Value Chain Management in the Chemical Industry

Matthias Kannegiesser

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Global Value Chain Planning of Commodities

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Author
Matthias Kannegiesser
Danziger Straße 35
10435 Berlin
Germany
mkannegiesser@yahoo.com

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Foreword

Over the last three decades, research and industry intensively investigated effective planning and control methods in the value chain. *Supply chain management* (SCM) and *Advanced Planning Systems* (APS) became key words at the interface between business administration, operations research and computer science. Among other industries, the process industry specifically chemicals, steel and food is a primary application area for SCM and APS due to decision complexity as well as volume and value importance of material flows. Research for these industries focused on production and supply network planning. Supply chain management started to overcome functional separation by organizational units and research disciplines in marketing, sales, logistics, production, procurement and controlling towards a process-oriented thinking. But still, there was a clear separation between demand and supply as well as volume and value focus leading to local but not global optima. While production – mostly the relatively inflexible part of the chain – was in the focus of optimization and simulation models, sales and procurement prices and volumes were mainly treated as given to be fulfilled and optimized locally. Profitability was mainly measured with ex-post or static contribution margin analysis by controlling functions.

This relatively stable system now faces increasing volatility and complexity due to volatile demand and raw material prices as well as globalization in markets and company networks. Specifically, price-volatile commodity products within the chemical industry require planning volumes together with values across sales to procurement. In this context, the work of Matthias Kannegiesser focuses on two research questions:

- How can volumes and values within the value chain be managed in an integrated way?
- Specifically, how can a global commodity value chain within the chemical industry be planned by values and volumes?

The first question targets an enhancement of *supply chain management* towards *value chain management* with integrated volumes *and* value planning. The second question is related to a specific industry type as basis to develop and evaluate a volume and value planning model in detail for a defined scope.

The study provides valuable insights for research and industrial practice. At the beginning, the author reviews different management concepts in the value chain either demand, supply or value-oriented. The author proposes an integrated framework for value chain management as an interdisciplinary structure consisting of separated concepts.

The study focuses then on value chain planning in the chemical industry and describes industry characteristics specifically for commodity products. Commodities are standard products produced in mass production of high volumes. They received less attention in supply chain management research due to a lack of complexity in production and distribution. Here, commodities are a suitable area for developing an end-to-end value chain planning model since sales and raw material price volatility needs to be jointly managed with volumes throughout the chain to ensure profitability. The study specifies planning requirements for a global commodity value chain in general. A state of the art analysis of recent literature reveals that requirements are covered only partly by developed specialized models with lack of integration.

In the main part of the study, the author develops a model fulfilling the postulated requirements and proves the applicability in a comprehensive industry case (research questions 1 and 2). The model contains new innovative solutions such as sales price and volume planning based on price-quantity functions and linear turnover approximation, planning of future inventory values, global transportation and transit inventory planning, production throughput smoothing or the handling of variable raw material consumptions rates in production. Industry case results show the importance of joined planning volumes and values in a global network: changes of prices or exchange rates require a change of volumes to ensure profitability.

As a result the study opens various new research areas investigating the joined management of volumes and values in different industries or on the strategic or operative value chain management level.

Prof. Dr. Paul van Beek
Prof. Dr. Hans-Otto Günther

Acknowledgements

Each path towards a remote goal starts with a first step. I remember the first step when discussing this project together with the first advisor Prof. Dr. Hans-Otto Günther in his Berlin office. The research approach to combine internationally-oriented, quantitative research with practice-orientation and industry application was a guiding principle for this project from the start. The research of the Department of Production Management at the Technical University of Berlin focusing on production and supply chain management as well as advanced planning systems and the process industry was a perfect competence basis for the study: many research results and practical experiences in the area of optimization, simulation and specifically supply chain management were relevant and important input. Besides, Prof. Günther provided continuous and ongoing guidance during the entire project and provided fruitful opportunities to discuss and exchange ideas with the national and international research and industry community. The second advisor Prof. Dr. Paul van Beek of the University of Wageningen (NL) is a close member of this international research community and provided very valuable specific feedback and guidance on the one hand but also broader perspectives on the research topic on the other hand. I really appreciated his personal engagement into the study as well as his detailed and constructive feedback during meetings and discussions.

