information by different methods. In order to determine the value of information, Li et al. have examined twelve representative models. Based on their comparative analysis they conclude that information sharing has value for SCM, but also that it may not be the only way to achieve optimal performance. In general, suppliers gain higher profits than retailers by sharing information. In terms of relevant factors influencing the value of information sharing, they conclude that it is highly dependent on the specific supply chain situation.[278] Cachon and Fisher and

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273 See Sabherwal, Rajiv and Sanjiv Sabherwal: Knowledge management using information technology: Determinants of short-term impact on firm value, in: Decision Sciences, Vol. 36 (2005), No. 4, December, pp. 533-536. For one of the first comprehensive books on the learning organization, see Senge, Peter M.: The fifth discipline, New York 1990.

274 Cf. Davenport: Process innovation, p. 71.

275 Cf. Moberg, Christopher R. *et al.*: Do the management components of supply chain management affect logistics performance? in: The International Journal of Logistics Management, Vol. 15 (2004), No. 2, p. 17.

276 Cf. Johnson, M. Eric and Seungjin Whang: E-business and supply chain management: An overview and framework, in: Production and Operations Management, Vol. 11 (2002), No. 4, p. 413.

277 Cf. Vakharia: E-business and supply chain management, p. 497.

278 Cf. Li, Gang *et al.*: Comparative analysis on value of information sharing in supply chains, in: Supply Chain Management: An International Journal, Vol. 10 (2005), No. 1,

Robinson, Sahin, and Gao have also provided an extensive literature review of a variety of models that investigate the impact of information sharing on performance in different settings. Again, depending on the specific settings, benefits vary, but in almost all models, information sharing improves supply chain cost performance directly or indirectly between 0% and 35%.[279]

Cachon and Fisher have also developed their own, distinct model. Their finding is that a quicker and more even flow of goods through the supply chain is more beneficial than information sharing.[280] Achieving a quicker and more even flow of goods requires at least improved information processing capabilities and therefore information sharing also influences that indirectly. It is also acknowledged that in an environment with higher demand uncertainty, the value of information sharing may increase.[281] Despite the proven impact of information sharing, Lee and Whang have pointed out that information sharing is only an enabler for better coordination and planning of the supply chain. Accordingly, companies must develop capabilities to make use of information.[282]

As for what information should be shared, it is clear that processes that span several companies can only be optimized if all information relevant to these processes is available to all companies involved. Typically, the following types of information are of relevance:[283]

– *Inventory level*. This includes all kinds of inventory, such as material, work in progress, finished goods, and goods in transit.

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pp. 42-44. This conclusion also underscores the importance of a contingency approach, as proposed on the normative level of the SCM framework.

279 Cf. Cachon, Gérard P. and Marshall Fisher: Supply chain inventory management and the value of shared information, in: Management Science, Vol. 46 (2000), No. 8, p. 1034; and Robinson Jr., E. Powell, Funda Sahin and Li-Lian Gao: The impact of e-replenishment strategy on make-to-order supply chain performance, in: Decision Sciences, Vol. 36 (2005), No. 2, p. 37.

280 Cf. Cachon and Fisher: Supply chain inventory management and the value of shared information, p. 1046. This supports the Theory of Swift, Even Flow postulated by Schmenner and Swink: On theory in operations management, pp. 102-103.

281 See Cachon and Fisher: Supply chain inventory management and the value of shared information, p. 1046.

282 Cf. Lee and Whang: Information sharing in a supply chain, p. 386.

283 According to Lee and Whang, cf. Lee and Whang: Information sharing in a supply chain, pp. 375-381.

- *Sales data*. Ultimate sales data lessen the negative effects of distorted demand information, as shown for example in the beer game[284], when simulated with visible end consumer demand.
- *Sales forecast*. Since companies adapt their plans to their forecasts, it is important to share these expectations. If sales data are shared, every company in the supply chain could do their forecasts based on ultimate sales data. However, different methods might lead to differing results.
- *Order status for tracking and tracing*. This supports mainly customer service and reduces uncertainty in the supply chain and for the ultimate customer.
- *Production and delivery schedules*. The different tiers in a supply chain can align their operations to support the whole process if production and delivery schedules are shared, as is the case for just-in-time relationships.
- *Capacity*. Sharing capacity information, especially production and transportation capacities, can mitigate shortage and gaming behavior and supports supply chain planning.
- *Performance metrics*. This includes all performance metrics that are relevant for the whole process under consideration. Examples are quality data, lead times, queuing delays, and service performance, to name a few.

In addition to the points listed, cost accounting figures are also of high relevance. Information about selling price, salvage value, variable production cost, and fixed production cost, for example, are important to complete the informational foundation necessary for optimal decisions. However, this kind of information is highly sensitive and reservations about sharing it do exist. The benefits of such shared information are undisputed and all information mentioned before could be used in highly integrated and aligned organizations for better decisions. Nevertheless, there are obstacles that prevent companies from sharing such information. This is mainly based on the prevailing belief that information represents power and sharing it would lead to a loss of power and threaten the sharer's position in the supply chain. Traditionally, relevant information has been a substantial source of strategic advantage, which is in line with economic theory, where a monopolistic or monopsonistic position promises to retain all profits.[285] Profits associated with superior information are often referred to as informational

[284] See Sterman: Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment, pp. 321-339.

[285] Cf. Kahl and Berquist: A primer on the internet supply chain, p. 48; and Lee and Whang: Information sharing in a supply chain, p. 385.

rent.[286] In such a constellation, however, available and retrievable information can only be exploited, but not properly leveraged.[287] This is a major challenge for supply chains and is therefore discussed in greater detail as part of section B.IV.

Another aspect of information sharing is the quality of shared information. Quality in general has many dimensions and its meaning depends highly on the context. One widely accepted definition of quality is provided by the International Organization of Standardization (ISO). They define quality as the degree to which a set of inherent features of a product or service fulfills customer requirements.[288] In the context of SCM, quality can be interpreted as the fulfillment of customer requirements in terms of physical-functional specifications of products or in terms of an expected outcome of processes.[289] Quality of information in supply chains can be interpreted similarly. In contrast to the customer orientation of entire supply chains, all supply chain members who rely on information are addressees, and therefore customers, of information. Therefore, quality of information must be defined according to how the information is perceived and used by each supply chain member separately.[290] Miller has presented ten dimensions of information quality that characterize the overall quality of information:[291]

- *Relevance*. The information addressee's needs define the relevance of information. This does not mean that irrelevant information is of poor quality *per se*, but in the wrong context, it might be irrelevant.
- *Accuracy*. Information should reflect the underlying reality. Problems may arise when information becomes too accurate for its purpose and lead to an information overload.
- *Timeliness*. In contrast, information can rarely be too timely. Stalk and Hout note that as information ages, it loses value. With time as an

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286 Cf. Lee and Whang: Information sharing in a supply chain, p. 385. For a game theoretical consideration of informational rents, see Fudenberg, Drew and Jean Tirole: Understanding rent dissipation: On the use of game theory in industrial organization, in: The American Economic Review, Vol. 77 (1987), No. 2, May, pp. 179-182.

287 Cf. Bowersox, Closs and Stank: Ten mega-trends that will revolutionize supply chain logistics, p. 10.

288 Cf. n.a.: International Organization of Standardization, section ISO 9000, introduction, understanding the basics.

289 See Heringer, Crispin: Qualitätsmanagement, in: Wannenwetsch, Helmut H. (Ed.): Vernetztes Supply Chain Management, Berlin Heidelberg New York 2005, p. 363.

290 Cf. Miller, Holmes: The multiple dimensions of information quality, in: Information Systems Management, Vol. 13 (1996), No. 2, Spring, p. 79.

291 Cf. Miller: The multiple dimensions of information quality, pp. 79-81.

increasingly important competitive factor, the importance of fresh and up-to-date information increases too.[292]

- *Completeness*. Completeness of information has to be seen in light of its context.
- *Coherence*. Though a separate dimension, it heavily relies on accuracy and/or timeliness. When information is incoherent, it usually is inaccurate and/or already too old.
- *Format*. The underlying form refers to the way information is presented.
- *Accessibility*. With increasing accessibility, the quality of information increases as well. Information that can not be obtained when needed is of very limited value. Accessibility is strongly associated with timeliness of information.
- *Compatibility*. This refers to how well information can be processed with tools and combined with other information.
- *Security*. Security can be divided into logical security, which refers to fraud protection, and disaster recovery, which refers to natural disasters and facility failure.
- *Validity*. Information is valid when its truth can be verified and it satisfies appropriate standards related to the other dimensions.

Gosain, Malhotra, and El Sawy have confirmed the importance of the above mentioned dimensions and point out that quality of information even gains in importance because manual filtering might disappear more and more. Although automated information processing prevents manual mistakes, it also makes the process less transparent and therefore, wrong information or information of low value might be generated if the information input is already of bad quality and not properly checked.[293]

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[292] Cf. Stalk and Hout: Competing against time, p. 238.

[293] See Gosain, Sanjay, Arvind Malhotra and Omar A. El Sawy: Coordinating for flexibility in e-business supply chains, in: Journal of Management Information Systems, Vol. 21 (2004), No. 3, Winter, pp. 31-32.

## III. Holistic View of Supply Chain Management

### *1. Role of Strategic Fit in Supply Chains*

In the context of supply chains, Fisher's contribution has often been cited as the foundation of strategic fit between product characteristics and supply chain characteristics.[294] The importance of matching the two dimensions is widely accepted. Essentially, Fisher's model states that in cases of uncertain demand, a supply chain should be designed in a responsive manner whereas stable demand indicates a more efficient approach.[295] This is translated into the distinction between innovative products for an uncertain environment characterized by shorter product life-cycles and functional products for a more stable environment with longer product life cycles. The underlying dimensions are unpredictable, uncertain demand versus stable, predictable demand.[296] The underlying concept of strategic fit can be traced back to Skinner's contribution on manufacturing and strategy.[297]

With regard to the manufacturing function, Skinner has made important remarks on several strategic shortcomings that can be applied not only to the manufacturing function but also to the current discussion on SCM. For a better understanding, it is useful to review Skinner's work more explicitly and more thoroughly.

One of Skinner's key observations has been the shortsighted view of managers to confuse productivity with competitiveness. The criticism was that manufacturing was expected to be efficient without specifying what is actually meant by efficiency. A tendency to define efficiency as low costs can cause the manufacturing functions to be misaligned with the overall strategic position.[298] The same can be said for SCM. Many still consider SCM to be an operational logistics concept, disregarding the greater significance of "real", holistic SCM.[299] Efficiency has to be seen relative to the strategic position, in line with Skinner's notion. Skinner has identified the following factors that lead to such misaligned

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[294] Cf. Fisher, Marshall L.: What is the right supply chain for your product? in: Harvard Business Review, Vol. 75 (1997), March-April, pp. 105-116.

[295] Cf. Fisher: What is the right supply chain for your product?, p. 109.

[296] Cf. Fisher: What is the right supply chain for your product?, pp. 106-109. It should be noted that long product life-cycles are not necessarily more stable, but they tend to.

[297] Cf. Hayes and Pisano: Beyond world-class: The new manufacturing strategy, p. 80; and Skinner, Wickham: Manufacturing - missing link in corporate strategy, in: Harvard Business Review, Vol. 47 (1969), May/June, pp. 136-137.

[298] Cf. Skinner: Manufacturing - missing link in corporate strategy, pp. 136-140.

[299] What is referred to as "real" SCM is the SCM framework identified in this text. It especially refers to the potential the holistic approach holds.

behavior: (1) personal inadequacy of managers and personnel in the function, and (2) lack of awareness of trade-offs and compromises.[300]

The first factor is especially relevant for SCM because the complexity to cope with in SCM is orders of magnitude larger than that of individual functions. The necessity of trade-offs is in line with subsequent work that has taken up this issue and developed it further, such as done by Porter.[301] Skinner has used an illustrative example to point this law of trade-offs out. Even almost forty years after Skinner has made this comparison, it is not possible to land a 500 passenger airplane on a carrier and break the sonic barrier, though each task in itself has been achieved by now.[302] There is no viable reason for which this law of trade-offs should not hold true for SCM.[303] Simchi-Levi, Kaminsky, and Simchi-Levi have identified five exemplary trade-offs: (1) lot-size vs. inventory, (2) inventory vs. transportation costs, (3) lead-time vs. transportation costs, (4) product variety vs. inventory, and (5) cost vs. customer service.[304] It follows that if a product or service is to compete on a certain set of characteristics, the supply chain is to be aligned so that it supports this set of characteristics in the best way achievable.[305] Effectiveness then relates to the achieved performance that is relevant for sustainable success, i.e. market position, and efficiency to operational effectiveness.[306]

Recognizing Porter's view of strategic fit and the existence of trade-offs, Chopra and Van Mieghem remarked: "The goal is to create a fit between the desired strategic position and the supply chain capabilities and processes used to satisfy customer needs and priorities."[307] The decision-making process follows a hierarchy that originates from strategic choices subject to capabilities at hand. In this sense, the possibilities suggested by the SCM framework extend those capabilities and provide a variety of choices for positioning a strategy. As generic determinants for the supply chain strategy, Fisher's dimensions may build the foundation.[308] Others have adopted and adjusted it later on. Chopra and Meindl,

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300 Cf. Skinner: Manufacturing - missing link in corporate strategy, p. 138.

301 Cf. Porter: What is strategy?, pp. 68-70.

302 This remark refers to an example provided by Skinner, see Skinner: Manufacturing - missing link in corporate strategy, p. 140.

303 Cf. Schmenner and Swink: On theory in operations management, pp. 106-107 for the notion on the law of trade-offs.

304 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 113-116.

305 The set of characteristics for competition consists of those perceived relevant by the customer, such as product-specific characteristics, price, distribution channels, and advertising, to name a few.

306 Cf. Porter: What is strategy?, pp. 61-64.

307 Chopra and Van Mieghem: Which e-business is right for your supply chain?, pp. 32-33. For a more detailed discussion of strategic fit, see Porter: What is strategy?, pp. 70-75.

308 Cf. Fisher: What is the right supply chain for your product?, pp. 107-108.

for example, have simply replaced functional and innovative products all together with the underlying demand uncertainty. The greater the demand uncertainty the more responsive the supply chain should be.[309] Based on this, Chopra and Meindl have noted that there indeed exists a right supply chain strategy for a given corporate strategy.[310] Moreover, they see a leverage of this idea by extending it to supply chain fit. Misalignments between companies are even more likely as organizations differ in their cultures. Therefore, achieving inter-company and inter-functional strategic fit is seen to lead to an overall more competitive supply chain.[311] Furthermore, as complexity increases drastically compared to a company-internal scope, such a constellation is much more sustainable as it is even harder to imitate.[312]

Instead of using the terms efficient supply chain and responsive supply chain, the terms agile and lean are preferred by several authors. In cases of long lead times and predictable demand, a lean supply chain setting is suggested by Christopher. In case of short lead times and unpredictable demand, an agile supply chain is indicated. In contrast to Fisher, Christopher considers the combination of unpredictable demand and long lead times as well as predictable demand with short lead times not necessarily as a mismatch. For an unpredictable demand with long lead times in the supply chain, a hybrid strategy is suggested that makes use of postponement. For a predictable demand environment with short lead times in the supply chain, a continuous replenishment strategy is suggested. These strategy suggestions make sense when there is little chance to influence lead times.[313]

Another variation is provided by Simchi-Levi, Kaminsky, and Simchi-Levi. Their generic supply chain strategies also share the notion of demand uncertainty. In supply chain characteristics, they have differentiated between pull systems and push systems.[314] Push systems rely on forecasts – that is why they are also sometimes called speculative processes[315] – and make use of economies of scale in order to achieve a cost efficient production or fulfillment. Therefore, they are related to an efficient supply chain. Pull systems, on the other hand, rely on short

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309 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 38.

310 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 40.

311 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 46-48.

312 Cf. Porter: What is strategy?, pp. 73-75.

313 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 117-119.

314 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 121-125.

315 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p 8. and p. 14.

lead times and hold little inventory. Therefore, they cannot make use of economies of scale and the planning horizon is relatively short. This is why pull systems are also called reactive systems.[316] In case of high demand uncertainty and low economies of scale, a pure pull strategy is indicated, which is similar to Christopher's agile supply chain. In case of low demand uncertainty and high economies of scale, a pure push-strategy is suggested, which relates to Christopher's lean supply chain.

Simchi-Levi, Kaminsky, and Simchi-Levi have been more cautious with their indications. In case of low demand uncertainty and low economies of scale, they suggest a push-pull strategy, requiring a decoupling point. The decoupling point can be seen as the point where the customer-facing part of a supply chain is separated from that part of the supply chain that is based on planning.[317] Therefore, inventory often buffers the fluctuating demand in order to smooth operations. Christopher has referred to this buffer inventory as "strategic inventory".[318] Furthermore, the two distinct supply chain parts coordinate at this point and exchange demand forecasts. The historical data used for a forecast is provided by the pull section and determines the supply chain planning process and buffer inventory.[319] If high demand uncertainty and high economies of scale are indicated, they have suggested a pull-push strategy, essentially turning the push-pull strategy around. Again, a decoupling point between these two different types of supply chains is required.[320]

The concept of postponement aims to increase the portion of the supply chain that operates in a pull mode.[321] The lean paradigm can be applied upstream from the decoupling point in the supply chain and downstream from the decoupling point, the agile paradigm is indicated. Consequently, the position of the decoupling point depends upon the longest lead time customers are willing to accept.[322]

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316 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 8 and p. 14.

317 Cf. Naylor, Ben J., Mohamed M. Naim and Danny Berry: Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain, in: International Journal of Production Economics, Vol. 62 (1999), p. 112.

318 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 119-121.

319 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 126-127.

320 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 124-125.

321 Cf. Chopra and Van Mieghem: Which e-business is right for your supply chain?, p. 35.

322 Cf. Naylor, Naim and Berry: Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain, pp. 112-115.

Although both paradigms are fundamentally different, efficient and responsive supply chains still share similarities. Both emphasize the use of market knowledge, benefit from integration, and highlight the importance of lead time compression, however, for different reasons. In a lean supply chain, lead time compression is an attempt to eliminate waste, whereas in a responsive supply chain the goal is to improve responsiveness.[323] Despite these similarities, fundamental differences include different objectives (minimizing cost vs. maximizing service level), complexity (high vs. low), focus (resource allocation vs. responsiveness), or lead time (short vs. long).[324]

This has motivated the positioning of strategic management decisions outside the core SCM model as depicted in *Figure B-6* in section B.I.3.c. The core elements of coordination, collaboration and integration are dependent on the strategic position of the supply chain.[325] This strategic position is determined by the appropriate competitive priorities, the supply chain structure, and the specific SCM processes.[326] Only after decisions in these areas are made – under consideration of the SCM framework and the potential it provides – that the remaining aspects of the SCM framework can be aligned and matched.

## 2. *Processes and Structures in Supply Chains*

### 2.a. Adopting a Process View of Supply Chain Operations

One of the core principles of SCM is that of looking at a system – the supply chain – in a systemic and holistic way. Thus, not only individual elements are monitored, managed and optimized, but an entire system of elements, i.e. companies and strategic business units. All companies of a supply chain network are connected by at least one of the three flows consisting of information, material, and financials; mostly by all three. These flows are essentially already processes, though in a very unspecified form. More importantly, internal processes are linked across supply chains through these three flows. Consequently, internal business processes become supply chain business processes.[327]

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323 Cf. Naylor, Naim and Berry: Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain, pp. 109-110.

324 See for example Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, p. 127 or Krajewski and Ritzman: Operations management, pp. 420-422.

325 Supply chain and not company it is, because different supply chains can exist in one company. This issue will be picked up in section B.IV.1.

326 The optimal supply chain structure also depends on competitive priorities, but often is harder to change, i.e. it is often reflected as industry structures.

327 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 2.

A process can be defined as a specific ordering of work activities across time and place, with a beginning, an end, and clearly defined inputs and outputs.[328] In that sense, a set of activities are taken together for a specific purpose and form a process.[329] Since focus lies on the outcome, the customer orientation is explicitly taken into account.[330] This view is prerequisite for a systematic process analysis, process improvement, and process reengineering.

It has been pointed out before that business processes are of particular strategic importance. Innovations in business processes outlast product innovations because they are much less transparent and more complex and therefore harder to imitate.[331] And even if individual processes are copied by competitors, it is much harder to match processes that involve several business partners.[332] That processes are considered to be strategic assets is visible in the fact that companies protect business processes through patents, with Amazon.com being one of the first to do so for their One-Click ordering process.[333] Building an organization around functions creates unnecessary time delays and buffer inventory, which are then necessary at the interfaces, especially along supply chains. In order to avoid such inefficiencies, a process-oriented organization is suggested by many.[334] This does not mean that functions are not important. Functional expertise is still needed along the business processes. It serves as a valuable input for process designs and execution.

The significance of business processes has been prominently promoted by Hammer and Champy's concept of business process reengineering.[335] In an update

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328 Cf. Davenport: Process innovation, p. 5.

329 Cf. Ittner, Christopher D. and David F. Larcker: The performance effects of process management techniques, in: Management Science, Vol. 43 (1997), No. 4, April, p. 523.

330 Cf. McCormack, Kevin and Bill Johnson: Business process orientation, supply chain management, and the e-corporation, in: IIE Solutions (2001), October, p. 34.

331 Cf. for example Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, p. 90. In fact, Kuhn and Hellingrath put special emphasis on business processes in their view of SCM, cf. Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, p. 101.

332 Cf. McCormack and Johnson: Business process orientation, supply chain management, and the e-corporation, p. 37.

333 Cf. McCormack and Johnson: Business process orientation, supply chain management, and the e-corporation, p. 33.

334 Cf. Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 177-178.

335 See Hammer, Michael: Reengineering work: Don't automate, obliterate, in: Harvard Business Review, Vol. 68 (1990), July/August.

to their seminal work, Hammer has stated: “Streamlining inter-company processes isn’t just an interesting idea: it’s the next frontier of efficiency.”[336]

Process management, however, goes beyond efficiency. Processes are also important for the strategic differentiation between push systems and pull systems, i.e. an efficient supply chain setup and a responsive supply chain setup. Consequently, the nature of the processes supporting each of the two can be distinguished as (1) push processes for efficient supply chains, and (2) pull processes for responsive supply chains. Push processes are designed so that an actual customer order triggers the process, and pull processes are designed in anticipation of customer orders.[337]

Although authors have defined SCM processes in different ways, they are not fundamentally different from what *Figure B-8* shows. They all have in common the basic understanding of a holistic process management approach in line with the overall SCM concept. In addition, they all point out the need for inter-company cooperation as all processes exceed one company’s boundaries. In terms of detailed process definitions, the SCOR model stands out. Because of its increasing acceptance in and significance for supply chains, it is described in more detail in the following section.

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[336] Cf. Hammer: The superefficient company, p. 91.

[337] Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 8 and p. 14.

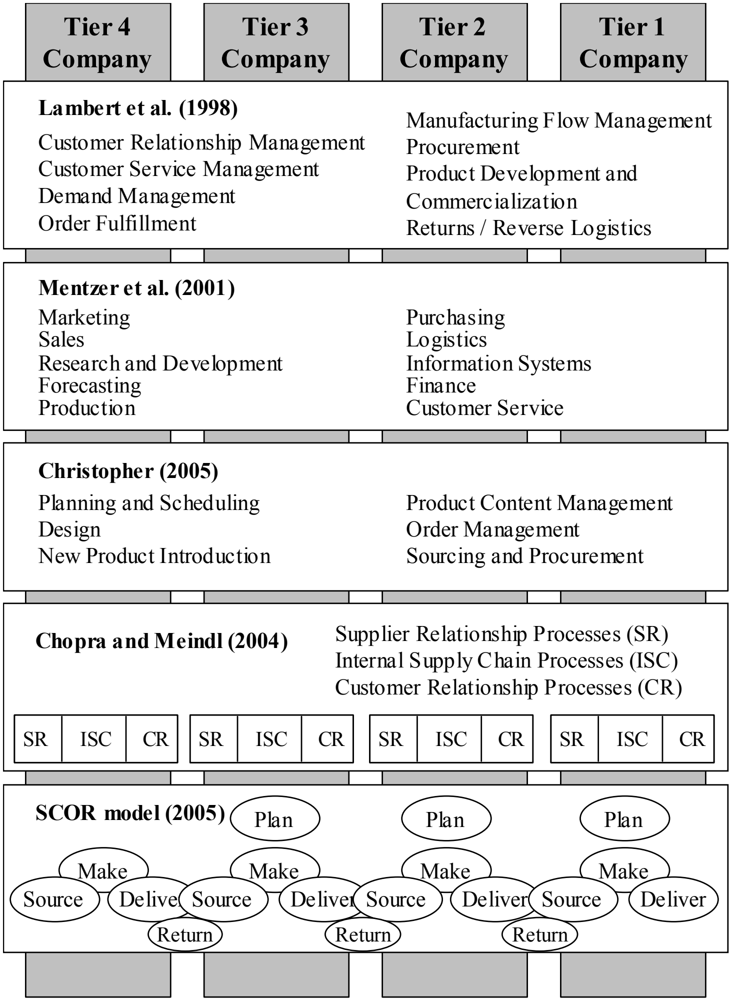


*Figure B-8: Different views on SCM processes*[338]

[338] These process categories can be found in Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 8-9, Mentzer *et al.*: Defining supply chain management, Christopher: Logistics and supply chain management: Creating value-adding networks, pp. 177-178, Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 17, and n.a.: Supply chain operations reference model version 7.0, 2005, p. 2.

## 2.b. Connecting Supply Chain Management Processes with the Supply Chain Operations Reference (SCOR) Model

Since supply chain business processes cross business unit and company boundaries, it is necessary to connect those processes as seamlessly as possible. In order to achieve this, a standardized process model is needed to avoid misunderstandings and interface problems. Therefore, in 1996, the Supply Chain Council (SCC) was organized by the consulting company Pittiglio Rabin Todd & McGrath (PRTM) and AMR Research and initially included 69 voluntary practitioner companies that met in an informal consortium. Then, as an independent, not-for-profit, global corporation, the SCC started to develop the SCOR model.[339] Today, the SCC has more than 800 members and maintains chapters worldwide. Membership is open not only to companies, but also to other organizations and institutions, including universities. The following descriptions are all based on documents, releases, presentations, and announcements issued by the SCC and the original SCOR model description in version 7.0.[340]

As a process-reference model, SCOR integrates the ideas of business process reengineering, benchmarking, and process measurement into one cross-functional framework. It contains standard descriptions of management processes, a framework of relationships among the standard processes, standard metrics to measure process performance, management practices that produce best-in-class performance, and standard alignment to features and functionality. The benefit of such a reference model is that it can be implemented purposefully, described unambiguously and communicated, managed, and revised to specific purposes.

Since SCOR can also be characterized as a total supply chain process model, it includes all customer interactions, all product transactions from the supplier's supplier to the customer's customer, and all market interactions from demand understanding to order fulfillment. It is suitable for narrow supply chains within one facility and also for more complex supply chains that span several tiers, as illustrated in the SCOR model overview in *Figure B-8*. It explicitly excludes, however, processes from the areas of sales and marketing, research and technology development, product development, and elements of post-delivery customer support. Issues of training, quality, information technology, and non-SCM administration are not explicitly addressed, but implicitly considered.

The SCOR model is structured hierarchically in four levels, with the first three levels being part of the SCOR model and the fourth level (and lower levels) being outside its scope. *Table B-4* provides an overview of the SCOR model structure.

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[339] In its ninth revision, the latest version 7.0 was officially introduced in April 2005.

[340] Cf. n.a.: Supply Chain Council, Inc.: http://www.supply-chain.org, 2005, retrieved on: February 15, 2006; and n.a.: Supply chain operations reference model version 7.0 for more detailed information. The following descriptions of the SCOR model are collected from various sources, all issued by the SCC, if not stated otherwise.

*Table B-4: Hierarchical structure of the SCOR model*

| **Level** | | **Processes** |
|---|---|---|
| 1 | Process Type (Top Level) | 5 Process Types: Plan, Source, Make, Deliver, Return (Enable) |
| 2 | Process Categories (Configuration Level) | 30 Process Categories: Plan (5 categories), Source (3 categories), Make (3 categories), Deliver (4 categories), Return (6 categories), Enable (9 categories) |
| 3 | Decompose Processes (Process Element Level) | Each of the 30 process categories is divided further into process elements (subcategories). Each process element is documented in detail in the SCOR model. |
| 4 | Decompose Process Elements (Implementation Level) | Undefined, company-specific. |

On level one, five process types define the scope and content of the SCOR model, i.e. the major management process types *plan*, *source*, *make*, *deliver*, and *return*. The *enable* process as a sixth one is generally excluded because it serves as an enabling process for the five other management processes *plan*, *source*, *make*, *deliver*, and *return*. As such, it only exists in conjunction with these five. The five core management processes are characterized by planning, executing, and enabling. *Plan* processes have the purpose of aligning expected resources to meet expected demand requirements. Execution processes – *source*, *make*, *deliver*, *return* – are triggered by planned demand or actual demand and change the state of material goods. These processes generally involve scheduling, product transformation, and transportation. *Enabling* processes prepare, maintain, or manage information or relationships, upon which the planning and execution processes rely.

Level two splits the process types into process categories. A company's supply chain can be configured based on 30 process categories.[341] *Figure B-9* provides an overview.

[341] Note that though the *enable* process has nine basic process categories, these change in content for each process type, essentially resulting in five times nine process categories.

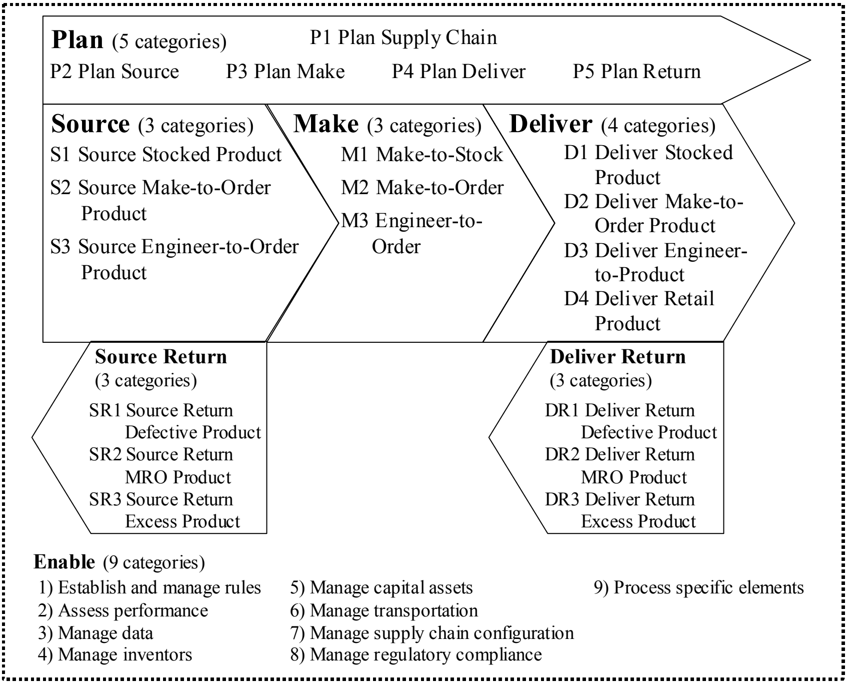


*Figure B-9: Overview of all SCOR process categories, according to the SCOR model*

On level three, process categories are further divided into process elements. Here, each process element is described and defined in detail. The definition includes the linkage to performance attributes, best practices for each process element, if identified, and inputs and outputs of the process element. All in all, the SCOR model in version 7.0 carries 177 process elements.

The following five performance attributes are identified by the SCOR model: (1) reliability, (2) responsiveness, (3) flexibility, (4) costs, and (5) assets. The performance attributes are defined as follows:[342]

– *Supply chain reliability*. The performance of the supply chain in delivering the correct product to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.
– *Supply chain responsiveness*. The speed at which a supply chain provides products to the customer.

[342] n.a.: Supply chain operations reference model version 7.0, p. 7.

- *Supply chain flexibility*. The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.
- *Supply chain costs*: The costs associated with operating the supply chain.
- *Supply chain asset management*. The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.

Performance attributes are organized hierarchically; therefore performance metrics identified in process elements are linked to these top level performance attributes. The SCOR model defines 144 performance metrics in total and includes even more with the process element descriptions. They are all linked to one of the five performance attributes described above. This is similar to existing hierarchical performance systems such as the DuPont system or the strategic Balanced Scorecard cause-and-effect map.[343]

Since the SCOR model aims to be independent from specific industries, no processes beyond the third level are defined. Instead, companies can implement their own management practices and processes. In fact, the operational implementation only takes place on level four and below. Managerial implementation of the SCOR model, however, takes place from level one to level three. In order to document processes on the lower levels, classical process decomposition is used. It is also explicitly pointed out by the SCOR model that competitive advantages by means of business processes are achieved on the operational implementation levels, i.e. level four and below.

The SCOR model provides several benefits. Especially attractive are the standardized processes of the model that enable a common language between supply chain partners. This ensures a better compatibility and the realization of synergies within partner nets.[344] The standardized process elements also provide a framework of relationships between the processes.[345] This is supported by Gosain, Malhotra, and El Sawy's call for business standards: "These standards need to be

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343 For the DuPont system of analysis, see for example Gitman, Lawrence J.: Principles of managerial finance, 11th ed., Boston 2006, pp. 75-77; and Kaplan, Robert S. and David P. Norton: Linking the balanced scorecard to strategy, in: California Management Review, Vol. 39 (1996), No. 1, p. 71.

344 Cf. Werner: Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling, pp. 26-27; Huan, Samuel H., Sunil K. Sheoran and Ge Wang: A review and analysis of supply chain operations reference (SCOR) model, in: Supply Chain Management: An International Journal, Vol. 9 (2004), No. 1, p. 24; and Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, p. 108.

345 Cf. Huan, Sheoran and Wang: A review and analysis of supply chain operations reference (SCOR) model, p. 24.

not merely technical but should include support for business rules, contracts, procedures for dispute resolution, and so on."[346]

Another benefit of the model is that implementation of the SCOR processes in a company forces that company to deal with its current practices and therefore also provides a framework for process reengineering initiatives.[347] In addition, the comprehensive set of performance metrics and the model's broad and growing acceptance are seen as benefits of the SCOR model.[348]

Despite the benefits the SCOR model provides, some critical remarks and shortcomings should be considered. Werner identifies four disadvantages of the SCOR model:[349]

- High level of abstraction.
- Requires a certain degree of continuity.
- Increases dependencies among supply chain partners.
- Close relationships lead to the revelation of sensitive information and the loss of know-how.

Besides Werner's criticism about the high level of abstraction, the identified concerns are not unique to the SCOR model but rather apply to any kind of close supply chain relationship. Furthermore, the observation that the level of abstraction is too high can also be questioned because the process elements defined in the SCOR model do provide a certain degree of detail, especially in conjunction with the process and performance metric definitions and best practice descriptions.

A more common concern is that the standardization of business processes might lead to competitive disadvantages. As such, business processes become the norm and companies have a harder time distinguishing themselves from the competition.[350] This is certainly a valid remark. The SCOR model, however, explicitly recognizes this concern by pointing out that companies should seek competitive advantages on the implementation levels of the SCOR model, i.e. the

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346 Gosain, Malhotra and El Sawy: Coordinating for flexibility in e-business supply chains, p. 33.

347 Cf. Werner: Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling, pp. 26-27.

348 Cf. Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, pp. 108-109.

349 Cf. Werner: Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling, pp. 26-27.

350 Cf. Göpfert: Einführung, Abgrenzung und Weiterentwicklung des Supply Chain Managements , p. 39.

levels where the SCOR model does not define processes. At these levels, management and business processes are company-specific and supply chain-specific. The question remains whether this is sufficient to provide a competitive advantage or if such competitive advantages can only be achieved on higher levels in the hierarchy.

Meyr, Rohde, and Stadtler have suggested a more detailed typology on the second process level, the process category level. They distinguish between functional attributes (procurement type, production type, distribution type, sales type) and structural attributes (topography of a supply chain, integration and coordination).[351] These are important remarks because they point out an important limitation of the SCOR model. It assumes that the supply chain and its members are known. No guidance is provided with regard to the definition of the overall supply chain network structure or its identification. Therefore, the structural attributes are neglected.

This leads to another observation. The SCOR model is a comprehensive operations model. It mainly supports operational processes. By explicitly leaving out issues of sales and marketing, and thus demand management, technology development, and product and process design, important aspects that are of high relevance for the supply chain are not considered. It really focuses on the operational perspective. For its intended scope, however, it is suitable and comprehensive.

Since the SCOR model is a reference model, it provides improvement suggestions based on identified best practices, but not optimization procedures. Consequently, its "optimal" application remains vague. Moreover, there are no explicit trade-off or risk considerations incorporated in the model. It is left to the user of the SCOR model to take these into account individually throughout the implementation process. Identified best practice processes, however, provide valuable input for process and supply chain design decisions.

In the next section, a formal model distinct from the SCOR model is developed, which addresses some of the limitations identified above. It should not be seen separately from the SCOR model, but rather as complementary to it. It mainly addresses structural considerations that are neglected in the SCOR model. Furthermore, a mathematical representation serves to illustrate important supply chain issues, such as supply chain design, supply chain added value, supply chain roles, and conflicting supply chain objectives.

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[351] Cf. Meyr, Herbert, Jens Rohde and Hartmut Stadtler: Basics for modelling, in: Stadtler, Hartmut and Christoph Kilger (Eds.): Supply chain management and advanced planning: concepts, models, software and case studies (2nd ed.), Berlin Heidelberg New York 2002, pp. 54-61.

## 2.c. A Formal Framework for Supply Chain Structures

The systemic and holistic view of supply chains makes it necessary to take a complex structure of linked companies into consideration. It is not sufficient to only focus on one company anymore. A commonly acknowledged definition of a supply chain has been provided by Christopher: "The supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer."[352] Additionally, Christopher remarked that "…the task of managing, co-ordinating and focusing this value-creating network might usefully be termed supply chain orchestration."[353] Therefore, it is of high importance to first identify the relevant supply chain structure in order to make sound SCM decisions. This has often been neglected in literature and most authors seem to assume that everyone knows who a member of the supply chain is and how they are connected.[354] Therefore, a model is needed that assists in mapping supply chain networks.[355] Based on such a model, a mathematical representation is developed that identifies all supply chain network elements and that defines an objective function formulation for overall supply chain profitability.

An approach suggested by Walker is used as foundation in order to derive such a model that can serve as a basis for supply chain mapping.[356] In addition, Lambert, Cooper, and Pagh have also suggested a model for supply chain network structures that provides additional valuable input.[357] Under Walker's approach, first the main thread in a supply chain should be identified. Mostly, the main thread constitutes the physical flow that carries the most added value.[358] In case of a service supply chain network, it might be an information flow as well. The emphasis lies on the value added by it. It can also be, however, a crucially

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[352] Christopher: Logistics and supply chain management: Creating value-adding networks, p. 17. Shawn uses the term business units instead of companies, pointing out the difference, cf. Shaw: Information-based manufacturing with the Web, p. 117.

[353] Christopher: Logistics and supply chain management: Creating value-adding networks, p. 293.

[354] Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 4.

[355] This need was also identified as a research question by Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 14.

[356] See Walker, William T.: Unbundling the corporation: A blueprint for supply chain networks, in: McCormack, Kevin and William C. Johnson (Eds.): Supply chain networks and business process orientation,Boca Raton, FL 2003, pp. 103-129.

[357] See Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 1-19.

[358] Cf. Walker: Unbundling the corporation: A blueprint for supply chain networks , pp. 104-105.

important link within the network without adding much monetary value. The rest of the network is built around the main thread. As a starting point, *Figure B-10* shows a simplified supply chain for an automobile manufacturer with an identified main thread. Those positions in the supply chain that provide value along the main thread are shaded grey. Though simplified, the underlying structure resembles a typical supply chain in this industry.

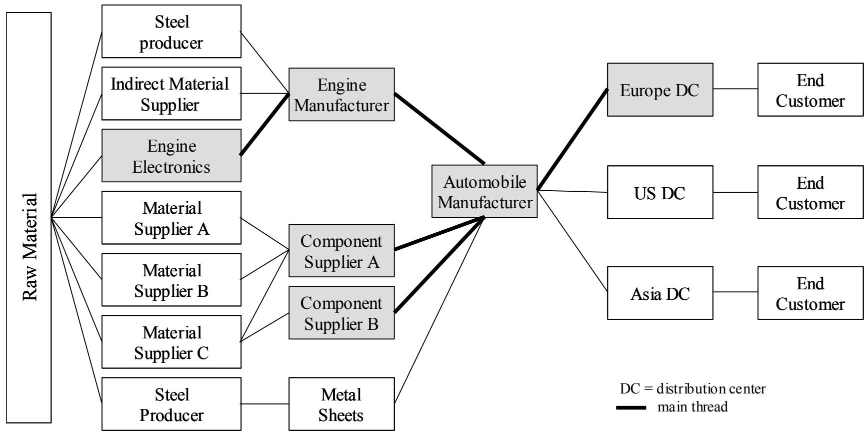


*Figure B-10: Simplified supply chain network structure*

The main thread indicates a sequential throughput. This is important for the formal model developed later on as it allows the division of the supply chain network into tiers. There is always at least one main thread position in each tier and main thread positions are connected to each other, i.e. a main thread position in a supply chain network cannot exist without being connected to all main thread positions through at least one other main thread, be it in a previous or in a following tier.[359] Instead of identifying main thread positions, Lambert, Cooper, and Pagh have distinguished between four types of business process links between supply chain partners: (1) managed process links, (2) monitored process links, (3) not-managed process links, and (4) non-member process links.[360] Delfmann and Albers have added commonly managed process links as another type that is positioned between managed and monitored process links.[361] Commonly managed process links are those that are jointly managed by the affected companies. One shortcoming of Lambert, Cooper, and Pagh's perception of business process links

359 Based on the definition of the model, no within-tier linkages exist.

360 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 7-8.

361 Cf. Delfmann and Albers: Supply chain management in the global context, p. 37.

is that they take the perspective from one company, what they call the focal company. The focal company can be any company within the supply chain network and therefore the structure looks different for each company.[362] This is not a desirable condition since the purpose is to capture an entire supply chain network with as little ambiguity as possible. It is otherwise difficult to provide assistance to optimize decisions within an entire supply chain as implied by the holistic and systemic nature taken at the normative level of SCM.

Another important factor is the identification of a supply chain driver, or, as Walker and McCormack and Johnson have put it, an orchestrator.[363] The supply chain driver is the member of the supply chain, which "owns" the key value to the supply chain.[364] For example, if a manufacturer holds a patent for a certain technology that defines the product or service, then this manufacturer possesses the most power within the supply chain. Consequently, this partner is responsible for taking the lead in defining the overall supply chain strategy. In case access to the customer is crucial, companies holding the key to customers constitute a relatively high control power over the supply chain, as it is the case for example for mail-order companies, department stores, discounters, hardware stores, or electronics superstores. It could also be that the supply chain driver is not even part of the physical supply chain, as in the case of Red Bull.[365] Red Bull only possesses its marketing power and drink recipe. The bottling and selling is done by supply chain network members that are independent of Red Bull. Still, Red Bull clearly drives its supply chain. Being aware of the supply chain driver is important when it comes to determining the key player in aligning and coordinating the supply chain to maximize total supply chain profitability. Pareto-

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362 Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 6-7.

363 Cf. Walker: Unbundling the corporation: A blueprint for supply chain networks , p. 108 and McCormack and Johnson: Supply chain networks and business process orientation: Advanced strategies and best practices, pp. 3-4. The need for such a supply chain leader is also identified by Langemann, Timo: Collaborative Supply Chain Management, in: Busch, Axel and Wilhelm Dangelmaier (Eds.): Integriertes Supply Chain Management: Theorie und Praxis effektiver unternehmensübergreifender Geschäftsprozesse (2nd ed.), Wiesbaden 2004, p. 442. Mentzer et al. see it even as a necessity to have a supply chain leader and compare it to a "channel captain", cf. Mentzer *et al.*: Defining supply chain management, p. 14.

364 Reasons for such a strong supply chain position can be size, economic power, proprietary technology, customer patronage, comprehensive trade franchise, or the initiation of the inter-firm relationships, cf. Mentzer *et al.*: Defining supply chain management, p. 14; and Walker: Unbundling the corporation: A blueprint for supply chain networks, p. 109.

365 Red Bull is a highly successful Austria-based energy drink company. Sales grew in 2004 by 32.3% to € 1,668 Mio.

efficient results are not desired and the allocation of profits and losses should be performed by the orchestrator.[366] This supply chain driver corresponds to what is referred to by some in the literature as *hub firm* or *focal company*.[367]

A distinction can also be drawn between hierarchic coordination and autonomic coordination. Hierarchic coordination refers to the supply chain orchestrator concept, whereas an autonomic coordination refers to market mechanisms such as price, temporary partnerships, values, or marketplaces. In a hierarchic supply chain setting, coordination can be achieved by direct order or by strategic alignment of dependent companies. Since the supply chain leader most likely cannot communicate directly with all tiers of the supply chain, the tiers in between serve as communicators of the message. Furthermore, programs and plans can serve as guidelines for all supply chain members.[368] Williamson has added the hybrid form of coordination positioned in between market and hierarchy and also remarked that positive factors might exist that benefit all three forms.[369]

The last key aspect of Walker's framework has been the explicit modeling of physical, information, and financial flows as *planes*.[370] These *planes* represent an explicit view of physical, information, and financial flows by separating them visually into three horizontal layers. By looking at them individually from a business process perspective, the linkages become clear while still being distinct. Within a company, they affect each other but between companies, each flow links with the corresponding one at the connected company. *Figure B-11* illustrates this for the previously depicted, simplified supply chain network. This network is aligned according to the main (physical) thread. Information and financial flows, however, can spread among all supply chain members, depending on the policies to which they are exposed. This is omitted at this point, but the possibility is considered later in the mathematical model.

Based on the presented framework, a formal model can now be developed that helps identify all supply chain network elements and helps define an objective function formulation for overall supply chain profitability. The advantage of such

366 Cf. Busch and Dangelmaier: Integriertes Supply Chain Management - ein koordinationsorientierter Überblick , pp. 12-20.

367 Cf. Delfmann and Albers: Supply chain management in the global context, p. 34.

368 Cf. Busch and Dangelmaier: Integriertes Supply Chain Management - ein koordinationsorientierter Überblick , pp. 12-20.

369 See Williamson: Comparative economic organization: The analysis of discrete structural alternatives. There, it is pointed out that the hybrid form is more than just merely a compromise of market and hierarchy organization, but has its own, unique position in between the other two.

370 Cf. Walker: Unbundling the corporation: A blueprint for supply chain networks, pp. 110-111.

a formal mathematical model is that it provides a higher level of precision.[371] A general framework is derived that has to be adapted to the requirements of the specific supply chain network under consideration. When applied, the model design depends highly on the individual supply chain network. One should therefore follow a contingency approach when applying it. Consequently, as with any model, it is of crucial importance that the system boundaries be chosen carefully. As a narrow definition of the supply chain boundaries can help companies get started, a total supply chain view offers the greatest potential while also requiring the most resources.[372] Lambert, Cooper, and Pagh have differentiated in this context between primary and supportive members or processes. Companies or business units who actually perform operational or managerial activities to produce a specific output for a particular supply chain are considered to be primary members of the supply chain. Supporting members, in contrast, simply provide resources for the primary members in form of services, knowledge, utilities, or assets.[373]

[371] Cf. Schmenner and Swink: On theory in operations management, p. 100.

[372] Cf. Poirer: Achieving supply chain connectivity, p. 17.

[373] Cf. Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, pp. 5-6. About choosing system boundaries in more general terms, see for example Forrester, Jay W.: Principles of systems, second preliminary edition, 2nd ed., Cambridge, Massachusetts 1969, pp. 4.1-4.5.

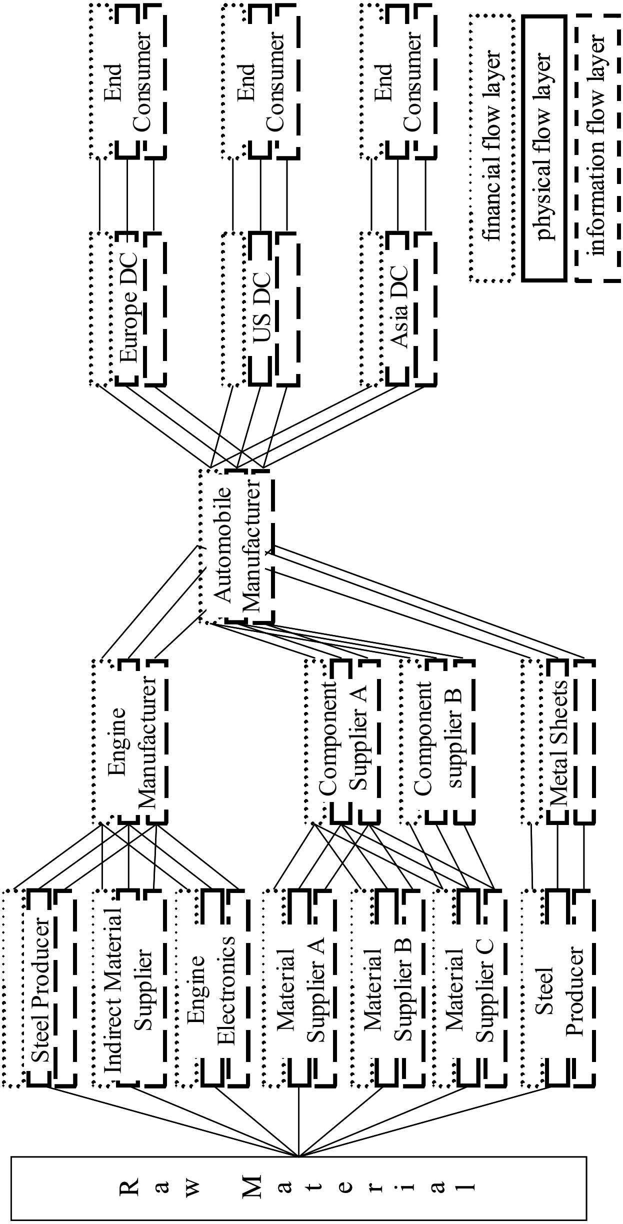


*Figure B-11: Simplified supply chain network, illustrating physical, information, and financial flows*

A supply chain network should be defined by its main product or service, because ultimately, each and every individual product or service has its own supply chain. Obviously, it is not feasible to model such a view. Even considering an aggregate view of a single product might be too narrow a focus. It seems to be suitable rather to form homogeneous product groups that generally share the same supply chain. For example, there are many different VW Golf models available, with diesel or gasoline engine, as convertible, station wagon or sedan and so forth. It is appropriate to build a homogeneous product group "Golf" instead of a group for each model variation. The main factor that should be considered when including several model variations is the implied changes necessary within a supply chain for each model. If the supply chain network structure changes significantly by including more product variations, they should not be included.[374] The total value created by such a defined supply chain network over a period of time can generally be described as follows:

[1]: $$X_{Pt} = s_{Pt} - v_{Pt}$$

with $X_{Pt}$ = total value created in period *t* by the supply chain network of product *P* that defines the supply chain network

$s_{Pt}$ = total sales revenue of product *P* in period *t*

$v_{Pt}$ = cost of material and services procured from outside the supply chain network in period *t*

In order to determine the span of value creation a supply chain network covers, a supply chain depth indicator $X_{P\Delta}$ can be calculated in the following way:

[2]: $$X_{P\Delta} = 1 - \frac{v_{Pt}}{s_{Pt}}$$

According to the supply chain network model, i=1,…,n tiers between the source and the end of the supply chain can be identified. The tiers are aligned according to the main thread. Each tier *i* holds j=1,…,$m_i$ positions for companies that contribute and add value to this supply chain network. *Figure B-12* illustrates this structure.

374 See Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 41.

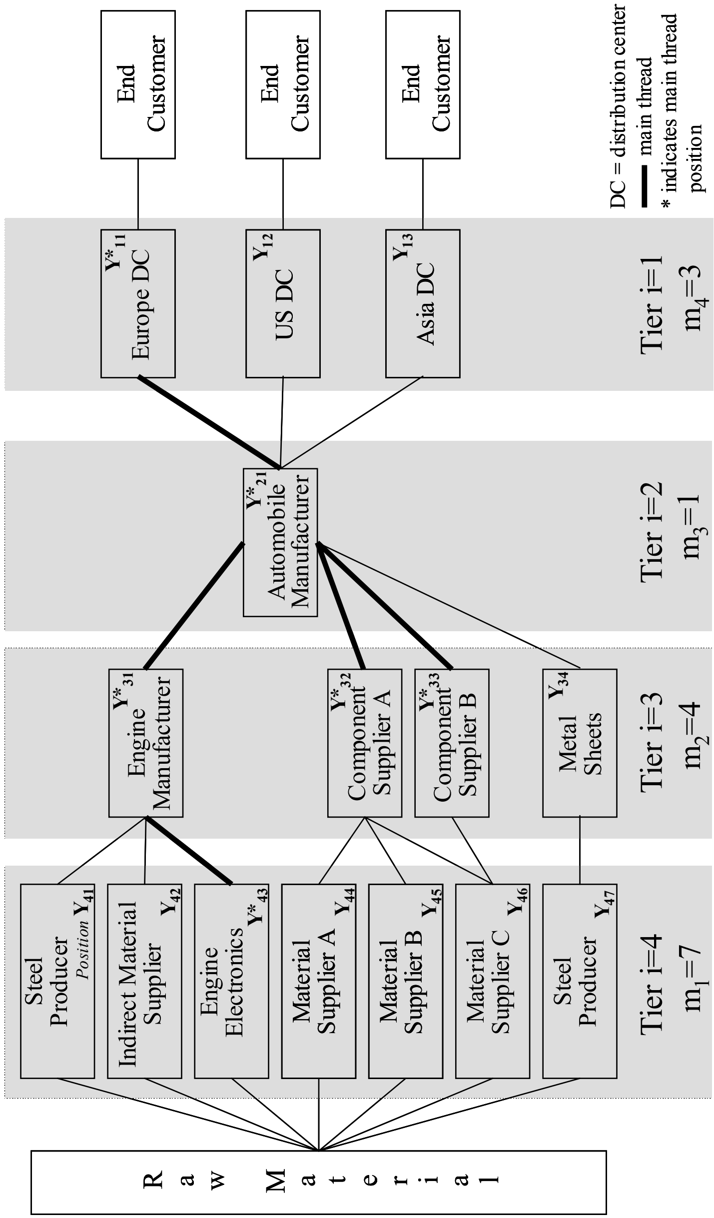


*Figure B-12: Supply chain network structure, including position notions*

The total value creation $X_{Pt}$ of a supply chain network is therefore the sum of the added values of all positions. Therefore, *Equation [1]* can be stated more detailed as follows:

$$[3]:\ X_{Pt} = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \left(X_{Pt}\right)_{ij}$$

with $X_{Pt}$ = total value created by the supply chain network of product *P* that defines the supply chain network, in period *t*

$(X_{Pt})_{ij}$ = incremental added value of position *ij* for product *P* in period *t*

i = supply chain network tier, i = 1 (customer tier), … , n (point of origin)

j = position within tier *i*, j=1, … , $m_i$

$(Y^*_P)_{ij}$ indicates a main thread position in *Figure B-12*

Starting the count at the tier closest to the customer is sensible since all supply chain activities focus on the end customer. To reflect this focus, the first tier should always be the one closest to the end customer. Mostly, the (physical) main thread routes through some kind of OEM. This OEM can serve as an orientation point for a supply chain network since the network “funnels” through this tier. Often, the OEM tier consists only of the OEM position.

The beginning of the scope of the supply chain network depends on the specific supply chain constellation. The (functioning and efficient) markets for raw materials are often a good starting point. The raw material tier should only be included if it represents a raw material that is of particular relevance for the supply chain. Commodity products can be excluded from the supply chain network perspective if an efficient supply is ensured and/or it is not particularly important or critical to the product. In some instances, it can make sense to go beyond these market boundaries in order to secure supply. From *Equation [1]*, it becomes clear that in the extreme case of including all companies connected to a supply chain, there would no longer be any outsiders to the supply chain and a total integration would be achieved, with $v_t$ being zero. End customers are not included in the supply chain network. In case a monopoly-like company controls the access to end customers, these companies could be also excluded, if they do not add significant value to the supply chain. However, in line with the SCM framework, also end customers can be an active part of the supply chain and therefore then represent the first tier.[375] Even if excluded, they build an important link to the first tier that has to be considered accordingly. *Figure B-13* illustrates the overall view of supply chain network tiers.

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[375] For example, Mentzer et al. consider the final consumer to be part of the supply chain, cf. Mentzer *et al.*: Defining supply chain management, p. 4.

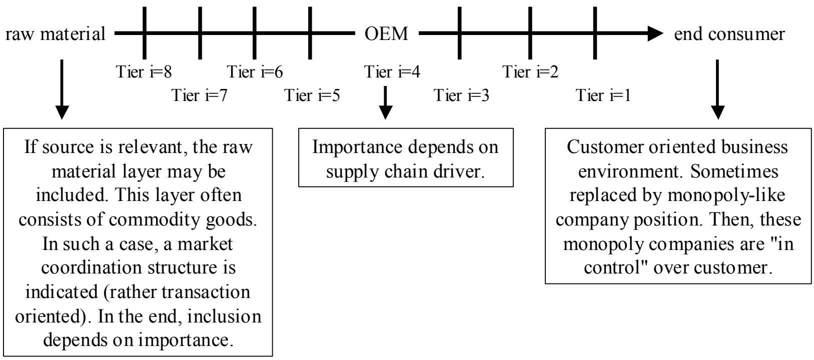


*Figure B-13: Tier depiction of a supply chain network*

From this, we derive the objective function for supply chain networks. One important aspect of SCM is to maximize total supply chain profitability.[376] However, profitability can have many different meanings, as can be the objectives of a supply chain.[377] In the model proposed, it is assumed that long-term profitability of the supply chain network should be maximized. While there are various profitability performance measures possible, the Net Discounted Cash Flow (NDCF) for *k* periods – the planning horizon – is chosen as an appropriate profitability measure. Nevertheless, other profitability or performance measures could also be used to determine supply chain objectives. The objective here, therefore, is to maximize the sum $Z_P$ of all supply chain network participants' individual NDCFs.

[4]: $$Z_P = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \left( NDCF_P \right)_{ij} \rightarrow \text{max! for } k \text{ periods}$$

with $(NDCF_P)_{ij}$ = Net Discounted Cash Flows of position *ij* in the supply chain network of product *P*, with a planning horizon of *k* periods

As can be seen in *Equation [4]*, total supply chain profitability depends on the profits made by all supply chain members. As profit sharing agreements are very difficult to achieve and therefore almost non-existent, each member aims to maximize its own profits independently. Furthermore, companies often participate in more than one supply chain, which complicates matters further. Each company *U*'s profitability function can be described as the sum of the profits made with all products and supply chains of this company *U*. It can be described as follows:

376 See for example Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 6.
377 For a discussion on supply chain objectives, see section B.I.3.a.

[5]: $Z_U = \sum_{P=p_1}^{p_{l_U}} \sum_{i=1}^{n} \sum_{j=1}^{m_i} \left(NDCF_P\right)_{ij} * c_U\left[\left(Y_P\right)_{ij}\right]$ → max! for *k* periods

with $c_U[(Y_P)_{ij}]$ = 1, if company *U* fills position *ij* in product *P*'s supply chain network, 0 otherwise

P = product or product group *P* with P=$p_1$, … , $p_{lU}$ ($l_U$ products company *U* is involved in)

where $(Y_P)_{ij}$ represents the supply chain position *ij* for product *P*

It can be observed that *Equations [4] and [5]* are only partly linked to each other. In general, only parts of the objective function of company *U* are also elements of the objective function of the supply chain network for a specific product *P*. In case company *U* is involved in more than one supply chain network, only parts of the objective function of the supply chain network for a particular product *P* are also elements of the objective function of company *U*. Therefore, without a perfect incentive policy, solutions are likely to be sub-optimal.[378]

Up to this point, the influence of the actual structure of a supply chain on effectiveness and efficiency of the entire supply chain network has not been formally reflected. Even if all participants of a supply chain network acted in the best interest of the entire supply chain, profitability might be limited due to the structure, i.e. the linkages between supply chain members. Changing the structure of a given network can move the efficient frontier outwards, i.e. expanding the effectiveness and efficiency potential of the network.[379] Consequently, this structure has to be formally represented as well. To achieve this, physical, information, and financial flow connections are identified as follows:

[6]: $M_{(Y_P)_{ij}(Y_P)_{i'j'}}$ := 1, if physical flow between $(Y_P)_{ij}$ and $(Y_P)_{i'j'}$ exists, 0 otherwise

with i≠i', if j=j' and j≠j', if i=i'

[7]: $I_{(Y_P)_{ij}(Y_P)_{i'j'}}$ := 1, if information flow between $(Y_P)_{ij}$ and $(Y_P)_{i'j'}$ exists, 0 otherwise

with i≠i', if j=j' and j≠j', if i=i'

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378 For a general discussion of incentive issues, see Narayanan, V. G. and Ananth Raman: Aligning incentives in supply chains, in: Harvard Business Review, Vol. 82 (2004), November, pp. 94-102.

379 Cf. for example Chopra and Van Mieghem: Which e-business is right for your supply chain?, pp. 33-34; and for a more detailed discussion, see section B.I.3.a

[8]: $F_{(Y_P)_{ij}(Y_P)_{i'j'}}$ := 1, if financial flow between $(Y_P)_{ij}$ and $(Y_P)_{i'j'}$ exists, 0 otherwise

with i≠i', if j=j' and j≠j', if i=i'

According to the model, the variables *M*, *I*, and *F* for physical, information, and financial flows merely define whether a flow exists or not. In case a flow exists, it is also important to define the characteristics of this flow both quantitatively and qualitatively. Additionally, structural changes may be established by changing connections within the existing supply chain network members or by adding/removing positions to/from the network. Furthermore, companies occupying certain network positions may also be changed. For all these considerations, it is a prerequisite to first know the existing supply chain network structure and linkages within it. For this purpose, the developed model above provides a valuable framework.

In order to apply the formal model for supply chain structures developed in this section, one has to investigate one specific supply chain environment. This serves the requirement of a contingency approach as postulated on the normative level of the SCM framework. Any given supply chain can be improved through the process of deriving the necessary information in order to create the supply chain map. The logical, formal connections can then be communicated easily and different scenarios can be elaborated. Mapping several supply chains of similar industries in the way described makes it also possible to identify best practice supply chain structures. In the analysis to follow in sections C and D, such a level of detail cannot be obtained through the available empirical database. Nevertheless, the awareness raised through this analysis is of great importance to evaluation of the analyses conducted later on. Other SCM analyses in the future can make use of the formal framework and its implications in order to identify best practice supply chain structures and to better understand the dynamics within and between supply chains.

After having discussed strategic management decisions of SCM above, the next section provides an overview of the currently most significant strategic physical and technical infrastructure toolset, namely e-business.

## *3. E-Business Enabled Supply Chain Management*

### 3.a. From Information and Communication Technology to E-Business

The histories of IT and communication technology are quite complementary to each other, with IT being the younger one of the two technologies. Network technology is considered in the traditional terminology to be part of IT sciences, with the Internet as the most prominent representative of networks. Though the term "network" has a stong grounding in traditional communication technology, the Internet is considered to be a derivative of the computer and IT field.[380] The following section is intended to provide a brief historical review of the circumstances that have led to the current status of IT and the Internet. This is followed by a definition of the scope of e-business as an outcome of these developments.[381]

It is deemed appropriate to give such a review in order to provide a better understanding of the rather solid foundation of these developments and their sustaining economic impact. In the field of SCM, many open issues remain in the area of managerial integration of independent entities. Similar barriers of integration existed in the beginning of the Internet, such as proprietary standards, conflicts of interest, or legacy systems. These barriers have been overcome by the Internet community. The historical developments as well as the current management of the Internet may provide ideas that support initiatives for industry-independent, total supply chain integration. Standardization is certainly one ingredient to consider more closely.[382] The SCOR model might serve as an example for such an initiative, but it is only a starting point compared to the necessary efforts that have been undertaken to make the Internet as successful as it is.

IT is closely connected to the invention of computers and related technology. Consequently, Zuse's invention of the Z1 Computer that started in 1936 and Aiken and Hopper's Harvard Mark I Computer, originally termed Automatic Sequence Controlled Calculator (ASCC) in 1944 can be considered to be the starting points of information sciences. The invention of integrated circuits in 1959 represented another significant milestone in the advance of IT.[383] Following

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380 Cf. Leiner, Barry M. *et al.*: A brief history of the Internet, 2003, http://www.isoc.org/internet/history/brief.shtml, retrieved on: February 15, 2006, p. 13.

381 There exist countless sources on the history of the Internet and IT developments. Therefore, the section on the history of the Internet is based primarily on a summary provided by the ones that actually did shape the Internet over the last decades, see Leiner *et al.*: A brief history of the Internet; and a widely acknowledged and comprehensive timeline of the history of the Internet by Hobbes, see Hobbes, Robert: Hobbes' Internet timeline, version 8.1, 2005, http://www.zakon.org/robert/internet/timeline/, retrieved on: February 15, 2006. Since Hobbes' timeline is heavily peer-reviewed, commented on and peer-authored, it is considered to be a highly reliable and trustworthy source. Also, several mirrors of this page exist.

382 Standardization is also seen as an important enabler in other areas, for example customization, see Swaminathan, Jayashankar M.: Enabling customization using standardized operations, in: California Management Review, Vol. 43 (2001), No. 3, Spring, pp. 125-135.

383 See Ceruzzi, Paul E.: Reckoners: The prehistory of the digital computer, Westport, Connecticut 1983, pp. 10-72; and Ceruzzi, Paul E.: A history of modern computing, Cambridge, Massachusetts 1998, pp. 178-179. These two sources also provide excellent

these groundbreaking inventions, a steady but nevertheless relatively slow process continued developing the field's potential. From the early 20th century until the years after the Second World War, transportation technology outpaced IT and communication technology in terms of economic impact, with the emergence of the aviation and automotive industry being the most significant representatives.[384]

For the development of IT, other major breakthroughs have been the invention of Random Access Memory (RAM) in 1949 by Jay W. Forrester, which has been practically used from 1952 on, dynamic Random Access Memory (DRAM) chips in 1970, the first microprocessor in 1971 and the first consumer computers in the mid-1970s.[385] Then, in 1979, the first spreadsheet software, VisiCalc, was introduced, followed by Rubenstein and Barnaby's word processing software WordStar. With these applications, computers began to deliver visible value for a wider user audience. In 1981, the IBM home computer with MS-DOS as its operating system was introduced and in 1985, Microsoft Windows followed.[386] Computer capabilities in terms of processing power, memory size, hard disk memory, graphic power and other performance and capacity measures continued to grow and still do. Furthermore, prices dropped to levels at which a broader user base was able to afford computers. Following the development of traditional computers, the processing power and miniaturization of electronics spread to other devices used for home entertainment, car controls, home appliances, industrial machinery and a myriad of other purposes.

Communication technology has had an even longer history. Foundations were laid by the first electromagnetic telegraphs in the mid 19th century and the invention of the telephone in the late 19th century. As early as 1886, Sears first sold watches via telegraph and hence telemarketing as well as Sears, Roebuck & Co. was born. Only in 1930 did the telephone network outgrow the telegraph network. The telephone network kept growing and phone technology kept developing steadily, with further milestones being the invention of the fax machine in 1960, the emergence of optical fiber wire technology in the mid-1960s and the first cellular phone communication network in 1979 in Japan. Telephone network technology, in its most basic sense, has also been the foundation of computer network technology development.

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overviews of the history of computing. See also the Computer history timeline, http://www.computerhistory.org/timeline/, Computer History Museum, retrieved on: February 15, 2006.

384 Cf. Delfmann and Albers: Supply chain management in the global context, p. 58.

385 See Ceruzzi: A history of modern computing, pp. 198-241. Despite his contributions to systems theory, to many Jay W. Forrester might be better known as the inventor of RAM.

386 See Brayton, Colin: Data visualization: A brief history, in: Securities Industry News, Vol. 17, No. Issue 2005, p. 7 and p. 29; and n.a.: 1978: The revolution begins, in: InfoWorld, Vol. 20, No. Issue 1998, pp. 3-35.

In 1969, the ARPANET, the first packet-switching network, was launched by the Advanced Research Projects Agency (ARPA).[387] The ARPANET can be seen as the incubator of the Internet as it is known today. The four founding nodes were the University of California, Los Angeles, the Stanford Research Institute, the University of California Santa Barbara and the University of Utah. Over the following years, the number of nodes and users grew to more than 35 hosts and approximately 2,000 users in 1973. The key developments in the ARPANET environment have been the following:

- 1972, introduction of e-mail in the form as it still is used today.
- 1982, introduction of the TCP/IP[388] network protocol, accompanied by one of the first definitions of the Internet. It defined "[…] an 'internet' as a connected set of networks, specifically those using TCP/IP, and 'Internet' as connected TCP/IP internets."[389] Work on the TCP/IP protocol started in 1972 and the ARPANET switched to TCP/IP on January 1, 1983.
- 1984, introduction of domain name system (DNS) makes it obsolete to know the exact numerical location of a server and replaces the numerical sequence by words.
- 1985, launch of the NSFNET program by the U.S. National Science Foundation (NSF) with the intent to link the entire higher education community together. TCP/IP was chosen as its network protocol. In the following years, many sub-nets based on TCP/IP have been established.
- 1990, disconnection of the ARPANET.

The NSFNET program continued to facilitate the growth of the ARPANET by coordinating Internet activities and providing physical infrastructure, such as the data transmission backbone. New countries were connected every year. The usage of the NSFNET backbone has been limited to research and education purposes. In order to lower operating costs, regionally limited commercial use was permitted. In 1988, the NSF started to develop plans to privatize and commercialize the Internet.

Although operating on the basis of the same protocols, namely TCP/IP, the Internet in the 1980s still consisted of separated networks and services. In 1989,

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387 The underlying theory on packet switching networks was first published by Kleinrock, Leonard: Information flow in large communication nets, in: RLE Quarterly Progress Report (1961), July. ARPA has changed names further on back and forth and is now referred to as the Defense Advanced Research Projects Agency (DARPA).

388 Transmission Control Protocol / Internet Protocol (TCP/IP).

389 Hobbes: Hobbes' Internet timeline, version 8.1, p. 6.

Berners-Lee has started to develop the World Wide Web (WWW) at CERN[390], which was further refined together with Cailliau.[391] One of the main characteristics of the WWW has been the application of hypertext that allows for referring to other documents and web pages by interactive links. As remarked on CERN's homepage: "The basic idea was to merge the technologies of personal computers, computer networking and hypertext into a powerful and easy to use global information system."[392] The key technologies behind the WWW have been, and still are, the hypertext transfer protocol (HTTP), the hypertext markup language (HTML) and uniform resource identifiers (URIs, also known as uniform resource locators, URLs).

Because the development of the WWW became increasingly time consuming, Berners-Lee asked other developers over the Internet to join the development efforts. As a result, several browsers were programmed to make using the WWW easier. In 1993, the first version of the Mosaic browser became available and versions for personal computers (PC) and Macintosh were launched shortly after. With easy to use browsers available for popular computer systems, as the PC and Macintosh were, the WWW gained quickly in popularity. In 1993, 1% of Internet traffic was conducted through the WWW and the known 500 web servers. By the end of 1994, ten million users had already made use of the WWW and 10,000 servers were available.[393] By 2004, almost one billion Internet users had been identified.[394]

In order to further maintain and develop Web standards, the World Wide Web Consortium (W3C) was founded. With Berners-Lee as the founding and current director of the W3C, the inventor of the WWW still drives its development. The W3C is jointly administered by the MIT Computer Science and Artificial Intelligence Laboratory in the USA, the European Research Consortium for Informatics and Mathematics in France and Keio University in Japan.[395] In 1994, the commercial use of the Internet was permitted and in 1995, the NSF completed its privatization efforts and focused solely on its research network again. The main

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390 Conseil Europeen pour la Recherche Nucleaire (CERN) or European Organization for Nuclear Research, Geneva, Switzerland, http://www.cern.ch.

391 Cf. CERN's greatest achievements, http://www.cern.ch, CERN,retrieved on: February 15, 2006.

392 CERN's greatest achievements, section on "The World Wide Web".

393 Cf. CERN's greatest achievements, section "history of the www", p. 2.

394 Cf. n.a.: Internet usage statistics - the big picture, 2005, Internet World Stats, http://www.internetworldstats.com/stats.htm, retrieved on: February 15, 2006 and n.a.: Worldwide Internet users will top 1 billion in 2005, Computer Industry Almanac, Inc., press release September 3, 2004, http://www.c-i-a.com/pr0904.htm, retrieved on: February 15, 2006.

395 Cf. About the World Wide Web Consortium, http://www.w3.org/Consortium/about-w3c.html, W3C,retrieved on: February 15, 2006, pp. 1-2.

backbone operations were now run by interconnected network providers and the WWW as it is perceived today was on the way.[396] The WWW is only one service on the Internet. Examples of other services are e-mail, with its simple mail transport protocol (SMTP), and the file transfer protocol (FTP).

The continuing development of the WWW is mainly driven by the W3C for WWW protocols and standards. The Internet is further developed by a cooperative and mutually supportive relationship of the Internet Activities Board (IAB), the Internet Engineering Task Force (IETF), and the Internet Society, which mainly facilitates the work of the IETF.[397] To illustrate the work performed at the W3C, the following examples are given of standards the consortium established. Such standards are the portable network graphics (PNG) format to provide an independent graphic format, the cascading style sheets (CSS) to add styles to web documents, HTML 4.0 as an extension of the original HTML formats to provide richer content, or XML 1.0, which in 1998 laid the foundation of the forthcoming developments of the extensible markup language (XML).[398] New developments comprise extensions of XML and the vision of a semantic Web.[399]

The W3C's mission is "to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure long-term growth for the Web."[400] This mission is further refined to provide the Web to

- everyone, regardless of culture or abilities;
- everything, from high-end computers to mobile devices;
- everywhere, from high to low bandwidth environments;
- diverse modes of interaction, that is to say all kinds of interacting technologies such as touch screen, pen, mouse, voice, assistive technologies or computer to computer; and
- enable computers to do more useful work, for example through advanced data searching and sharing.[401]

This mission makes it clear that the Web aims to reach beyond current applications and to provide a platform-independent application environment. Although developments in mobile and wireless technologies require adjustments of protocols and standards on both the network communication level and the

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396 Hobbes: Hobbes' Internet timeline, version 8.1, p. 14.
397 Cf. Leiner *et al.*: A brief history of the Internet, p. 11.
398 Cf. About the World Wide Web Consortium, pp. 13-15.
399 For more information on the latest developments of the WWW, see W3C's webpage, http://www.w3.org.
400 About the World Wide Web Consortium, p. 1.
401 Cf. About the World Wide Web Consortium, p. 16.

service level, the main characteristic of distributed networking remains the same. This characteristic embraces a maximum reach through commonly accepted and open standards. Furthermore, these standards need constant refinements and adjustments, which are conducted based on the principles that incubated the Internet and the Web. According to that, standards have to be open documents, be freely available, and be developed in a collaborative effort. As Leiner et al. remarked:

> "The most pressing question for the future of the Internet is not how the technology will change, but how the process of change and evolution itself is managed. […] If the Internet struggles, it will not be because we lack for technology, vision, or motivation. It will be because we cannot set a direction and march collectively in the future."[402]

Besides the above mentioned consortia, independent vendors provided consortium-independent inventions to the Web. In 1995, Sun launched Java and Javascript as platform-independent programming languages. In the same year, RealAudio launched its streaming technology that allows for near real-time radio broadcasts. In 1998, the MPG3 audio format, developed by the "Frauenhofer Institut Integrierte Schaltungen", arrived at the Internet, though it had been already developed in 1987 and has been applied by the Motion Picture Experts Group (MPEG) for video signals before. MPG3 files are considerably smaller than original audio files without a perceivable loss of quality. Based on this, peer-to-peer file sharing became popular in 1999 through Napster, a highly controversial file sharing application. After a heated debate, however, and the loss of several law suits, claiming infringement of copyrighted materials, Napster stopped its service. Another de-facto standard has become the sharing of documents based on Adobe's portable document format (PDF). The main advantages of the PDF format are the customizable document quality and therefore file size and its ready-to-print format that displays documents the same way without ambiguity, independently from operating system or application. The key to its position and wide distribution has been that the required viewer has become freely available. Based the postscript format, a professional printing layout technology, it provides unlimited freedom in terms of layout and also features Web capabilities, such as Internet links.[403]

As pointed out, standards have been the one underlying force that has been driving the diffusion of IT, the Internet and the WWW. Being a network technology in the literal sense, it benefits from network externalities. It is in the nature of network externalities that "…the utility that a user derives from consumption of the good increases with the number of other agents consuming the

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402 Leiner *et al.*: A brief history of the Internet, p. 14.
403 See Hobbes: Hobbes' Internet timeline, version 8.1.

good."[404] In the diffusion process of the Internet, the first widespread standard was the IBM personal computer platform on the computer level and TCP/IP and the WWW have been the driving standards behind the Internet diffusion that built the basis for the possibility of network externality effects.

Besides standardization, the acceptance and diffusion of network technology in the early 1990s can be attributed to three more trends. These are digitalization, broadband transmission, and increased performance of distributed computation power.[405] Enhanced by these values, e-business is a direct consequence of the diffusion of IT, the Internet and the accompanying creation and establishment of standards. The importance of standards also is treated in the following sections.

### 3.b. A Business View of E-Business

E-business can be considered an offspring of the development of IT and network technology, with the Internet being the most significant part. IT received increasing consideration in the late 1980s/early 1990s through the recognition of information-based organizations.[406] In the mid-1990s, when Internet technology opened up to the public and began its diffusion, the term e-commerce was introduced in connection with the first online sales appearances on the Internet. Over time, the definition has broadened and has started to include not only the sale of products but also precedent activities. Bloch, Pigneur, and Segev have defined e-commerce as "the buying and selling of information, products, and services via computer networks [and the] support for any kind of business transactions over a digital infrastructure."[407] Watson et al. have seen e-commerce as the usage of IT in order to extend communication and transaction possibilities with the stakeholders of an organization. Furthermore, according to Watson et al., these stakeholders comprise customers, suppliers, administration, financial institutes, managers, employees and the public in general.[408]

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404 Katz, Michael L. and Carl Shapiro: Network externalities, competition, and compatibility, in: American Economic Review, Vol. 75 (1985), p. 424.

405 Cf. Fulkerson: Information-based manufacturing in the informational age, p. 134.

406 See for example Drucker, Peter F.: The coming of the new organization, in: Harvard Business Review, Vol. 66 (1988), January/February, pp. 49-50 and Porter: The competitive advantage of nations, p. 17 and p. 55.

407 Bloch, Michael, Yves Pigneur and Arie Segev: On the road of electronic commerce - a business value framework, gaining competitive advantage and some research issues (No. 1013) 1996, Berkeley, http://groups.haas.berkeley.edu/citm/publications/papers/wp-1013.html, retrieved on: February 15, 2006, p. 2.

408 Cf. Watson, Richard T. *et al.*: Electronic commerce: The strategic perspective, Fort Worth 2000, p. 1.

IBM has coined the term e-business in 1996 through an advertising campaign resulting in a more differentiated meaning of the terminology.[409] In the following years, e-business and e-commerce have been (too) often considered to be interchangeable.[410] Since then, a more distinguished understanding, however, has prevailed in which e-commerce represents that part of the much more comprehensive e-business that embraces the sales-related usage of electronic media. E-procurement as the supply counterpart represents the procurement-related part.[411]

There is some ambiguity among researchers and authors whether or not to include Internet technology in the general definition of e-business. For example, Lee and Whang have defined e-business in the context of supply chain integration as "the planning and execution of the front-end and back-end operations in a supply chain using the Internet."[412] Chopra and Meindl have noted that "e-business is the execution of business transactions via the Internet."[413] Swaminathan and Tayur remark that "e-business can be loosely defined as a business process that uses the Internet or other electronic medium as a channel to complete business transactions."[414] Croom, on the other hand, has defined e-business "[…] as the use of systems and open communication channels for information exchange, commercial transactions and knowledge sharing between organizations."[415]

In light of these different interpretations, e-business can be seen as the electronic support of business processes and relationships with business partners, employees, customers and other stakeholders.[416] This general definition does not

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409 Cf. Biggs, Maggie: E-commerce is hot today, but e-business is the gift that keeps on giving all year long, in: Infoworld, Vol. 20 (1998), No. 21, p. 82.

410 For such a view, see Hoffmann, Christoph: Logistik und Electronic Business, Wiesbaden 2001, pp. 54-57.

411 This view is shared by numerous authors. For an overview, see Cagliano, Raffaella, Federico Caniato and Gianluca Spina: E-business strategy: How companies are shaping their supply chain through the internet, in: International Journal of Operations & Production Management, Vol. 23 (2003), No. 10, pp. 1143-1144.

412 Lee, Hau L. and Seungjin Whang: E-business and supply chain integration, Stanford Global Supply Chain Management Forum 2001, p. 2.

413 Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 527.

414 Swaminathan and Tayur: Models for supply chains in e-business, p. 1389.

415 Croom, Simon R.: The impact of e-business on supply chain management, in: International Journal of Operations & Production Management, Vol. 25 (2005), No. 1, p. 55.

416 This definition appears with slight variations frequently in the literature. Examples can be found in Schubert, Petra, Dorian Selz and Patrick Haertsch: Digital erfolgreich, Fallstudien zu strategischen E-Business-Konzepten, Berlin Heidelberg 2001, p. 14;

directly relate e-business to any particular technology, especially not to Internet technology. This understanding emphasizes the fact that e-business had also been applicable to technologies before the advent of the Internet and the term e-business itself. More importantly, the definition should be open to new (electronic) technologies to come. Furthermore, e-business also applies to technologies that do not actually involve the Internet, especially those that can be considered to be intra-organizational, such as integrated phone systems, electronic employee management, digital picture processing, and document management systems.[417]

It can be concluded, however, that Internet technology greatly enhances the possibilities of e-business. Its major advantages are cheap access, common standards, fast transmission of data, and a widespread digital infrastructure. Kahl and Berquist have identified the following unique features of the Internet: (1) ubiquity and pervasiveness, (2) standardization, i.e. common communication protocol and provision of standardized data transmission, (3) real-time communication, (4) variety of data structures, which includes product designs, market data, web site links and production plans, and (5) many-to-many network configuration, which includes market places, community tools and messenger tools.[418] With further increasing processing power and the improving convenience of devices, Internet technology drives the "efficient frontier" of e-business outwards, that is to say it increases product value to customers for the same process costs or lowers process costs providing the same product value to customers.[419] Standards, transmission technology, devices and applications are likely to change and to continue developing. E-business developments beyond the principle capabilities of the underlying Internet technology as pointed out earlier, however, are hard to imagine at the moment.

The following interview quote by John Bermudez, AMR research analyst, illustrates fairly well the significance and status of the Internet:

> "The next big thing is 'the real application of the Internet in business. […] I think it is probably similar to the PC market. […] if you said in 1986 – or whenever the IBM A.T. was introduced – 'Oh, the next big thing is the PC,' people would have responded, 'But we've had PCs for four or five years.

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Scheffler, Wolfram *et al.*: Entwicklungsperspektiven im Electronic Business, Wiesbaden 2000, p. 5; or Dolmetsch, Ralph: eProcurement, München 2000, p. 27.

417 Besides the "classic" e-business categories, involving businesses, customers and government as B2B, B2C and so on, also intra-business and non-business as e-business categories have been included, see Phan, Dien D.: E-business management strategies: A business-to-business case study, in: Information Systems Management, Vol. 18 (2001), Fall, pp. 61-69.

418 Cf. Kahl and Berquist: A primer on the internet supply chain, pp. 42-43.

419 Cf. Chopra and Van Mieghem: Which e-business is right for your supply chain?, p. 33.

What's the big deal?' The big deal is going from being (something of a curiosity) to something that supports a bunch of $30 billion companies."[420]

Porter has identified five overlapping stages in the evolution of IT and e-business. The first stage enabled the automation of discrete transactions. In the second stage, more automation and functional enhancement was achieved, for example through Computer Aided Design (CAD) and other applications. Cross-activity integration was added in stage three by linking sales activities with the order processing process. CIM belongs to this stage and the Internet has already been involved, although on a rather low level. Currently ongoing is stage four, where the integration of the value chain and entire value systems is enabled. It aims at end-to-end applications from the point-of-origin to the point-of-consumption. Porter has envisioned a fifth stage, which is thought of integrating product development and moving Internet procurement from standardized commodities to engineered items.[421] This fifth stage could also be considered as part of the previous one instead of as a separate entity.