Having made the first step, the up coming way in the project was sometimes stony and foggy: getting into the subject, detailing the scope and starting the model development as well as the computational implementation was a challenge specifically using specialized tools and developing new systems. Prof. Günther's team at the Department of Production Management supported me in an outstanding way during this period and along the project. His former co-worker Prof. Dr. Martin Grunow impressed me with his broad and at the same time deep expertise in very different industries and academic fields that he could challenge developed models from various perspectives and provide great guidance in moving forward. I'm also grateful being integrated into the research team of Ph.D. students at the department supported by Hanni Just with Matthias Lehmann, Ulf Neuhaus, Markus Meiler and Ihsan Onur Yilmaz. I really appreciated the intense and fruitful discussions especially on study approaches and system usages at the department, joined conferences, seminars and workshops we spent together. I would also like to send a special thanks to Christoph Habla and Derya Kurus for their master thesis contribution and ideas, which really made a difference to the model and the study results.

Half way of the journey was characterized by model evaluation and enha ncement together with the industry partner. I'm very grateful to the industry partner supporting the study actively with a dedicated team and resources. I would like to thank specifically the unit leadership and the leadership team of supply chain management for establishing the basis for this study and supporting it until the end. In addition, I would like to thank the entire planning and decision support team for the joined time and many hours spent in requirements workshops, data gathering and model testing as well as evaluation. It was a joined success that the developed model was not only developed for academic research purpose but could also be used in the monthly planning process and quickly provided decision support on volumes and value decisions in order to return the invest into this research.

The total path would not have been possible without the organizational and financial support from A.T. Kearney providing the opportunity to taking a leave of absence from consulting work for this study. Specifically, I would like to thank Dietrich Neumann, Dr. Dirk Buchta, Thomas Rings, Holger Röder, Dr. Marcus Eul, Dr. Otto Schulz and Erik Thiry, who supported the project with their guidance, senior counseling and mentoring. I would also like to thank Katharina Mosters and Hans Rustemeyer supporting this process from a Human Resource perspective in a very flexible and unbureaucratic way as well as Dr. Marianne Denk-Helmold, Cornelia Colsman, Margot Jung and Ben Perry for the indispensable support in reviewing and ensuring quality from an editor perspective. Matthias Lütke Entrup inspired this project significantly with his work on *Advanced Planning in Fresh Food Industries* including many fruitful discussions around optimization in the industry: thank you not only for the insights about poultry, sausage and yogurt production!

When reaching the end of the path, I would like to share this moment with family and friends and thank them for their continuous love and support during this challenging period of life.

April 2008 M. Kannegiesser

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Abbreviations

3PL	3rd Party Logistics
AGVS	Automated Guided Vehicle Systems
APP	Aggregate Production Planning
APS	Advanced Planning Systems
ATP	Available-to-Promise
Bc	Base Currency
BOM	Bill of Material
C	Constraint
CEFIC	Conseil Européen de l'Industrie Chimique
CM I	Contribution Margin I
CM II	Contribution Margin II
CP	Constraint Programming
CPFR	Collaborative Planning, Forecasting and Replenishment
CRM	Customer Relationship Management
d	Day
DC	Distribution Center
e.g.	exempli gratia
EBIT	Earnings Before Interests and Tax
EBITDA	Earnings Before Interest, Tax, Depreciation and Amortization
EBT	Earnings Before Tax
ECP	European Contract Price
ECR	Efficient Consumer Response
EMEA	Europe, Middle East and Africa
EPC	Event-driven Process Chain
ERP	Enterprise Resource Planning
et al.	et alteri
EU	European Union
EUR	Euro
EVA®	Economic Value Added
EVCM	Extended Value Chain Management
fc	Foreign Currency
FIFO	First in, First out
GA	Genetic Algorithms
GATT	General Agreement on Tariffs and Trade

GDP	Gross Domestic Product
H	Hour
HPP	Hierarchical Production Planning
HR	Human Resources
IAS	International Accounting Standards
IL	Inventory Level
IR	Inventory Range
IRV	Inventory Range Valued
IT	Information Technology
JIT	Just In Time
KPI	Key Performance Indicator
LIFO	Last in, First out
LP	Linear Programming
M	Month
MILP	Mixed Integer Linear Programming
MIP	Mixed Integer Programming
MIT	Massachusetts Institute of Technology
MRP I	Material Requirement Planning
MRP II	Manufacturing Resource Planning
NAFTA	North American Free Trade Association
NOA	Net Operating Assets
NOPAT	Net Operating Profit After Taxes
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OPL	Optimization Programming Language
P&L	Profit & Loss
PC	Personal Computer
PE	Polyethylene
PL	Procurement Level
POS	Point-of-Sale
PP	Polypropylene
QP	Quadratic Programming
RFP	Request for Proposal
RM	Revenue Management
ROA	Return on Assets
ROCE	Return on Capital Employed
RSM	Response Surface Methodology
S&OP	Sales & Operations Planning
SCC	Supply Chain Council
SCM	Supply Chain Management
SCOR®	Supply Chain Operations Reference
SCP	Supply Chain Planning