SAP as the leading provider of ERP systems has classified companies with regard to their SCM IT capabilities along four stages, the "stages of excellence":[422]

- *Stage 1: disconnected systems*. These systems focus on automating existing functions with a low degree of integration.
- *Stage 2: internal and external interfaces*. IT systems are still organized functionally but show a high degree of internal integration. No Web capability leverage exists and external links are decentralized. Information exchange happens through e-mail and the Internet.
- *Stage 3: internal integration and limited external integration efficiency*. At this stage, companies are cross-functionally organized. The internal systems are integrated. Suppliers are linked to the back-end systems and integrated with buyer front-end system. These systems already show important supply chain capabilities, such as integrated supply chain information to plan operations and inter-company process designs.

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420 n.a.: Why the Internet is still the 'next big thing', in: Supply Chain Management Review (2002), May/June, p. 58.

421 Cf. Porter, Michael E.: Strategy and the Internet, in: Harvard Business Review, Vol. 79 (2001), March, p. 74.

422 The four stages of excellence have been incorporated in SAP's SCM solutions, currently mySAP SCM as part of their product "Value Calculator." See also n.a.: Full Service, in: SAP INFO, No. Issue, May 15, 2002; and their press release on September 19, 2001: "Customers model return on technology investment benefits with free online tool from SAP", SAP Press Release.

– *Stage 4: multi-enterprise integration*. Such comprehensive integration refers to the full application of SCM potential. This includes common business objectives, seamless information sharing, knowledge organizations and automated and interactive collaborations. As a result of end-to-end integration, total visibility into the supply chain network is available. Trading partners are linked through collaboration and enabled to operate as one entity.

In conclusion, the full economic impact of IT, the Internet, and e-business materializes towards the end of their evolution. The latest evolutions, in Porter's view stage four and five and according to SAP's classification stages three and four, especially underline the importance of e-business for SCM. This constitutes greatly enhanced capabilities in the areas of coordination, collaboration, and integration.

### 3.c. E-Business as a Catalyst for Supply Chain Management

The previous sections have indicated that e-business is the technology that currently has a significant impact on SCM. E-business can be considered a result of the shift towards the information age. This is not to say that advances in other technologies are irrelevant or insignificant. In terms of importance for SCM, however, e-business is currently the most influential one. As pointed out earlier, information is of crucial importance for improvements in supply chain performance. Consequently, the technology that processes information is of significance.

New technologies and especially e-business capabilities have to be considered when designing business and supply chain processes. Nevertheless, they should not drive the design process *per se* in spite of their seemingly obvious significance. The business model should lay the foundation for any technology adoption. Even more so, it is believed that IT and therefore e-business does not deliver added value in itself, but through the alignment between business strategy and technology.[423]

Although this is widely acknowledged, technology-driven implementations are still considered the area where most IT implementation failures originate. This can be attributed to the fact that technology overshadows business process requirements.[424] A successful minimalist approach to IT adoption by the Spanish

[423] Cf. Park, Sung-Yeon and Gi Woong Yun: The impact of internet-based communication systems on supply chain management: An application of transaction cost analysis, in: Journal of Computer Mediated Communication, Vol. 10 (2004), No. 1, November, p. 3.

[424] Cf., for example, Field, Alan M.: Think it through, in: The Journal of Commerce (2005), January 24, 2005, pp. 36-37.

fashion clothing company Zara has been documented by McAfee.[425] Based on this case study, McAfee identified the following guiding principles for the adoption of IT.[426]

- *IT as an aid to judgment*. As such, it is not seen as a substitute for human experience and judgment.
- *Standardized and targeted IT adoption.* Consequently, only systems and applications that are seen to provide value are adopted.
- *IT starts from within.* Given that, business goals should shape a company's use of technology.
- *Processes at the center.* IT systems focus on processes and not on functions.
- *Pervasive alignment.* Not only should IT systems be aligned throughout the organization, but also aligned with the employee's belief and support of the IT systems.

These principles have to be carefully applied, though they certainly help to avoid common mistakes. For example, a too cautious attitude towards the beneficial nature of IT systems and e-business applications can prevent companies from adopting them. This might be especially dangerous if certain technologies emerge as industry standards. It could also impede first mover advantages. Furthermore, if evaluated separately, certain IT applications might not appear very beneficial, but if adopted together, their contributions can be much higher than the sum of its parts.[427] Another principle that should be handled with care is the management of decision support systems. Though this is not supposed to replace human judgment, it is important to emphasize that human judgment has its own shortcomings. Thus, decision assistance is of value and should be considered as such. In line with this, McAfee has explicitly pointed out benefits linked to IT systems. These comprise, among others, process standardization and deployment; assurance of compliance with new processes; optimization potentials; automation; monitoring of processes; comprehensive analyses; control; and reporting. Many of these processes could not be performed at all or at least not to the degree possible through e-business systems. In that sense, it can be asserted that e-business has the potential to reshape coordination, collaboration, and integration between supply chain partners and to optimize the structure of the supply chain itself.[428]

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425 See McAfee, Andrew: Do you have too much IT? in: MIT Sloan Management Review (2004), Spring, pp. 18-22.
426 Cf. McAfee: Do you have too much IT?, pp. 20-22.
427 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, p. 286.
428 Cf. McAfee: Do you have too much IT?, p. 22.

Porter referred to the Internet as being "[…] the most powerful tool available today for enhancing operational effectiveness."[429] Only if this enhanced and superior operational effectiveness is sustainable, competitive advantage is achieved. Standard applications rarely provide such durable advantages. Porter has argued therefore that strategic positioning becomes even more important: "While Internet applications have an important influence on the cost and quality of activities, they are neither the only nor the dominant influence."[430] In line with this view, Delfmann and Albers have argued that standardized IT and flexibility at low cost might lead to the consequence that IT can no longer be a competitive differentiator. In their view, the proportion and importance of physical logistics compared to the information logistics will increase again.[431]

Kim and Narasimhan have identified two major points that should be considered when evaluating e-business activities. The first point is to think beyond sole information processing capabilities and to recognize the utilization of technology in order to alter the existing value chain or to engage in a new value chain. The second point is to consider the capabilities of optimizing structural connections among supply chain activities. This second point particularly brings SCM considerations to the forefront.[432] This can be summarized as a shift from viewing IT as an infrastructural support towards understanding IT as a source for value creation and competitive advantage. This aspect could as well be seen as the evolution from IT as it was known in the early 1990s to e-business with its enhanced network characteristics.

Some researchers refer to the Internet when analyzing the potential of e-business. E-business comprises more than the Internet and these authors indeed refer to the entirety that is defined here as e-business. Several authors have pointed out that the Internet itself does not provide supply chain innovation but the underlying concepts, such as outsourcing, collaboration, or differentiation, have been available before the Internet emerged. It is undoubted, however, that the

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429 Porter: Strategy and the Internet, p. 70.

430 Porter: Strategy and the Internet, p. 75.

431 Cf. Delfmann and Albers: Supply chain management in the global context, p. 68.

432 Cf. Kim, Soo Wook and Ram Narasimhan: Information system utilization in supply chain integration efforts, in: International Journal of Production Research, Vol. 40 (2002), No. 18, pp. 4587-4588. These two points were identified based on a review of the views on IT by Earl, M. J.: Management strategies for information technology, Englewood Cliffs 1989; and Porter, Michael E. and Victor E. Millar: How information gives you competitive advantage, in: Harvard Business Review, Vol. 63 (1985), July/August, pp. 149-160.

arrival of the Internet and the accompanying e-business increases the speed of adoption and the possible scope of these concepts.[433]

Since each value activity in a supply chain consists of a physical and an information-processing component, it creates and uses information in different ways. The impact of IT becomes obvious when linked to the nine categories of value activities identified by Porter. These are firm infrastructure; human resource management; technology development; and procurement as supporting activities and inbound logistics; operations; outbound logistics; marketing and sales; and after-sales service as primary activities. Before the Internet, IT capabilities have mainly enhanced each value chain activity independently. Even without the knowledge of future Internet capabilities, IT alone has already been considered for creating new linkages and better coordination between these value activities.[434] In 2001, Porter has expanded this analysis to the Internet and e-business capabilities.[435]

According to Chopra and Meindl, e-business is likely to provide value if any of the following indications is evident:[436]

- The company is exposed to frequent and small sized transactions, uses predominantly phone and fax, and puts lots of effort in reconciling product and financial flow.
- Transactions require limited buyer or seller qualification, there exists a fragmented and competitive market, and the online site is attractive and easy to use.
- The bullwhip effect is significantly present due to information distortion; low inventory turns; poor product availability; little collaboration for promotions and new product introductions; and short product life cycles.

The Internet as well as e-business can be seen as enabling technologies, providing “a powerful set of tools that can be used, wisely or unwisely, in almost any industry and as part of almost any strategy.”[437] Internet and e-business are considered to be complementary to existing strategies. Additionally, they provide new opportunities and possibilities for shaping those strategies. The bottom line is that the Internet as well as IT and e-business are of no economic value in

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433 Cf. Sharman, Graham: How the internet is accelerating supply chain trends, in: Supply Chain Management Review (2002), March/April, p. 19.

434 Cf. Porter and Millar: How information gives you competitive advantage, pp. 151-153.

435 See Porter: Strategy and the Internet, pp. 63-78.

436 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, pp. 549-550.

437 Porter: Strategy and the Internet, p. 64.

themelves unless they are put to use in the correct and appropriate context.[438] Nevertheless, direct impacts on all nine value activities have been identified. The conclusion provided by Porter and Millar in 1985 still holds without restrictions: "The importance of the information revolution is not in dispute: the question is not whether IT [and e-business] will have a significant impact on a company's competitive position; rather the question is when and how the impact will strike."[439]

Amit and Zott have examined the source of value creation possibilities through e-business. They identified four sources of value creation in e-business that expand the strategic options of a company:[440]

- *Efficiency*. Includes gains in search costs; selection range; symmetric information; simplicity; speed; economies of scale; communication costs; and transaction processing costs.
- *Complementarities*. Refers to the fundamental theory that two or more products can be more valuable together rather than individually. In e-business, this can occur between products and services for customers, online and offline assets, technologies and activities.
- *Lock-in*. Creates value through e-business by establishing higher switching costs achieved through loyalty programs, a dominant design, trust, and high degree of customization. Additionally, positive network externalities can create value through a lock-in, as for example in the size of a marketplace such as eBay.
- *Novelty*. Refers mainly to first mover advantages and includes new transaction structures, new transactional content, new participants, and other novel elements.

Information is of special importance for SCM as it enables many positive effects in supply chains. Whereas the basic value of information sharing was analyzed earlier in section B.II.3., e-business and its information systems determine the infrastructure and technical capabilities to realize the desired degree, extent, and quality of information sharing.[441] To shape these dimensions,

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438 Cf. Porter: Strategy and the Internet, p. 65.

439 Porter and Millar: How information gives you competitive advantage, p. 160.

440 Cf. Amit, Raphael and Christoph Zott: Value creation in e-business, in: Strategic Management Journal, Vol. 22 (2001), No. 6/7, June/July, pp. 503-509.

441 See Li *et al.*: Comparative analysis on value of information sharing in supply chains, p. 35.

several technologies have been developed and are available.[442] Those will be discussed in the following section.

### 3.d. Applications and Developments of E-Business in Supply Chain Management

In order to employ e-business to shape and enable SCM, the IT systems of participants have to fulfill fundamental requirements. Without these basic capabilities it is unlikely that the diverse information systems can ensure a seamless information, material, and financial flow.

On the IT system level, the IT infrastructure is of crucial importance for the realization of e-business systems. IT infrastructure consists of components that build the basis for the collection of data, transactions, system access, and communication. The following components have been identified by Simchi-Levi, Kaminsky and Simchi-Levi and represent only the very fundamental ones; more advanced and recent technologies and applications are subsequently discussed.[443]

- *Interface and presentation devices*. In general, interface devices include all kinds of devices that make it more efficient to gather and represent data and information. They also include the usage of Universal Product Code (UPC), which was introduced in 1973 and is based on barcode technology. By using barcode scanners, products and processes can easily be recorded and tracked. The next generation of product identification is most likely going to be radio frequency identification (RFID), discussed later in this section.
- *Communication*. Fundamental communication modes in the e-business era are e-mail and formal data exchange by means of EDI.
- *Databases*. As the amount of data gathered and stored grows constantly, it has to be properly organized to retain its value. Gathered data include transaction information, status information, and general information. It becomes also increasingly important to comply with legal regulations when electronic archiving of documents is to replace physical document archives. E-business applications that involve external members of the supply chain require advanced, integrated database systems, such as data warehouses, data marts, and groupware databases.
- *System architecture*. The most common internal network architecture is a client/server system, employing middleware. With increasingly connected

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442 What is referred to as technologies here comprises developments in specific standards, protocols, interfaces, and general computing hardware.

443 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, p. 274-279.

and homogeneous systems, a special emphasis has to be placed on system security in terms of fraud, system manipulation, and failures.

Horvath has identified more fundamental attributes for an IT infrastructure suitable for SCM. An exact definition, however, depends on the specific circumstances. Nicolai has also named several preconditions for applying e-business in SCM. These fundamental attributes brought forward by these two authors include: open standards; low-cost connectivity; large and flexible data storage capabilities; data maintenance of existing system structures and Enterprise Application Integration (EAI); systems and channel integration; higher-level self service capabilities; intelligence gathering and analysis; supply chain collaboration exchanges; sophisticated security capabilities that ensure safe network structures (through firewalls, virus scanners, encryption of data and backup systems); and advanced e-commerce capabilities.[444] Additionally, Horvath remarks that the implementation of new SCM capabilities should become a collaborative process in itself.[445] This underlines the meta-policies on the normative SCM level developed in this text.

In light of these fundamental requirements towards information systems, it becomes clear that the integration of applications into ERP systems can be seen as an important prerequisite to e-business enabled SCM.[446] For example, when adopting an ERP system, typically the need for integrated databases or data warehouses is realized. The storage and quick retrieval of information is one of the main characteristics of this system and therefore these capabilities are in place with a running ERP system. If such data warehouses are transferred to an SCM system then this can be referred to as business warehouse.[447]

Ideally, companies possess unique business processes that are mainly correct, sometimes providing them with a competitive advantage. Then, adopting a standard ERP system would cause the loss of this competitive advantage and, in

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444 Cf. Horvath: Collaboration: The key to value creation in supply chain management, pp. 206-207; and Nicolai, Sascha: eSupply Chain Management als strategisches Managementkonzept, in: Wannenwetsch, Helmut H. and Sascha Nicolai (Eds.): E-Supply-Chain-Management: Grundlagen, Strategien, Praxisanwendungen,Wiesbaden 2002, p. 11.

445 Cf. Horvath: Collaboration: The key to value creation in supply chain management, pp. 207.

446 See also n.a.: Energizing the supply chain: Trends and issues in supply chain management, p. 20 and Schreiner, Wilhelm: Entwicklungen und Implementierung von SCM-Strategien, in: Wannenwetsch, Helmut H. (Ed.): Vernetztes Supply Chain Management, Berlin Heidelberg New York 2005, p. 381.

447 Cf. Illgner, Elke: Praxisinstrumente für eine erfolgreiche SCM-Realisierung, in: Wannenwetsch, Helmut H. (Ed.): Vernetztes Supply Chain Management, Berlin Heidelberg New York 2005, pp. 89-94.

fact, worsen its operations. In such a case it makes sense to customize the ERP system in a way that fits these unique business processes.[448] If this is not done internally, the company might run the risk that the knowledge about these unique business processes are communicated through the software vendor. Therefore, it has to be managed with care.

In themselves, ERP systems have often been seen as a source for providing additional benefits or competitive advantage. As IT capabilities spread more widely, however, ERP systems might as well become a necessity for remaining competitive. ERP systems are not just trivial applications but rather "[…] an infrastructure that supports the capabilities of all other information tools and processes utilized by a firm."[449] As such, they decisively build the foundation for externally integrated ERP systems that therefore support SCM capabilities. This view is also shared by Chopra and Van Mieghem who posit that "information-processing costs […] tend to be lower for an e-business if it has successfully integrated systems across the supply chain."[450]

In the context of ERP implementation, McAfee has reported an interesting observation. In a case study analysis conducted immediately after the implementation of an ERP system, first performance worsened but then improved over time along a learning curve.[451] This phenomenon is also known as the "worse-before-better" effect and has also been documented by Repenning and Sterman in the context of quality improvement programs.[452] When implementing an ERP system, the possibility of such performance dips should be considered and resources should be planned accordingly.

One fundamental function SCM applications have to fulfill is the sharing of planning and forecasting information in order to improve supply chain coordination. By doing that, total supply chain costs can be reduced while demand can be better matched with supply.[453] Another crucial objective is to integrate diverse business systems and applications and through this a seamless information

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448 Cf. Bendoly, Elliot and Tobias Schoenherr: ERP system and implementation process benefits. Implications for B2B e-procurement, in: International Journal of Operations & Production Management, Vol. 25 (2005), No. 4, p. 307.

449 Bendoly and Schoenherr: ERP system and implementation process benefits. Implications for B2B e-procurement, p. 306.

450 Chopra and Van Mieghem: Which e-business is right for your supply chain?, p. 35.

451 Cf. McAfee, Andrew: The impact of enterprise information technology adoption on operational performance: An empirical investigation, in: Production and Operations Management, Vol. 11 (2002), No. 1, Spring, pp. 40-43.

452 Cf. Repenning, Nelson P. and John D. Sterman: Nobody ever gets credit for fixing problems that never happened, in: California Management Review, Vol. 43 (2001), No. 4, Summer, p. 73.

453 Cf. Chopra and Van Mieghem: Which e-business is right for your supply chain?, p. 35.

exchange. As Houlihan already noted in 1985: "Integration, not simply interface, is the key."[454] The difference between integration and interfaces is that interfaces are always associated with interruptions. This is not limited to information systems. When interfaces are present, additional applications or devices are necessary to transfer information, documents or even physical goods from one system to the other. As an example, the JIT II concept, where independent supply chain members share one facility to assemble a final product can be seen as an integrative physical effort.[455] Similarly, independent integrated systems exchange information as if they were one.

One of the first achieved integrative efficiency gains by IT in inter-company transactions were realized through EDI. The basic idea of EDI has been to avoid redundant recording work and thus to ensure a seamless data exchange. To achieve this, companies have developed interfaces for their systems that have allowed for the automated exchange of standard business documents. It is important to differentiate between EDI as the underlying concept of electronic data interchange in the literal sense and the protocols and formats with which this is realized. In the very beginning, even the data transmission protocols were customized, with connections either directly established through the telephone network or through proprietary, physically-connected wide area networks. Because of the lack of standard transmission protocols and formats, these first applications were individual linkages between two business partners and the relationship-specificity was very high. Subsequently, industry-specific and often country-specific protocol format standards have been developed, such as EDI for administration, commerce and transport (EDIFACT) or the standard developed by the organization for data exchange by teletransmission in Europe for the automotive industry, ODETTE.[456] Though data transmission has also been transferred to the TCP/IP network protocol and the Internet has been used as the transmission network, data protocols and formats remained different. Consequently, these separate EDI legacy systems are generally incompatible with each other and the installations are rather expensive.[457]

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454 Houlihan, John B.: International supply chain management, in: International Journal of Physical Distribution & Materials Management, Vol. 15 (1985), No. 1, p. 27.

455 See for example Krajewski and Ritzman: Operations management, p. 495.

456 See Nicolai, Sascha: Praxisinstrumente für eine erfolgreiche eSCM-Realisierung, in: Wannenwetsch, Helmut H. and Sascha Nicolai (Eds.): E-Supply-Chain-Management: Grundlagen, Strategien, Praxisanwendungen, Wiesbaden 2002, p. 70.

457 Cf. Evans, Philip and Thomas S. Wurster: Blown to bits, Boston, Massachusetts 2000, pp. 174-175.

Technical compatibility of physical components and software applications continues to be a challenge for supply chains.[458] There are developments under way, however, that aim to resolve compatibility problems, and the development of the Internet and the WWW may serve as a prime example for this process. The two major categories that drive this development are component technology and extranet technology. Both categories emphasize the importance of standards. Developments in component technology are rather technical and IT specific. The concepts of modularization, encapsulation and plug-and-play component development, however, are key characteristics that are also of interest for other areas where integration is of importance, being seen as driving forces for the development of network technologies.[459]

In terms of extranet technology, the Internet, based on the TCP/IP network protocol, is the network technology that links most business partners with each other. In terms of Internet services, one of the most promising and relevant emerging data format standards, in particular for SCM, is XML. Tan, Shaw and Fulkerson see it as "…a set of rules, guidelines and conventions for designing text formats for structured data so that it is easy to generate and read (by a computer), can be interpreted unambiguously, extensible, supports internationalization/localization, and is platform-independent."[460] It does so by embedding tags in the document that carry structural information and attributes. These tags make information self-descriptive and indicate the specific meanings of the information.[461] Because of this characteristic, XML documents can be read independently from a particular application in the way the author intended. XML has therefore been considered to be the ASCII code of the future.[462] Based on the indicated type, the document can be processed in the specified way after reception, for example as an order, invoice, complaint or other business document. However, the further processing of the transmitted information depends on the recipient's system. This can be overcome by building a joint, vertical vocabulary that clarifies such remaining ambiguity.[463]

This view alone would underrate the versatility of the protocol. Special specifications exist and can be summarized in four categories: (1) foundation

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458 Cf., for example, Siau, Keng and Yuhong Tian: Supply chains integration: architecture and enabling technologies, in: The Journal of Computer Information Systems, Vol. 44 (2004), No. 3, Spring, p. 70.

459 Cf. Tan, Shaw and Fulkerson: Web-based supply chain management, pp. 43-45.

460 Tan, Shaw and Fulkerson: Web-based supply chain management, p. 46.

461 Cf. Siau and Tian: Supply chains integration: architecture and enabling technologies, p. 70.

462 Cf. Tan, Shaw and Fulkerson: Web-based supply chain management, p. 46. ASCII stands for American Standard Code for Information Interchange.

463 Cf. Siau and Tian: Supply chains integration: architecture and enabling technologies, p. 70.

specifications, (2) software infrastructure specifications, (3) semantic specifications, and (4) application specifications. Though this implies that again incompatibility is created through these different specifications, the common and readable underlying format structure using tags remains independent from specifications. Therefore, even humans would be able to interpret these documents.[464] With these functionalities, XML-based data interchange overcomes the inherent problems of conventional EDI, namely proprietary standards and necessary individual customization that cause relatively high implementation costs, and therefore builds the foundation for a wider adoption in business data interchange.[465]

A relatively new protocol to exchange XML messages is SOAP,[466] situated below the network communication protocols TCP/IP and HTTP. These network protocols were chosen because of their wide acceptance and unproblematic compatibility with firewalls. SOAP's main characteristic is that it allows Internet communication between systems that is independent from platforms and programming languages.[467] The W3C is responsible for the maintenance and development of the SOAP protocol and does so within its XML working group.[468] Because of the relevance of XML and SOAP, these are also at the core of Microsoft's ".NET" technology.[469]

Although standards have been driving the success of the Internet and the information society, there are several challenges in connection with this. One is certainly creating and establishing a standard. First of all, high costs are incurred by the one creating a standard. Once this is established, however, there is a lot of power connected to the one owning it. With the growing community of open source developers, it is becoming increasingly difficult to enforce proprietary standards.

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464 Cf. Tan, Shaw and Fulkerson: Web-based supply chain management, pp. 46-47, also for a more detailed description of the technical aspects only briefly mentioned here.

465 Cf. Gosain, Malhotra and El Sawy: Coordinating for flexibility in e-business supply chains, p. 32.

466 Originally, SOAP was an acronym for Simple Object Access Protocol. However, in its recent version, this was dropped because of its inaccuracy. Therefore, SOAP is not an acronym for anything anymore.

467 Cf. Siau and Tian: Supply chains integration: architecture and enabling technologies, p. 71.

468 See World Wide Web Consortium, http://www.w3.org, W3C,retrieved on: February 15, 2006.

469 .NET is a platform developed by Microsoft that comprises Web service servers, developer tools, applications, and a certified partner organization network to support the technology. It aims at connecting information, people, systems, and devices through software, using the Internet. For more information, see http://www.microsoft.com, category "developer tools", retrieved on: February 10, 2006.

The long lasting power of Microsoft office document standards can serve as one example. Microsoft Office document formats became a standard that prevented many from switching to competing software packages because of the vast amount of existing files in this format. This might change with the latest Open Office version 2.0 that not only is able to process existing Microsoft formats but is also founded on a new, XML-based open standard document format, known as the “OASIS” format because it has been developed by the Organization for the Advancement of Structured Information Standards (OASIS). This format is the result of an international collaboration effort, led by open source developers and major software companies that joined forces in OASIS. The main advantage of this new document specification is that it is independent from a specific software application and is also readable if the respective application does not exist anymore. Therefore, files can be archived over a long period of time in a machine-readable way – important for both, private users and companies.[470]

Increasing standardization also led to the emergence of ERP systems. Even before ERP systems arrived in the business world, internal integration aspirations were sought through Computer Integrated Manufacturing (CIM) systems. Then, IT standards were not advanced enough and the realization of full CIM was expensive. CIM, however, shared already many basic ideas of current ERP systems.[471]

The next step under way is to achieve external information system integration by means of ERP systems. The term ERP II has been introduced by the Gartner Group for such extended ERP systems.[472] Others refer to such systems simply as SCM systems.[473] Their functions have been expanded to fit the holistic understanding of SCM. This expansion aims to enable collaborative SCM instead of company-internal optimization; to include the supplier side, internal operations and the customer side; to align system processes across the supply chain; to apply Web-based and open standards; and to shift from internally generated and consumed information to internally and externally generated and shared information.[474] Extranet technology and the need for integrating business partners makes it necessary to adapt existing ERP systems, as they were originally

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470 Cf. Open Office.org, http://www.openoffice.org, Open Office.org,retrieved on: February 15, 2006; and Weidemann, Tobias: Open Office 2.0: Das beste Office der Welt, in: PC-Welt, No. Issue, December, 2005, p. 49.

471 Cf. Kuhn and Hellingrath: Supply Chain Management: Optimierte Zusammenarbeit in der Wertschöpfungskette, p. 135.

472 Cf. GartnerGroup, Bond, B. *et al.*: ERP is dead - long live ERP II 2000.

473 For example, cf. Tarn, Michael J., David C. Yen and Marcus Beaumont: Exploring the rationales for ERP and SCM integration, in: Industrial Management & Data Systems, Vol. 102 (2002), No. 1, p. 30.

474 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 272-273.

designed only for integrating internal functions and processes. Nevertheless, existing ERP systems and their underlying integrative idea have built the foundation for upcoming ERP II systems. Therefore, existing ERP vendors like SAP are best suited to extend these systems to fit these changing requirements best.[475] It can also be concluded that companies that integrate ERP systems well with their business processes and individual requirements have a solid starting point to explore possibilities of ERP II or SCM systems.[476]

Besides advances in software applications, their integration, and network technologies, physical tools and devices have also been developed to leverage the foundations laid down. Major relevant areas for SCM are currently mobile computing power, wireless networking, and new tracking technology.

Mobile computing and wireless networking, often referred to as mobile business, enhance the capabilities of existing e-business by making it independent from fixed physical working places and network plugs. The driving technologies are wireless local area networks (WLAN) and conventional mobile communication networks, such as the global system for communication (GSM) or the universal mobile telecommunications system (UMTS). In addition, the global positioning system (GPS) combined with mobile computing power opens entirely new navigation related applications. Developments in these areas are likely to shape and drive e-business and related strategies over the upcoming years by adding truly ubiquitous network accessibility. Thereby building on previously developed and established e-business technologies.[477]

Advances in tracking and tracing technology are of special importance for SCM. In 1973, barcode technology revolutionized information recording and processing and is a system still widely used. It works by coding an identification number in a barcode which can be read automatically by scanners. This information then is processed through a database that carries relevant information and returns a certain outcome. In case of a cashier application, it is mainly the price of a product and a short description. Barcodes are also used in logistics. FedEx invented online package tracking based on a barcode system. Each package carries an unique barcode which is recorded at each processing stage. Connected to a database, which is also connected to the Internet, a package's status can be tracked at any time.

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[475] Bond *et al.*: ERP is dead - long live ERP II, p. 2.

[476] Cf. Tarn, Yen and Beaumont: Exploring the rationales for ERP and SCM integration, p. 33.

[477] See also Siau and Tian: Supply chains integration: architecture and enabling technologies, p. 70; and Illgner, Elke: Grundlagen und Anwendungen der Internettechnologie im SCM, in: Wannenwetsch, Helmut H. (Ed.): Vernetztes Supply Chain Management, Berlin Heidelberg New York 2005, p. 44-45.

RFID now is the technology seeking to replace barcode technology. While barcodes can be printed on almost any kind of package, RFID works with tags, so-called RFID or simply RF tags, which cab be active or passive.[478] Active tags carry their own power supply and therefore are able to send signals whereas passive tags carry no power supply and are only activated through a suitable scanner. Thus, active RF tags can be located over longer distances than passive tags. RFID technology has several advantages over barcode technology:[479]

- Many RF tags can be read simultaneously by a scanner, speeding up the capturing process.
- No direct in-sight connection is necessary. Therefore, RF tags can be read through closed packages or cartons.
- RF tags can store data and information independently from a database.

With these capabilities go along new functionalities and application opportunities. For example, warehouse or store inventory can be frequently recorded in an efficient manner, improving tracking physical items throughout the supply chain. In a recent study, Thonemann et al. found that retailers and consumer goods manufacturers see the major impact of RFID over the next five years in logistics, i.e. transportation and storage processes, and the tracability of goods.[480] A study conducted by the University of Arkansas shows a 16 percent reduction on out-of-stock products and improvements in speed of shelf replenishment in Wal-Mart stores that track product cases with RFID compared to those that are still using barcode technology.[481] Also, as RF tag technology develops, more advanced RF tags that contain integrated circuits can be connected with other systems such as those which document for example temperature exposure which could be of importance for frozen food or pharmaceutical products.

As it has been always one aim that RFID technology would replace barcode technology, a standard for uniquely identifying items was required. Initially developed at MIT together with industry leaders and other academic institutions, the electronic product code (EPC) has evolved and has become the standard for

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[478] Cf. Prater, Edmund, Gregory V. Frazier and Pedro M. Reyes: Future impacts of RFID on e-supply chains in grocery retailing, in: Supply Chain Management: An International Journal, Vol. 10 (2005), No. 2, p. 138.

[479] Cf. Sheffi, Yossi: RFID and the innovation cycle, in: The International Journal of Logistics Management, Vol. 15 (2004), No. 1, p. 1.

[480] Cf. Thonemann, Ulrich *et al.*: Supply chain excellence im Handel, Wiesbaden 2005, pp. 194-196.

[481] Cf. n.a.: Report shows how Wal-Mart did it, in: RFID Journal, No. Issue, November 14, 2005, http://www.rfidjournal.com, retrieved on November 18, 2005.

RF tag identification. Consequently, the EPCglobal Network as the association to maintain and administrate EPC technology is a joint appointment from EAN International and the Uniform Code Council, Inc. (UCC), the institutions responsible for barcode technology standards and in particular the universal product codes (UPC).[482] The major feature of the EPC is the code number itself. Storing only this information requires the least technical capability on the tag side, i.e. no integrated circuit is required but only a suitable antenna, thereby keeping costs low for such applications.[483]

Essentially, EPC aims to integrate the Internet with RF technology. The following only briefly describes how EPC based on RFID is supposed to work. A manufacturer who releases an item into the supply chain defines the information for the item and stores it in its own EPC information service database. The entry is reported to the centralized object naming service (ONS), maintained by the EPCglobal Network. Whenever an item is identified along the supply chain, the respective readers request item information through a service called EPC discovery service, which provides the location of the EPC information service that stores it. The request is then sent to the EPC information service, maintained by the manufacturer of the item, which in turn provides the requested information. The structure of the EPC is capable of identifying up to 268 million unique manufacturers, 16 million product types, and up to 68 billion individual items. Consequently, the format is capable of identifying hundreds of trillions of unique items.[484]

Although major retailers have expressed their intent to introduce RF tags on their products and RF tags are already used in industrial environments, for a broader application there are still challenges that have to be resolved. For example, RF tags are still relatively expensive, though prices are expected to drop to 5 US cents, which is considered to be the level at which demand is going to soar significantly. This point should be reached in the not-too-distant future.[485] Application on an item level, however, especially for inexepensive consumer products, is unlikely for the next several years.[486]

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[482] EAN stands for the European Article Numbering system.

[483] See Heires, Katherine and Ajit Kambil: Tracking RFID's next wave to gain strategic advantage 2004.

[484] Cf. VeriSign, Inc., White Paper, n.a.: The EPCglobal Network: Enhancing the supply chain 2005; and EPCglobal, n.a.: The EPCglobal Network: Overview of design, benefits, and security 2004.

[485] Cf. Prater, Frazier and Reyes: Future impacts of RFID on e-supply chains in grocery retailing, p. 138.

[486] See Deloitte & Touche USA LLP, Fitzgibbons, Daniel, Lawrence Hutter and Scott Sopher: Radio frequency identification (RFID): Critical considerations for manufacturers 2004, p. 3.

Other problems are more of technical nature. For example, RF tags have some interference problems with metallic material and liquids and RF tag scanners have certain limits in terms of reach. Furthermore, problems exist in the application of the technology. There is no assigned frequency for RFID and therefore interference with other applications could occur. Additionally, there exists no common standard for RFID communication – problematic because of the importance of standards for a seamless integration and their network effects, as previously discussed in the context of other standards. There is also the envisioning of recording the information of all RF tags in one common database, which then could be accessed through the Internet. In conjunction with this vision, concerns about privacy, security, necessity, feasibility and desirability have been raised. Though these problems are indicators for the early development stage of RFID, few doubt its further application and wide adoption.[487] As the major retailers – Wal-Mart in the USA and Metro in Europe – further expand RFID applications, the adoption of RFID technology will be inevitably catalyzed.[488]

E-business in all its varieties will shape and define SCM practices in the upcoming future. But it also has become clear that technology alone is unlikely to yield significant benefits without a solid managerial foundation based on SCM principles. As all core elements of successful SCM have been introduced and discussed, inherent challenges of the comprehensive nature of SCM as it is proposed in this text remain to be addressed.

## IV. Challenges for Supply Chain Management

### *1. Involvement in Multiple Supply Chains*

Maximizing the monetary overall supply chain profitability with network members is not an insignificant task, especially when members belong to more than one supply chain network. In part, this is due to frequently conflicting objective functions, even within company boundaries.[489] This misalignment of objectives is not necessarily only a policy problem. Often, companies are involved in more than one supply chain and these rarely share the same objectives and priorities. Thus, different policies, priorities, and requirements exist, naturally affecting all supply chains since it is difficult to totally separate them.

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[487] Cf. Sheffi: RFID and the innovation cycle, p. 2 and p. 9.

[488] See Thonemann *et al.*: Supply chain excellence im Handel, pp. 191-192.

[489] See Fleischmann, Bernhard, Herbert Meyr and Michael Wagner: Advanced Planning, in: Stadtler, Hartmut and Christoph Kilger (Eds.): Supply chain management and advanced planning: concepts, models, software and case studies (2nd ed.), Berlin Heidelberg New York 2002, pp. 72-73; Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 3-4; or Tan: A framework of supply chain management literature, p. 46.

A company for example might carry innovative products and functional products, each requiring its own supply chain configuration.[490] Consequently, the supply chains for each product group should be managed separately. Because this proves to be a challenging task within an organization, mismatches often arise.[491] *Table B-5* illustrates possible constellations and generic implications of such constellations. These constellations also raise additional issues that will be outlined later.

*Table B-5: Complicating matters of multiple supply chains within a company and their implications*

| *Supplier sells also* | *Implication* |
|---|---|
| Independent products | Problem of overhead cost allocation. Maybe different strategic orientation and competitive situation of different supply chains. |
| Same product to competing supply chain network | Hard to establish a trust-based relationship. Protective attitude of customer, likely to hold back information. Hard to achieve advantage over other supply chain. |
| Competing products | Difficult to share confidential information. Supplier might tend to benefit the stronger customer. |
| Substitute products | Difficult to share confidential information. Supplier likely to shift focus. |
| Complementary products | Little friction. Likely to follow similar objectives. Still competition for incentive allocation. Perhaps different supply chain configuration required. |

Even with independent products, such separated supply chains within a company might affect each other. One problem that can arise is that of cost allocation, especially if overhead costs are a large portion of the total. Additionally, the supply chains might be very distinct and require different, conflicting strategic configurations.

Another problem arises when a company sells the same product to a competing supply chain network. In this case, establishing a trust-based relationship might

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490 See Fisher: What is the right supply chain for your product?, pp. 106-109; and chapter B.III.1.

491 Cf. Lee, Hau L.: Letters to the editor, in: Harvard Business Review, Vol. 75 (1997), May/June, p. 191.

prove to be very difficult. Downstream supply chain partners are likely to be reluctant to share sensitive information. In such a constellation, the product under consideration and the relationship with the supplier is unlikely to support a competitive advantage over the competing supply chain network.

A similar constellation can be observed with competing and substitute products. If a supplier also sells competing products – to a competing supply chain network, obviously – it again is difficult to share confidential information. Additionally, a supplier might tend to favor the stronger customer or decide to support one product over the other. With substitute products, this is very likely if the market potential indicates a switch to the substitute.

Little friction exists with complementary products, as it is very likely that objectives are not conflicting. Furthermore, by definition, the products could be considered as sharing the same supply chain or at least their supply chains are interdependent. A few problems could arise in terms of incentive allocation and differing supply chain requirements even among complementary products.

The identification of multiple supply chains within a company is important in order to deal with the implications. An implicit concern in all the above constellations is that of confidentiality and antagonistic behavior. Partners may try to achieve competitive advantage over their suppliers or customers in order to replace them all together or at least to apply pressure on them.[492] In such situations, information may become too visible and companies would be concerned that other partners take advantage of this. Relevant asymmetric information can exist in a variety of areas, such as product design, inventory, costs, demand, and capacity.[493] Regarding those costs, "old" thinking states that the seller is better off the less information she/he shares with her/his buyer. Now that information is supposed to be shared openly because of its possible, mutually beneficial effects, it has to be determined how this can be managed successfully and under what conditions.[494]

General suggestions to mitigate negative side effects have been proposed by Liker and Choi. One of them is to share information intensively – albeit selectively, thus promising improved forecasting, better information visibility, and timely responses. This way, benefits are grounded in the process, not the information itself. Selective information sharing refers to risks associated with information itself. By selecting information and by that taking it to some extent out of context, its value to others can be limited. Another suggestion is to engage

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492 Cf. Knolmayer, Mertens and Zeier: Supply Chain Management Based on SAP Systems, p. 17.

493 Cf. Swaminathan and Tayur: Models for supply chains in e-business, p. 1388.

494 See Carter, Joseph R. and Bruce G. Ferrin: The impact of transportation costs on supply chain management, in: Journal of Business Logistics, Vol. 16 (1995), No. 1, pp. 189-190.

in joint improvement activities and building relation-specific benefits that are harder to transfer to other relationships.[495]

*2. Power Regimes in Supply Chains*

Besides a collaborative relationship style as mainly proposed here, there obviously exist also non-cooperative relationship settings that are actually more commonly adopted based on ”old” thinking. An ignorant attitude towards the possible benefits of collaboration aside, there are also well-founded reasons in certain circumstances for adopting transactional relationships.[496]

Therefore, it is of importance to understand under what circumstances which relationship designs are beneficial.[497] Cox has identified four basic relationship management choices. These depend on two dimensions: (1) the power condition of the relationship, or, as Cox calls it, the degree of value appropriation, i.e. adversarial or non-adversarial, and (2) the relationship style, either arm’s length or collaborative:[498]

- *Adversarial arm’s length relationship*. This is present when an exchange partner seeks to maximize its value share and regularly tests the market for new opportunities.
- *Non-adversarial arm’s length relationship*. This is present when an exchange partner accepts the current market price without overly bargaining, but still seeks actively for new market opportunities.
- *Adversarial collaborative relationship*. This is present when an exchange partner engages in extensive operational linkages and relationship-specific adaptations, but still aims to maximize the appropriation of value.
- *Non-adversarial collaborative relationship*. This is present when exchange partners operate as true partners, aiming for a long-term relationship based on trust and commitment and share any commercial benefits resulting from this relationship equally.

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495 Cf. Liker, Jeffrey K. and Thomas Y. Choi: Building deep supplier relationships, in: Harvard Business Review, Vol. 82 (2004), No. 12, December, pp. 104-113.

496 Croom found in a recent empirical study that also companies who are aware of the benefits of supply chain integration recognize that there exist “[…] limits to the extent to which it is necessary or desirable to integrate the links across the whole supply-side of the chain.” Croom: The impact of e-business on supply chain management, p. 60.

497 Cf. Swaminathan and Tayur: Models for supply chains in e-business, p. 1392.

498 Cf. Cox, Andrew: The art of the possible: Relationship management in power regimes and supply chains, in: Supply Chain Management: An International Journal, Vol. 9 (2004), No. 5, p. 353.

In order to further refine the definition of the relationship between buyers and suppliers, Cox developed the power matrix where the following relationships are identified: buyer dominated relationships; supplier dominated relationships; a relationship characterized by independence where both parties do not depend on each other in a significant way and therefore is of rather low importance for both; and interdependent relationships where the relationship is of high importance for both.[499] In case of buyer or seller dominated relationships, one party dominates the relationship with superior power over the other.[500] Combining the power regimes and relationship styles, Cox has derived the following *Figure B-14*.

| | | | |
|---|---|---|---|
| Arm's Length Relationship | Buyer dominant arm's length relationship | Buyer-supplier independent arm's length relationship | Supplier dominant arm's length relationship |
| Collaborative Relationship | Buyer dominant collaborative relationship | Buyer-supplier interdependent collaborative relationship | Supplier dominant collaborative relationship |
| | *Inequity*<br>Buyer Dominance | *Equity*<br>Power Equality | *Inequity*<br>Supplier Dominance |

*Figure B-14: Power regimes and relationship styles*[501]

Whereas an independent relationship between a buyer and a supplier can well be for low volume purchasing of commodity goods, a perfectly equal, interdependent power situation is rare, because generally, there is at least a tendency towards one side being more dominant than the other. The power

499 Cf. Cox: The art of the possible: Relationship management in power regimes and supply chains, pp. 351-352.

500 Cf. Cox: The art of the possible: Relationship management in power regimes and supply chains, p. 352 for detailed attributes of each power regime, i.e. power constellation.

501 Adopted from Cox, Andrew: Business relationships for competitive advantage, Basingstoke 2004, p. 97.

regimes identified by Cox can be transferred into an overall supply chain context by using the formal framework derived in section B.III.2.c.

Instead of comparing only two parties – supplier and buyer – independently, each participant in a supply chain should be seen in the context of the entire supply chain. In order to derive the power position of a supply chain member, the value contribution to the supply chain must be determined. The value contribution in competitive markets can be measured fairly well by the monetary value added to the supply chain. The following definitions are used, for the supply chain of product *Q*:

[9]: $X_{Qt} = s_{Qt} - v_{Qt}$

with $X_{Qt}$ = total value created in period *t* by the supply chain network of product *Q* that defines the supply chain network

$s_{Qt}$ = total sales revenue of product *Q* in period *t*

$v_{Qt}$ = cost of material and services procured from outside the supply chain network in period *t*

The value contribution of a company *U* to the supply chain of product *Q* is defined as:

[10]: $X_{UQt} = s_{UQt} - v_{UQt}$

with $X_{UQt}$ = total value created in period *t* by company *U* for product *Q*

$s_{UQt}$ = total sales revenue of company *U* with product *Q* in period *t*

$v_{UQt}$ = cost of material and services procured from outside by company *U* for product *Q* in period *t*

Another variable necessary to fully represent supply chain related power regimes is company *U*'s total value creation over all its products *P*:

[11]: $X_{Ut} = \sum_{P=p_1}^{p_{lU}} X_{UPt}$

with $X_{Ut}$ = total value created in period *t* by company *U* over all products *P*

$X_{UPt}$ = value created by company *U* with products *P* in period *t*, with $P = p_1, \dots, p_{lU}$ (*lU* products company *U* is involved in, *Q* being one of *lU* products)

The reciprocal power relationships can be calculated by relating the above defined measures to each other to form a supply chain power index and a company power index, defined as follows:

[12]: $$SC_{powerindex} = \frac{X_{UQt}}{X_{Ut}}$$

with $SC_{powerindex}$ = value between 0 and 1; with 0 meaning that company *U* is not dependent on the supply chain of product *Q*, because it is only a marginal fraction of the company's total value creation, and 1 meaning that company *U* is totally dependent on the supply chain of product *Q*, because it is the only product the company produces.

[13]: $$C_{powerindex} = \frac{X_{UQt}}{X_{Qt}}$$

with $C_{powerindex}$ = value between 0 and 1; with 0 meaning that the supply chain for product *Q* is independent from company *U* because company *U*'s contribution is only marginal, and 1 meaning that the supply chain is totally dependent on company *U*, with no other supply chain member involved. A value of 1 indicates total vertical integration.

In summary, both power indices have a continuous range between 0 and 1. Values towards 1 indicate a higher power position. A value towards 1 in the *SCpowerindex* indicates that a company is more dependent on the supply chain. A value towards 1 in the *Cpowerindex*, in contrast, means that the supply chain is more dependent on a company. *Figure B-15* illustrates four resulting, generic supply chain power regimes, similar to the ones Cox has defined for dyadic power regimes.[502]

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502 See Cox: The art of the possible: Relationship management in power regimes and supply chains, p. 352.

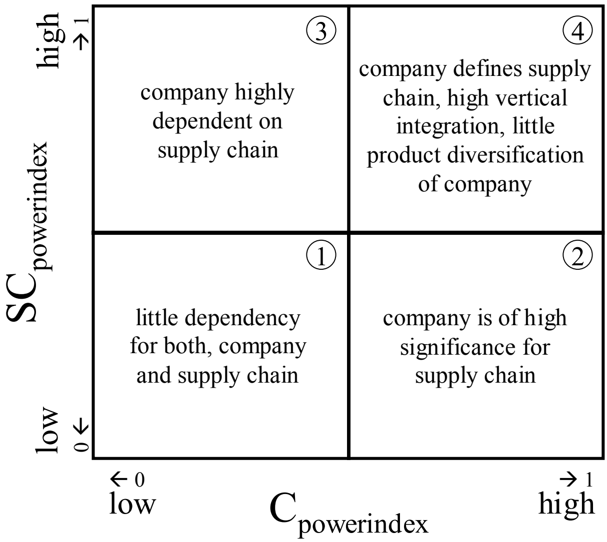


*Figure B-15: Supply chain power regimes*

In the first case – where the company-specific contribution to a supply chain is low and the supply chain portion of a company's total value creation is also little – there is little dependency for both. Such a position is of little importance and it is likely that the relationship can be characterized as a non-adversarial arm's length relationship.

In quadrant 2 and 3 in *Figure B-15*, either the company or the supply chain is relatively more dependent on the other. A company's position in quadrant 2 indicates a strong supply chain position, therefore it is likely that a supply chain driver role is or can be obtained.[503] Then, a company can decide what relationship it pursues with its supply chain partner, i.e. adversarial or non-adversarial, and arm's length or collaborative. In quadrant 3, the supply chain obtains higher bargaining power and often, an adversarial collaborative or arm's length relationship occurs. Ideally, this can be turned into a non-adversarial relationship with increasing collaborative elements the more important the company's contribution to the supply chain is. This relationship should be guided by a dominant supply chain member or a group of supply chain drivers.

Quadrant 4 depicts the situation of a highly integrated supply chain, where little value comes from outside the company. A company in such a position controls the majority of its supply chain. With regard to an increasing focus on

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[503] See also section B.III.2.

core competencies, such a position is not always desirable and a company might outsource activities and move more towards a quadrant 2 position.

It should be noted that this framework can be extended beyond the purely quantitative approach, as defined by *Equations [12] and [13]*, and include qualitative elements. Then, both power indices can be determined through a weighted scorecard approach, with individual factors defined by a specific supply chain environment.

The implications of both approaches – the power regimes developed by Cox and the one derived here – are similar. Whenever one party dominates the other or others (in the case of the supply chain), the less powerful partner has to be convinced to engage in collaborative efforts and coordination activities that yield the highest overall supply chain return. This is especially true for information sharing as this is a major constitutive source of power in supply chains. The dominant party is not eager to relinquish its position nor does the less dominant party want to become even more vulnerable. Clearly, information is not the only constituent of power in relationships, but as previously discussed an important one.

Being aware of power regimes in relationships and supply chains is an significant factor when designing supply chain policies. In order to engage partners in supply chain cooperation, the issue of incentive allocation is paramount.

Since SCM is concerned with global supply chain alignment, pareto-efficient solutions are not desired[504] and most likely individual supply chain members would have to compromise their own profitability in order to ensure such an overall improved solution. Therefore, a sound benefit allocation should be in place to obtain the buy-in of those supply chain members that are required to take more burden than others and thus sacrifice their own profitability. For example, moving to Vendor Managed Inventory (VMI) adds necessary tasks for the supplier and therefore requires resources.[505] An improvement of overall supply chain efficiency and effectiveness is assumed but often no benefit allocation is established, thereby supporting the creation of antagonistic behavior. A questionable example is provided by Dell, which is proud to collect cash from its customers before actually paying its suppliers.[506] The financing of the goods has not become obsolete, it has just moved to another supply chain position. Without a more in-depth analysis, the supplier has to also consider this in the pricing. Such an in-depth cost accounting

504 Cf. Busch and Dangelmaier: Integriertes Supply Chain Management - ein koordinationsorientierter Überblick, pp. 12-20.

505 Cf. Subramani, Mani: How do suppliers benefit from information technology use in supply chain relationships? in: MIS Quarterly, Vol. 28 (2004), No. 1, p. 1388.

506 Cf. Chopra and Meindl: Supply chain management: Strategy, planning, and operation, p. 19.

analysis requires not only the sharing of sensitive information, but is further complicated by the problem of assigning the correct costs to specific supply chains or relationships. Similar problems are encountered when different products are coupled.[507] Establishing a sound benefit allocation is therefore a challenging task in supply chains and one that has to be integrated into the overall SCM context.[508]

### *3. A Note on Vertical Integration and Uncertainties*

A contributing factor to the challenge of overall SCM context consideration is the implied complexity of a holistic SCM approach. Even a small number of supply chain combinations can create an almost infinite set of alternatives.[509] Operations research and management sciences deal with such problems, although primarily with quantitative dimensions. Adding qualitative elements makes this a highly complex task. Additionally, supply chains are dynamic systems that evolve over time.[510] This is why some executives favor a more integrated supply chain where more power can be imposed on the individual supply chain positions.[511] Indeed, many of the problems described so far are at least mitigated.[512] Such a highly integrated approach has been documented to have been successfully implemented by the Spanish clothing company Zara. By not including many external companies, Zara is able to apply full control over most of its supply chain, having "…five fingers touching the factory and five touching the customer."[513]

However, due to several factors, most often such a high integration is not feasible.[514] Economically, disintegration is based on transaction cost theory. The underlying theory for such make or buy decisions was first introduced by Coase and then decisively extended by Williamson.[515] Basically it states that if an

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507 Cf. Knolmayer, Mertens and Zeier: Supply Chain Management Based on SAP Systems, pp. 18-19.

508 See for example Delfmann and Albers: Supply chain management in the global context, pp. 39-40; and Tan: A framework of supply chain management literature, p. 46.

509 Cf. Fleischmann, Meyr and Wagner: Advanced Planning , pp. 72-73.

510 Cf. Simchi-Levi, Kaminsky and Simchi-Levi: Designing and managing the supply chain: Concepts, strategies, and case studies, pp. 2-3.

511 See Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 3.

512 See Munson, Hu and Rosenblatt: Teaching the costs of uncoordinated supply chains, p. 37, who come to a similar conclusion based on quantitative methods.

513 Cf. Ferdows, Kasra, Michael Lewis and Jose A. D. Machuca: Rapid-fire fulfillment, in: Harvard Business Review, Vol. 82 (2004), No. 11, November, p. 106.

514 See Williamson, Oliver E.: The economic institutions of capitalism: Firms, markets, relational contracting, New York 1985, pp. 85-130.

515 See Coase: The nature of the firm, p. 392, and Williamson: The economic institutions of capitalism: Firms, markets, relational contracting, pp. 15-43.

organization can perform an activity better than an external company, it would do so. According to Coase, a firm reaches a point where an increase in size leads to diminishing returns because of management inefficiencies, i.e. it becomes more difficult to control a company as its size increases.[516] Again, Williamson has expanded this view and has also identified disadvantageous factors independently from firm size.[517]

Additionally, Williamson has pointed out two main conditions under which a firm would internalize activities: asset specificity and demand externality. In general terms, asset specificity, also called more precisely transaction asset specificity, refers to those assets that are specific to the very purpose of an activity. However, an external company can posses specific assets that are relevant for a firm. Transaction asset specificity can be broken down into site specificity, human asset specificity, physical asset specificity, dedicated assets, brand name capital, and temporal specificity.[518] The second component, demand externality, refers to aspects that could harm a supply chain upstream company due to the behavior of companies downstream the supply chain. More broadly, this includes general environmental uncertainty and behavioral uncertainty.[519]

If overall acquisition costs are lower than the own production of an activity, a firm would favor buying such an activity instead of self-production. Acquisition costs consist of multiple dimensions. According to Clemons, Reddi, and Row, the total cost of acquisition consists of production costs and transaction costs. Transaction costs can be broken down into coordination cost, operations risk, and opportunism risk.[520]

Coordination cost covers all direct and indirect costs related to the necessary coordination because of a non-hierarchical relationship. This includes costs related to various kinds of information exchange and to additional activities necessary to

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516 Cf. Coase: The nature of the firm, pp. 394-395.

517 Cf. Williamson, Oliver E.: Markets and hierarchies: Analysis and antitrust implications, New York 1975, pp. 117-131.

518 Cf. Williamson: Comparative economic organization: The analysis of discrete structural alternatives, p. 281. This classification is widely accepted, but other classifications exist, for example see Cousins, Paul D.: The alignment of appropriate firm and supply strategies for competitive advantage, in: International Journal of Operations & Production Management, Vol. 25 (2005), No. 5, p. 407.

519 Cf. Williamson: Markets and hierarchies: Analysis and antitrust implications, pp. 8-10; and Park and Yun: The impact of internet-based communication systems on supply chain management: An application of transaction cost analysis, p. 4.

520 See Clemons, Eric K., Sashidhar P. Reddi and Michael C. Row: The impact of information technology on the organization of economic activity: The 'move to the middle' hypothesis, in: Journal of Management Information Systems, Vol. 10 (1993), No. 2, pp. 9-35.

reduce uncertainty or to mitigate its effects. Operations risk includes not only additional operational uncertainties in terms of on-time delivery and other increased fulfillment uncertainties, but also uncertainties toward the honesty and trustworthiness of the other party. It is unrealistic to cover all eventualities that can occur in a relationship beforehand and therefore differences in interpretation and commitment are nebulous. Opportunism risk, in contrast, refers to the difference of bargaining power before and after the engagement in a relationship. Three sources of opportunism risk have been identified: relationship-specific investments, small numbers bargaining, and loss of resource control.[521] This last element – loss of resource control – is of especial importance with regard to technology transfer accompanied by a shift of production to emerging countries.

The idea of transaction cost theory can be directly linked to Porter's five forces model. Two of the five forces that define industry attractiveness and profitability refer to bargaining power,[522] the level of which is determined to a large extent by the elements of transaction cost theory. Low bargaining power not only exists if a supplier is easy to replace but also if the provided activity can be easily internalized.

Developments in IT and e-business are believed to reduce coordination costs and as a consequence to favor market-based relationships. In spite of this, the number of suppliers has not increased. Bakos and Brynjolfsson have concluded that this is due to an increased importance of noncontractible investments which require fewer suppliers in order to provide the necessary investment incentives.[523] In a more recent and broader analysis, Park and Yun have confirmed that effects on exchange mechanisms are not straightforward and depend on multiple effects on both transaction costs and production costs. Whereas reductions in transaction costs benefit market systems, reductions in production costs favor hierarchical systems. In conclusion, they have found no evidence for drastic changes in existing relationship structures and mechanisms as a result of the developments in e-business.[524]

Thus far, the discussion has focused mainly on dyadic relationships. But relationships within a supply chain network are more subtle. Hammer has accounted for this by noting that there exist no terms for relationships that go beyond traditional relationships. For these, the designations of supplier, customer,

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[521] Cf. Clemons, Reddi and Row: The impact of information technology on the organization of economic activity: The 'move to the middle' hypothesis, pp. 15-17.

[522] See Porter, Michael E.: Competitive strategy, New York 1980, pp.24-29.

[523] Cf. Bakos, J. Yannis and Erik Brynjolfsson: Information technology, incentives, and the optimal number of suppliers, in: Journal of Management Information Systems, Vol. 10 (1993), No. 2, pp. 49-50.

[524] Cf. Park and Yun: The impact of internet-based communication systems on supply chain management: An application of transaction cost analysis, pp. 14-17.

and competitor clearly distinguish the role of the respective party. But within a network, other relevant relationships exist. For example, two companies buy the same product from the same supplier. (See the second constellation in *Table B-5*.) Currently, there exists no appropriate term for this. Another constellation exists when two suppliers sell different products to the same customer. This constellation is easier to grasp because less conflict exists. Hammer has defined the relationship between these two suppliers as *cosuppliers*. Within such a relationship, synergy potentials can be sought and used, such as joint transportation or the combining of non-core activities.[525]

One concern raised with regard to vertical integration is that benefits gained from it and/or close cooperation and the accompanying information sharing might lead to monopolistic power of the whole supply chain, thus leading to the incitement of anti-trust actions. This is not a new concern. In the 1950s, the US Supreme Court has looked upon this issue of vertical integration. Spengler has analyzed the effect and came to the conclusion that only horizontal integration potentially if at all suppresses competition. Vertical integration as such does not necessarily suppress competition.[526] Hoyt and Huq have come to the same conclusion. They remark that "[…] a competitive advantage derived from trust-based, collaborative supply chain alliances will be insufficient to justify anti-trust actions against the partners."[527]

Another challenge for supply chains is that of uncertainty as a complex network carries many different kinds of uncertainties. Though uncertainty should always be eliminated as much as possible in supply chains in order to avoid waste, it is also an inherent part of it. Capacities have to be planned long before actual demand. For manufacturing capacity planning especially, forecasts are still a necessity and forecast errors cannot be avoided.[528] Inherent uncertainties, besides the common demand and supply uncertainties, are damages in transportation, custom procedures, accidents, terror attacks, or natural disasters, among others. Uncertainties that can be influenced more directly and thus be controlled for to some degree are those caused by supply chain policies and structures, a lack of visibility, or lack of cooperation.[529]

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525 Cf. Hammer: The superefficient company, pp. 88-89. See the same source for a broader discussion of this aspect.

526 Cf. Spengler: Vertical integration and antitrust policy, p. 351, and Williamson: Markets and hierarchies: Analysis and antitrust implications, pp. 258-259.

527 Hoyt, James and Faizul Huq: From arms-length to collaborative relationships in the supply chain: an evolutionary process, in: International Journal of Physical Distribution & Logistics Management, Vol. 30 (2000), No. 9, pp. 760-761.

528 Cf. Fleischmann, Meyr and Wagner: Advanced Planning, pp. 72-73.

529 See Geary, Childerhouse and Towill: Uncertainty and the seamless supply chain, p. 53.

Geary, Childerhouse, and Towill have identified (1) process uncertainty, (2) supply uncertainty, (3) demand uncertainty, and (4) control uncertainty as general types of uncertainty. Process uncertainty involves internal operations; supply uncertainty refers to uncertainties of supply of upstream supply chain partners; demand uncertainty refers to uncertainties in ultimate demand or uncertainties due to wrong demand signaling up the supply chain; and control uncertainty refers to those posed by algorithms that transfer customer requirements into production targets and supplier raw material requests.[530] Because of market requirements, companies themselves are sometimes forced to increase demand uncertainties by introducing a greater variety of products, making forecasting increasingly difficult as demand can no longer be aggregated. One way to especially counter-balance such demand uncertainties is the adoption of mass customization and postponement through modular designs as module demand can be better aggregated. Thus, the effect of demand uncertainties of individual products can be tempered.[531]

Closely related to uncertainty is the issue of risk which can be defined as the product of uncertainty and impact. Whereas uncertainty refers to the probability of certain events to happen, impact defines the extent and associated costs of such events. When supply chains "lean out", risks are often not adequately considered because of an inability to realistically grasp uncertainty and therefore risk.[532] Consequently, adversarial, non-cooperative relationships are naturally more likely to disregard risks as competitive prices tend to approach marginal costs. In such transactions, quotes tend to disregard intangible costs, of which risk can be considered to be one because of *ex ante* absence of impact. If impact occurs, consequences can be severe.

Given a certain service level, uncertainties lead to variations in all operational metrics and increase costs along the supply chain in form of larger operational cushions, such as capacities, longer planned lead times, and higher safety stocks. Consequently, ways to reduce uncertainty are to be sought and the elements of the SCM framework are capable of dealing with uncertainty issues in the context of implied cooperative, holistic, and process-oriented attitudes.

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530 Cf. Geary, Childerhouse and Towill: Uncertainty and the seamless supply chain, p. 55.

531 Cf. Swaminathan: Enabling customization using standardized operations, p. 127.

532 See Zsidisin, George A., Gary L. Ragatz and Steven A. Melnyk: The dark side of supply chain management, in: Supply Chain Management Review (2005), March, pp. 46-52. For the definition of risk, see especially p. 48.

# C. Supply Chain Management and E-Business in Manufacturing Companies – a Descriptive Analysis of Practices

## I. Overview of the High Performance Manufacturing (HPM) Project

After laying out the foundations of SCM, it is the aim of this text to empirically analyze SCM practices in more detail. The analysis is built on the international research project High Performance Manufacturing (HPM) and data collected in its second international round in 2004. The HPM research project was firstly conducted on an international scale in 1996, with the data available in 1997 and this can be referred to as the first round of the HPM project. At the time, it was called the World Class Manufacturing (WCM) project, but is now referred to as the HPM project.[533]

Since its induction, its main target has been to identify those practices that determine exceptional performance in manufacturing.[534] The underlying HPM model can be seen as a development and extension of earlier work by Hayes and Wheelwright and Schonberger and thus more comprehensive.[535] The HPM model identifies six manufacturing practice areas that are seen as determinants of manufacturing performance:[536]

- Manufacturing strategy
- Total quality management

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[533] Before the international rollout, the research framework has been developed to analyze US owned and Japanese owned manufacturing companies in the USA, see Flynn, Barbara B., Roger G. Schroeder and Sadao Sakakibara: A framework for quality management research and an associated measurement instrument, in: Journal of Operations Management, Vol. 11 (1994), pp. 339-366. For detailed analyses of the first international round, see Schroeder, Roger G. and Barbara B. Flynn: High performance manufacturing - global perspectives, New York 2001.

[534] See Flynn, Barbara B. *et al.*: World class manufacturing project - overview and selected results, in: International Journal of Operations & Production Management, Vol. 17 (1997), No. 7, pp. 671-685.

[535] For these contributions, see Hayes, Robert H. and Steven C. Wheelwright: Restoring our competitive edge - competing through manufacturing, New York 1984 and Schonberger, Richard J.: World class manufacturing - the lessons of simplicity applied, New York London 1986.

[536] Cf. Schroeder and Flynn: High performance manufacturing: Just another fad?, pp. 6-9.

– Just-in-time
– Human resources
– Information systems
– Technology management

The underlying procedure of rolling out the survey in the participating plants remained the same as in 1996. However, based on the experiences of the first round, the questionnaires have been slightly changed and expanded. Most noteworthy and especially relevant for the analysis here has been the extension of the model through scales that are attributed to SCM and e-business. In 2004, twelve different questionnaires were designed to receive detailed data from the following members of all hierarchical levels of the participating manufacturing plants: plant superintendent, plant manager, plant accounting manager, human resources manager, production control manager, inventory manager, information systems manager, process engineer, quality manager, member of product development team, supervisor (three different), and direct labor (ten different).[537] If all questionnaires are retrieved and completed, a comprehensive picture of the plant based on answers from 23 different employees from different hierarchical levels is obtained. The objective of this approach is to gather information that covers a multitude of aspects of state-of-the-art manufacturing company structures. Using many different questionnaires in this way not only assured that data from different departments and competent persons were collected but also that information from entire plants was gathered. Comprehensive analyses then are possible. Besides subjective measurement scales, a variety of objective measures are obtained from key informants of the plants. This approach differentiates the HPM approach from many other empirical investigations.[538]

Subjective measures have been gathered mainly by asking one or more respondents about previously defined constructs through 7-point Likert scales. Objective measures have been collected by asking those managers who are supposed to have this information as part of their functional job assignment. For example, employee fluctuation was answered by the human resources manager, defect rates by the quality manager, and general financial information by the plant accounting manager. This way, key informants for such information were chosen.

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[537] From the direct labor and supervisor level, the same questionnaire has been answered by ten, respectively three different employees from this level. However, not all plants were able to provide always all ten questionnaires from direct labor or three from supervisors. Four returned questionnaires by direct labor and even only one on the supervisor level have been accepted as being sufficient.

[538] See Flynn *et al.*: World class manufacturing project - overview and selected results, pp. 671-685.

The survey focuses on the following industries: automotive, electronic, and machinery. These industries have been chosen because they are important sectors of industrialized production.[539] Potential participants have been identified based on their industry code according to the North American Industry Classification System (NAICS) or the equivalent systems used in the different countries.[540] Additionally, the aim was to approach manufacturing plants from these industries with more than 100 employees.

In the second round, the number of participating countries also expanded. Whereas in 1996 five countries participated – the USA, Japan, Italy, Germany, and the UK – the data collection in 2004 provides current data from six countries: Finland, the USA, Japan, Germany, Sweden, and South Korea.[541] It is important in such an international data collection to ensure uniformity of the questionnaires in the different languages and to avoid ambiguity. Since the participating universities are experts in the field, special terms are transferred properly into the respective languages. Furthermore, reverse translation has been used to ensure correctness.[542]

After completion of the data collection, 189 plants participated and were included in the international database. Six companies have been excluded from this analysis because of their reported number of employees. Five of them do not fulfill the requirement of at least 100 employees. One plant is excluded because it shows a significantly higher number of employees, i.e. 41,589, which is a clear outlier. *Table C-1* provides an overview of the structure of the remaining 183 companies of the survey sample by country and industry.

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539 Cf. Devaraj, Sarv, David G. Hollingworth and Roger G. Schroeder: Generic manufacturing strategies and plant performance, in: Journal of Operations Management, Vol. 22 (2004), p. 320.

540 In Europe, the respective NACE codes are 29.41, 29.42, 31.1, 31.2, and 34.3.

541 At the time of the analysis in this text, four more countries have been in the process of collecting data: Italy, the UK, Spain, and Austria. Because the time delay of the data collection in these countries might pose a problem in terms of comparability, it would make no sense to wait for completion in these countries.

542 Cf. Devaraj, Hollingworth and Schroeder: Generic manufacturing strategies and plant performance, p. 320.

*Table C-1: Structure of data sample of the second round of the HPM project*

| *Industry* / *Country* | Electronic Industry | Machinery Industry | Automotive Industry | *Total* |
|---|---|---|---|---|
| Finland | 11 | 6 | 10 | *27* |
| Germany | 9 | 13 | 19 | *41* |
| Japan | 10 | 11 | 12 | *33* |
| South Korea | 10 | 9 | 11 | *30* |
| Sweden | 7 | 9 | 7 | *23* |
| USA | 9 | 11 | 9 | *29* |
| *Total* | *56* | *59* | *68* | 183 |
| | *30.60%* | *32.24%* | *37.16%* | |

The automotive industry represents the largest industry in the sample. The industry allocation is considered to be satisfactory with 30.60% of respondents from the electronic industry, 32.24% from the machinery industry, and 37.16% from the automotive industry.

Furthermore, a more detailed look at the number of employees of the participating plants is of interest. *Table C-2* gives an overview.

*Table C-2: Number of employees in the HPM project dataset, according to industry and in total*

| | Industry | | | |
|---|---|---|---|---|
| | E | M | A | *Total* |
| Minimum | 156.00 | 114.00 | 123.00 | *114.00* |
| 1st Quartile | 262.00 | 203.50 | 240.75 | *240.00* |
| Median | 486.00 | 293.00 | 453.00 | *414.00* |
| 3rd Quartile | 1,084.00 | 536.75 | 896.50 | *798.00* |
| Maximum | 2,453.00 | 2,256.00 | 7,080.00 | *7,080.00* |
| Mean | 730.88 | 459.40 | 1,067.80 | *770.53* |
| Valid Cases | 47 | 48 | 56 | *151* |
| Missing Cases | 9 | 11 | 12 | *32* |

Of the remaining 183 plants, 32 did not provide information about the number of employed personnel. It is assumed that those plants fit into the sample because of the careful identification and selection of companies according to the objectives of the HPM project.[543] In summary, the average manufacturing company in terms of median value in this sample employs 414 people, with 75% of the plants having up to 798 employees. Thus, it can be concluded that the sample represents a well balanced mix of mid-size and large manufacturing plants as they are typical for the industries under consideration.[544]

## II. Role of Manufacturing Companies in Supply Chains

### *1. Positions of HPM Plants in Their Supply Chains*

In previous chapters it has been highlighted that supply chain networks are characterized by different power positions. In particular, it has been suggested that in most cases, one company is a dominant player that holds the main value for a certain supply chain. This dominant player has been called supply chain driver or orchestrator. A framework to identify this player has been suggested based on Cox' power regimes that have been adapted to supply chains.[545] In order to apply this, however, crucial information about the contributions in terms of added value of each supply chain member are needed to determine their importance and role for the supply chain. Though information about the value creation of manufacturing plants has been collected in the HPM project and will be analyzed in the next section, this information alone is not sufficient to ultimately derive the role of these plants in their supply chains.

Another important indicator can be based on an analysis of the sales channels. Those plants that are closer to the end customer are more likely to possess additional value of the supply chain because of their direct relationship to the ultimate demand and thus additional value creating activities. Additionally, more power and control over ultimate demand can be assumed in case a manufacturer also maintains close proximity to end customers.[546] This is similar to the position

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543 Some of these plants provided information about their sales volume. These numbers also indicate that these plants employ more than 100 employees.

544 According to the U.S. Census Bureau, in 2002 11.24% of manufacturing companies from the industries considered for this survey had more than 100 employees and these companies employed 83.68% of all people in these industries, see U.S. Census Bureau, statistics of U.S. businesses, http://www.census.gov/csd/susb/, U.S. Department of Commerce,retrieved on: February 15, 2006.

545 See Cox: The art of the possible: Relationship management in power regimes and supply chains, pp. 346-356, and section B.IV. before.

546 See Kotler, Philip and Kevin Keller: Marketing management, 12th ed., Upper Saddle River 2006, pp. 467-499 for a general discussion of distribution channels, and Butaney,

of an OEM car manufacturer. The following descriptive analysis is based on this assumption.

The customer structure of the analyzed plants is used to evaluate the different positions in the supply chain. Plants were asked to indicate their customer channels by the given choices (1) end consumer, (2) retailer, (3) wholesaler, (4) distributor, (5) assembler, and (6) manufacturer. Two-stage-clustering is used to identify clusters based on their customer structure. In two-stage-clustering, Ward's method using the squared euclidean distance measure is used to determine a suitable number of clusters and cluster means. These are then used as starting point for the following K-Means clustering method. By combining these two methods, advantages of both methods can be combined to improve cluster allocations.[547] For the cluster determination, only four customer segments out of six are considered because the retailer and wholesaler segments show very low values in all manufacturing plants. Therefore, it is suggested excluding such variables from the cluster analysis because those variables are rather irrelevant and likely to influence the cluster allocation negatively.[548]

Based on the percentage of sales to different customer segments, four clusters can be identified:

- Cluster 1 (*s-to-m*), supplier to manufacturer
- Cluster 2 (*s-to-a*), supplier to assembler
- Cluster 3 (*s-to-d*), supplier to distributor
- Cluster 4 (*s-to-c*), supplier to end consumers

The characteristics of each cluster are depicted in *Table C-5* below and are clearly distinct from each other. In order to formally asses this statistically, a discriminant analysis is conducted, allowing the analysis of whether two or more groups are significantly different with regard to more than one variable.[549] Two measures are important in order to asses whether differences are significant or not:

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Gul and Lawrence H. Wortzel: Distributor power versus manufacturer power: The customer role, in: Journal of Marketing, Vol. 52 (1988), January, pp. 52-63 for a more in-depth analysis on channel power.

547 Cf. Backhaus, Klaus *et al.*: Multivariate Analysemethoden, 11th ed., Berlin Heidelberg New York 2006, p. 551. The second step – the K-Means clustering – does not necessarily improve cluster allocations. In this case, the Ward method leads to a "good" allocation in most conditions, cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 527-528.

548 Cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 549.

549 If differences of groups with regards to only one variable are of interest, *t*-est or analysis of variance can be used, cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 156.

Wilks' Lambda and Chi-square. Wilks' Lambda is determined by dividing unexplained variance by total variance. Therefore, a direct link to Eigenvalues exists since Eigenvalues are determined by the ratio of explained variance and unexplained variance.[550] Wilks' Lambda can be transformed into a probabilistic variable and so it is possible to draw conclusions with regard to the significance of dissimilarities between groups. The resulting Chi-square is calculated by the following formula:[551]

[14]: $$X^2 = -\left[ N - \frac{J+G}{2} - 1 \right] \ln \Lambda$$

with N = number of cases

J = number of variables

G = number of groups

Λ = Wilks' Lambda

ln = natural logarithm

From this definition, it becomes also clear that smaller values of Wilks' Lambda lead to higher significance. In order to evaluate dissimilarity of multiple groups, univariate Lambdas are multiplied to return a multivariate Wilks' Lambda.[552] This is shown in the following *Table C-3* in the first row, function 1 through 3.

*Table C-3: Discriminant goodness measures for customer segment clusters*

| *Test of function(s)* | *Wilks' Lambda* | *Chi-square* | *df* | *Sig.* |
|---|---|---|---|---|
| 1 through 3 | 0.002 | 824.817 | 12 | .000 |
| 2 through 3 | 0.028 | 489.341 | 6 | .000 |
| 3 | 0.193 | 225.254 | 2 | .000 |

*Table C-3* shows that all three discriminant functions contribute significantly to the dissimilarity of the groups. In order to assess whether the results of the discriminant analysis also possesses predictive power, actual group memberships as defined by cluster analysis are compared to predicted group membership through a cross-table. *Table C-4* shows the classification results of the

550 Cf. Field, Andy: Discovering statistics using SPSS, 2nd ed., London 2005, p. 592.

551 Backhaus *et al.*: Multivariate Analysemethoden, p. 183.

552 Cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 184.

discriminant analysis. In 96.5% of the cases, group prediction is correct and therefore a high predictive power can be asserted.[553]

*Table C-4: Classification results for customer segment clusters*

| *Original group* | *Predicted group membership* | | | | *Total* |
|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | |
| 1 | 36 | 0 | 1 | 0 | 37 |
| 2 | 0 | 25 | 0 | 1 | 26 |
| 3 | 0 | 0 | 24 | 1 | 25 |
| 4 | 0 | 2 | 0 | 52 | 54 |

It can be concluded that the identified clusters are significantly dissimilar and the results of a discriminant analysis show high predictive power. Therefore, the identified clusters are used for further analysis.

As pointed out before, the wholesaler channel and the retailer channel play no important role for all manufacturers. It is noticeable that 38% of the plants that answered this question sell predominantly to end consumers. The remaining manufacturers sell to other manufacturers (26%), assemblers (18%), and distributors (18%). In terms of procurement channels, those selling mainly to distributors source most of their materials from other manufacturers and distributors. The other three clusters purchase mainly from other manufacturers and raw material suppliers, as depicted in *Table C-5*.

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[553] Group allocation by chance would result in only 25% correct predictions.

*Table C-5: Clusters according to customer segments*

| | *Cluster* | | | |
|---|---|---|---|---|
| *Percentage of sales to* | *s-to-m* | *s-to-a* | *s-to-d* | *s-to-c* |
| end consumers | 0.43% | 3.81% | 4.88% | **79.81%** |
| retailers | 3.51% | 0.58% | 2.67% | 5.19% |
| wholesalers | 0.41% | 5.08% | 10.20% | 2.31% |
| distributors | 7.97% | 2.85% | **73.54%** | 3.76% |
| assemblers | 1.00% | **79.81%** | 3.20% | 5.91% |
| manufacturers | **86.68%** | 7.88% | 4.32% | 3.02% |
| *Number of cases* | *37* | *26* | *25* | *54* |
| *Percentage of procurement from* | *1* | *2* | *3* | *4* |
| raw material suppliers | 34.48% | 26.88% | 15.79% | 25.14% |
| manufacturers | 40.66% | 47.98% | 45.78% | 46.99% |
| assemblers | 7.06% | 12.02% | 9.00% | 15.06% |
| distributors | 15.28% | 5.42% | 20.71% | 7.52% |
| wholesalers | 2.58% | 7.70% | 8.76% | 5.33% |

The cluster allocation shows some differences between industries, as summarized in *Table C-6*. The automotive industry dominates cluster 2 as suppliers to assemblers and as such they are generally classified as so-called tier 1 suppliers to OEMs. As many as 21 plants from the automotive industry, however, also claim to sell predominantly to end consumers. Plants from the electronic industry sell mainly to manufacturers and end consumers; two very distinct customer groups. And finally, manufacturers from the machinery industry sell mainly to what they consider as end consumers, but also to other manufacturers and distributors. The plants from this industry do not sell to assemblers.

The high ratio of the end consumer segment is surprising for these kinds of industries. It is very likely that the term end consumer has been understood differently by the plants responding to the survey. Thus, respondents might consider their customers as end consumers for their specific products because maybe there exists no “real” consumer market, but only professional buyers. One example could be special purpose machines for the public sector or other companies. In the case of public sectors, these machines are essentially used to provide services to the public and then in such a way lead to consumption. In the case of other companies, machines are used in the transformation process of other products. Only through further processing do they find their way as value to the customer in a more subtle and indirect manner.

*Table C-6: Cluster allocation by industry based on customer segment clusters*

| *Industry* / *Cluster* | Electronic Industry | Machinery Industry | Automotive Industry | *Total* |
|---|---|---|---|---|
| s-to-m | 14 | 12 | 11 | *37* |
| s-to-a | 6 | 2 | 18 | *26* |
| s-to-d | 10 | 12 | 3 | *25* |
| s-to-c | 15 | 18 | 21 | *54* |
| *Total* | *45* | *44* | *53* | 142 |
| | *30.82%* | *30.14%* | *36.30%* | |

As *Table C-5* shows, plants in cluster 4 (s-to-c) also source from rather early stages in the supply chain. Early stage sourcing indicates high vertical integration for this cluster because it seems to fulfill also sales channel functions besides production. Therefore, it can be suspected that those plants have a rather high vertical supply chain integration. To further examine this, the next section investigates value creation of manufacturing companies in more detail.

## *2. Value Creation of Manufacturing Companies*

The value creation process is of particular interest in supply chains because it not only defines the outcome of supply chains in form of products or services but is also the battlefield for competitive advantage. Added value is an important measure for evaluating the role and position in a supply chain and an indication for power regimes in supply chains.[554] In the HPM project only limited information about added value is available. It is almost impossible to obtain all necessary information in a survey of this scale and scope. An approximation of total added value per manufacturing plant, however, can be calculated.

In the questionnaires, participants were asked to report sales value of production and manufacturing costs, allowing an approximation of added value to be calculated.[555] For the analysis, 113 useful responses are available. Conclusions

[554] Besides the power associated with the value creation proportion of a supply chain member, of course practices of the value creation process are important determinants for competitiveness.

[555] An analysis of the numbers provided shows some inconsistencies. For example, profits based on the financials provided reveal that more than 50% of the respondents would

drawn from this calculation have to be used cautiously because of problems in obtaining correct financial numbers and a high potential of ambiguity. Based on the information available through the questionnaires, the total added value is calculated according to the following formula:

[15]: total added value = sales – manufacturing costs * % material costs

This total added value is related to sales value. It can be observed in *Table C-7* that plants of cluster 4 (*s-to-c*) indeed show the highest added value. Since these plants are also in direct contact with the ultimate end of the supply chain, it can be concluded that they are likely to have the highest vertical supply chain integration. Plants that sell predominantly to distributors (*s-to-d*) show the lowest added value on the plant level. Thus, it can be suspected that those plants provide less relative added value to the whole supply chain than others.

*Table C-7: Mean and median for total added value per plant for each cluster*

| | *Cluster* | | | |
|---|---|---|---|---|
| | *s-to-m* | *s-to-a* | *s-to-d* | *s-to-c* |
| Mean | 57.70% | 55.97% | 51.47% | 61.21% |
| Median | 61.51% | 56.38% | 44.37% | 62.89% |
| Valid Cases | 26 | 23 | 16 | 44 |
| Missing Cases | 11 | 3 | 9 | 10 |

In contrast to total added value, more detailed information is available about the structure of manufacturing costs alone. Therefore, added value in the manufacturing operations can be determined more precisely. For this analysis, 131 valid responses are available.[556] The added value within the manufacturing cost

have a profit/sales ratio of 19% or higher. Furthermore, 20% report a profit/sales ratio of more than 35.8%. Therefore, it is very likely that the questions regarding absolute sales and cost values were ambiguous. In particular, the sales figures might refer to the sales value of an entire plant as it is stated in the financial statements and not refer to the actual production value. Additional value added activities, such as sales, marketing, and research and development activities, would have to be considered as costs as well. However, only information about manufacturing costs was provided. Consequently, many costs and activities are likely not to be reflected in these figures. For a detailed value creation analysis, detailed balance sheets and cost accounting numbers would be necessary, but are unrealistic to obtain in such a survey.

[556] In order to control for irregularities, responses are checked by summing up all three cost blocks of manufacturing costs, i.e. direct labor, material, and overhead. The sum of

block is calculated by subtracting the portion of material costs from overall costs. *Equation [16]* shows the simple formula:

[16]: % of added value in manufacturing = manufacturing costs (100%) – % of material costs

By only subtracting material costs from manufacturing costs, it is assumed that overhead costs account for added value, something which could be questioned. External services and general investment costs would have to be subtracted in addition to the material costs, whereas personnel and management salaries should be included. In order to clarify this definition of added value, an explanatory note seems to be appropriate.

In contrast to many financial interpretations of added value, operational added value refers to the process of adding value to a product by combining input factors. Purchased materials and services therefore have to be excluded because they are the result of the value creation process of another organization. Human resources, however, are not considered as an input factor of another organization and their value contribution is specific to the organization where they are employed and thus they add value to a specific supply chain in the context of an organization. This context is part of the value creation process because input factors are transformed into sold products or services and are therefore included.[557]

By balancing the major cost blocks of overhead costs as defined above, the value creation portion outweighs external components and as a result overhead costs are included as value added activities. Consequently, this calculation tends to overestimate the value creation of the plants.

*Figure C-1* provides an illustration of the distribution of the proportion of overhead costs in manufacturing costs in the HPM sample. This allows assessing the possible effect of this overestimation. With a mean value of 21% and a median value of 16%, the inherent overestimation is rather low.

these should be close to or exactly 100%. If the checksum deviates more than 5%, the answers are not collectively exhaustive enough and companies are likely to have misinterpreted the question to an extent that affects valid interpretations of the analysis. Such cases are excluded from the added value analysis. Overall, more cases are available than for the financial value creation analysis.

557 For a description of the operational value creation process, see Krajewski and Ritzman: Operations management, pp. 3-10.

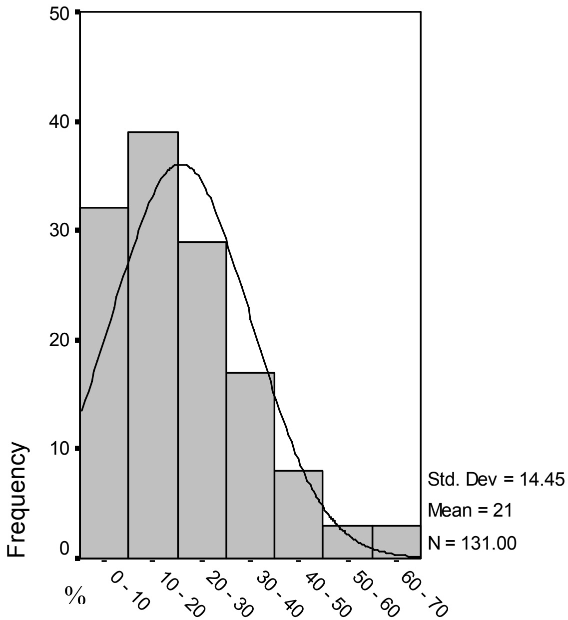


*Figure C-1: Distribution of overhead cost portion as percentage of manufacturing costs in the HPM sample*

In order to evaluate possible structural differences between the industries of the sample, the added value distribution within the manufacturing activities of each industry is analyzed and shown in *Table C-8*.