SD	System Dynamics
SL	Sales Level
SME	Small and Medium Enterprise
SNP	Supply Network Planning
SRM	Supplier Relationship Management
t	Ton
TP	Transfer Point
TTG	Total Relative Turnover Gap
UL	Utilization Level
US	United States
USD	United States Dollar
US-GAAP	United States Generally Accepted Accounting Principles
VA	Value-Added
VAL	Value-Added Level
VCM	Value Chain Management
VMI	Vendor Managed Inventory
WACC	Weighted Average Cost of Capital
WTO	World Trade Organization
XTG	Maximum Relative Turnover Gap

1 Introduction

In human history, global trade existed already in the ancient world, when people started to trade natural resources, animals or products with other global regions. Early examples are the imports of domesticated animals from Asia to the Sahara between 7,500 and 4,000 BC, the Silk Road from Southern Asia across the Middle East to Europe or the Amber Road. In the Middle Ages, international sea trade was fostered in Europe around cities of Venice, Genoa, Dutch and Flemish cities or by the Hanseatic League. The search for new global trade routes was a driver for discoveries like the arrival of Columbus in America looking for a new sea trade route to India (N.N. 2005a; N.N. 2005b; N.N. 2005c). Global trade in ancient world was challenged by significant transportation time, risks and costs, as well as demand and supply information asymmetry between regions and trade barriers such as tariffs or missing convertibility of currencies.

With the beginning of the 21st century, global transportation times, risks and costs decreased dramatically, communication and information technology enabled people to overcome geographical distances and to reduce information asymmetry between global regions. In addition, trade barriers and market protectionism were systematically reduced through trade agreements like the General Agreement on Tariffs and Trade (GATT) and organizations like the World Trade Organization (WTO).

On the micro-economic level, simple company value chains consisting of buying products to optionally make other products out of it, to distribute and sell these products with a margin to customers become complex networks with globally spread out locations. Globally operating companies face the task to manage volumes and values in this network in a profitable way to ensure competitiveness and business sustainability.

This work investigates the problem to jointly plan volumes and values in a global value chain network for commodity products in the chemical industry. The chemical industry is a process industry sector offering products produced in repetitive production processes carrying out specific physical and chemical reactions (Günther/van Beek 2003a, p. 2). The chemical industry is one of the key global industries with chemical product sales of € 1,776 billion globally in 2004 (CEFIC 2005, p. 3). Globalization with regional growth differences and commoditization with price pressure are important trends within the chemical industry (CEFIC 2005, p. 17 and pp. 28-30; Rammer et al. 2005, pp. 37-48). The management of global material flows poses new challenges on the chemical industry companies since considerable value can be gained from optimizing of the complex global networks (Günther/van Beek 2003a, p. 5).

Additional challenges exist specifically for chemical *commodities*. Commodities are standard products with a defined quality, where price is the key buying criterion. Commodities are often volatile in sales and purchasing prices as well as volumes: increasing crude oil prices lead to higher raw material prices in procurement while dynamic customer markets specifically in Asia lead to a sales price and volume volatility. These dynamics in volumes and values through the value chain directly impact company's profitability as shown in fig. 1.

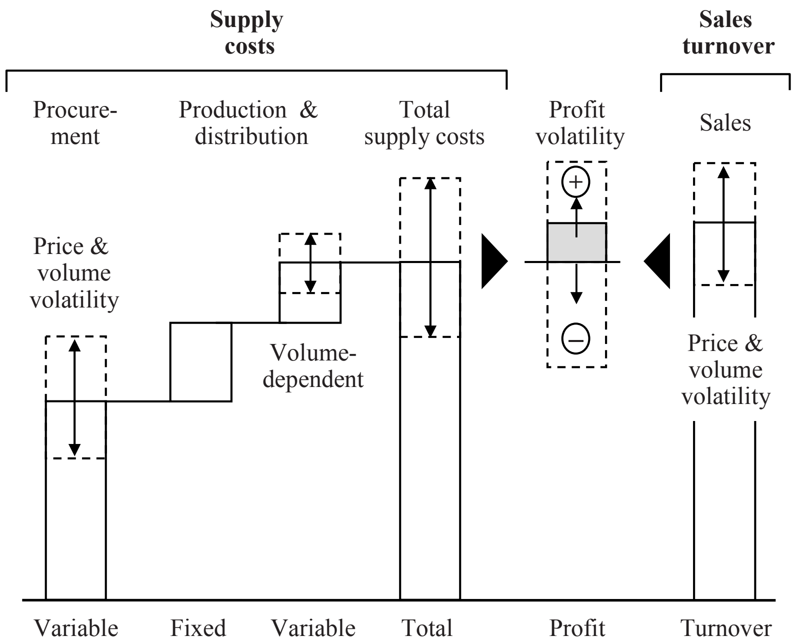

Fig. 1 Challenges to manage values and volumes in a commodity value chain

We give some explanation on fig. 1.