*Table C-8: Added value in manufacturing function of plants in the HPM project by industry, in percentage of total manufacturing costs*

| | *Industry* | | | |
|---|---|---|---|---|
| | *E* | *M* | *A* | *Total* |
| Minimum | 6.47% | 9.00% | 9.20% | 6.47% |
| 1st Quartile | 20.00% | 25.50% | 20.80% | 22.40% |
| Median | 34.00% | 38.00% | 30.00% | 35.70% |
| 3rd Quartile | 47.90% | 48.50% | 46.00% | 47.00% |
| Maximum | 79.00% | 95.80% | 84.00% | 95.80% |
| Mean | 35.16% | 40.09% | 36.51% | 37.22% |
| Valid Cases | 45 | 43 | 43 | 131 |
| Missing Cases | 11 | 16 | 25 | 52 |

The values show no great differences between industries and these differences are not significant.[558] The added value ranges from a minimum value of 6.47% to a maximum of 95.80%. This maximum is almost equivalent to total vertical integration up to this point in the supply chain. On average, the manufacturing plants of the sample show an average added value of 37.22%, or 35.70% when considering the median value.

The added value within the manufacturing function differs substantially depending on the customer segment being served. *Table C-9* shows that those plants that mainly sell to other manufacturers and assemblers have a higher added value within their manufacturing function than plants that sell to distributors and end consumers. An ANOVA analysis shows that the difference in mean value between the *s-to-m* cluster and the *s-to-d* cluster is significant at the $p<0.05$ level. This particular result confirms the previous result using the approximation of total added value, as defined in *Equation [16]*. For the other clusters, no further conclusions can be drawn because these results are not significant.

558 The variance is not significantly different between the groups based on a Levine's test. Based on a one-way independent ANOVA analysis, there exists no significant difference of means between the groups, with $F(2,128)=0.774$, $p>0.05$. Hochberg's GT2 post hoc procedure has been applied as it is suggested as the appropriate test if sample sizes between groups differ, cf. Field: Discovering statistics using SPSS, p. 341.

*Table C-9: Added value in manufacturing function of plants according to customer segment structure*

| | Cluster | | | |
|---|---|---|---|---|
| | *s-to-m* | *s-to-a* | *s-to-d* | *s-to-c* |
| Minimum | 9.00% | 12.00% | 6.47% | 9.20% |
| 1st Quartile | 34.53% | 32.08% | 15.90% | 22.40% |
| Median | 44.00% | 43.15% | 22.40% | 38.00% |
| 3rd Quartile | 65.33% | 55.35% | 42.60% | 49.30% |
| Maximum | 98.00% | 98.00% | 94.00% | 95.80% |
| Mean | 48.70% | 45.88% | 32.85% | 40.31% |
| Valid Cases | 30 | 24 | 21 | 51 |
| Missing Cases | 7 | 2 | 4 | 3 |

In order to determine supply chain power regimes, more detailed information is necessary.[559] Unfortunately, neither the supply chain power index nor the company power index can be calculated because the necessary objective data about total supply chain value creation are not available. In order to perform the necessary calculation, a specific supply chain of one product group has to be defined and separate cost and sales information for this supply chain, both internal and total supply chain figures, have to be reported.

Although such precise information is not available, plant managers were asked to evaluate the degree of vertial integration with respect to their total supply chain. This could be considered an approximation to determine a plant's supply chain power position. According to their own judgement, the manufacturing plants in the HPM sample represent a rather important role in their supply chains. 74.2% think that they create a medium or high portion of total value of the products they produce in the hands of the consumers, see *Table C-10*. Though there are differences between industries evident, they are not significant.[560] According to this result, 25.8% of manufacturing plants in the sample can be considered to hold a rather strong position with a high portion of added value in the hands of the end consumer in their supply chain. Again, it is of interest to compare this perceived degree of vertical supply chain integration among the previously identified customer segment clusters. *Table C-11* provides an overview.

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559 See the definition of supply chain power regimes in section B.IV., pp. 130-136.

560 Based on one-way independent ANOVA analysis, all differences are insignificant with $F(2,156)=0.681$, $p>0.05$. Using Hochberg's GT2 post hoc procedure, between group comparisons also show no significant differences.

*Table C-10: Perceived vertical supply chain integration of the sample*

| Degree of perceived vertical supply chain integration / Industry | E | M | A | *Total* |
|---|---|---|---|---|
| Very low | 4.3% | 0.0% | 3.3% | *2.5%* |
| Low | 19.1% | 25.5% | 24.6% | *23.3%* |
| Medium | 42.6% | 60.8% | 42.6% | *48.4%* |
| High | 34.0% | 13.7% | 29.5% | *25.8%* |
| Valid Cases | 47 | 51 | 61 | *159* |
| Missing Cases | 9 | 8 | 7 | *24* |

*Table C-11: Perceived vertical supply chain integration by customer segment cluster*

| Degree of perceived vertical supply chain integration / Cluster | s-to-m | s-to-a | s-to-d | s-to-c |
|---|---|---|---|---|
| Very low | 3.4% | 4.3% | 0.0% | 3.9% |
| Low | 27.6% | 21.7% | 16.7% | 31.4% |
| Medium | 48.3% | 52.2% | 58.3% | 35.3% |
| High | 20.7% | 21.7% | 25.0% | 29.4% |
| *Medium and High combined* | *69.0%* | *73.9%* | *83.3%* | *64.7%* |
| Valid Cases | 29 | 23 | 24 | 51 |
| Missing Cases | 8 | 3 | 1 | 3 |

In contrast to the analysis of added value based on available financial numbers, plants selling predominantly to distributors believe that they are accountable for either a medium or high portion of the total value delivered to the end consumer, indicating a relatively strong position in the supply chain.[561] A benefit of the analysis based on subjective assessment over a strictly financial analysis is that the surveyed plant managers are qualified to also consider intangible factors as sources of value, such as knowledge and capabilities. A limitation of this particular measure is that only one informant was asked, although the plant manager can be considered to be the key informant for this information. In conclusion, both implications are possible – that plants overstate their own role in the value creation process or the analysis based on financial information is erroreneous and that distribution is overall not a major value-creating activity.

Though this information based on this analysis is valuable in order to underscore the importance of manufacturing plants in the supply chain, the items in the HPM database are not suitable for drawing more definitive conclusions regarding the power position of a specific operation in its supply chain.

An area closely related to vertical integration and value creation structure is that of outsourcing. The concentration on core competencies has led to increasing importance of outsourcing for companies, especially for non-core competence activities. Outsourcing refers mainly to the fact that formerly internally performed activities are transferred to an external partner, who is thought to provide the same activity more efficiently. In the long-run, it is believed that the effectiveness of an organization also improves by being more focused. If competitive resources are affected, it is important to safeguard this in some way, for example through contracts or copyrights.[562]

It is of interest to what extent global manufacturers make use of outsourcing and in what areas, so future research can better define manufacturing supply chain structures and manufacturing functions in the value creation process. In the HPM project, six operational manufacturing activities that are considered to be at the core of manufacturing activities are of interest in terms of their degree of outsourcing: (1) warehousing, (2) transportation, (3) manufacturing, (4) assembly, (5) design, and (6) reverse logistics. Additionally, the degree of outsourcing of administrative, i.e. supportive, activities is asked for. The inventory manager has been identified as the key informant for these items. All items were rated from one to five, i.e. from being performed completely internally, predominantly internally, nearly half and half, predominately outsourced, and totally outsourced.

The analysis of outsourcing activities, as depicted in *Table C-12*, shows that only the transportation activity is mainly outsourced. Reverse logistics activities

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561 However, the differences between customer segment clusters are insignificant, with $F(3,98)=0.378$, $p<0.5$.

562 See Quinn, James B. and Frederick G. Hilmer: Strategic outsourcing, in: Sloan Management Review, Vol. 35 (1994), No. 4, Summer, pp. 43-55; and Hagel III, John and Marc Singer: Unbundling the corporation, in: Harvard Business Review, Vol. 77 (1999), March/April, pp. 133-141.

show an outsourcing level of about 50% on average. All other activities are still performed either predominately internally or totally internally.[563] Most differences between industries were insignificant. However, a one-way ANOVA analysis revealed two significant differences of means. First, the comparison of means for the assembly function shows a significant difference with $F(2,151)=5.191$, $p<0.01$. The electronics industry shows a lower degree of outsourcing in assembly than the machinery industry with a mean difference of 0.45, $p<0.01$. This significant but minimal difference indicates that outsourcing in the electronics industry is of relatively more importance. Second, the comparison of means for the reverse logistics function also indicates a significant difference between industries with $F(2,148)=3.872$, $p<0.05$. The automotive industry outsources the reverse logistics function significantly more than the electronics industry with a mean difference of 0.77, $p<0.05$. This might be due to historically stricter regulatory rules for the automotive industry. *Table C-12* gives an overall overview of outsourcing in global manufacturing plants, independent from industry.

*Table C-12: Outsourcing of selected activities of manufacturing plants*

| | Ware-housing | Transpor-tation | Manufac-turing | Assembly | Design | Admini-stration | Reverse logistics |
|---|---|---|---|---|---|---|---|
| Minimum | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1st Quartile | 1.00 | 4.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Median | 2.00 | 5.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 3rd Quartile | 2.00 | 5.00 | 3.00 | 2.00 | 2.00 | 2.00 | 4.00 |
| Maximum | 5.00 | 5.00 | 5.00 | 4.00 | 5.00 | 4.00 | 5.00 |
| *Mean* | *2.01* | *4.03* | *2.28* | *1.74* | *1.87* | *1.63* | *2.81* |
| Valid Cases | 163 | 162 | 163 | 154 | 158 | 163 | 151 |
| Missing Cases | 20 | 21 | 20 | 29 | 25 | 20 | 32 |

Another area of interest, especially in light of the omnipresent discussion of globalization, is the amount of international purchasing and selling in manufacturing plants. The data of the HPM project provide evidence that although purchasing is still mainly conducted through domestic partners as *Table C-13* shows, there is a considerable portion of international purchasing visible. Plants in the electronics industry source significantly more from other countries than the other two industries. The machinery industry and the automotive industry do not

[563] This analysis is not illustrated in detail here because only few implications can be derived from it and are described in the text.

show significant differences and source more from their home country.[564] Purchased items in these industries might cause relatively higher transportation costs and require a higher degree of interaction.

An analysis of sales by countries shows that manufacturing plants also sell mainly to domestic customers. However, the numbers indicate that sales are more international than purchases. *Table C-14* gives an overview of this. On the sales side, no significant differences between industries exist. However, the automotive industry deviates from the other two industries slightly in that they seem to sell less internationally than the other two. This reflects the tendency of this industry to locate suppliers around an OEM, which in most cases means suppliers are located within the same country.[565]

*Table C-13: Percentage of purchases from home country, by industry and in total*

| | Industry | | | |
|---|---|---|---|---|
| | E | M | A | *Total* |
| Minimum | 10.00% | 0.00% | 5.00% | *0.00%* |
| 1st Quartile | 30.00% | 70.00% | 65.75% | *51.50%* |
| Median | 54.00% | 80.00% | 80.00% | *80.00%* |
| 3rd Quartile | 81.25% | 90.00% | 90.00% | *90.00%* |
| Maximum | 98.00% | 100.00% | 100.00% | *100.00%* |
| Mean | 56.08% | 75.21% | 75.64% | *69.28%* |
| Valid Cases | 50 | 49 | 58 | *157* |
| Missing Cases | 6 | 10 | 10 | *26* |

564 Levine's test for equality of variances has been used to determine whether equal variance can be assumed or not. The null hypothesis of the Levine's test is that the variances are homogeneous and therefore are the groups. Equality can be rejected if the Levine's test is significant at the $p < 0.05$ level. In this case, the null hypothesis of equality of variances is rejected. Therefore, instead of the ANOVA results, robust tests of equality of means have to be considered. Based on this, geographical purchasing shows significant differences between industries, with a Welch $F$-ratio of $F(2,99.44)=9.463$, $p<0.001$. A post hoc analysis shows that plants from the electronics industry source significantly more from other countries than plants from the machinery and automotive industries.

565 Based on an ANOVA analysis, differences between groups are not significant with $F(2,151)=2.691$, $p>0.05$, and all multiple comparisons are insignificant based on Hochberg's GT2 post hoc procedure.

*Table C-14: Percentage of sales to home country, by industry and in total*

| | Industry | | | |
|---|---|---|---|---|
| | E | M | A | *Total* |
| Minimum | 2.00% | 0.00% | 0.00% | *0.00%* |
| 1st Quartile | 20.00% | 20.00% | 42.00% | *32.63%* |
| Median | 59.50% | 50.00% | 65.00% | *60.00%* |
| 3rd Quartile | 80.00% | 75.00% | 90.00% | *85.00%* |
| Maximum | 100.00% | 100.00% | 100.00% | *100.00%* |
| Mean | 53.46% | 50.02% | 62.96% | *56.05%* |
| Valid Cases | 48 | 47 | 59 | *154* |
| Missing Cases | 8 | 12 | 9 | *29* |

In conclusion, manufacturing plants still seem to perform most traditional manufacturing functions internally. As the transportation industry matures, most manufacturers do not perform transportation themselves but rather rely on external transportation providers. For geographical sourcing and selling, globalization is a factor for manufacturing plants, though the analysis shows that average plants source mainly on domestic markets and that more than half of their sales are on average to domestic customers.

## *3. Supply Chain Management Practices and Performance – Empirical Evidence*

### 3.a. Operationalizing Supply Chain Management

To analyze SCM practices, its elements have to be conceptualized based on the available HPM database. As described earlier, the HPM project collects a variety of data from each manufacturing plant. The scales have been developed based on experiences of earlier data collections. Based on the SCM framework previously developed in this text, the codebook of the HPM database has been screened and those scale items are identified that are adequate to represent the core model of SCM, namely SCM cooperation.[566] Scale development, therefore, is strictly theory driven, though based on an existing database.

The elements coordination and collaboration are divided into internal and external characteristics. Separating internal and external coordination and collaboration is important because they represent distinct, but nevertheless

[566] According to the SCM framework, SCM cooperation consists of coordination, collaboration, and integration, see section B.I.3c. and *Appendix 1*.

interdependent characteristics. Furthermore, their relationship towards each other is of interest. From a theoretical viewpoint, one would assume that internal coordination and collaboration are the basis for their external counterparts. Several studies have shown that external collaboration plays an intermediary role in that it is considered a necessary but not sufficient element. Instead, only through its internal counterpart is it possible to achieve performance gains.[567]

For internal coordination, five items have been identified. This scale not only measures the degree to which a plant coordinates activities within its own plant, but also with other divisions within the same corporation. Respondents have been asked to assess such kinds of coordination in areas like distribution, planning, innovation transfer, sales communication, and manufacturing communication. These five items have been reduced through factor analysis, resulting in one factor that reflects internal coordination. Four factor loadings are greater than 0.7 and one item shows a factor loading of greater than 0.6. Cronbach's alpha is 0.806 with an explained variance of 56.9%. These values satisfy generally suggested reliability values.[568]

In contrast, external coordination aims at a plant's coordination efforts that reach clearly beyond its own boundaries and considers other supply chain tiers. Aspects for assessing external coordination cover planning of supply chain activities; consideration of external forecasts in own planning; total, i.e. holistic, supply chain consideration; performance tracking of supply chain partners; and overall monitoring of supply chain performance indicators. Out of the five items identified, four show factor loadings greater than 0.7 and one carries a value of greater than 0.6. The Cronbach's alpha value of 0.810 and explained variance of 57.17% confirm scale reliability.

As with coordination, collaboration has been split up into internal and external collaboration. Internal collaboration aims at the degree of teamwork-like efforts within a plant and is measured by whether teamwork is encouraged and conducted. Items that reflect this measure ask respondents about the usage of

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567 Cf. Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, pp. 38-39; and Sanders, Nada R. and Robert Premus: Modeling the relationship between firm IT capability, collaboration, and performance, in: Journal of Business Logistics, Vol. 26 (2005), No. 1, pp. 14-15. Subrami implies that external communication is constrained by internal communication processes, cf. Subramani: How do suppliers benefit from information technology use in supply chain relationships?, p. 52. This issue will be picked up in more detail later in section D.

568 See for example Homburg, Christian and Hans Baumgartner: Beurteilung von Kausalmodellen - Bestandsaufnahme und Anwendungsempfehlungen, in: Marketing - Zeitschrift für Forschung und Praxis, Vol. 17 (1995), No. 3, p. 172. This and all following scales are documented in *Appendix 3,* including item reliability and scale reliability.

teams and small group sessions for problem solving, the impact of such teams in the improvement process, and the degree of encouragement for independent problem solving. The factor loadings of all five items are greater than 0.7 and Cronbach's alpha is 0.893 with 70.18% variance explained.

External collaboration with customers and suppliers measures collaborative efforts that reach beyond coordination. External collaboration aims at a more direct working partnership than coordination. Questions to assess the degree of external collaboration cover the working relationship with customers and suppliers, economic attitude towards suppliers, support of suppliers to improve quality, and communication about quality considerations and design changes. Three items show factor loadings of greater than 0.8, one is greater than 0.6, and one item has a rather low factor loading of 0.460. This item is different to the others because it measures the involvement of customers whereas the other four aim at supplier relationships. Because this item incorporates a customer side perspective in collaboration efforts, it is not dropped in order to ensure that external collaboration with both suppliers and customers is reflected. Overall reliability is satisfactory with a Cronbach's alpha of 0.784 and 56.01% variance explained.

Integration as the third element of the core SCM model has not been covered appropriately through the items in the HPM questionnaire. Integration represents the seamless material and information flow along supply chains. Therefore, it can be seen as an enhancement of the managerial components coordination and collaboration, which is mainly driven through e-business capabilities. At this point, only the purely managerial part of the SCM model is analyzed. In section C.IV., all elements of the core SCM model are considered. In section D, the SCM framework is conceptualized more in its entirety.

### 3.b. Determination and Validity of SCM Practice Clusters

The identified measures of SCM practices are the foundation for grouping plants according to their SCM practice adoption. A factor analysis based on principal components determined a factor score for each scale and case (plant). Based on these scores, plants can be clustered according to their relative SCM practice adoption. Two-stage clustering is applied because the K-Means algorithm has proved to improve the previously established cluster allocation based on Ward's method in so that low and high SCM practice plants are more clearly separated.[569]

Based on this procedure, four clusters are identified. Differences between those clusters can be evaluated based on *t*-values. *T*-values are norm values. A positive (negative) *t*-value indicates that a variable in this particular group is over-represented (under-represented) compared to the entire sample. Therefore, it

[569] Cf. Backhaus *et al.*: Multivariate Analysemethoden, pp. 513-514.

allows for an interpretation of clusters. *T*-values are calculated by the following formula:[570]

$$[17]:\ t = \frac{\overline{X}(J,G) - \overline{X}(J)}{S(J)}$$

with (J,G): mean of variable *J* of observations in group *G*

(J): mean of variable *J* of all observations

S (J): standard deviation of variable *J* over all observations

*Table C-15* displays the *t*-values for all four clusters. The differences between *t*-values of the clusters show how they differ and also confirm the clear distinction between them. According to these *t*-values, the following four distinct clusters can be established:

- Cluster 1, representing *low SCM practice*. Plants show an overall low degree of SCM practice adoption.
- Cluster 2, representing *internal SCM orientation*. Plants show a relatively higher degree in internal coordination, are average in external coordination and internal collaboration, and show below average practices of external collaboration.
- Cluster 3, representing *external SCM orientation*. In contrast to the previous cluster, plants show a lower degree of internal coordination, have a slightly higher adoption of external coordination and internal collaboration practices, but show a much higher degree of external collaboration.
- Cluster 4, representing *high SCM practice*. Plants in this cluster show an overall high adoption of SCM practices.

*Figure C-2* provides an illustration of the four identified clusters, based on their *t*-values.

[570] Cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 546.

*Table C-15: T-values for SCM clusters*

| | *Cluster* | | | |
|---|---|---|---|---|
| | *low SCM practice* | *internal SCM orientation* | *external SCM orientation* | *high SCM practice* |
| Internal coordination | -1.175 | 0.365 | -0.184 | 1.177 |
| External coordination | -1.104 | -0.158 | 0.383 | 0.991 |
| Internal collaboration | -0.811 | -0.186 | 0.070 | 1.109 |
| External collaboration | -0.812 | -0.664 | 0.829 | 0.685 |
| Cases | 44 | 48 | 51 | 37 |
| % of all cases | 24.44% | 26.67% | 28.33% | 20.56% |

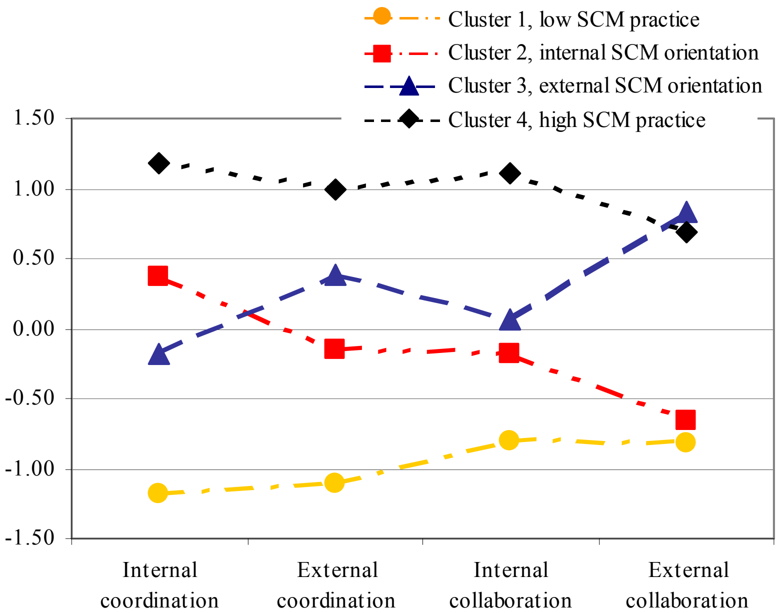


*Figure C-2: Identified SCM clusters of HPM plants, based on t-values*

*F*-values provide a criterion to evaluate the homogeneity of groups established by a cluster analysis. They are calculated as follows:[571]

$$[18]: \; F = \frac{V(J,G)}{V(J)}$$

with V(J,G): variance of variable *J* in group *G*

V(J): variance of variable *J* over all observations

The smaller an *F*-value is the lower the variance of this variable in a group (cluster) in comparison to the entire sample. *F*-values should not be larger than one. A cluster is considered to be homogenous if all *F*-values are smaller than one.[572] As depicted in *Table C-16*, all *F*-values for the identified four clusters show values of less than one and are therefore considered to be homogeneous.

*Table C-16: F-values for SCM clusters*

| | *Cluster* | | | |
|---|---|---|---|---|
| *cluster* / variables | *low SCM practice* | *internal SCM orientation* | *external SCM orientation* | *high SCM practice* |
| Internal coordination | 0.404 | 0.248 | 0.365 | 0.325 |
| External coordination | 0.332 | 0.337 | 0.577 | 0.594 |
| Internal collaboration | 0.747 | 0.374 | 0.741 | 0.441 |
| External collaboration | 0.603 | 0.356 | 0.314 | 0.503 |

In addition, a discriminant analysis is conducted in order to evaluate whether dissimilarities are significant. The following *Tables C-17 and C-18* show the results. All three discriminant functions contribute significantly to the dissimilarity of the groups. The classification results show 97.2% correctly classified cases and therefore the predictive power of the outcome is verified.[573]

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571 Cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 545.

572 Cf. Backhaus *et al.*: Multivariate Analysemethoden, p. 545.

573 Group allocation by chance would result in only 25% correct predictions.

*Table C-17: Discriminant goodness measures for SCM practice clusters*

| *Test of function(s)* | *Wilks' Lambda* | *Chi-square* | *df* | *Sig.* |
|---|---|---|---|---|
| 1 through 3 | 0.097 | 407.663 | 12 | .000 |
| 2 through 3 | 0.493 | 123.903 | 6 | .000 |
| 3 | 0.965 | 6.172 | 2 | .046 |

*Table C-18: Classification results for SCM practice clusters*

| *Original group* | *Predicted group membership* | | | | *Total* |
|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | |
| 1 | 42 | 2 | 0 | 0 | 44 |
| 2 | 1 | 46 | 0 | 1 | 48 |
| 3 | 0 | 0 | 51 | 0 | 51 |
| 4 | 0 | 0 | 1 | 36 | 37 |

It can be concluded that the identified clusters are significantly dissimilar and the results of discriminant analysis show high predictive power. Therefore, the identified clusters can be used for further analysis.

### 3.c. Performance Implications of Supply Chain Management Practices

The previously determined clusters are now used to investigate whether or not differences in performance can be attributed to the degree of SCM practices applied in a plant. The following performance measures are considered and subsequently detailed:

- Eight subjective, single-item performance measures, assessed by plant manager.
- Three objective performance measures, namely on-time delivery, internal scrap and rework, and returned defective products.
- Two subjective, multi-item, multi-informant performance measures that reflect customer satisfaction and distinctive competencies.

The eight subjective, single-item performance measures reflect the assessment of the plant manager as key informant. The plant manager is a reliable informant for competitive performance because she/he has all necessary insights to give a reliable assessment.[574] She/he was asked to rate competitive performance as superior, better than average, average, equivalent to competition, or at the low end of the industry on a global basis. The following eight performance items were rated: (1) unit cost of manufacturing, (2) conformance to product specifications, (3) on-time delivery, (4) flexibility to change in product mix and volume,[575] (5) inventory turn, (6) cycle time from raw material reception to delivery of final products, (7) product capability and performance, and (8) product innovativeness. For a better comparison of performance, these eight measures are standardized. Standardized values greater than zero indicate an above average performance whereas values below zero indicate below average performance.

Three objective performance measures are considered. The first is percentage of orders shipped on time. Most plants do track their on-time delivery performance as this is easy to measure and of relatively high importance. It is also a measure that is independent from general industry characteristics. In competitive markets, the deliver to promise in terms of delivery date should approach 100% in all industries, though it can be acknowledged that there might exist slight differences in terms of relative importance. The same consideration applies for the performance measure of returned defective products. This second objective performance item measures the percentage of returned defective products. It should carry little ambiguity as this can be easily measured. It is also one of special importance because returned products have high external effects as they have already been in contact with the customer. They also cause high direct costs because of the necessary transportation and redundant inbound and outbound logistics processes within own operations as well as on the customer's side.

The third ratio used for objective performance comparisons is the percentage of internal scrap and rework. In this item, varying interpretations are possible. Some plants might not precisely measure rework or scrap. Others might differ in their interpretation of what rework and scrap are. For example, the number of rework incidents along the production process might be enumerated. However, one product could cause several such incidents and therefore be counted more than once. Others might measure the cost implications of rework and scrap. Then, differences might occur due to different cost accounting policies. In conclusion, though rework and scrap is an important performance item for operations, the way the question has been raised in the questionnaires might be ambiguous. Despite these concerns, the ratio is considered for performance comparisons here;

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[574] About the appropriateness of only one key informant, see Devaraj, Hollingworth and Schroeder: Generic manufacturing strategies and plant performance, p. 321.

[575] Flexibility is measured by two separate items. These two items are combined through factor analysis, with item reliability of 0.87 for both items, a Cronbach's alpha of 0.68 and an explained variance of 75.72%.

although it is important that these concerns are considered when interpreting the results.

Two constructs, represented by designated scales in the HPM database, represent perceptual performance measures obtained through multi-item scales that are chosen to compare performance on a broader level. One scale measures customer satisfaction and the other one evaluates distinctive competencies of the plants compared to their competition. For both scales, multiple informants in the plants have been used in order to ensure a high degree of validity of the responses. It has been suggested that perceptual (subjective) measures can be used instead of objective measures because they are either not available or, if they are, considered to be unreliable because of ambiguities. For both measures, no other, more objective, information is available. The subjective measures, however, are capable of reflecting the underlying objective reality fairly well.[576]

Multi-informant responses increase reliability and validity of perceptual measures, and this is especially important for performance measures.[577] *Table C-19* shows the informants for the scales considered in this study. Note that up to three supervisors and up to ten direct labor workers returned answers to the items. Several of these scales have been already introduced in the context of SCM practices. These are internal and external coordination, internal and external collaboration, and ERP integration.[578] The two constructs trust and customer orientation will be introduced in section D as they are of relevance for the SEM analysis.

Customer satisfaction was rated on a 7-point Likert scale by the quality manager, up to three supervisors, and up to ten production workers. The responses of the supervisors and production workers are first averaged and then all three values are averaged again to return the overall plant evaluation for each item. Overall, five items define the scale. Customer satisfaction is an especially suitable measure for performance in supply chains because it reflects not only the required customer focus in SCM but also gives a more embracing picture of a manufacturing plant's performance.[579] It is also a measure that reflects performance independently from industry and plant size. To measure distinctive

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[576] Cf. Dess, Gregory G. and Richard B. Robinson Jr.: Measuring organizational performance in the absence of objective measures: The case of the privately-held firm and conglomerate business unit, in: Strategic Management Journal, Vol. 5 (1984), July-September, pp. 270-271.

[577] For a in-depth analysis of validity and reliability of perceptual measures, see Ketokivi, Mikko A. and Roger G. Schroeder: Perceptual measures of performance: Fact or fiction? in: Journal of Operations Management, Vol. 22 (2004), especially p. 262.

[578] See section C.II.3.a. before.

[579] For a more detailed discussion of customer satisfaction, see section D.II.

competencies of the plants compared to their competition, the following six items were selected: (1) supplier relations, (2) customer relations, (3) enterprise resource planning, (4) quality improvement programs, (5) SCM, and (6) JIT. Respondents were the plant manager, the quality manager, and the plant superintendent.

*Table C-19: Informants of measurement constructs*

| *Scale* | *Informant(s)* |
|---|---|
| Customer satisfaction | Quality manager<br>Supervisor(s)<br>Direct labor |
| Distinctive competencies | Plant superintendent<br>Plant manager<br>Quality manager |
| Internal collaboration | Quality manager<br>Supervisor(s)<br>Direct labor |
| External collaboration | Plant manager<br>Quality manager<br>Inventory manager<br>Supervisor(s)<br>Direct labor |
| Internal coordination | Plant superintendent<br>Inventory manager<br>Supervisor(s) |
| External coordination | Plant superintendent<br>Inventory manager<br>Supervisor(s) |
| Trust | Plant superintendent<br>Inventory manager<br>Supervisor(s) |
| Customer orientation | Quality manager<br>Supervisor(s)<br>Direct labor |
| ERP adoption | Information systems manager |

Both scales, customer satisfaction and distinctive competencies, are reduced through factor analysis and the resulting factor scores are used. Consequently, values greater than zero represent above average performance whereas values below zero represent below average performance.[580] Both scales and the respective items are reliable. *Appendix 3* provides details together with the other scales.

The objective performance measures have been screened for outliers. Some plants might have encountered special circumstances in their specific environment or have submitted erroneous information. By identifying outliers and excluding them appropriately, these effects can be mitigated. Each of the three measures has been examined individually. Although this approach is highly subjective, logical considerations are combined with general considerations for removing outliers. For example, it has been suggested that outliers can be excluded by defining value ranges around the mean. Then, only a certain percentage within the range of the mean are considered.[581]

For the on-time delivery performance measure, plants that reported a on-time delivery performance below 70% are considered to be outliers, which represent the lowest five percent values. In this case, only the worst performing plants have been excluded. Sometimes, responses from both the top and the bottom of the range are excluded. In this case, the top five percent cannot be uniquely identified.[582] Additionally, there is little reason to believe that these are erroneous. In order to control for extreme cases in the scrap and rework performance measure, both the highest and the lowest five percent of the responses could be uniquely identified and have been removed. A closer examination of frequencies of returned defective products raised doubts about six cases because the percentage was above 50% and appeared unreasonably high. Therefore, these six plants representing the worst five percent of the responses were removed. Again, the highest five percent cannot be identified uniquely, but since removals are done based on the assumption that they have been erroneous, this is not inconsistent.

The identified performance measures are now confronted with the four distinct SCM practice clusters. They are also used for performance comparisons throughout the next section. *Table C-20* gives an overview of the results. Mean differences between low SCM practice and high SCM practice are calculated in the last column and the significance of this difference is indicated.[583]

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580 A Pearson correlation reveals a highly significant positive correlation of 0.346 between the two scales, with $p<0.001$. Although this correlation indicates the existence of interdependence between the two constructs, they are clearly distinct from each other. By conducting a factor analyis, items of each scale load on two separate factors, suggesting the distinction of the constructs.

581 Cf. Bortz, Jürgen: Statistik für Sozialwissenschaftler, 4th ed., Berlin Heidelberg New York 1993, p. 30 and p. 40.

582 13.2% of the respondents reported a 100% on-time delivery rate.

583 The following symbols are used: (*)=$p<0.1$, *=$p<0.05$, **=$p<0.01$, ***=$p<0.001$.

Besides cycle time, all differences in single-item, subjective performance measures between the low SCM practice group and the high SCM practice group are significant. The largest difference, 1.007, can be observed with regard to flexibility. This indicates the special importance of SCM practices for flexibility in product changes and production volume. Such flexibility is required particularily in responsive supply chain settings.[584] With shorter product life cycles and an increasingly unstable demand, flexibility skills gain also generally in importance and SCM practices prove to be especially beneficial for that. For all other subjective single-item performance measures, the absolute differences in mean values lie between 0.566 and 0.769.

Differences in objective performance measures are evident, but not on a significant level. The percentage of on-time delivery is 2.36% higher for plants with a high SCM practice level compared to the one with a low SCM practice level. In contrast, internal scrap and rework are 1.22% higher for plants with high SCM practice adoption compared to the low adopters. A reason for this may be that plants with a higher commitment towards coordination and collaboration are better at detecting mistakes throughout the process and also record those mistakes in a proper manner. Low adopters might have a worse performance but simply are not aware of it.

This interpretation is supported by the third objective performance measure, the percentage of returned defective products. Effectiveness with regard to delivering quality products is best assessed by this performance measure. These products have been considered internally as being flawless, and in accordance with quality standards and customer expectations. However, the fact that products are returned as defective shows not only that this was not the case in the first place but also impacted customer perception negatively. Here, high SCM practice adopters receive 1.50% less returns than low adopters. This difference is even more impressive when considering that this equals a reduction of 55.76%. Plants that show an external SCM orientation with a high degree of external collaboration have an even lower return rate of 0.83%.

Customer satisfaction and distinctive competencies as multi-item perceptual performance measures show large and highly significant differences between low SCM practice adopters and high SCM practice adopters as well as a gradually increasing performance for the groups with an internal SCM and external SCM orientation. The same pattern is evident for distinctive competencies. This gradual increase is not so evident with all the other performance measures. The difference of 1.564 in customer satisfaction is remarkable, especially in light of its suitability to reflect an aggregated view of overall performance. This underscores the strategic importance of SCM and supports the assumed positive impact of SCM practices on overall performance.

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[584] See Fisher: What is the right supply chain for your product?, pp. 105-116.

*Table C-20: Performance comparison for different degrees of SCM practices*

| | | *low SCM practice* | *internal SCM orientation* | *external SCM orientation* | *high SCM practice* | *mean diff. low/high* |
|---|---|---|---|---|---|---|
| Manufacturing costs | Mean | -0.390 | 0.131 | 0.010 | 0.268 | *0.658*** |
| | StDev | 0.848 | 0.967 | 0.978 | 1.137 | |
| | Valid cases | 41 | 42 | 46 | 34 | |
| Conformance to product specifications | Mean | -0.251 | 0.043 | -0.002 | 0.328 | *0.579*** |
| | StDev | 0.944 | 0.970 | 1.084 | 0.919 | |
| | Valid cases | 42 | 42 | 46 | 34 | |
| On-time delivery | Mean | -0.463 | 0.065 | 0.199 | 0.217 | *0.680*** |
| | StDev | 1.101 | 0.908 | 0.983 | 0.859 | |
| | Valid cases | 42 | 42 | 46 | 34 | |
| Flexibility in product change and volume | Mean | -0.407 | 0.071 | -0.132 | 0.600 | *1.007*** |
| | StDev | 1.009 | 0.736 | 1.129 | 0.841 | |
| | Valid cases | 42 | 41 | 45 | 33 | |
| Inventory turn | Mean | -0.337 | 0.068 | -0.066 | 0.432 | *0.769*** |
| | StDev | 1.026 | 0.782 | 1.086 | 0.969 | |
| | Valid cases | 42 | 41 | 44 | 34 | |
| Cycle time | Mean | -0.301 | 0.135 | -0.034 | 0.265 | *0.566** |
| | StDev | 0.982 | 0.828 | 0.957 | 1.200 | |
| | Valid cases | 42 | 42 | 43 | 34 | |
| Product capability | Mean | -0.268 | 0.007 | -0.011 | 0.368 | *0.636*** |
| | StDev | 1.117 | 0.887 | 1.050 | 0.829 | |
| | Valid cases | 42 | 41 | 46 | 34 | |
| Innovativeness | Mean | -0.356 | 0.217 | -0.118 | 0.326 | *0.682*** |
| | StDev | 1.008 | 0.941 | 1.130 | 0.718 | |
| | Valid cases | 42 | 41 | 44 | 33 | |
| On-time delivery, in % | Mean | 92.83% | 92.61% | 92.65% | 95.19% | *2.36%* |
| | StDev | 6.67% | 6.90% | 7.08% | 6.24% | |
| | Valid cases | 30 | 37 | 39 | 30 | |
| Internal scrap and rework, in % | Mean | 5.14% | 4.95% | 4.46% | 6.36% | *1.22%* |
| | StDev | 5.74% | 6.37% | 6.23% | 5.78% | |
| | Valid cases | 35 | 31 | 37 | 28 | |
| Returned defective products, in % | Mean | 2.69% | 1.23% | 0.83% | 1.20% | *-1.50%* |
| | StDev | 5.14% | 2.47% | 1.35% | 2.11% | |
| | Valid cases | 31 | 33 | 41 | 26 | |
| Customer satisfaction | Mean | -0.791 | -0.184 | 0.302 | 0.773 | *1.564**** |
| | StDev | 0.985 | 0.799 | 0.758 | 0.833 | |
| | Valid cases | 44 | 48 | 51 | 37 | |
| Distinctive competences | Mean | -0.474 | -0.100 | 0.220 | 0.341 | *0.815**** |
| | StDev | 0.743 | 0.988 | 0.973 | 1.111 | |
| | Valid cases | 44 | 47 | 51 | 37 | |

After this analysis of SCM practices and their impact on performance, the next section analyzes e-business applications and practices in manufacturing plants in detail. This then builds the foundation for the subsequent synthesis of SCM practices and e-business capabilities of manufacturing plants so that more precise management implications can be derived.

## III. E-Business Applications and Practices of Manufacturing Companies

### *1. E-Business Usage in Manufacturing Companies*

As previously discussed, at the moment e-business represents the most significant technology for SCM. Though the social impact of the Internet and communication technology is quite visible, on the manufacturer's level it is more subtle. Despite all e-commerce and e-business innovations, in order to sell goods they first have to be produced and be available. For manufacturers, CIM technology and automation have been the most pressing technologies to pursue in the past. CIM has now been integrated into more comprehensive and wide reaching ERP systems.[585] Therefore, the prophecy of integrated manufacturing, planning, and execution systems has become a reality. Consequently, IT systems are now part of every large manufacturing plant.

All together, in the HPM project 31 areas for IT application support are defined. Only 19 of these are seen to be of immediate relevance for SCM.[586] The plants were asked whether a function is supported by software and if so, if it is integrated in an ERP system. A comparison of the six countries shows that there exist different degrees of SCM software support and especially ERP integration. German plants, for example, show the highest degree of software support for SCM application areas, closely followed by plants located in the USA and Japanese plants as shown in *Table C-21*. The low software support rate of South Korean plants can be accounted for by the economic environment of this country. Lower relative wages may lead to a higher degree of activities done manually.[587]

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585 CIM technology has been further developed. SAP, for example, refers to its solution that covers product development and production processes as Product Lifecycle Management, see http://www.sap.com.

586 See *Appendix 2* for the list of all application areas considered to be relevant for SCM.

587 For South Korea, in 2005 labor productivity in US$ per hour has been on average 50% lower than for the other countries in the database. However, since 1990 it has been improved by 100% compared to around 30% in the other countries. This shows the economic development of South Korea of the last years. See Total economy database, http://www.ggdc.net, The Conference Board and Groningen Growth and Development Centre,retrieved on: February 15, 2006.

*Table C-21: Software support of selected SCM applications by country*

| | **Software support of selected applications** | | **ERP integration of selected applications** | |
|---|---|---|---|---|
| **Country** | **Rank among countries** | **Average %** | **Rank among countries** | **Average %** |
| Germany | 1 | 77.7% | 1 | 53.9% |
| USA | 2 | 77.2% | 3 | 40.9% |
| Japan | 3 | 74.3% | 6 | 23.0% |
| Sweden | 4 | 68.1% | 4 | 38.0% |
| Finland | 5 | 63.4% | 2 | 41.3% |
| South Korea | 6 | 57.3% | 5 | 28.0% |

ERP integration presents a different picture. German plants still show the highest degree of ERP integration, followed by Finland, the USA, and Sweden. Though Japan ranks third in terms of SCM software support, when it comes to ERP integration, it drops to last by quite some margin. Japanese manufacturing plants seem to see no necessity of extensive ERP integration of their software applications and rather work with more isolated systems. This is illustrated in *Figure C-3*.

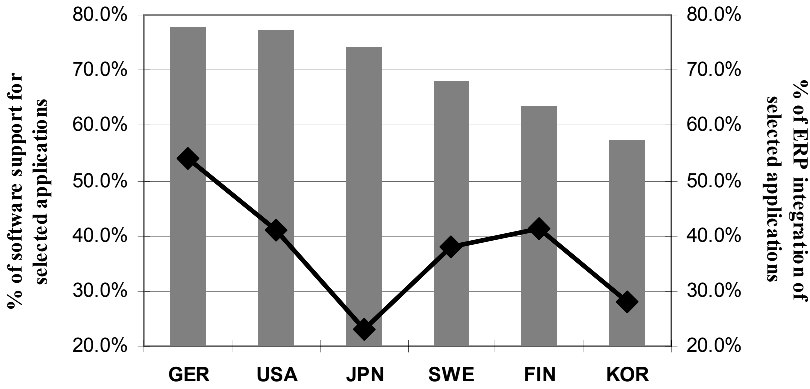


*Figure C-3: Illustration of SCM software support and ERP integration*[588]

This overall picture differs substantially in two application areas. Though Japan and South Korea show overall a low degree of ERP integration, in the application and ERP integration of groupware tools they show higher percentages than the other countries. 96.3% of all Japanese plants in the sample use groupware tools and 18.5% integrate them into their ERP systems. With 78.6%, South Korean plants show an unusually high software support of groupware tools and with 14.3% in this application the second highest ERP integration after Japan. This indicates that Asian plants see a higher need for software support in group activities relative to the other countries and therefore it can be suspected that they emphasize these kinds of activities over other areas. Besides this deviation in the application of groupware tools, 85.2% of the Japanese manufacturing plants support their product configuration by software applications and 33.3% integrate this function into their ERP systems. This software support is again the highest among all countries.

As IT becomes increasingly important for operations, the associated costs are of interest. Often, this is used as a benchmark of a company's IT activity and proficiency. *Figure C-4* shows the median values and range of IT expenses of the analyzed manufacturing plants as a percentage of manufacturing costs by country. The median is favored over the mean because the sample shows high standard deviations and therefore outliers affect the mean too much. With a median of 3.5% of overall manufacturing costs, South Korean plants show the highest average IT cost proportion, followed by Japanese plants with a value of 3% and German plants with 2.9%. In comparison to other cost components, IT expenses might be

[588] The bar chart refers to the percentage of software support and the line chart within refers to the percentage of ERP integration.

relatively higher for South Korean plants as facilities and labor costs are relatively lower compared to the other countries participating in the HPM study, thus leading to a higher cost proportion in manufacturing costs. Considering the high degree of IT adoption in German plants, it comes as no surprise that these plants spend slightly more on IT than other countries in a comparable economic environment.

Both, South Korea and Japan, with a relativly low ERP integration rate show higher median (and also mean) IT expenses of manufacturing costs than the other countries. This suggests that a less integrated approach tends to cause higher overall IT costs. German plants, however, show the third highest IT expense ratio although still being the most integrated ones. Nevertheless, a closer look at all three measures combined – software support, ERP integration, and IT expenses – may provide an explanation. It can be observed that IT productivity – measured in general by the ratio of output to input – might well be best for German plants because of the disproportionally higher service offering. Under this assumption, the conclusion that a less integrated approach tends to cause relatively higher IT costs holds.[589]

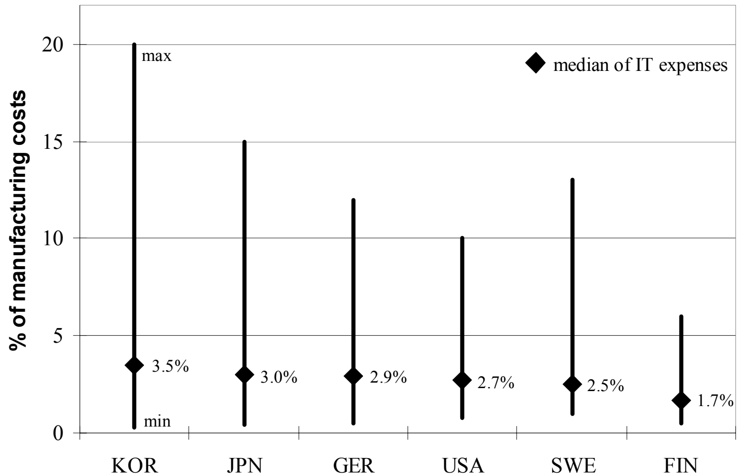


*Figure C-4: Reported median of IT expenses and range as percentage of manufacturing costs by country*

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589 It should be noted that these numbers are based on a relatively low overall response rate of 112 plants.

Besides software support and their internal integration, the Internet has provided a variety of new possible service offerings for suppliers and customers of manufacturing plants. Several possible uses of the Internet in terms of procurement and sales activities have been of interest in the HPM project. In terms of procurement, the Internet is mostly used for scanning the market for new sources. Also, 57.9% of manufacturing plants use the Internet for transmitting orders to suppliers and 39.8% use it for tracking and tracing orders. *Table C-22* gives an overview. Bold figures indicate the highest value for each Internet activity. So far, it seems that there is little use of the Internet as a platform for collaborative activities, real-time integration, and dynamic pricing. Either manufacturers do not see a benefit in these activities or their supply chains are not responsive to these activities. With all the possibilities of the Internet, this indicates either that the real application of the Internet is still in an early stage or that these functions are not perceived as beneficial at the moment or both.[590]

*Table C-22: Usage of the Internet for procurement activities by country and in total*

| | scanning market for potential new sources | receiving and comparing supplier offers | provide dynamic pricing | transmitting orders to suppliers | tracking and tracing orders | real-time integration | support coll. product design and impr. | support coll. process design and impr. |
|---|---|---|---|---|---|---|---|---|
| **FIN** | 40.7% | 11.1% | 14.8% | 55.6% | 29.6% | 14.8% | **22.2%** | 0.0% |
| **USA** | 78.6% | **57.7%** | 28.0% | **76.9%** | **82.1%** | **34.6%** | 16.7% | 20.0% |
| **JPN** | 75.0% | 37.5% | 29.2% | 75.0% | 33.3% | 20.8% | 12.5% | 4.2% |
| **GER** | 85.0% | 47.5% | 20.0% | 52.5% | 25.0% | 5.0% | 15.0% | 10.0% |
| **SWE** | **89.5%** | 36.8% | 10.5% | 57.9% | 57.9% | 5.3% | 5.3% | 10.5% |
| **KOR** | 53.6% | 28.6% | **32.1%** | 35.7% | 21.4% | 14.3% | 17.9% | **21.4%** |
| **Total** | 70.5% | 37.2% | 22.7% | 57.9% | 39.8% | 15.2% | 15.4% | 11.0% |

Using the Internet on the sales side of the plants is dominated by two areas: presenting information, and providing a sales product catalog. Online order entry and checking delivery status online for business partners follow by considerable margins. *Table C-23* provides an overview.

590 One limitation of these items is certainly that the wording is rather vague and therefore it might have been unclear to the respondents what exactly was meant by these Internet activities.

*Table C-23: Usage of the Internet for sales activities by country and in total*

| | presenting information | presenting sales product catalog | online product configuration | fixed pricing offers | dynamic pricing offers | online order entry | check delivery status online |
|---|---|---|---|---|---|---|---|
| **FIN** | 88.9% | 40.7% | 11.1% | 3.7% | 3.7% | 11.1% | 11.1% |
| **USA** | **90.0%** | 42.1% | 12.5% | **23.5%** | **18.8%** | **41.2%** | 23.5% |
| **JPN** | 77.3% | **77.3%** | 9.1% | 13.6% | 9.1% | 31.8% | 9.1% |
| **GER** | 87.8% | 72.5% | 17.5% | 15.0% | 12.5% | 20.0% | 22.5% |
| **SWE** | 89.5% | 63.2% | **31.6%** | 21.1% | 0.0% | 36.8% | **31.6%** |
| **KOR** | 60.7% | 64.3% | 21.4% | 14.3% | 0.0% | 17.9% | 21.4% |
| **Total** | 82.2% | 61.3% | 17.1% | 14.4% | 7.2% | 24.2% | 19.6% |

The usage of the Internet according to customer segments provides additional insights into how Internet services are used by manufacturing plants involved in different sales channels. It has been suggested that the Internet as a procurement, marketing, and sales channel should be designed and used according to customer needs.[591] The analysis depicted in *Table C-24* shows that plants that primarily sell to distributors use the Internet the most for their sales activities. Only plants selling mainly to end consumers have a higher Internet usage in presenting information on the Internet. Bold figures indicate the highest value for each Internet activity.

*Table C-24: Usage of the Internet for sales activities by cluster and over all clusters*

| Cluster | presenting information | presenting sales product catalog | online product configuration | fixed pricing offers | dynamic pricing offers | online order entry | check delivery status online |
|---|---|---|---|---|---|---|---|
| s-to-m | 79.2% | 50.0% | 9.5% | 13.6% | 4.8% | 27.3% | 18.2% |
| s-to-a | 79.2% | 60.9% | 13.0% | 13.0% | 0.0% | 17.4% | 8.7% |
| s-to-d | 73.9% | **69.6%** | **30.4%** | **26.1%** | **13.0%** | **39.1%** | **26.1%** |
| s-to-c | **88.5%** | 63.5% | 13.5% | 11.5% | 9.6% | 19.2% | 17.3% |
| **Total** | 82.1% | 61.5% | 16.0% | 15.0% | 7.6% | 24.2% | 17.5% |

591 See Fritz, Wolfgang: Internet-Marketing und Electronic Commerce, 3rd ed., Wiesbaden 2004, pp. 131-140.

For sales activities, mainly generic functionalities are adopted, as is the case for presenting information or presenting a sales product catalog. Order entries through a webpage are only adopted by 24.2% of the plants. However, this function is most likely fulfilled through a more integrated approach, such as the automatic exchange of standard information through EDI. Unfortunately, these areas are not covered in more detail and consequently this cannot be answered definitively.

Besides sales activities over the Internet, procurement activities using the Internet by each cluster are also analyzed, as depicted in *Table C-25*. Plants selling predominately to distributors show a relatively intensive usage of the Internet. They use the Internet more than the other clusters in receiving and comparing supplier offers, providing dynamic pricing, transmitting orders to suppliers, and supporting collaborative product design and improvement. Plants selling mainly to manufacturers use the Internet intensively in scanning the market for potential new sources, tracking and tracing orders, real-time integration, and support of collaborative process design and improvement.

*Table C-25: Usage of the Internet for procurement activities by cluster and over all clusters*

| Cluster | scanning market for potential new sources | receiving and comparing supplier offers | provide dynamic pricing | transmitting orders to suppliers | tracking and tracing orders | real-time integration | support coll. product design and impr. | support coll. process design and impr. |
|---|---|---|---|---|---|---|---|---|
| s-to-m | **86.2%** | 35.7% | 18.5% | 59.3% | **51.7%** | **22.2%** | 7.7% | **19.2%** |
| s-to-a | 77.3% | 36.4% | 22.7% | 54.5% | 40.9% | 18.2% | 13.6% | 4.5% |
| s-to-d | 54.2% | **45.8%** | **41.7%** | **75.0%** | 37.5% | 20.8% | **33.3%** | 16.7% |
| s-to-c | 81.5% | 44.4% | 18.5% | 53.7% | 38.9% | 7.4% | 13.0% | 9.3% |
| **Total** | 76.7% | 41.4% | 23.6% | 59.1% | 41.9% | 15.0% | 15.9% | 11.9% |

It can be concluded that manufacturing plants make use of the Internet and the WWW more intensively for procurement activities than for sales activities. Besides the more generic usage for scanning the market for potential new sources and comparing supplier offers, more operational functions are of importance, such as the transmission of orders to suppliers, or tracking and tracing orders. For this, the Internet represents not only a cheap communication channel with advanced self service functions but also contributes potentially to a lower data recording error rate. More advanced, but also admittably less developed functionalities, such as real-time integration or support for collaborative processes, are not very widespread among manufacturers yet. It seems as if so far these functionalities are not capable of replacing the existing processes efficiently.

### 2. *Electronic Integration of Business Partners in Manufacturing Supply Chains*

Information and especially the sharing of it is of high importance for SCM. In order to create a seamless supply chain, information sharing processes should also be integrated and automated. Ideally, ERP systems of business partners exchange information in a structured way so they can be processed without manual interference.

The most common way to conduct such a structured information exchange is through EDI. In the HPM project, 24.7% of the manufacturing plants exchange structured information with either their customers or their suppliers; in addition, 49.4% out of 166 responses recorded in this particular item report doing so with both. This is a quite high adoption rate. Independently from this, plants were asked about their usage of the Internet in the purchasing and sales processes. With this question, the degree of Internet-based supply chain integration can be determined similar to the framework suggested by Frohlich and Westbrook.[592] However, a rather low adoption rate becomes evident. Most companies report that they make only little use of the Internet in their purchasing and sales processes. This is in contrast to the previous outcome, because the exchange of structured information should be also part of purchasing and sales processes and one could assume that this exchange is conducted over the Internet.

This contradiction raises questions about the validity of responses. One explanation might be that the respondents misinterpreted the questions. Plants have not been explained what exactly is meant by structured information or for what purposes or to what extent they actually exchange structured information. It might be that it is not the case for major supply chain processes, such as processing purchases or sales. Additionally, it is possible that respondents failed to make the connection between EDI system exchange and the Internet due to different perceptions of the Internet, i.e. interpreting it as the WWW.

Bearing this in mind, it is of interest whether plants with a high Internet adoption rate perform better than their low adoption counter parts. In order to identify plants with a high Internet adoption for their purchasing and sales processes, a cluster analysis using Ward's method was conducted. Five homogeneous clusters were identified based on the usage of the Internet for purchasing and sales processes. *Figure C-5* provides an overview and *Table C-26* shows the mean values for these clusters.[593]

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592 See Frohlich and Westbrook: Demand chain management in manufacturing and services: Web-based integration, drivers and performance, p. 731.

593 For this analysis, a two-stage-clustering analysis did not improve the results. In the second stage, only four clusters were identified. By reviewing the cluster means, a five cluster allocation seems to be the better solution because they show five distinct positions with regard to the usage of the Internet for purchasing and sales activities.

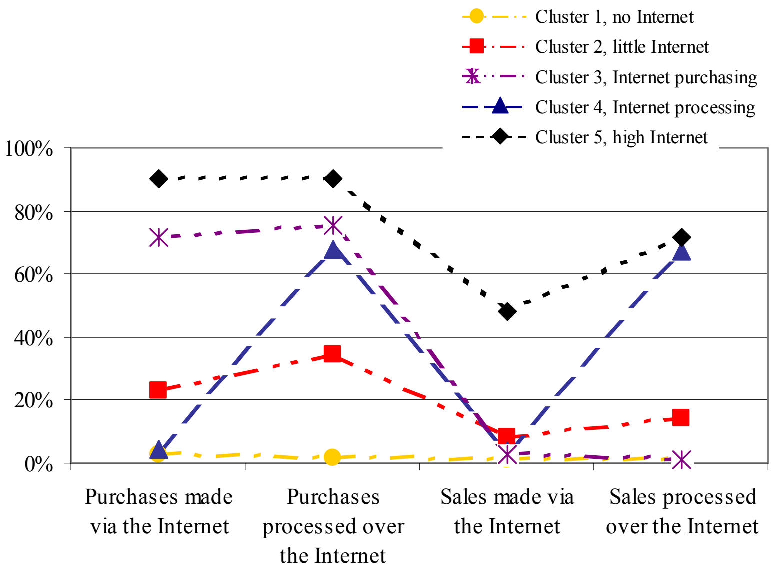


*Figure C-5: Illustration of Internet adoption of purchasing and sales processes*

As *Figure C-5* illustrates, the following five homogeneous clusters can be extracted:

- Cluster 1 (*no Internet*), with an overall very low usage of the Internet in purchasing and sales activities.
- Cluster 2 (*little Internet*), with low Internet usage to make and process purchases, but a very low usage in sales activities.
- Cluster 3 (*Internet purchasing*), with a high usage of the Internet to make and process purchases, but a very low usage in sales activities.
- Cluster 4 (*Internet processing*), uses the Internet to process purchasing and sales orders, but does not use it to place or receive orders.
- Cluster 5 (*high Internet*), with an overall high adoption of the Internet in all purchasing and sales activities.

The cluster means for all four categories of Internet usage and the five identified clusters based on these categories are depicted in *Table C-26*.

*Table C-26: Cluster analysis based on Internet adoption for purchasing and sales processes, means of clusters*

| | *Cluster* | | | | |
|---|---|---|---|---|---|
| | *no Internet* | *little Internet* | *Internet purchasing* | *Internet processing* | *high Internet* |
| Purchases made via the Internet | 2.78% | 22.78% | 71.70% | 4.43% | 90.00% |
| Purchases processed over the Internet | 1.77% | 34.61% | 75.40% | 67.71% | 90.00% |
| Sales made via the Internet | 0.82% | 8.17% | 2.62% | 3.57% | 48.33% |
| Sales processed over the Internet | 0.89% | 14.33% | 0.85% | 67.43% | 71.67% |
| Cases | 78 | 18 | 10 | 7 | 3 |
| % of all cases | 67.24% | 15.52% | 8.62% | 6.03% | 2.59% |

The cluster with most cases is the one with the lowest adoption rate of the Internet in purchasing and sales processes. Together with cluster 2, plants that make little use of the Internet and only then mainly for their purchasing processes account for 82.76%. Again, the question might have been misleading. This outcome could be influenced by the perception of the Internet as the WWW. Even if orders are processed by EDI, respondents might not have made the connection to the Internet as the underlying TCP/IP driven network that characterizes the Internet.[594]

Nevertheless, three plants report a high usage of the Internet in their purchasing and sales processes. Together with plants that use the Internet considerably in their purchasing activities and plants that manage purchasing and sales processes over the Internet, they account for the remaining 17.24%.

Practices and characteristics of these "high Internet adopters" can be compared to the other manufacturers in order to find out if this yields any benefits for them. In order to evaluate the performance levels of these two groups, the previously introduced performance measures are chosen from the HPM dataset.[595] However, differences remain very little and high Internet adopters show either no, or at least no significant performance advantage over low adopters.

The HPM database provides no information that allows for a comprehensive analysis of the way external supply chain partners are connected. The questions that aim at providing this information carry too much ambiguity for such an analysis. Without explaining more precisely what is meant by structured

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594 See section B.III.3.a.

595 See section C.II.3.

information exchange and a detailed outline of the kind of IT support for such an exchange, no meaningful results can be obtained. However, it has to be acknowledged that at the time the HPM scales were developed, this area was less obvious and no dedicated SCM software and ERP II solutions were available. The rapid development in this area makes it hard for a research project of this scale and scope to account for such technological state-of-the-art applications. Nevertheless, it is likely that the adoption of these applications is not very far advanced and this area of the questionnaire should be redesigned for possible following rounds of the HPM project.

### 3. *Evidence for the Impact of Software Support and ERP Integration on Manufacturing Supply Chains*

In order to exchange electronic information with business partners, it has to be gathered and processed internally first. ERP systems are a major source for gathering and providing such information. They are designed to integrate business functions and allow data sharing across functional boundaries within a company. As such, ERP systems are considered to be a prerequisite for SCM systems that broaden the scope of ERP systems to not only integrate cross-functionally but also to cross entire supply chains and therefore for e-business in general.[596]

Stand alone business applications already accomplish direct benefits such as local optimization and business process automation. ERP systems aim at providing an infrastructure that leverages those capabilities, providing critical support for strategic and operational management. Consequently, possessing such leveraged information may prove to be a substantial leverage for overall competitive advantage.[597]

Lopez et al. identify major benefits of ERP systems. These include (1) unified real-time interfaces across the entire corporation, (2) streamlined and accelerated business processes, (3) increased flexibility through quicker reactions, (4) the capability to integrate dispersed divisions of a company along with supply chain activities, and (5) increased possibilities to align own practices with practices identified by ERP vendors.[598] Bendoly and Schoenherr link the benefits of ERP systems to the Theory of Swift, Even Flow, introduced by Schmenner and Swink because of its capability of reducing processing time and variances associated with this. In addition, Bendoly and Schoenherr suggest that ERP systems in themselves

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[596] Cf. Tarn, Yen and Beaumont: Exploring the rationales for ERP and SCM integration, p. 26.

[597] See Bendoly and Schoenherr: ERP system and implementation process benefits. Implications for B2B e-procurement, p. 317.

[598] Cf. Lopez, David *et al.*: Impact of information technology and e-commerce on supply chain management: Survey evidence from manufacturing companies in Michigan, in: Journal of E-Business, Vol. 4 (2004), No. 1, June, p. 2.

may indicate an overall competitive advantage.[599] This seems like a bold statement. It is more reasonable to assume that the process of implementing an ERP system and accompanying process and structure adjustment are more likely the source of a possible competitive advantage together with an ERP system. Without adjustments, benefits do not likely materialize.

Many authors identify customer satisfaction as one indicator for competitive advantage. In the context of SCM, especially this customer orientation is seen as crucial for success.[600] Because of the synergetic relationship between SCM and ERP systems, customer satisfaction should also be positively affected by ERP systems as they can provide higher responsiveness to customer requests due to better information availability.

Little empirical research is available on the performance impact of ERP systems. McAfee presents a thorough experimental analysis to show direct, operational benefits of an ERP implementation for a variety of performance measures, such as on-time delivery or average lead time per order.[601] To conduct a broader empirical analysis as evidence, the HPM project builds a solid foundation because it provides detailed information about software applications, ERP integration, and a variety of performance measures. First, operational performance of manufacturing plants based on different degrees of software support for selected business functions are compared. In a second step, companies that show low software support with little to no integration, i.e. ERP laggards are compared with ERP system champions that are characterized by an overall high, integrated software support.

From the questionnaire, 19 software support functions have been identified as especially relevant in light of the importance of SCM. *Appendix 2* provides an overview of these. Based on these applications, the degree of software support and ERP integration are determined as a composite index score. The lowest 20.5% for software support and 26.4% for ERP integration respectively are considered to be low adopters and the highest 17.6% for software support and 27.8% for ERP integration are considered to be high adopters.[602] Though interdependence is inevitable, the two groups are not mutually inclusive, i.e. low software support does not necessarily indicate low ERP integration if the few applications are all

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599 See Bendoly and Schoenherr: ERP system and implementation process benefits. Implications for B2B e-procurement, pp. 307-317.

600 For example, see Stevens: Integrating the supply chain, p.3; and Mentzer *et al.*: Defining supply chain management, p. 15.

601 Cf. McAfee: The impact of enterprise information technology adoption on operational performance: An empirical investigation, pp. 33-52.

602 The commonly adopted first and fourth quartile thresholds are chosen to determine the cluster thresholds. The thresholds are not equal because threshold categories included multiple cases and therefore only either all or none can be removed.

integrated into a ERP system. However, there is no case that shows high ERP integration but a low software support.

These different groups and constellations are now analyzed in terms of differences in performance. As performance measures, again the previously developed performance measures from the three categories subjective single-item, objective, and subjective multi-item measures are considered.

The following null-hypotheses are formulated:[603]

$H_1$: Manufacturing plants with a high degree of software support for relevant business functions do not show better performance than plants with a low degree of software support.

$H_2$: Manufacturing plants with a high degree of software support and a high degree of ERP integration for relevant business functions do not show better performance than plants with a low degree of software support and low ERP integration.

The comparison of low and high software support adopters is depicted in *Table C-27*. The analysis suggests that a higher degree of software support indeed yields a better operational performance. However, based on independent *t*-tests, only the higher performance in cycle time between the two groups is significant, with $t(68)=-2.014$ and $p<0.05$; this represents a medium sized effect of $r=0.24$. The difference in manufacturing costs is significant only at $p<0.1$. For these two measures, the null-hypothesis $H_1$ can be rejected. The other differences hint towards $H_1$, but require follow-up research. For customer satisfaction, the mean values show no considerable difference at all, which is in line with the previous argument, i.e. that integration might lead to positive, direct customer effects, but software alone does not.

603 Bortz: Statistik für Sozialwissenschaftler, pp. 106-107 for a discussion of hypothesis building.

*Table C-27: Comparison of selected performance measures for low and high software adopters*

| | | *low software support* | *high software support* | *mean diff. low/high* |
|---|---|---|---|---|
| Manufacturing costs | Mean | -0.179 | 0.232 | *0.410(*)* |
| | StDev | 1.015 | 1.095 | |
| | Valid cases | 33 | 37 | |
| Conformance to product specifications | Mean | 0.005 | 0.244 | *0.239* |
| | StDev | 1.078 | 0.887 | |
| | Valid cases | 34 | 37 | |
| On-time delivery | Mean | 0.114 | -0.041 | *-0.155* |
| | StDev | 0.974 | 1.012 | |
| | Valid cases | 34 | 37 | |
| Flexibility in product change and volume | Mean | -0.163 | 0.032 | *0.195* |
| | StDev | 1.165 | 1.049 | |
| | Valid cases | 33 | 35 | |
| Inventory turn | Mean | 0.076 | 0.062 | *-0.015* |
| | StDev | 0.729 | 1.079 | |
| | Valid cases | 34 | 35 | |
| Cycle time | Mean | -0.235 | 0.218 | *0.453** |
| | StDev | 0.809 | 1.051 | |
| | Valid cases | 34 | 36 | |
| Product capability | Mean | 0.141 | 0.174 | *0.033* |
| | StDev | 0.942 | 0.925 | |
| | Valid cases | 33 | 36 | |
| Innovativeness | Mean | 0.011 | 0.333 | *0.323* |
| | StDev | 1.082 | 0.919 | |
| | Valid cases | 32 | 35 | |
| On-time delivery, in % | Mean | 93.20% | 93.47% | *0.27%* |
| | StDev | 8.37% | 7.12% | |
| | Valid cases | 26 | 29 | |
| Internal scrap and rework, in % | Mean | 5.80% | 5.17% | *-0.63%* |
| | StDev | 5.92% | 5.82% | |
| | Valid cases | 26 | 31 | |
| Returned defective products, in % | Mean | 1.75% | 1.52% | *-0.23%* |
| | StDev | 2.85% | 3.89% | |
| | Valid cases | 29 | 32 | |
| Customer satisfaction | Mean | 0.043 | -0.036 | *-0.079* |
| | StDev | 0.900 | 0.985 | |
| | Valid cases | 36 | 42 | |
| Distinctive competencies | Mean | -0.061 | 0.050 | *0.111* |
| | StDev | 0.975 | 1.187 | |
| | Valid cases | 36 | 42 | |

By combining the degree of software support and ERP integration, it is possible to identify “low IT adopters” and “high IT adopters”. The latter show higher values in all performance measures but internal scrap and rework, as can be observed in *Table C-28*. The fact that the amount of returned defective products is lower suggests that internal mistakes are not necessarily prevented but at least detected which in turn leads to a lower return rate. This is the same phenomenon as observed in the previous SCM practice analysis.[604] The difference in manufacturing costs between IT low adopters and IT high adopters is significant, with $t(38)=-2.523$ and $p<0.05$; this represents a rather strong effect of $r=0.38$. Consequently, $H_2$ can be rejected for manufacturing costs.

From comparing *Table C-27* and *Table C-28*, it becomes evident that the difference in customer satisfaction between low adopters and high adopters increases by including the ERP integration perspective, though not on a significant level. Therefore, the ERP effect without considering software application adoption is tested. Because of the relatively narrow spread within the composite software adoption index, relatively high software adopters – though not identified as high in the software adoption cluster due to this stricter separation – that show high ERP integration are excluded from the analysis in *Table C-28*. Consequently, the sole effect of ERP integration on customer satisfaction is tested separately, as stated in $H_3$.

$H_3$: Manufacturing plants with a high degree of ERP integration for relevant business functions do not show higher customer satisfaction than plants with a low degree of ERP integration.

[604] See section C.II.3.

*Table C-28: Comparison of selected performance measures for overall low and high IT adopters*

| | | *low software, low ERP integration* | *high software, high ERP integration* | *mean diff. low/high* |
|---|---|---|---|---|
| Manufacturing costs | Mean | -0.350 | 0.441 | *0.791** |
| | StDev | 1.039 | 0.944 | |
| | Valid cases | 19 | 21 | |
| Conformance to product specifications | Mean | -0.068 | 0.207 | *0.275* |
| | StDev | 1.056 | 0.870 | |
| | Valid cases | 20 | 21 | |
| On-time delivery | Mean | 0.207 | 0.037 | *-0.170* |
| | StDev | 0.964 | 0.970 | |
| | Valid cases | 20 | 21 | |
| Flexibility in product change and volume | Mean | -0.115 | 0.083 | *0.198* |
| | StDev | 1.282 | 0.761 | |
| | Valid cases | 19 | 19 | |
| Inventory turn | Mean | 0.164 | 0.254 | *0.090* |
| | StDev | 0.755 | 0.985 | |
| | Valid cases | 20 | 19 | |
| Cycle time | Mean | -0.254 | 0.269 | *0.523(*)* |
| | StDev | 0.938 | 1.064 | |
| | Valid cases | 20 | 20 | |
| Product capability | Mean | 0.102 | 0.037 | *-0.065* |
| | StDev | 0.939 | 0.782 | |
| | Valid cases | 20 | 20 | |
| Innovativeness | Mean | -0.064 | 0.407 | *0.471* |
| | StDev | 1.127 | 0.817 | |
| | Valid cases | 19 | 21 | |
| On-time delivery, in % | Mean | 93.69% | 95.44% | *1.75%* |
| | StDev | 8.55% | 4.06% | |
| | Valid cases | 17 | 16 | |
| Internal scrap and rework, in % | Mean | 5.47% | 5.50% | *0.03%* |
| | StDev | 6.69% | 6.49% | |
| | Valid cases | 17 | 18 | |
| Returned defective products, in % | Mean | 2.28% | 1.68% | *-0.60%* |
| | StDev | 3.39% | 4.92% | |
| | Valid cases | 17 | 16 | |
| Customer satisfaction | Mean | -0.050 | 0.231 | *0.281* |
| | StDev | 0.910 | 0.886 | |
| | Valid cases | 22 | 23 | |
| Distinctive competencies | Mean | -0.200 | -0.072 | *0.127* |
| | StDev | 0.996 | 1.322 | |
| | Valid cases | 22 | 23 | |

Based on an independent *t*-test, the difference in customer satisfaction performance between plants with low ERP integration and those that show a high degree of ERP integration is significant, with t(94)=-3.005 and $p<0.01$, as shown in *Table C-29*. Therefore, $H_3$ can be rejected. It can be concluded that a high degree of ERP integration indeed leads to higher customer satisfaction. The fact that a high degree of software support alone does not show this effect indicates that the positive effects of ERP integration reach beyond company boundaries.

*Table C-29: Customer satisfaction for plants with low and high ERP integration*

| | | *low ERP integration* | *high ERP integration* | *mean diff. low/high* |
|---|---|---|---|---|
| Customer satisfaction | Mean | -0.345 | 0.225 | *0.570*** |
| | StDev | 0.905 | 0.950 | |
| | Valid cases | 47 | 49 | |

This analysis shows that ERP integration contributes significantly to customer satisfaction. Since customer satisfaction aggregates overall performance up to this point in a supply chain, ERP integration can be seen as a beneficial tool for supply chain success and therefore proves to be an important factor for competitive advantage for manufacturing companies. Furthermore, the analysis also suggests that software support improves operational performance in selected areas, such as manufacturing costs and cycle time independently from ERP integration. However, ERP high adopters who combine a high degree of software support and integrate those applications in a comprehensive ERP system show an even better performance. As a consequence, those 26 high ERP adopters that do not fall into the high software support category can excel by extending their overall software support.

Although the results show more support towards the hypotheses, many of the performance differences are not significant. This is partly due to a rather small sample size after clustering the groups. Furthermore, due to the descriptive nature of our analysis, no causal links can be established. Thus, other factors such as SCM practices that might be of importance are not considered. This omission will be picked up in section D, which investigates causal relationships between SCM practices, ERP integration, and performance.

## IV. Evidence for Superior Performance of SCM Integration Champions

So far, SCM practices have been considered independently from e-business capabilities. For SCM practices, four constructs that define SCM practices within manufacturing plants have been operationalized. The management of the integration of seamless material and information flows could not be captured based on data available from the HPM project. Therefore, ERP integration is now considered as a substitute to reflect integration at least within the plants. As pointed out in the previous section, ERP systems serve as the backbone for further SCM system adoption and therefore provide a seamless information flow across company borders.

In order to derive empirical evidence for the relationship between practices and performance, respondents of the HPM study are divided into four groups along the dimensions *degree of ERP integration* and *SCM practices adoption* as defined through the previous cluster analysis.[605] The groups are well separated as can be observed in *Figure C-6*. Omitting all other plants that are positioned between these four groups provides a clearer distinction of the four groups identified below:

- *SCM laggards*. In this category, plants that fall into the first quartile in terms of ERP integration and plants that belong to the low SCM practice cluster or show overall low SCM practice with an internal orientation are considered. In total, 24 plants are identified that show these characteristics.
- *SCM champions*. Plants that belong to the fourth quartile in terms of ERP integration and that show the highest SCM practice among all plants as identified by the cluster analysis in section C.II.3 are identified as SCM champions. Because of this strict selection, only true SCM champions are identified and only 11 plants qualify for this group.
- *ERP savvy plants*. Plants that show overall a low SCM practice adoption or low SCM practice with an internal orientation but belong to the top quartile with regard to ERP integration belong to this category. They are therefore considered to be technology-driven in the context of SCM. There are 23 respondents identified as ERP savvy plants.
- *SCM advocates*. In this group, plants show commitment to SCM practices without a high degree of technology support compared to other manufacturers. Plants that show medium SCM practices with a high commitment to external collaboration or high SCM practice adopters and plants that belong to the first two quartiles with regard to ERP integration are investigated. In total, 49 plants are identified as SCM advocates.

Performance of manufacturing plants can now be investigated to find out whether differences between these four groups are evident and to what extent the explicit consideration of ERP integration provides additional insights.

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[605] See section C.II.3.

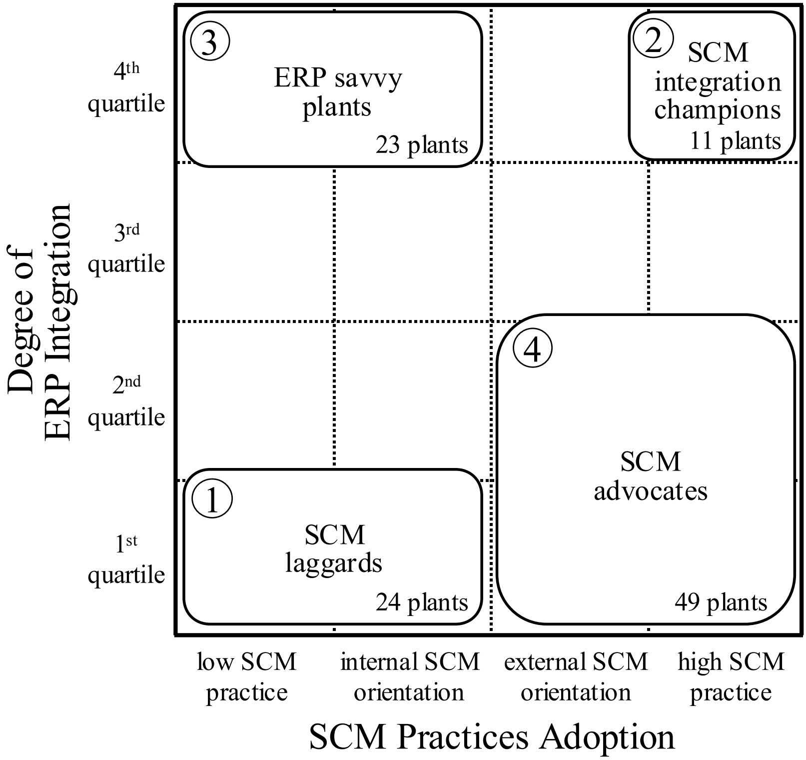


*Figure C-6: Portfolio classification according to SCM integration capabilities*

The hypothesis based on these four proposed groups is that SCM champions generally show a better performance than SCM laggards. Therefore, $H_4$ states as the following:

$H_4$: Those plants that show a high degree of SCM practice and a high degree of ERP integration (*SCM champions*) do not perform better than plants with a low degree of SCM practice and a low degree of ERP integration (*SCM laggards*).

Starting from the top of *Table C-30*, all subjective single-item performance measures show better values for SCM champions. However, the differences between the two groups are not statistically significant.[606] Two measures – flexibility in product change and volume and cycle time – are significant on a lower level, i.e. $p<0.1$. Nevertheless, the magnitude of the mean differences

[606] Statistical significance is accomplished with $p<0.05$.

provides an indication for a better performance of SCM champions. The greatest difference is observed in flexibility. High levels of SCM and internal integration of software support seem to enable plants to react more quickly to market demands and variations in terms of product changes and volume adjustments. Furthermore, cycle time seems to benefit especially from this combination as this shows the second highest mean difference among this performance measure category. It is likely that cycle time benefits especially from better planning capabilities of SCM champions compared to SCM laggards. This enables plants to better schedule their production flows, the associated procurement process, and resource allocations. Better performance in inventory turnover and lower manufacturing costs can draw on the same characteristics.

Besides higher efficiency, innovativeness and product capability also seem to benefit. One could assume that especially cooperative skills lead to this sort of performance improvements instead of IT capabilities and that efficiency gains can be attributed especially to the combination of SCM practices and ERP integration. A closer look at mean differences between all groups reveals, however, that the differences between ERP savvy plants and SCM advocates are not very high with regard to innovativeness and product capability. In fact, ERP savvy plants even show a slightly better performance. In contrast, SCM advocates seem to benefit relatively more in efficiency performance measures compared to ERP savvy plants.

*Table C-30: Performance overview SCM integration groups*

| | | *SCM laggards (1)* | *SCM champions (2)* | *mean diff. 1/2* | *ERP savvy plants* | *SCM advocates* |
|---|---|---|---|---|---|---|
| Manufacturing costs | Mean | -0.024 | 0.413 | *0.437* | -0.127 | 0.074 |
| | StDev | 0.926 | 1.013 | | 1.110 | 1.054 |
| | Valid cases | 21 | 11 | | 21 | 43 |
| Conformance to product specifications | Mean | -0.043 | 0.207 | *0.250* | 0.142 | 0.143 |
| | StDev | 1.008 | 0.870 | | 0.920 | 1.121 |
| | Valid cases | 22 | 11 | | 21 | 43 |
| On-time delivery | Mean | -0.170 | -0.064 | *0.106* | -0.018 | 0.393 |
| | StDev | 1.308 | 0.876 | | 0.849 | 0.903 |
| | Valid cases | 22 | 11 | | 21 | 43 |
| Flexibility in product change and volume | Mean | -0.257 | 0.441 | *0.698(*)* | -0.303 | 0.098 |
| | StDev | 1.139 | 0.860 | | 0.879 | 1.133 |
| | Valid cases | 22 | 11 | | 20 | 42 |
| Inventory turn | Mean | -0.091 | 0.459 | *0.550* | -0.111 | 0.345 |
| | StDev | 0.984 | 0.960 | | 1.077 | 0.919 |
| | Valid cases | 22 | 11 | | 20 | 42 |
| Cycle time | Mean | -0.225 | 0.370 | *0.595(*)* | -0.021 | 0.135 |
| | StDev | 0.919 | 1.029 | | 1.061 | 1.127 |
| | Valid cases | 22 | 11 | | 21 | 42 |
| Product capability | Mean | -0.192 | 0.220 | *0.412* | -0.145 | 0.073 |
| | StDev | 1.051 | 0.698 | | 0.879 | 1.098 |
| | Valid cases | 22 | 11 | | 21 | 44 |
| Innovativeness | Mean | -0.243 | 0.259 | *0.502* | -0.014 | -0.093 |
| | StDev | 1.158 | 0.666 | | 0.961 | 1.031 |
| | Valid cases | 22 | 11 | | 21 | 40 |
| On-time delivery, in % | Mean | 92.66% | 96.17% | *3.51%* | 93.78% | 93.42% |
| | StDev | 8.77% | 3.14% | | 6.26% | 7.33% |
| | Valid cases | 16 | 10 | | 17 | 37 |
| Internal scrap and rework, in % | Mean | 2.21% | 4.86% | *2.65%(*)* | 6.26% | 5.84% |
| | StDev | 3.63% | 3.58% | | 7.25% | 6.42% |
| | Valid cases | 17 | 9 | | 20 | 35 |
| Returned defective products, in % | Mean | 2.81% | 1.37% | *-1.44%* | 2.52% | 1.06% |
| | StDev | 3.95% | 3.07% | | 5.23% | 1.45% |
| | Valid cases | 16 | 10 | | 14 | 36 |
| Customer satisfaction | Mean | -0.793 | 1.247 | *2.040**** | -0.346 | 0.363 |
| | StDev | 0.876 | 0.533 | | 0.783 | 0.818 |
| | Valid cases | 24 | 11 | | 23 | 49 |
| Distinctive competencies | Mean | -0.525 | 0.690 | *1.215**** | -0.494 | 0.107 |
| | StDev | 1.034 | 0.930 | | 0.995 | 1.095 |
| | Valid cases | 24 | 11 | | 23 | 49 |

Reviewing objective performance measures reveals that SCM champions show a higher percentage of on-time deliveries compared to all the other three groups. Apparently, only the combination of SCM practices and ERP integration actually improves on-time delivery, a quality which has been also considered as a subjectively assessed performance measure. Comparing the subjective assessment with the objective data reveals some inconsistencies. Whereas SCM advocates believe that they perform better than their competitors, this cannot be confirmed objectively. This might be due to difficulties in evaluating on-time delivery performance of competitors. Although this can also be said for all other seven performance measures of this category, on some measures it is much easier to obtain competitor information. For example, on product capability, innovativeness, flexibility, or cycle time, feedback and information through industry insiders are likely to be more precise than on on-time delievery performance. Consequently, plant managers tend to be better in assessing these than on-time delivery performance.

Internal scrap and rework is more than 50% lower for SCM laggards than for SCM champions. This may seem surprising; however, because SCM laggards are also characterized by a low level of internal coordination and collaboration, they might not only detect fewer mistakes throughout the process but also not record costs associated with detected in-process mistakes. SCM champions perform better in revealing internal scrap and rework and because of their higher commitment towards collaboration, they also record these properly.[607] SCM advocates and ERP savvy plants show an even higher level of internal scrap and rework. This indicates that both groups are also better in detecting and recording these measures but are less effective in using this information for reducing scrap and rework. For ERP savvy plants, it might be that information is gathered and recorded efficiently but not processed managerial to reduce scrap and rework. SCM advocates might be not equipped with the necessary IT support and integration to improve performance beyond levels that can be achieved through coordination and especially through external collaboration alone.

Effectiveness with regard to delivering quality products is best assessed by the percentage of returned defective products. These products have been considered internally as being flawless and in accordance to quality standards and customer expectations. The fact that products are returned as defective, however, not only shows that it has not been the case in the first place but also impacts customer perception negatively. SCM champions with 1.37% returned defective products show a 51.2% lower return rate than SCM laggards. Also, ERP capabilities alone do not positively influence this performance measure much. SCM advocates, however, report on average an even lower return rate of 1.06% than SCM champions. This leads to the assumption that a high degree of SCM practice

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607 This finding is in line with the previous analysis.

adoption affects delivered quality positively, an assumption which has been also found in the previous analysis of SCM practices by themselves.[608]

The last group of performance measures contains the subjective, multi-item, multi-informant measures customer satisfaction and distinctive competencies. SCM champions show a significantly higher level of customer satisfaction than SCM laggards, with a mean difference of 2.040, $t(33)=-7.072$, and $p<0.001$. From all previously conducted analyses, identifying SCM champions and laggards segregates integrative SCM practices most appropriately and explains different levels of customer satisfaction best. High levels of customer satisfaction as a reflection of an overall superior, customer oriented performance can only be achieved by plants that apply a high level of all SCM components, namely internal coordination and collaboration, external coordination and collaboration, and internal integration of e-business modules. Though it is not possible to test external integration based on the HPM database, it can be suspected that this last missing link only further strengthens the other elements. What also becomes evident is that SCM advocates are better suited to achieve higher levels of customer satisfaction than ERP savvy plants. This suggests that the best path of improvement for SCM laggards is to build managerial SCM capabilities first and then focus on integrating these.

Distinctive competencies support the findings regarding customer satisfaction. Not only does superior customer satisfaction performance benefit from integrative SCM but also does a combination of selected distinctive competencies. Therefore, integrative SCM shows the same effect on better competencies in the areas of supplier and customer relations, ERP, quality improvement, SCM, and JIT as on customer satisfaction, though to a lower degree.

Overall, it can be concluded that there is evidence that integrative SCM practices – reflected by SCM champions – indeed lead to higher performance. Its holistic, systemic impact is best reflected by the significantly higher performance levels of SCM champions regarding the scales customer satisfaction and distinctive competencies. Differences in the characteristics of ERP savvy plants and SCM advocates regarding returned defective products suggests a path of improvement that first leads to strengthening and building SCM practices and then to pursuing integration supported by IT capabilities in form of ERP integration. This way, companies are likely to achieve relatively quick performance improvements. The often referred to “worse-before-better” effect can be mitigated. This builds the foundation for sustaining motivation for further improvement efforts.

608 See section C.II.3.c.

# D. Analysis of the Supply Chain Management Framework

Up to this point, general important implications of SCM practices and e-business adoption have been derived through cluster analysis and mean comparisons. In order to analyze the SCM framework developed in section B.I.3.c. and its implications, more complex analyses are necessary. Structural equation modeling (SEM) is capable of doing this. In general, SEM allows estimating a hypotheses model in its entirety and therefore considers hypothesized relationships in its overall estimation.[609] In this analysis, the partial least squares (PLS) method has been chosen to conduct SEM for the SCM framework. Since this methodology is not as common as other causal modeling techniques, such as LISREL, first PLS is introduced and subsequently, the SCM framework is estimated using the PLS methodology and implications are drawn upon the results.

## I. Path Model Estimation Using Partial Least Squares (PLS)

Structural equation models (SEM) have been gaining popularity since the beginning of the 1970s.[610] They are characterized by evaluating relationships between latent, i.e. not directly measurable, variables.[611] These are conceptualized by indicators that reflect or influence them. The partial least square (PLS) method is a variance-based causal modeling approach, developed in the 1960s by Herman Wold.[612] In contrast to PLS, most other SEM are covariance-based, with LISREL (Linear Structural Relation) being the most prominent.[613] Both approaches are

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609 See Homburg, Christian and Lutz Hildebrandt: Die Kausalanalyse: Bestandsaufnahme, Entwicklungsrichtungen, Problemfelder, in: Hildebrandt, Lutz and Christian Homburg (Eds.): Die Kausalanalyse: Instrumente der empirischen betriebswirtschaftlichen Forschung, Stuttgart 1998, pp. 17-19.

610 See Homburg and Baumgartner: Beurteilung von Kausalmodellen - Bestandsaufnahme und Anwendungsempfehlungen, pp. 162-176.

611 Cf. Herrmann, Andreas, Frank Huber and Frank Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, forthcoming in: Zeitschrift für betriebswirtschafltiche Forschung, Vol. 58 (2006), No. 2, p. 35.

612 One of the first publications of the PLS method can be found in Wold, Herman: Path models with latent variables: The NIPALS approach, in: Blalock, Hubert M. (Ed.): Quantitative sociology: International perspectives on mathematical and statistical modeling, New York 1975.

613 See Fornell, Claes and Fred L. Bookstein: Two structural equation models: LISREL and PLS applied to consumer exit-voice theory, in: Journal of Marketing Research, Vol. 19 (1982), No. 4, November, pp. 440-452.

used to analyze similar models[614] and PLS and LISREL are considered to be complementary rather than competitive.[615] After the introduction of PLS, it will be compared to LISREL in order to point out important differences and the conditions under which the application of each is more suitable. Finally, the methodological application and interpretation of PLS, including procedures how to validate models, will be illustrated.

### *1. Partial Least Squares as a Causal Modeling Technique*

PLS is a so-called "second generation" modeling technique[616] that covers and extends traditional, "first generation", analysis techniques such as canonical correlation, redundancy analysis, multiple regression, multivariate analysis of variance, and factor analysis in order to formulate and estimate more complex path models.[617] One of the main problems under which those traditional, first generation multivariate analysis methods[618] suffer compared to second generation techniques is that "the measurement model, analogous to factor analysis, is tested independently of the structural model, created by regression. Thus, a maximally efficient fit between the data and a structural model is not likely to occur."[619] This deficit is addressed by SEMs such as LISREL and PLS as they combine the elements of path and factor analysis in one comprehensive model.[620]

The variance-based PLS is the preferred method if researchers are interested in a good explanation of changes or in the prediction of objective variables, as it is able to give explanations of variances. Furthermore, it is more suitable than other

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614 Cf. Fornell and Bookstein: Two structural equation models: LISREL and PLS applied to consumer exit-voice theory, pp. 449 et sqq.

615 See Wold, Herman: Soft modeling: The basic design and some extensions, in: Jöreskog, Karl G. and Herman Wold (Eds.): Systems under indirect observation, Part II, Amsterdam 1982, pp. 1-54.

616 For example, cf. Chin, Wynne W.: The partial least squares approach to structural equation modeling, in: Marcoulides, G. A. (Ed.): Modern methods for business research, Mahwah 1998, p. 296.

617 Cf. Chin, Wynne W., Barbara L. Marcolin and Peter R. Newsted: A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion / adoption study, in: Information Systems Research, Vol. 14 (2003), No. 2, June, Appendix A, p. 5.

618 See Backhaus *et al.*: Multivariate Analysemethoden for a comprehensive coverage of multivariate analysis methods.

619 Amoroso, Donald L. and Paul H. Cheney: Testing a causal model of end-user application effectiveness, in: Journal of Management Information Systems, Vol. 8 (1991), No. 1, Summer, p. 77.

620 See Hildebrandt, Lutz: Kausalanalytische Validierung in der Marketingforschung, in: Hildebrandt, Lutz and Christian Homburg (Eds.): Die Kausalanalyse, Stuttgart 1998, p. 87 and p. 95.

techniques in the theory-generation process because the inclusion of indicators with uncertain validity is less problematic with regard to the overall model estimation.[621]

PLS consists of indicator variables and latent variables, with latent variables being constructs of these indicators. The relationships between the indicator variables and the latent variables are specified by the measurement (outer) model, whereas the relationships between latent variables are specified by the structural (inner) model. Both models are estimated together.[622] *Figure D-1* provides a schematic overview of a PLS measurement model.

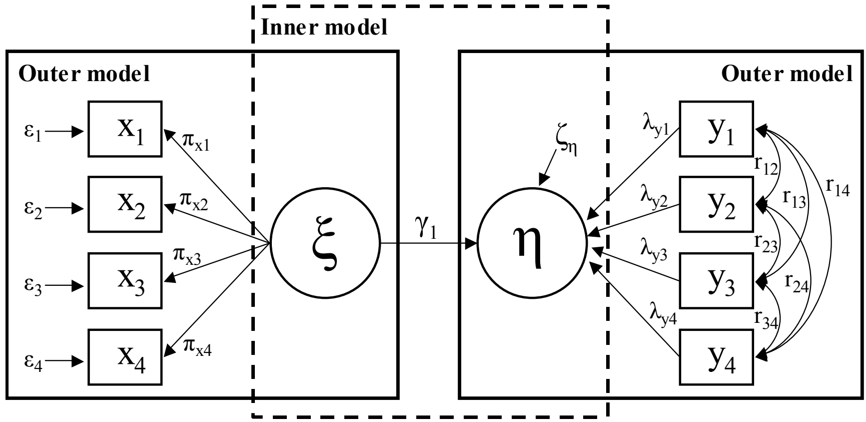


*Figure D-1: Schematic PLS model.*[623]

There exist two different kinds of indicators: reflective indicators and formative indicators.[624]

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621 Cf. Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, p.45. For more details on model selection, see section D.I.2.

622 Barclay et al. provide a thorough overview of PLS, see Barclay, D.W., C. Higgins and R. Thompson: The partial least squares (PLS) approach to causal modeling: Personal computer adaptation and use as an illustration, in: Technology Studies, Vol. 2 (1995), No. 2, pp. 285-309; see also Hulland, John: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, in: Strategic Management Journal, Vol. 20 (1999), No. 2, p. 196.

623 The schematic figure is adopted from Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, pp. 36-37; as usual for structural equation models, Greek symbols are used according to the LISREL model, cf. Backhaus *et al.*: Multivariate Analysemethoden, pp. 348 et sqqq.

Reflective indicators, or effect indicators, are reflections of the extent a latent variable is characterized, but they do not directly influence them.[625] Therefore, they could be exchanged without a loss of validity if a better way is indicated to reflect a latent variable. As an example, in order to find out the health status of a person, a set of questions can indicate this. Although, there is an almost infinitely large number of questions that can determine a health status, only few are necessary to derive a reliable answer. To illustrate reflective indicators in a PLS model, arrows point from the latent variable to the indicators, as shown in *Figure D-1* for indicators $x_1 - x_4$ and the latent variable $\xi$. Reflective indicators can be tested by means of factor analysis. In the PLS model, weights $\pi_{x1} - \pi_{x4}$ are assigned to the loadings. These weights are the results of the overall model estimation.

In contrast to reflective indicators, formative indicators determine a latent variable directly. Formative indicators, also called cause indicators, are often neglected.[626] Changing a formative indicator also changes the actual construct value. Therefore, they cannot be excluded without a strong theoretical justification. As an example, in order to determine a health factor for a specific task, a certain number of health indicators return a health factor. These indicators are carefully chosen as they specifically determine health suitability for this task. Such a case could be determining the specific health suitability for astronauts. Consequently, removing an indicator alters the construct substantially. Such an indicator, previously identified as important, would be missing and the overall result would not be valid anymore. Generally, a formative indicator cannot be removed, only exchanged if another indicator measures the same underlying fact.

With formative indicators, index variables or composite measures can be built. One example where formative indicators were chosen intentionally is provided by Homburg, Workman, and Krohmer, who formed a market complexity measure for their analysis.[627] More examples are provided by Diamantopoulos and Winklhofer.[628] Although formative indicators can be correlated positively,

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[624] Unless stated otherwise, the following explanations of reflective and formative indicators and selection criteria are mainly based on: Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, pp. 46-49.

[625] Cf. Bollen, Kenneth A.: Structural equations with latent variables, New York et al. 1989, p. 65.

[626] Bollen: Structural equations with latent variables, p. 65.

[627] See Homburg, Christian, John P. Workman and Harley Krohmer: Marketing's influence within the firm, in: Journal of Marketing, Vol. 63 (1999), No. 4, April, pp. 1-17.

[628] Cf. Diamantopoulos, Adamantios and Heidi M. Winklhofer: Index construction with formative indicators: An alternative to scale development, in: Journal of Marketing Research, Vol. 38 (2001), No. 2, p. 270. This publication provides also a thorough analysis on selection and analysis of formative indicators.

negatively, or be neutral to each other, generally they should not be correlated on a significant level. In cases where indicators are significantly correlated, it is possible that the indicators contain redundant information.[629] Such redundancy is not a problem for reflective measures. They are always required to be positively correlated. The correlation between formative indicators is displayed in the schematic PLS model in *Figure D-1* through the *r* symbol and the respective indicator numbers as subscript. To illustrate formative indicators in a PLS model, arrows point from the indicators to the latent variable, as can be seen in *Figure D-1* for the indicators $y_1 - y_4$ and the latent variable $\eta$; $\lambda_{y1} - \lambda_{y4}$ represent the weights assigned to the indicators after model estimation. The variable *r* shows the correlation between each indicator of a formative measure.

One of the strengths of the PLS approach is that it is capable of not only including reflective indicators, but also formative indicators. With respect to reflective indicators, the selection of appropriate indicators that *reflect* the corresponding latent variables is subject to debate among researchers. Whereas some researchers suggest using quantitative methods in order to identify relevant indicators, while others argue that only theoretical and logical considerations and justifications should be the basis for the proper indicator selection.[630] Furthermore, the decision between the formative and the reflective nature of the indicators should follow the causal reasoning between indicators and construct. Though statistical methods may assist in identifying relevant indicators, the substantive knowledge and theoretical justification should be the major concern.[631]

At this point, a reminder about the nature of causal modeling seems to be appropriate. Despite the fact that the term "causal" implies that causal models are able to identify causal relationships, this is not entirely true. Such causal relationships are believed to be only testable in experimental settings.[632] According to Sterman, other methods to determine reliable causality are randomized, double-blind trials; large samples; long-term follow-up studies; replication; and statistical interference. Sterman also remarked that the application of such reliable methods in social and human sciences is difficult, rare, and in fact often impossible.[633] Statistical correlation as means to deduce causality, however, has to be preceded by a combination of strong theoretical foundation, logical

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[629] Cf. Diamantopoulos and Winklhofer: Index construction with formative indicators: An alternative to scale development, p. 272.

[630] See Rossiter, John: The C-OAR-SE procedure for scale development in marketing, in: International Journal of Research in Marketing, Vol. 19 (2002), pp. 318 et sqq.

[631] Cf. Chin, Wynne W. and Peter A. Todd: On the use, usefulness, and ease of use of structural equation modeling in MIS research: A note of caution, in: MIS Quarterly, Vol. 19 (1995), June, pp. 239-240.

[632] Cf. Homburg and Hildebrandt: Die Kausalanalyse: Bestandsaufnahme, Entwicklungsrichtungen, Problemfelder, p. 17.

[633] Cf. Sterman, John D.: Business Dynamics, Boston 2000, p. 142.

considerations and common sense. Moreover, it can only reject or support causality, but never by itself ultimately confirm it.[634]

These pre-considerations are necessary in order to formulate appropriate hypotheses for causal relationships. Also, as mentioned before, experimental tests can be included in these pre-considerations. Then, correlation analysis or SEMs can test the formulated hypotheses in order to support, not confirm, or to reject them.[635] This directly leads to the scientific requirement to formulate hypotheses as null-hypotheses, i.e. as negative or inverse hypotheses. Since hypotheses can only be rejected, positively formulated hypotheses could never be confirmed. However, formulated as null-hypotheses, they can be rejected. In a strict scientific manner, therefore, using null-hypotheses is the most accurate method. Ideally, these formulations are precise enough so that rather clear implications can be derived.[636] Obviously, the more restrictive hypotheses are formulated the harder it will be to reject them.[637]

This said, it has to be noted that it is still common practice in the scientific community to use positively formulated hypotheses that are then, in a strict scientific manner, falsely confirmed. This could be attributed to linguistic style. As long as one is aware of the restrictions described above, this does not have be of too much concern.[638]

The general concern of using causal terminology is a rather old one. Blalock has remarked in 1968 that sociologists tried to avoid causal terminology by using

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634 There might exist other, not observed dominant factors influencing the correlated measures that in fact define the observed correlation, cf. Bortz: Statistik für Sozialwissenschaftler, p. 217 and p. 239.

635 Cf. Bortz: Statistik für Sozialwissenschaftler, p. 217.

636 See Chmielewicz, Klaus: Forschungskonzeptionen der Wirtschaftswissenschaft, 3rd ed., Stuttgart 1994, pp. 100-105 for a more detailed discussion on the necessity to differentiate between verification and falsification.

637 Vaguely formulated hypotheses allow for more distinct research constellations. Therefore, it is then generally easier to find exceptional constellations that allow to reject a hypothesis.

638 For several examples of this practice, see the following publications: Bharadwaj, Anandhi S.: A resource-based perspective on information technology capability and firm performance: An empirical investigation, in: MIS Quarterly, Vol. 24 (2000), No. 1, p. 176; Sanders and Premus: Modeling the relationship between firm IT capability, collaboration, and performance, pp. 4-5; Wisner, Joel D.: A structural equation model for supply chain management strategies and firm performance, in: Journal of Business Logistics, Vol. 24 (2003), No. 1, pp. 6-7; Sanders and Premus: Modeling the relationship between firm IT capability, collaboration, and performance, pp. 4-5; Duffy, Richard and Andrew Fearne: The impact of supply chain partnerships on supplier performance, in: The International Journal of Logistics Management, Vol. 15 (2004), No. 1, p. 61.

the terms structures and functions instead. However, this did not fundamentally solve the problem as it merely gave it another name.[639] Nevertheless, this controversy seems to be ongoing. In order to avoid unnecessary complications, it seems appropriate to follow Homburg and Hildebrandt's suggestion to continue using causal terminology, keeping these necessary remarks in mind.[640]

Returning to the PLS methodology, PLS assesses the relationships between constructs and their indicators, and among constructs with the aim to minimize error variance. In doing so, it "assesses the predictive relationships in the model and tests how well one part of the model predicts values in other parts."[641] The estimation of the PLS model is conducted in three stages:[642]

1. The first stage consists of an iterative estimation of weights and latent variable scores. Based on a random start matrix of outside approximation, first inner weights are estimated, followed by an inside approximation. Then, the outer weights are determined, followed by an outside approximation. This procedure continues until no further changes occur and therefore convergence is obtained.
2. In stage two, factor loadings and path coefficients are estimated using ordinary least square regression.
3. In stage three, the location parameters of the linear regression functions are estimated.

Wynne W. Chin and Peter R. Newsted summarize this procedure as follows:

> "The PLS procedure is then used to estimate the latent variables as an exact linear combination of its indicators with the goal of maximizing the explained variance for the indicators and latent variables. Following a series of ordinary least squares analyses, PLS optimally weights the indicators such that a resulting latent variable estimate can be obtained. The weights provide an exact linear combination of the indicators for forming the latent variable score which is not only maximally correlated with its own set of indicators

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639 Cf. Blalock, Hubert M.: Theory building and causal interferences, in: Blalock, Hubert M. and Ann B. Blalock (Eds.): Methodology in social research, New York St. Louis London 1968, p. 162.

640 Cf. Homburg and Hildebrandt: Die Kausalanalyse: Bestandsaufnahme, Entwicklungsrichtungen, Problemfelder, p. 17.

641 Ranganathan, C., Jasbir S. Dhaliwal and Thompson S.H. Teo: Assimilation and diffusion of web technologies in supply-chain management: An examination of key drivers and performance impacts, in: International Journal of Electronic Commerce, Vol. 9 (2004), No. 1, p. 145.

642 Based on Lohmöller, Jan-Bernd: Latent path modeling with partial least squares, Heidelberg 1989, pp. 30-31. The reader is referred to this source for a detailed description of the procedure.

(as in component analysis), but also correlated with other latent variables according to the structural (i.e. theoretical) model."[643]

An unfavorable characteristic of PLS is the fact that constructs, i.e. latent variables, incorporate the measurement error of its indicators. Therefore, construct values and model parameter estimates based on those are inconsistent.[644] Since construct values are closer to their indicators, these relationships are overestimated whereas relationships between constructs are underestimated. Nevertheless, these estimates are considered to be conservative. However, the prediction quality of PLS remains untouched as these two effects approximately level out. Furthermore, the order of effects and their relation to each other remain almost proportional.[645] In order to return fairly correct estimates, the number of indicators per latent variable should be large enough or the indicator loadings should display values greater than 0.8.[646] This is referred to as "consistency at large". Under these conditions and compared to other methods, large sample sizes are not required.[647]

### 2. *Comparison of Partial Least Squares with Linear Structural Relation (LISREL) Modeling*

The application of LISREL models is more common than the application of PLS ones. Ringle attributes this to the fact that no adequate software was available until PLS-Graph 3.0, developed by Wynne W. Chin, with an easy to use interface became available.[648] Another software application has also become available,

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643 Chin, Wynne W. and Peter R. Newsted: Strutural equation modeling analysis with small samples using partial least squares, in: Hoyle, Rick H. (Ed.): Strategies for small sample research, Thousand Oaks, CA 1999, p. 26.

644 For a more detailed treatment of this topic, see Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, pp. 40-41; Fornell, Claes and Jaesung Cha: Partial least squares, in: Bagozzi, Richard P. (Ed.): Advanced methods of marketing research, Cambridge, MA 1994, 66.

645 Cf. Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, p. 41.

646 Cf. Chin, Marcolin and Newsted: A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion / adoption study, Appendix D, p. 10.

647 Chin, Marcolin and Newsted: A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion / adoption study, Appendices A, D, pp. 6-10.

648 Cf. Ringle, Christian M.: Messung von Kausalmodellen, Industrielles Management Working Papers (No. 14) 2004, Hamburg, p. 28. Though there was a DOS-based program available, LVPSL, programmed by Jan-Bernd Lohmöller, it was relatively complicated to use. Unfortunately, no official service of PLS-Graph 3.0 is available, but

SmartPLS 2.0, which is fairly similar to PLS-Graph. Since it is a Java-based program, it is even easier to use and provides additional features, for example it can process larger models. Furthermore, it is freely available. SmartPLS is currently under development and new releases are frequently provided.[649]

As already pointed out, LISREL is a covariance-based method whereas PLS is a variance-based approach. LISREL is of confirmatory nature as it tests a model and produces goodness-of-fit measures that explain how well the observed data corresponds to the theoretical model; i.e. LISREL attempts to explain observed covariance. However, the requirements and assumptions towards the data are rather restrictive. For example, data have to be normally distributed and rather large sample sizes are required. In contrast, PLS does not perform as well on parameter estimation but in turn is able to explain variances, the extent to which latent variables relate to each other, and the extent to which indicators are able to describe a construct. Thus, PLS analysis puts emphasis on the estimation of the relation weights.[650] Additionally, PLS requires smaller sample sizes and has no demands in terms of data distribution. *Table D-1* compares PLS and covariance-based methods.[651] Researchers should be aware of the attributes of both covariance-based and variance-based methods before choosing one over the other.[652]

Fornell and Bookstein remarked that "[…] the choice between LISREL and PLS is neither arbitrary nor straightforward."[653] In fact, they were among the first that summarized the different characteristics of LISREL and PLS. In the study under consideration here and described in section D.III., PLS is the appropriate measurement method. Firstly, the degree of influence of the constructs on each other and on performance is of interest. Only then can the model provide decision making support for manufacturing companies as to where to set priorities in improvement initiatives. Secondly, the underlying theory has not been fully developed yet. Furthermore, though the survey design is theoretical and concept

at the time of this text, the following webpage provided information for interested Beta-users: http://disc-nt.cba.uh.edu/plsgraph/, retrieved on January 27, 2006.

649 Cf. Hansmann, Karl-Werner and Christian M. Ringle: SmartPLS Benutzerhandbuch, 2004, http://www.smartpls.de, retrieved on: February 15, 2006. SmartPLS is currently available in version 2.0 beta.

650 Cf. Haenlein, Michael and Andreas M. Kaplan: A beginner's guide to partial least squares analysis, in: Understanding Statistics, Vol. 3 (2004), No. 4, p. 291.

651 Cf. Chin and Newsted: Strutural equation modeling analysis with small samples using partial least squares .

652 See Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, p. 55.

653 Fornell and Bookstein: Two structural equation models: LISREL and PLS applied to consumer exit-voice theory, p. 450.

based, it was not designed for this specific analysis. Therefore, it is likely that there exists an inherent measurement error to some degree. Thirdly, though the sample size is relatively large, it is by some not considered large enough as the minimum sample size for a LISREL model.[654]

The issue of formative indicators is also of relevance in the SEM model under consideration. The HPM database does not provide for an appropriate reflective measure of integration. Therefore, the degree of ERP adoption has been chosen to give an indication of integration among the sample. The way to operationalize ERP adoption is to build a composite index that measures the degree of ERP adoption.[655] Another construct where it could be an issue would be the performance construct. In the model under consideration, however, the performance construct is of a more abstract nature that is assumed to explain identified performance indicators. In such a design, performance indicators are of reflective nature. This would be different if the performance indicators actually defined the performance construct. In this case, the performance construct would be a formative one.

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654 For a more detailed discussion on sample sizes, cf. Marsh, Herbert W., John Balla and Roderick P. McDonald: Goodness-of-fit indices in confirmatory factor analysis: Effects of sample size, in: Psychological Bulleting, Vol. 103 (1988), pp. 391-411.

655 See sections C.III.2 and D.II.

*Table D-1: Comparison of PLS and covariance-based SEMs (e.g., LISREL).*

| *Criterion* | *PLS* | *Covariance-based SEM (e.g., LISREL)* |
|---|---|---|
| Objective | Prediction oriented | Parameter oriented |
| Approach | Variance based | Covariance based |
| Assumptions | Predictor specification (non parametric) | Typically multivariate normal distribution and independent observations (parametric) |
| Parameter estimates | Consistent as indicators and sample size increase (i.e., consistency at large) | Consistent |
| Latent variable scores | Explicitly estimated | Indeterminate |
| Epistemic relationship[656] between a latent variable and its measures | Can be modeled in either formative or reflective mode | Typically only with reflective indicators (however, procedures to consider formative indicators exist)[657] |
| Implications | Optimal for prediction accuracy | Optimal for parameter accuracy |
| Model complexity | Large complexity (e.g., 100 constructs and 1000 indicators) | Small to moderate complexity (e.g., less than 100 indicators) |
| Sample size | Power analysis based on the portion of the model with the largest number of predictors. Minimal recommendations range from 30 to 100 cases | Ideally based on power analysis of specific model – minimal recommendations range from 100 to 800.[658] |

656 Epistemic relationships refer to the nature of the links between constructs and indicators, i.e., reflective or formative, cf. Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, p. 201.

657 See Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, pp. 55-57.

658 Cf. Homburg and Hildebrandt: Die Kausalanalyse: Bestandsaufnahme, Entwicklungsrichtungen, Problemfelder, p. 23 for the suggestion of 100 as the smallest sample size, others suggest 200.

### 3. *Methodological Application and Interpretation of the Partial Least Squares Method*

In PLS, parameter estimation is not conducted simultaneously. Therefore, no overall goodness-of-fit measures exist that assess the overall model fit, as it is the case for covariance-based methods. In order to evaluate the PLS outcome and its validity, several methods and procedures considering the different measurement models should be applied as follows.

Generally, PLS models are analyzed and interpreted in two consecutive steps.[659] First, the reliability and validity of the measurement model is assessed and then secondly, the structural model is assessed. By following this sequence, it can be assured that reliable and valid measures of constructs are used before the construct relationships are interpreted. Three methods for measurement model assessment are available:[660]

1. Individual item reliability examines the loadings of measures with their respective construct. Generally, loadings higher than 0.7 are indicated. However, often researchers find lower loadings. The ultimate threshold researchers suggest varies between 0.4 and 0.5.[661] The higher the measure loadings, the lower the required number of indicators to explain a construct.[662] In the case of formative indicators, the values correspond to simple correlations with the construct and no loadings can be established.
2. Convergent validity, also called composite reliability, measures the combined construct validity. A commonly used reliability measure is Cronbach's alpha, where a value of 0.7 is considered to be a good threshold for composite reliability.[663] PLS, though, uses a slightly different approach to determine composite reliability. Developed by Erts, Linn, and Jöresog, it does not

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[659] See Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, p. 198.

[660] See Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, pp. 198-200; Amoroso and Cheney: Testing a causal model of end-user application effectiveness, pp. 78-81.

[661] Cf. Gammelgaard, Britta and Paul D. Larson: Logistics skills and competencies for supply chain management, in: Journal of Business Logistics, Vol. 22 (2001), No. 2, p. 35; and Hair, Joseph F., Rolph E. Anderson and Ronald L. Tatham: Multivariate data analysis, 2nd ed., New York 1987, p. 249.

[662] Cf. Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, pp. 198-199.

[663] See Nunnally, Jum C.: Psychometric theory, 2nd ed., New York 1978, p. 245; and Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, p. 199. See also Cronbach, Lee J.: Coefficient alpha and the internal structure of tests, in: Psychometrika, Vol. 16 (1951), pp. 297-334.

assume equally weighted indicators.[664] Values of >0.8 are considered to show a good composite reliability.

3. Discriminant validity measures how indicators of one construct differ from the indicators of other constructs in the same model, i.e. discriminate other constructs. One criterion for discriminant validity is that the square root of average variance explained by a construct should be greater than the correlations among other constructs.[665] The same can be achieved by comparing the average variance explained with the square of correlations between latent variables.[666]

The reliability and validity measures described above are only meaningful for reflective indicators and not for formative indicators which do not have to be correlated among each other. Instead, solid theory should be employed when building a construct with formative indicators.

After the measurement model is assessed, the structural model can be interpreted. As pointed out above, no proper overall goodness-of-fit measures exist for PLS models because of a lack of simultaneous parameter estimation.[667] As it is the objective of PLS to explain variances, it is important to report $R^2$ values. The higher the reported $R^2$ values, the better the model's variance explanation and therefore its predictive power. Researchers suggest different values for $R^2$ for a "good" variance explanation. According to Chin, a value of 0.67 is considered to be substantial, 0.33 average, and 0.19 weak.[668]

The change in $R^2$ is used to assess the impact of a specific latent variable on other latent variables and the effect size is measured by $f^2$:

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664 Cf. Chin: The partial least squares approach to structural equation modeling, p. 320. See also Werts, Charles E., Robert L. Linn and Karl G. Jöreskog: Interclass reliability estimates: Testing structural assumptions, in: Educational and Psychological Measurement, Vol. 34 (1974), pp. 25-33.

665 Cf. Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, pp. 199-200; and Chin: The partial least squares approach to structural equation modeling, p. 321.

666 Cf. Fornell, Claes and David F. Larcker: Evaluating structural equation models with unobservable variables and measurement error, in: Journal of Marketing Research, Vol. 18 (1981), No. 1, pp. 39-50; Chin: The partial least squares approach to structural equation modeling , p. 321; and Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, p. 199

667 Cf. Herrmann, Huber and Kressmann: Partial least squares - Ein Leitfaden zur Spezifikation, Schätzung und Beurteilung varianzbasierter Strukturgleichungsmodelle, p. 58.

668 Cf. Chin and Newsted: Strutural equation modeling analysis with small samples using partial least squares, p. 316.

$$[18]: f^2 = \frac{R^2_{included} - R^2_{excluded}}{1 - R^2_{included}}$$

By comparing $R^2$ before and after exclusion of a latent variable, the effect can be assessed. Values of 0.02, 0.15, and 0.35 for $f^2$ are considered to imply a small, medium, or large effect at the structural level.[669]

The model can be interpreted based on the estimated path coefficients, which indicate the direction of a relationship, i.e. negative, positive, or neutral. T-statistics show the significance of these path coefficients. Lohmöller considers a minimum path coefficient of 0.1, whereas Chin states significant path coefficient values only above 0.2.[670]

PLS does not automatically report significance. Therefore, bootstrapping or jackknifing procedures are used to determine the significance of the stated means of path coefficients and weights. Comparing the two methods, bootstrapping should be preferred because jackknifing can be considered to be an approximation of the bootstrap procedure.[671] Bootstrapping means that the model is estimated a certain number of times (a standard iteration number is 100) with changing fractions of the sample. Then, the resulting means of this procedure are compared with the model results and tested for significance.

If a reflective model is analyzed, the predictive power can also be evaluated with the $Q^2$ Stone-Geisser test, which essentially examines how well the model performs compared to performance by chance by using blindfolding procedures. The larger the $Q^2$ value, the better the models' predictive power. Values below zero indicate that the trivial prediction is better than the model equation prediction and so results might be misleading. When noise predictors are removed from the model, this might lead to an increase in $Q^2$ values as well as significance, in contrast to $R^2$, which always decreases with such a deletion.[672] It is differentiated between a cross-validated communality $Q^2$ and a cross-validated redundancy $Q^2$. The latter is suggested if the predictive relevance of a theoretical, causal model is examined or if prediction is made by those latent variables that predict a dependent variable under consideration.[673]

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669 Cf. Chin: The partial least squares approach to structural equation modeling , pp. 316-317.

670 Cf. Lohmöller: Latent path modeling with partial least squares, p. 60; and Chin: The partial least squares approach to structural equation modeling, p. 324.

671 Cf. Chin: The partial least squares approach to structural equation modeling, p. 320.

672 Cf. Sellin, Norbert: Partial least squares modeling in research on educational achievement, in: Bos, Wilfried and Rainer H. Lehmann (Eds.): Reflections on educational achievement, Münster New York München Berlin 1995, pp. 262-263.

673 Cf. Chin: The partial least squares approach to structural equation modeling, pp. 317-318.

A procedure equivalent to that of the $f^2$ values to determine the impact of a specific latent variable on $R^2$ exists also for $Q^2$. In order to determine the influence of a latent variable on the predictive power of the model, $q^2$ can be calculated in a similar way as $f^2$. $Q^2$ is determined excluding the latent variable under consideration and compared to before $Q^2$ exclusion, as shown in *Equation [19]*.[674]

$$[19]:\ q^2 = \frac{Q^2_{included} - Q^2_{excluded}}{1 - Q^2_{included}}$$

In contrast to $f^2$, $q^2$ can also be negative values and in that case exclusion of a latent variable can increase the predictive power of a model and therefore the value for $Q^2$. In this circumstance, such a latent variable would be considered to add noise to the model.[675]

Using the procedures described above, it is possible to verify the validity and meaning of PLS models fairly well. The PLS methodology can now be used in order to verify the SCM framework developed in this text.

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674 Cf. Chin: The partial least squares approach to structural equation modeling, pp. 317-318.

675 Cf. Chin: The partial least squares approach to structural equation modeling, p. 318.

## II. Supply Chain Management, E-Business Factors, and Performance for the PLS Analysis

In order to derive a SEM to test the previously developed SCM framework, the existing HPM database is used. As described before, the HPM project collects a wide variety of data from each manufacturing plant. The scales have been developed based on experiences of earlier data collections. However, they have not been specifically designed for this framework. Therefore, compromises have to be made in order to match available items and scales of the database with the hypothesized model.[676] Nevertheless, the scale identification is strictly theory driven.

The major building blocks for the path model have been conceptualized before as internal coordination, external coordination, internal collaboration, external collaboration, and ERP integration.

Coordination and collaboration have been split into internal and external components, as introduced in section C.II.3. Separating internal and external coordination and collaboration is important because they represent distinct, but nevertheless interdependent characteristics and their relationship towards each other is of interest. Theoretically, one would assume that internal coordination and collaboration are the basis for their external counterparts. Therefore, the assumed causal relationship leads to arrows pointing from internal elements to external elements. However, a study conducted by Stank, Keller, and Daugherty found that external collaboration has no direct impact on performance but only an indirect one through the element internal collaboration, which plays an intermediary role in their analysis.[677] Other studies confirm this finding and this will be tested in this analysis as well.[678]

On the normative SCM framework level, customer orientation has been identified as one of five meta-policies for SCM.[679] This is accounted for in the model through four items that measure the degree to which customers are

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[676] See Narasimhan, Ram and Jayanth Jayaram: Causal linkages in supply chain management: An exploratory study of North American manufacturing firms, in: Decision Sciences, Vol. 29 (1998), No. 3, pp. 588-589, and section D.III.3. for a discussion of these issues with regard to the analysis at hand.

[677] See Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, pp. 38-39.

[678] Cf. Sanders and Premus: Modeling the relationship between firm IT capability, collaboration, and performance, pp. 14-15. Subrami implies that external communication is constrained by internal communication processes, cf. Subramani: How do suppliers benefit from information technology use in supply chain relationships?, p. 52.

[679] For a review, see section B.I.3.c and *Appendix 1*.

considered in the decision making process. Three items show factor loadings greater than 0.7 and one item has a factor loading of 0.69. Cronbach's alpha is 0.779 for this scale, with 61.33% explained variance.

Trust has been identified as the key SCM antecedent out of the ones listed in the SCM framework.[680] As trust is mainly of significance for partnerships, it is assumed to have a positive impact on external coordination. Its relationship with external collaboration could be seen in two ways. One is that trust is an important prerequisite for external collaboration[681] while on the other hand, as trust is considered to build over time, external collaboration could be well a major determinant for building trust in relationships.[682] This latter view is taken in the initial model.

Trust is measured by four items and all only refer to trust towards a plant's suppliers. Trust towards suppliers is more relevant because generally customers are in a more powerful position and therefore tend to be accountable for the characteristics of the relationship. If a company decides to have a trust-based relationship with its suppliers, this reflects its attitude in this regard well. Therefore, it is not seen as a problem that trust in customer relationships has not been explicitly asked for separately. In the hypothesized model, a direct connection between trust and customer satisfaction is established to examine its possible impact. It is, however, rather unlikely to show a significant impact in itself without mediating factors. Three indicators of trust have factor loadings greater than 0.8 and one shows a factor loading of greater than 0.6. Cronbach's alpha is satisfactory with 0.771 and explained variance is 61.06%.

The factor ERP adoption is used as a rough approximation to determine the degree of integration in the sample. It does not, however, clearly indicate the degree to which a seamless information and material flow is accomplished. Nevertheless, plants with a higher degree of ERP integration of their software applications are considered to provide more support for seamless material and information flows than those with a low adoption rate. This wider importance and benefit of ERP integration in line with the purpose in the context of the analysis in this text has been also suggested by Bendoly and Schoenherr. They base their understanding of ERP integration on existing theories and confirm it through statistical analyses and also suggest testing the impact outside their framework. The SCM framework is well suitable for such an alternative environment.[683]

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680 Cf. *Appendix 1*.

681 See Spekman, Kamauff Jr. and Myhr: An empirical investigation into supply chain management: A perspective on partnerships, p. 66.

682 Cf. Rousseau *et al.*: Not so different after all: A cross-discipline view of trust, pp. 396-397.

683 Cf. Bendoly and Schoenherr: ERP system and implementation process benefits. Implications for B2B e-procurement, pp. 316-317.

Other studies operationalize the use of IT or IT competency by reflective, perceptual measures. For example, Sanders and Premus form a factor “firm IT capability” to operationalize IT competency in companies.[684] Since such measures are not available in the HPM questionnaire, a composite score is determined. As mentioned before, 19 application areas out of 31 have been chosen to represent those applications that are relevant for SCM. This measure is operationalized in a formative manner. As such, a composite score is established to determine the degree of ERP integration. Each application that has been integrated in an ERP system receives one point, so that a maximum of 19 points can be achieved. This score determines the degree of overall ERP integration. Being a formative measure, no reliability or validity measures can be calculated. Furthermore, the composite score is used in the PLS model as one variable. Therefore, no further analysis within the PLS model can be conducted but is also not necessary.

Based on these identified scales in the HPM database, a causal model is proposed as depicted in *Figure D-2*. Performance is used as dependent variable in the structural model. Customer satisfaction is selected as a performance measure. This reflects not only the required customer focus in SCM, but also gives a more encompassing picture of a manufacturing plant’s performance.

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[684] Cf. Sanders and Premus: Modeling the relationship between firm IT capability, collaboration, and performance, pp. 8-10; and also see Kearns, Grover S. and Albert L. Lederer: A resource-based view of strategic IT alignment: How knowledge sharing creates competitive advantage, in: Decision Sciences, Vol. 34 (2003), No. 1, pp. 8-11.

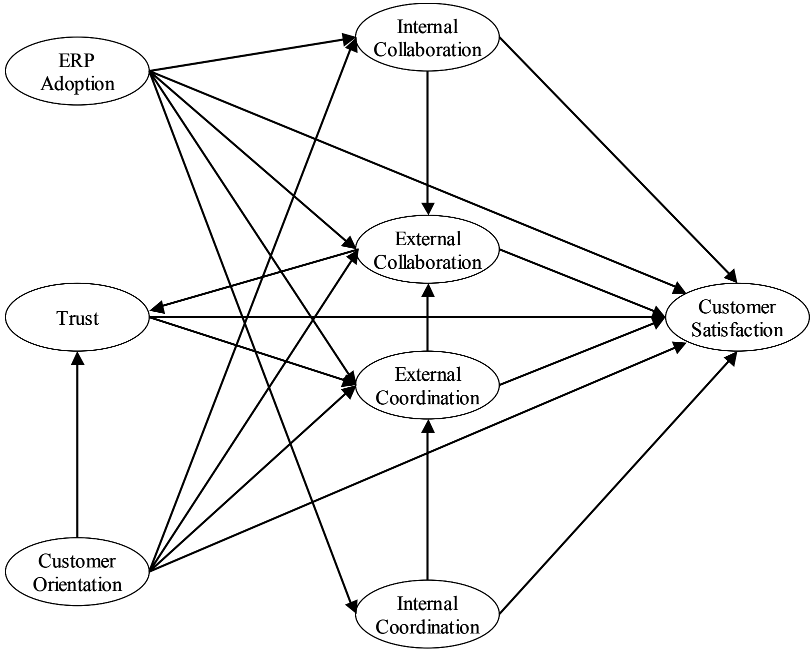


*Figure D-2: Hypothesized causal SCM model, based on available HPM scales*[685]

Many have pointed out the general positive link between customer satisfaction and economic success.[686] It is also a measure that reflects performance independently from industry and plant size. Additionally, it can be assumed that if customer satisfaction is high, overall supply chain performance is likely to satisfy customer expectations up to the point of the customer's customer. Obviously, if a customer's customer is not satisfied and this dissatisfaction can be traced back by the immediate customer to bad performance of the supply chain examined in this

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685 All latent variables but ERP integration are reflective measures. ERP integration is formative.

686 See Homburg, Christian and Matthias Bucerius: Kundenzufriedenheit als Managementherausforderung, in: Homburg, Christian (Ed.): Kundenzufriedenheit (5th ed.), Wiesbaden 2003, pp. 63-66; Homburg, Christian and Bettina Rudolph: Customer satisfaction in industrial markets: dimensional and multiple role issues, in: Journal of Business Research, Vol. 52 (2001), No. 1, pp. 15-33; Lee, Hau L. and Corey Billington: Managing supply chain inventory: Pitfalls and opportunities, in: Sloan Management Review, Vol. 33 (1992), Spring, pp. 66-67; and Dresner, Martin and Kefeng Xu: Customer service, customer satisfaction, and corporate performance in the service sector, in: Journal of Business Logistics, Vol. 16 (1995), No. 1, p. 37.

analysis, customer satisfaction will be lower compared to better performing supply chains. Consequently, it is better suited to reflect total supply chain performance than measures that reflect only selected performances.

Although the HPM questionnaire was not explicitly designed for testing the SCM framework, it has been possible to derive its key elements from the database and these, represented by the identified scales, show satisfactory validity and item and scale reliability. Therefore, they can be used for the causal model. *Table D-2* shows all scales and their characteristics.[687]

*Table D-2: Overview of reliability of reflective scales used in the causal model*

| *Scale* | *Cronbach's alpha* | *Variance explained* |
|---|---|---|
| Customer satisfaction | 0.863 | 65.84% |
| Internal coordination | 0.806 | 56.90% |
| External coordination | 0.810 | 57.17% |
| Internal collaboration | 0.893 | 70.18% |
| External collaboration | 0.784 | 56.01% |
| Customer orientation | 0.779 | 61.33% |
| Trust | 0.771 | 61.06% |

[687] Details are provided in *Appendix 3*.

## III. PLS Analysis of the Supply Chain Management Framework

### *1. Path Model Estimation of Supply Chain Management Framework*

After the identification of variables and the model structure, PLS is applied to estimate path relationships. First, the entire hypothesized causal model structure, as depicted in *Figure D-2*, is estimated. *Table D-3* shows all resulting path coefficients of the initial model. Based on this result, all insignificant links are removed and the model is estimated again. The result of this second estimation shows that all connections are significant at the $p<0.05$ level. The resulting model structure with the new path coefficients and $R^2$ are depicted in *Figure D-3*.

*Table D-3: Path coefficients of initial model estimation*

| to \ from | *External Collaboration* | *Internal Collaboration* | *Trust* | *External Coordination* | *Internal Coordination* | *Customer Orientation* | *ERP Application* |
|---|---|---|---|---|---|---|---|
| *Performance* | 0.120* | 0.312** | 0.011 | 0.017 | 0.159** | 0.252** | 0.155** |
| *External Collaboration* | | 0.296** | | 0.261** | | 0.366** | -0.102* |
| *Internal Collaboration* | | | | | | 0.456** | -0.070 |
| *Trust* | 0.458** | | | | | 0.178* | |
| *External Coordination* | | | 0.422** | | 0.372** | 0.166** | 0.017 |
| *Internal Coordination* | | | | | | 0.243** | -0.070 |

* *significant at p<0.10*
** *significant, p<0.005*

The first obviousness is the negative path coefficient between ERP adoption and external collaboration. This suggests that a high ERP adoption rate indicates lower external collaboration engagement. Such a result raises doubts about the assumed complementary nature of ERP adoption and external collaborative efforts. Nevertheless, the direct links from ERP adoption and external collaboration to customer satisfaction show a positive impact for both elements.

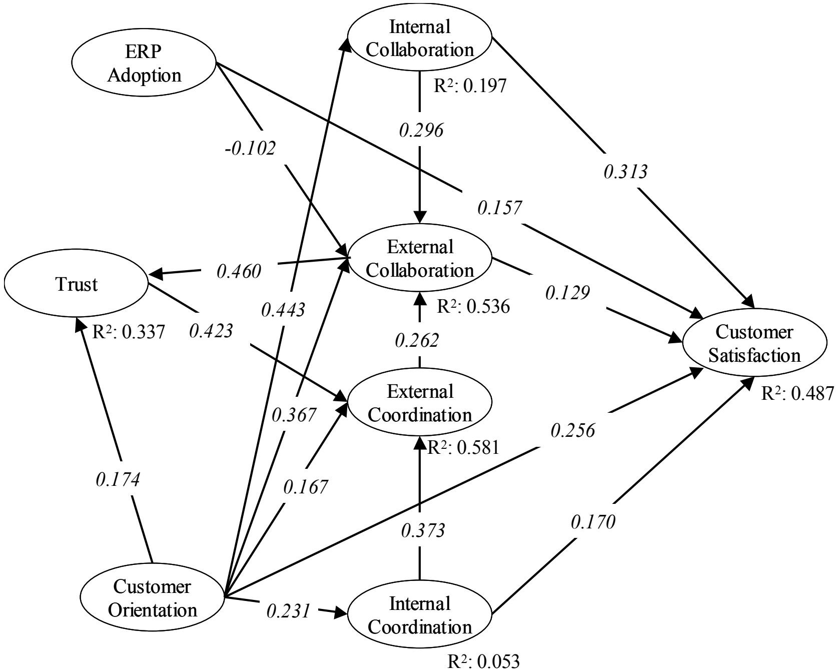


*Figure D-3: Initial model path coefficients after removing insignificant links*

Other obvious points are the low $R^2$ values for internal coordination and internal collaboration. Thus, following Stank, Keller, and Daugherty's as well as Sanders and Premus' findings, the links are reversed and the model is estimated again.[688] As a result, both $R^2$ values increase significantly while the reduction in $R^2$ in external coordination and external collaboration decrease by a smaller amount. Thus, the overall model fit increases. Furthermore, the path coefficients increase significantly. This is an important outcome as it supports the findings of other authors mentioned above who have identified this mediating function of internal collaboration for external collaboration as well. As a side effect, path coefficients from customer orientation decrease and the link between customer orientation and internal coordination becomes insignificant. *Figure D-4* shows the final model estimation with all significant path connections.

[688] Cf. Stank, Keller and Daugherty: Supply chain collaboration and logistical service performance, pp. 14-15 and Sanders and Premus: Modeling the relationship between firm IT capability, collaboration, and performance, pp. 38-19.

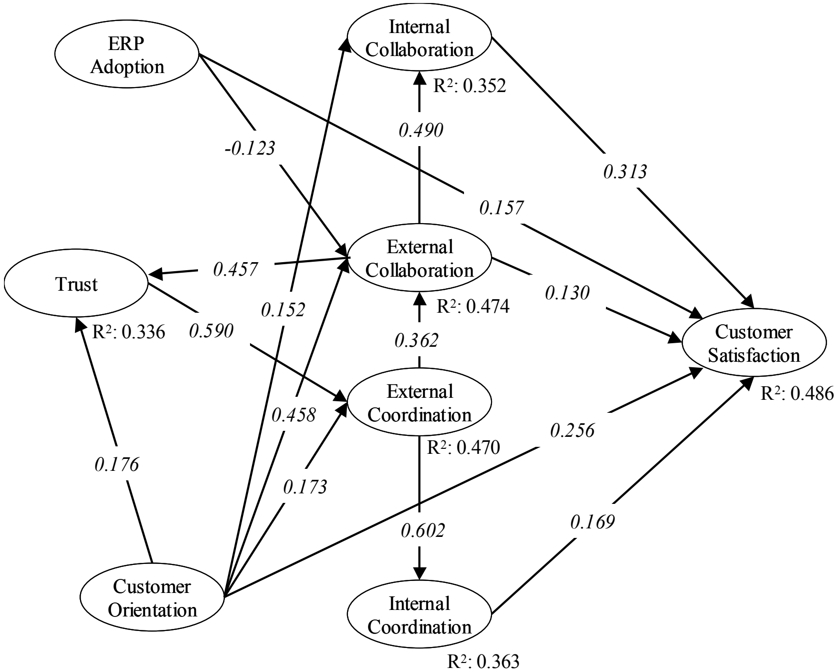


*Figure D-4: Final PLS model configuration with best model fit for SCM framework*

In another model run, not depicted here, it has been also tested what impact reversing the link from external collaboration to trust has on the model estimation. As assumed in the hypothesized model, the model estimation worsens with lower variance explained within the model structure. Thus, the hypothesized causality is supported and external collaboration seems to influence trust more positively than *vice versa*.

A first indicator for evaluating the complete structural PLS model is the $R^2$ value of the dependent latent variable as this reflects explained variance. The $R^2$ value obtained for the dependent latent variable in the PLS model for the SCM framework, i.e. performance in terms of customer satisfaction, is 0.486 or 48.6% variance explained by the model, as can be observed in the model overview in *Figure D-4*. Considering that the indicators and constructs have not been developed for this specific analysis, this is a very good value as for such studies, $R^2$ is frequently lower.[689]

689 Cf. Narasimhan and Jayaram: Causal linkages in supply chain management: An exploratory study of North American manufacturing firms, p. 597.

The precision of the PLS estimates can be measured through bootstrapping. As a result, *t*-statistics provide the necessary information about the significance levels of the construct linkages. Insignificant model paths have been already removed from the model in *Figure D-4*. *Table D-4* displays path coefficients and respective significance levels, as they are also shown in *Figure D-4*.

*Table D-4: Path coefficients of structural equation model*

| to \ from | *External Collaboration* | *Internal Collaboration* | *Trust* | *External Coordination* | *Internal Coordination* | *Customer Orientation* | *ERP Application* |
|---|---|---|---|---|---|---|---|
| *Performance* | 0.130* | 0.313** | | | 0.169** | 0.256** | 0.157** |
| *External Collaboration* | | | | 0.362** | | 0.458** | -0.123* |
| *Internal Collaboration* | 0.490** | | | | | 0.152* | |
| *Trust* | 0.457** | | | | | 0.176* | |
| *External Coordination* | | | 0.590** | | | 0.174* | |
| *Internal Coordination* | | | | 0.602** | | | |

* *significant, p<0.05 level*
** *significant, p<0.01 level*

Overall, the model shows not only a high $R^2$ value, but most of the postulated relationships are also supported through significant path coefficients. In the next section, the quality of the model estimation is examined and then, the findings are discussed.

## 2. *Quality, Validity, and Reliability of PLS Model Results*

Convergent validity is calculated slightly differently in PLS compared to the commonly used Cronbach's alpha, though they are closely related. The difference is that the PLS composite reliability measure considers item loadings obtained within the causal model. Generally, Cronbach's alpha is considered to be a conservative measure, representing the lower bound estimate of reliability.[690] *Table D-5* compares the composite reliability of PLS with the Cronbach's alphas of the constructs and also shows the average variance explained. All values fulfill

[690] Cf. Chin: The partial least squares approach to structural equation modeling , p. 320, Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, p. 199; and Fornell and Larcker: Evaluating structural equation models with unobservable variables and measurement error, pp. 39-50.

the requirements of composite reliability greater than 0.8, Cronbach's alpha greater than 0.7, and average variance explained greater than 0.5.

*Table D-5: Composite reliability, Cronbach's alpha, and average variance explained for reflective scales*

| *Construct* | *Composite Reliability* | *Cronbach's alpha* | *Average Variance explained* |
|---|---|---|---|
| Customer satisfaction | 0.905 | 0.863 | 0.657 |
| External collaboration | 0.862 | 0.784 | 0.561 |
| Internal collaboration | 0.921 | 0.893 | 0.701 |
| Trust | 0.860 | 0.771 | 0.610 |
| External coordination | 0.866 | 0.810 | 0.566 |
| Internal coordination | 0.866 | 0.806 | 0.564 |
| Customer orientation | 0.861 | 0.779 | 0.610 |

Discriminant validity assesses "[…] the extent to which measures of a given construct differ from measures of other constructs in the same model."[691] *Table D-6* shows the correlation matrix for the model. It can be observed that all squared correlation values are well below the average variance explained by each latent variable. The results therefore confirm discriminant validity of the constructs.

691 Hulland: Use of partial least squares (PLS) in strategic management research: A review of four recent studies, p. 199.

*Table D-6: Assessing discriminant validity*

| | *Performance* | *External Collaboration* | *Internal Collaboration* | *Trust* | *External Coordination* | *Internal Coordination* | *Customer Orientation* |
|---|---|---|---|---|---|---|---|
| *Performance* | **0.657*** | | | | | | |
| *External Collaboration* | 0.271** | **0.562** | | | | | |
| *Internal Collaboration* | 0.332 | 0.336 | **0.701** | | | | |
| *Trust* | 0.174 | 0.312 | 0.168 | **0.610** | | | |
| *External Coordination* | 0.207 | 0.304 | 0.221 | 0.446 | **0.566** | | |
| *Internal Coordination* | 0.162 | 0.121 | 0.184 | 0.204 | 0.362 | **0.566** | |
| *Customer Orientation* | 0.291 | 0.354 | 0.196 | 0.203 | 0.193 | 0.050 | **0.610** |

* Average Variance Explained (AVE) of constructs, bold numbers on diagonal
** Square of correlations between latent variables, numbers below diagonal

The predictive power of a model is assessed by Stone and Geisser's $Q^2$. Since the developed PLS model represents a theoretical, causal model, the cross-validated redundancy measure is chosen and a $Q^2$ value of 0.236 is obtained, thus implying that the model has predictive relevance.[692]

In order to evaluate the impact of a specific latent variable on the dependent variable(s) in the structural model, $f^2$ values are calculated. *Table D-7* shows the $f^2$ values for all latent variables.

692 Cf. Chin: The partial least squares approach to structural equation modeling, p. 318.

*Table D-7: $f^2$ values for dependent latent variables*

| | Performance | External Collaboration | Internal Collaboration | Trust | External Coordination | Internal Coordination |
|---|---|---|---|---|---|---|
| Initial R-Square | 0.486 | | | | | |
| External Collaboration | 0.012 | | 0.239 | 0.199 | | |
| Internal Collaboration | 0.101 | | | | | |
| Trust | 0.000 | | | | 0.504 | |
| External Coordination | 0.000 | 0.120 | | | | 0.570 |
| Internal Coordination | 0.041 | | | | | |
| Customer Orientation | 0.079 | 0.298 | 0.014 | 0.015 | 0.047 | |
| ERP adoption | 0.041 | 0.025 | | | | |

Though some latent variables in the model show little to no impact on the dependent variable performance, they do have an impact on other latent variables. Trust, for example, shows no $f^2$ value for performance, but a strong value for external coordination. Also, external coordination in itself shows no impact on overall $R^2$, but a rather high impact on internal coordination. Similarily, although external collaboration demonstrates a significant relationship with performance, it only displays a high $f^2$ value for internal collaboration, which in turn has a medium impact on overall $R^2$.

It is noticeable that no single latent variable has a substantial impact on the dependent variable performance, indicating that the model is relatively robust and well-balanced and that not a single construct dominates the others.

As the impact of each latent variable on explained variance can be examined by calculating the respective $f^2$ values, the same can be performed with regard to $Q^2$. *Table D-8* shows $q^2$ values for all independent latent variables.

*Table D-8: $q^2$ values for all independent latent variables*

| *Latent Variable* | *$q^2$ value* |
|---|---|
| Initial $Q^2$ | 0.236 |
| External Collaboration | 0.004 |
| Internal Collaboration | 0.072 |
| Trust | -0.001 |
| External Coordination | -0.001 |
| Internal Coordination | 0.027 |
| Customer Orientation | 0.045 |
| ERP Application | 0.025 |

It is evident from comparing *Table D-7* with *Table D-8* that both, $f^2$ and $q^2$ values show the same implications. Latent variables that show a low influence on explained variance in the ultimate dependent variable, i.e. performance, also have a low to even slightly negative impact on the predictive power of the model.

In conclusion, internal collaboration and internal coordination exhibit an impact on the overall model estimation, whereas external collaboration and external coordination have a low impact or no impact whatsoever. Based on path coefficients and $f^2$ values, however, external coordination and collaboration do have a significant impact on their internal counterparts and are therefore still of high importance. Furthermore, the model highlights the importance of customer orientation, the relationship between external collaboration and trust, and the direct impact of information system integration through ERP systems on performance.

## *3. Insights from and Limitations of the Empirical Investigation of the Supply Chain Management Framework*

After assessing the overall model, more detailed results can be interpreted. Several outputs of PLS build the foundation for this. Path coefficients give an indication of the extent of an effect between two latent variables. The higher the path coefficient, the stronger the observed effect. Furthermore, $f^2$ and $q^2$ values provide additional information about the impact of latent variables on each other and on the overall model estimation. This way, individual impacts can be better attributed to a construct. Before beginning with this analysis, the usage of an existing database for a newly developed framework is discussed because this renders some difficulties for the definiteness of the obtained results.

Several other studies have also used databases that were not specifically designed for their research settings. In the field of operations management, two studies can serve as an example. An analysis by Wathen that aims to examine the relationship between production process focus and financial performance is based on the Profit Impact on Marketing Strategies (PIMS) database, as are also several studies in other research fields.[693] A study conducted by Narasimhan and Jayaram focused on the relationship among sourcing decisions, manufacturing goals, customer responsiveness, and manufacturing performance using data from the Global Manufacturing Research Group (GMRG) questionnaire II. In this analysis, issues arising from the usage of available databases in research are addressed.[694]

In that context, Narasimhan and Jayaram identify four issues which are: (1) unit of analysis and the associated frame of inference, (2) measurement issues, (3) validity and generalizability issues, and (4) theory building via replication studies.[695] As a consequence, model results show lower values of explained variance and overall reliability and validity tends to be lower. In the following, the study at hand based on the HPM database is confronted with these issues in order to determine the impact of limitations that might arise from the usage of this specific database for testing the SCM framework.

The unit of analysis refers to problems that may arise when an existing database includes data from a wide variety of industries, from different company sizes, or from diverse products or markets. Consequently, it might be difficult to establish valid comparisons and analyses. In the case of the HPM project, data collection has been focused on three specific industries and the unit of analysis has been the manufacturing business unit or plant level. Furthermore, six different countries have been included so as to enable analyses of country-specific differences. As a result, the unit of analysis and the purpose of analyzing SCM matters match well.

Measurement issues arise if an available dataset does not provide specific constructs for the object of analysis thus limiting the proper operationalization of constructs. Therefore, available items have to be carefully screened and then selected based on support provided through literature or logical considerations.

693 See Wathen, Samuel: Manufacturing strategy in business units, in: International Journal of Operations & Production Management, Vol. 15 (1994), No. 8, p. 6.

694 See Narasimhan and Jayaram: Causal linkages in supply chain management: An exploratory study of North American manufacturing firms, p. 595.

695 For a more detailed description of these four issues, cf. Narasimhan and Jayaram: Causal linkages in supply chain management: An exploratory study of North American manufacturing firms, p. 594. The following discussion is based on suggestions raised by these authors, cf. Narasimhan and Jayaram: Causal linkages in supply chain management: An exploratory study of North American manufacturing firms, pp. 594-597.

After constructs have been identified and designed, factor and reliability analysis are used to evaluate the derived constructs. In the study at hand, this has been carefully considered. Nevertheless, more accurate results could be gathered if scales are developed for a specific research subject. The study conducted in this text is hindered by the lack of an adequate scale reflecting supply chain integration in the way it is intended in the context of the SCM core model, i.e. to measure to what degree a seamless material and information flow is accomplished.

In terms of validity and accuracy, caution is indicated if data originates from one single informant. It is suggested aiming for multi-informant responses in order to mitigate this effect. Fortunately, this has been considered in the HPM project and many items have been collected in the plants from more than one informant.

For the purpose of theory-building and theory-testing, as this is the aim of the present analysis, different model designs should arrive at the same conclusions so as to ensure convergence of findings. Convergence of findings is inherently different from replication of findings because for convergence, different items and scales are used. In contrast, replication uses an identical research design. Though the SCM framework is unique, it builds on previously identified elements and empirical findings. Furthermore, SEM supports previous findings within the new, unique model structure, consequently contributing to the theory-building process in SCM and operations management in general.

As a consequence of applying a theoretical model to an existing database, explained variance measured by $R^2$ is most likely lower compared to dedicated studies and therefore findings should be interpreted according to model specifications. However, this has not been experienced in the present study. $R^2$ shows a rather high value indicating that the above mentioned concerns play a less important role in this study. An explanation might be that the questionnaire design considered issues such as single informant bias and that the questionnaires do have a focus close to the subject under consideration. Nevertheless, the findings are still to be interpreted in the context of model specifications. Although the lack of an appropriate operationalization of SCM integration imposes a limitation of the analysis, it sufficiently reflects ERP system integration, which in turn builds the foundation for SCM integration systems. In light of this, reliability and validity of the model are very good and therefore, a strong empirical support of the hypothesized model of the SCM framework is clearly evident.

Comparing the first model estimation, depicted in *Figure D-3*, with the second, shown in *Figure D-4*, the interdependence between internal and external components becomes clear. As in previous studies, the model results suggest a causal relationship from external coordination and collaboration to their respective internal counterparts. The main positive performance impact emerges from the degree of internal collaboration and internal coordination. Both external components, however, are shown to have a medium to high impact on their internal counterparts.[696]

This suggests that internal practices benefit significantly from external coordination and collaboration activities with customers and suppliers. If a higher level of external coordination is implemented, it seems that internal coordination will improve as a consequence. The same can be concluded with respect to collaboration suggesting that it is beneficial for manufacturing plants to go ahead with external initiatives because the organization will likely adapt internally afterwards. Although there is strong support from external initiatives, not all variance can be explained by them. It is important to note that additional efforts to support internal coordination and collaboration are beneficial. Only if these two are improved can a positive effect on performance be achieved. Besides the positive effect of customer orientation on internal collaboration, no other such efforts could be identified in this model.

External coordination shows no direct significant impact on performance. The lack of the establishment of a direct connection between external coordination and performance is reasonable because coordination relies more heavily on internal communication than external collaboration relies on internal collaboration. Without internal coordination, no overall positive effect can be achieved because information communicated with external partners is pointless if it is not processed internally as well. External collaboration, in contrast, shows a significant direct effect on performance because it can also work to some degree without internal collaboration. Its effect, however, is much weaker than that of internal collaboration. In fact, internal collaboration shows the highest direct effect on customer satisfaction and explains the highest portion of total variance, with a $f^2$ value of 0.101. Consequently, plants have to get their internal practices right, especially internal collaboration practices as well as their external linkages. In conclusion, external coordination and external collaboration are necessary and of high importance but not sufficient to achieve superior performance.

In the model, the relationship between external collaboration, external coordination, and trust becomes clear. External collaboration has a significant and medium-sized effect on trust. This suggests that external collaboration contributes to trust-building in relationships and this is in line with others who also suggest such a positive impact on trust.[697] Spekman, Kamauff Jr., and Myhr state that collaboration requires a higher degree of trust than coordination, suggesting that

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[696] Effect size from weak to high are assumed from 0.1 on upwards, with 0.5 representing a medium-sized effect. These are conservative numbers in light of the usage of an existing database.

[697] See Rousseau *et al.*: Not so different after all: A cross-discipline view of trust, pp. 396-397.

collaboration is a consequence of trust.[698] In the model at hand, however, such a link between trust and external collaboration is mediated by external coordination.

External coordination is strongly influenced by trust whereby a higher level of trust enables more external coordination in relationships. Exchanging and sharing information, process visibility, and availability of supply chain information in general make information readily available although individual companies have little to no control over the usage of this information. Therefore, a higher level of trust is required and leads to a higher level of external coordination. External coordination shows to have a medium size effect on external collaboration. If the link between the two is reversed, this effect is not evident to this extent.

Thus, it can be concluded that engagement in external collaboration leads to higher levels of trust, which in turn leads to higher levels of coordination in the supply chain relationships examined. Such higher levels of coordinations then lead to higher levels of collaboration. This triangle constellation suggests a positive interdependence of these three latent variables. With a $f^2$ value of 0.199, external collaboration shows a medium to high effect on explained variance of trust. Customer orientation, as the second determinant of trust in the model, shows only a weak effect on trust. Trust, in turn, indicates a high effect on the explained variance of external coordination, with a $f^2$ value of 0.504. External coordination, then, shows a medium effect on explained variance of external collaboration. With a $f^2$ value of 0.120, this effect is the weakest within this triangle. Therefore, external collaboration can be considered as the starting point for the positive effects within this triangle.

The positive impact of ERP integration on customer satisfaction has already been uncovered in section C.III.3. In the context of the overall SCM framework, this direct effect is also supported. It is surprising, however, that a negative, though weak, effect exists between the level of ERP integration and external collaboration. One would assume that integration at least does not harm external collaboration. The previous identification of SCM champions returned eleven plants that display high ERP integration and high levels of SCM practice adoption. Considering all plants, however, a weak but significant negative impact of ERP integration on external collaboration capabilities exists. If SCM practices are not developed to a high extent, ERP integration might lead to an increasingly internal focus, thereby resulting in weaker external collaboration. ERP integration efforts should therefore be accompanied by initiatives that prevent this increasing internal focus so as to avoid its potential negative effect.

A customer oriented company culture mostly benefits the degree of external collaboration. The other two determinants of external collaboration, ERP integration and external coordination, explain less variance than customer

698 See Spekman, Kamauff Jr. and Myhr: An empirical investigation into supply chain management: A perspective on partnerships, p. 56 and p. 66.

orientation. This finding suggests that a high customer focus leads to higher levels of external collaboration.

The multiple interrelations of customer orientation with other elements of the framework underline the benefits of applying SEM and PLS. Insights such as the previously described interdependencies among the various latent variables lead to more differentiated implications. To a different extent, creating a customer oriented mindset affects other areas of the company. Regarding customer orientation practices, a weak to medium effect on customer satisfaction exists. Customer oriented plants are indeed better equipped to meet customer expectations. Nevertheless, internal collaboration has a stronger effect than customer orientation. Therefore, customer orientation alone seems to be insufficient and can be leveraged substantially by taking advantage of it for establishing or improving external collaboration as well as internal collaboration, external coordination, and trust.

# E. Theoretical and Practical Implications for Successful Supply Chain Management

The concept of SCM has been comprehensively discussed in this text. Based on an extensive literature review, a third generation SCM framework has been developed that is believed to provide a structure for future research and development of SCM. In doing so, the framework should contribute to organizing the art of holistic and systemic SCM and to building a new basis for further developments in the field.[699]

Often, the question is raised whether a concept remains or becomes just another fad that will fade out after the hype.[700] SCM has been identified as a framework that comprises a philosophy with concrete, practical implications for the competitiveness and efficiency of entire supply chains and its member companies. Consequently, the SCM framework developed in this text is proposed for providing the frame for further research on the different levels of SCM, i.e. the normative, strategic, and operational levels. It is also a consequent development of previous different management concept streams, such as quality management, process reengineering, and customer orientation. Indisputably, all these concepts have shown and still show an impact on competitiveness and efficiency of companies.

As with marketing, it has been suggested considering SCM as an organizational mindset that should be reflected throughout an organization and in conjunction with other management approaches.[701] The empirical analysis in this text shows clear indications of the operational and strategic impact SCM practices have on performance and competitiveness. This impact and the embracing scope of SCM indicate that SCM is not a fad but a comprehensive management framework with sustaining impact on organizational development.

One concern raised in the past has been that if taken too far, SCM might well be considered as synonymous to management.[702] Indeed, this is an important remark as it points out the need to define the scope of SCM appropriately thus preventing a loss of focus and precision. This has been considered in the third

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699 The SCM framework follows therefore the evolutionary path of scientific development outlined by Forrester, see Forrester: Industrial dynamics, p. 2.

700 See Chandra and Kumar: Supply chain management in theory and practice: A passing fad or a fundamental change?, pp. 100-113; and Schroeder and Flynn: High performance manufacturing: Just another fad?, pp. 3-17.

701 See Lambert, Cooper and Pagh: Supply chain management: Implementation issues and research opportunities, p. 2.

702 Cf. Delfmann and Albers: Supply chain management in the global context, p. 5.

generation SCM framework developed in this text. By identifying a core SCM model consisting of coordination, collaboration, and integration, linkages have been clarified and the interfaces and interdependencies have become clear.

In the context of the overall analysis, several relevant SCM issues become evident. Researchers should consider placing special emphasis on these which are:

- Defining the scope of individual supply chains.
- Considering interdependencies between different supply chains and the associated network complexity. Often, such interdependencies between different supply chains exist even within one organization.
- Enabling a swift and even flow along a supply chain to improve efficiency.[703]
- Determining and managing power regimes in supply chains.
- Identifying efficient performance frontiers in supply chains.

Within the discussion of SCM, several approaches have been proposed in this text to address these issues. The definition of scope of supply chains appears to be most appropriate along homogeneous product groups and according to the overall value creation process, as outlined in section B.III.2.c. Once identified, interdependencies and interferences between supply chains are easier to spot and consequently also considered. Closely related to this is the determination of power regimes in supply chains. Here, purely monetary considerations of value creation might fall short. This is especially important when it comes to determining the member(s) who predominately *drive(s)* the supply chain.[704] Consequently, more research into determinants of power and its implications for supply chains needs to be conducted and related to the management of supply chains. A formal procedure based on monetary considerations has been proposed in section B.IV.2.

The Theory of Swift, Even Flow is of high relevance for supply chain improvement and competitiveness. Integration as one element of the core SCM model together with process alignment initiatives and e-business capabilities have been identified in this text as crucial enablers of a more swift and even flow along supply chains.[705] According to the theory, such a swift and even flow yields a more efficient process. Being of technological nature, these enablers affect mainly the efficient asset performance frontier. Managerial practices in coordination and collaboration, in contrast, are likely to move the operating frontier even beyond

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[703] See Schmenner and Swink: On theory in operations management, pp. 102-103.

[704] Cf. Walker: Unbundling the corporation: A blueprint for supply chain networks, p. 108; and Mentzer *et al.*: Defining supply chain management, p. 14.

[705] For some general remarks about what is beneficial for a swift and even flow, see Schmenner and Swink: On theory in operations management, p. 104.

the asset frontier. In an ideal situation, both frontiers match and are therefore balanced. Organizations are well advised to improve their competitive position towards the efficient performance frontier by making use of available technologies and management practices. The identification of both the efficient asset and the efficient operating performance frontier is therefore subject to ongoing research by monitoring company and competitor performance capabilities.

Several aspects of SCM have been clarified in this text. In the context of the international research project High Performance Manufacturing, the link between the core elements of the SCM model and strategic performance is empirically supported. Important implications have been derived from the analysis by applying PLS as an SEM method. The validity of the basic structure of the third generation SCM framework is supported through the empirical data. This builds therefore a solid foundation for future empirical research. Not all elements could be conceptualized in the model, for example integration practices and a more detailed e-business support. Consequently, this should be a focus of future research.

In terms of integration, some conclusions can be derived. SCM champions have been identified, i.e. plants that show high SCM practice adoption and high ERP integration, and compared with SCM laggards, ERP savvy plants, and SCM practice advocates. In addition, differences with regard to several performance measures have been identified, and SCM champions show better performance in almost all performance measures compared to the other groups. Significance, however, could only be established for the measures customer satisfaction and distinctive competencies. Future empirical research should therefore make an effort to distinguish these groups more precisely and aim to establish significant proof of performance differences.

For practitioners, the model estimation results yield valuable insights. First and foremost, external practices in coordination and collaboration lead to higher internal coordination and collaboration. Organizations are therefore implored to go ahead with external supply chain initiatives because this seems to have a pull-effect on internal practices. It is important, however, to additionally foster the internal counterparts of coordination and collaboration and not only rely on this pull-effect. Ultimate performance impact can only be established through more intensive internal coordination and collaboration. External coordination and collaboration have shown to have no or only a weak direct effect on performance in the absence of their internal counterparts. Additionally, organizations should consider prioritizing collaborative initiatives over coordinative initiatives as the former proved to have a larger impact on performance. Furthermore, it has been shown that external collaboration has a significant impact on trust. Higher levels of trust lead to improved external coordination, followed by higher levels of internal coordination and ultimately better overall performance.

Another practical implication is the recognition of customer orientation as a foundation for better supply chain relationships and improved performance. Customer orientation directly influences overall performance positively and supports strongly external collaboration in supply chain relationships.

These findings support a positive overall impact of SCM. They, however, refer mainly to strategic relationships with suppliers and customers where a higher level of interdependency can be assumed. These findings should therefore be considered for such relationships and according to the appropriateness of relationships. Arm’s length relationships are likely to require different priorities. Future research should therefore also investigate SCM practices according to the power regimes of supply chain relationships. As most value of supply chains lies in strategic relationships, however, the findings derived here are of high relevance for supply chain competitiveness. In addition, they encourage organizations that hold a powerful supply chain position to engage in cooperative supply chain initiatives in the context of the SCM framework.

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# Appendices

## Appendix 1

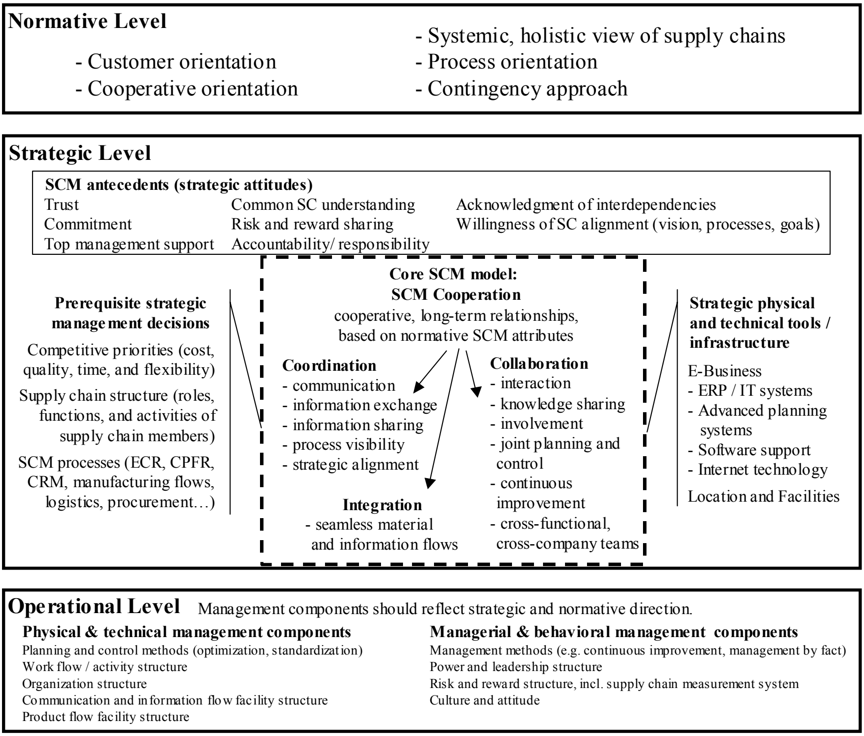


*Figure Appendix-1: Details of third generation SCM framework*

## Appendix 2

*Table Appendix-1: Overview of applications seen to be especially relevant for SCM*

| |
|---|
| Master production schedule |
| Material requirements planning |
| Capacity requirements planning |
| Finite capacity scheduling |
| Shop floor control |
| Inventory management |
| Purchasing |
| Demand planning |
| Order management |
| Distribution management |
| Product data management |
| Quality documentation management |
| Quality control and improvement |
| Performance measurement system |
| Workflow management |
| Business intelligence |
| Simulation and optimization of production and logistics planning |
| Groupware tools |
| Product configuration |

## Appendix 3

*Table Appendix-2: Scale "internal coordination"*

| | *Factor Loading* |
|---|---|
| Our corporation implements ordering and stock management policies, on a global scale, in order to coordinate distribution. | 0.795 |
| Our corporation performs aggregate planning for plants, according to our global distribution needs. | 0.765 |
| Managerial innovations are transferred among plants within our corporation. | 0.795 |
| Our corporation transfers technological innovations and know-how between plants. | 0.756 |
| Sales and manufacturing personnel communicate well with each other in this organization. | 0.651 |
| *Cronbach's alpha:*<br>*Variance explained:* | *0.806*<br>*56.90%* |

*Table Appendix-3: Scale "external coordination"*

| | *Factor Loading* |
|---|---|
| We actively plan supply chain activities. | 0.799 |
| We consider our customers' forecasts in our supply chain planning. | 0.644 |
| We strive to manage each of our supply chains as a whole. | 0.747 |
| We monitor the performance of members of our supply chains, in order to adjust supply chain plans. | 0.762 |
| We gather indicators of supply chain performance. | 0.871 |
| *Cronbach's alpha:*<br>*Variance explained:* | *0.810*<br>*57.17%* |

*Table Appendix-4: Scale "internal collaboration"*

| | *Factor Loading* |
|---|---|
| Our plant forms teams to solve problems. | 0.849 |
| In the past three years, many problems have been solved through small group sessions. | 0.878 |
| Problem solving teams have helped improve manufacturing processes at this plant. | 0.850 |
| Employee teams are encouraged to try to solve their own problems, as much as possible. | 0.753 |
| We don't use problem solving teams much, in this plant. (Reverse.) | 0.853 |
| *Cronbach's alpha:*<br>*Variance explained:* | *0.893*<br>*70.18%* |

*Table Appendix-5: Scale "external collaboration"*

| | *Factor Loading* |
|---|---|
| We work as a partner with our customers. | 0.460 |
| We maintain cooperative relationships with our suppliers. | 0.850 |
| We provide a fair return to our suppliers. | 0.625 |
| We help our suppliers to improve their quality. | 0.840 |
| We maintain close communications with suppliers about quality considerations and design changes. | 0.879 |
| *Cronbach's alpha:*<br>*Variance explained:* | *0.784*<br>*56.01%* |

*Table Appendix-6: Scale "customer orientation"*

| | *Factor Loading* |
|---|---|
| We frequently are in close contact with our customers. | 0.849 |
| Our customers give us feedback on our quality and delivery performance. | 0.863 |
| Our customers are actively involved in our product design process. | 0.689 |
| We strive to be highly responsive to our customers' needs. | 0.716 |
| *Cronbach's alpha:*<br>*Variance explained:* | *0.779*<br>*61.33%* |

*Table Appendix-7: Scale "trust"*

| | *Factor Loading* |
|---|---|
| We are comfortable sharing problems with our suppliers. | 0.843 |
| In dealing with our suppliers, we are willing to change assumptions, in order to find more effective solutions. | 0.613 |
| We believe that cooperating with our suppliers is beneficial. | 0.825 |
| We emphasize openness of communications in collaborating with our suppliers. | 0.823 |
| *Cronbach's alpha:*<br>*Variance explained:* | *0.771*<br>*61.06%* |

*Table Appendix-8: Scale "customer satisfaction"*

| | *Factor Loading* |
|---|---|
| Our customers are pleased with the products and services we provide them. | 0.881 |
| Our customers seem happy with our responsiveness to their problems. | 0.778 |
| Customer standards are always met by our plant. | 0.811 |
| Our customers have been well satisfied with the quality of our products, over the past three years. | 0.871 |
| In general, our plant's level of quality performance over the past three years has been low, relative to industry norms. (Reverse.) | 0.702 |
| *Cronbach's alpha:*<br>*Variance explained* | *0.863*<br>*65.84%* |

*Table Appendix-9: Scale "distinctive competencies"*

| | *Factor Loading* |
|---|---|
| Competitive position globally in supplier relation. | 0.805 |
| Competitive position globally in customer relation. | 0.694 |
| Competitive position globally in enterprise resource planning. | 0.689 |
| Competitive position globally in quality improvement program. | 0.814 |
| Competitive position globally in SCM. | 0.758 |
| Competitive position globally in JIT. | 0.680 |
| *Cronbach's alpha:*<br>*Variance explained* | *0.830*<br>*55.06%* |

# Short Curriculum Vitae Andreas Hammer

## University Education

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|---|---|
| 11/1996 – 09/1998 | Undergraduate studies in business administration at the University of Nürnberg-Erlangen. Degree: *Vordiplom* |
| 10/1998 – 03/2002 | Graduate studies in business administration at the University of Mannheim. Degree: *Diplom-Kaufmann* |
| 08/1999 – 08/2000 | Graduate studies at Creighton University, USA. Degree: *Master of Business Administration* |
| 09/2002 – 05/2006 | Postgraduate studies at the University of Mannheim, Department of Operations Management Prof. Dr. Milling. Degree: *Dr. rer. pol.* |

## Professional Assignments

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| 11/1995 – 07/1999 | Fa. Jörg Hammer GmbH, Pforzheim. *Project work*. |
| 10/2000 – 04/2002 | UDF Consulting AG, Stuttgart. *Junior Consultant*. |
| 05/2002 – 05/2006 | Andreas Hammer Consulting, Pforzheim. *Consultant*. |
| 09/2002 – 02/2006 | International University in Germany, Bruchsal, Department of Operations Management Prof. Dr. Maier. *Research and Teaching Associate*. |
| 08/2004 – 04/2006 | nordic, Stuttgart. Design fashion and lifestyle products. *Managing Director*. |
| Since 06/2006 | Bain & Company, Munich. *Consultant*. |

The term Supply Chain management (SCM) has become a cornerstone term in the academic business literature as well as in general publications on business management. Over the last two decades, many different viewpoints, concepts and frameworks have been introduced to the literature. Yet, a comprehensive structure that puts the underlying ideas in an overall context is still missing. Furthermore, empirical evidence of causes and effects in SCM is limited.

An extensive meta-analysis has been conducted to provide one comprehensive, sound, and consistent SCM framework. This „third generation" SCM framework distinguishes between a normative, a strategic, and an operative level. Its core is situated on the strategic level and builds around the three carefully separated elements coordination, collaboration, and integration. The analysis shows that these terms have to be distinguished and that they are all important levers for successful SCM. The international research project High Performance Manufacturing (HPM) builds the basis for the empirical part of this text. A descriptive analysis shows that so-called SCM champions achieve higher performance levels than so-called SCM laggards. Then, the third generation SCM framework is validated empirically through structural equation modeling, i.e. by means of Partial Least Squares (PLS). The objective has been to not only show the beneficial impact of SCM on plant performance, but also to identify and better understand the exact drivers of this performance and their individual impact. As such key success drivers are identified: internal collaboration, customer orientation, internal coordination, ERP adoption (as a proxy for integration), external collaboration, and trust.

In addition to this core content, the book also describes key challenges for SCM and provides ideas to resolve them. The impact identified in this text and the embracing scope of SCM show that SCM is not a fad but - if understood and applied correctly - a comprehensive management framework with sustaining impact on organizational development.

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