- Sales turnover on the right side of the figure is volatile not only by volatile sales volumes and prices
- Supply costs on the left side of the figure are volatile mainly caused by volatile procurement volumes and prices; within supply, fixed production costs are given and not decision relevant in the short/medium term;

variable production and distribution costs such as transportation and warehousing are variable dependent on volumes
- Overall commodity businesses face a high margin volatility as a consequence of the volatility in turnover and supply costs requiring to manage volumes and values in an integrated way

Cause-effect-relations of these dynamics in the value chain may still be obvious, when operating a simple value chain comprising few products, locations and production steps. Considering the global multi-stage, multi-location value chain network, price changes in raw materials cannot directly be related to intermediate or even sales products and their prices. This problem requires specific planning models and methods.

1.1 Research Field Overview

The research field related to the problem to plan values and volumes of a global chemical commodity value chain network is structured into:

- a general research field overview to define the interdisciplinary research field of value chain management as theoretic background combining specialized research fields that investigate the value chain and appropriate management concepts
- a specific research field overview of state of the art research results related to the problem of planning a global chemical commodity value chain network

General Research Field Overview

Management concepts in the value chain are the generally relevant research fields for the work. *Value chain* as a term was initially defined by Porter "*disaggregating a firm into its strategically relevant activities in order to understand the behavior of costs and the existing and potential sources of differentiation*". Porter's value chain consists of a "*set of activities that are performed to design, produce, market, deliver and support its product*" (Porter 1985, pp. 33-40). Developed *management concept areas* for the value chain can be classified by specialization on values, demand or supply:

- *Value-oriented management concepts* focus on determination of ex-post profitability in the value chain as well as decision support value indicators based on given demand and supply volumes. Sub-fields are financial accounting, profit and cost controlling (Götze 2004; Götze/Bloech

2004) as well as recent value-based management concepts (Hostettler 2002; Revsine et al. 2004).

- *Demand-oriented management concepts* focus on sales price and sales quantity decisions to maximize turnover with a given or unrestricted supply. Demand-oriented research areas are micro-economics specifically for price mechanisms (Varian 1994), sales and marketing (Effort 1998; Kilter/Keller 2005) and recently revenue management (Cross 2001; Tallury/Van Ryzin 2005).
- *Supply-oriented management concepts* focus on procurement, production and distribution decisions to minimize supply costs for a given demand. Supply-oriented research areas are production management (Günther/Tempelmeier 2003), logistics management (Schönsleben 2004), supply chain management and advanced planning (Shapiro 2001; Chopra/Meindl 2004; Stadtler/Kilger 2005; Bartsch/Bickenbach 2002; Dickersbach 2004; Günther 2005) as well as procurement and sourcing (Dobler et al. 1977; Large 2000; Chen et al. 2002; Talluri/Narasimhan 2004; Monczka et al. 2004; Melzer-Ridinger 2004).

The specialization of management concepts lead to several problems in planning a global commodity value chain: maximizing sales volumes and production utilization only can reduce profitability due to high raw material costs; maximizing purchasing volumes only can reduce profitability due to high inventory costs and/or missing demand. The planning problem requires an integrated approach across the value chain from sales to procurement. The specialized research areas have to be combined to an integrated value chain management framework as the basis for the specific tasks for planning a global value chain for commodities in the process industry.

Problem-specific Research Field Overview

The problem to monthly plan a global value chain for commodities in the chemical industry puts specific requirements considering on the aspects of values, sales, distribution, production and procurement planning in a global network. Recent research related to value chain planning can be clustered into global-oriented, chemical industry-oriented or commodity-oriented research.

Models with a *global* scope are found mainly for strategic network design problems, where location decisions in a global company network need to be optimized (Arntzen et al. 1995; Vidal/Goetschalckx 2001; Goetschalckx et al. 2002). These models consider exchange rate, import tariffs and tax rate differences as global specifics in network design decisions. Recent papers develop also global planning models on a more tactical level

(Chakravarty 2005; Kazaz et al. 2005). Industry-specific global planning models on a monthly level considering also transportation lead times between regions or transit inventories could not be found in current literature.

Supply chain management, production management and planning models in the *chemical industry* have been a field of intensive research in practice and science during the last years. Several industry studies analyze the status, requirements and areas of supply chain management also considering the chemical industry (Chakravarty 2005; Kazaz et al. 2005). Scientific research focuses on production (Günther/van Beek 2003b). Subjects to research are the production and logistics characteristics and planning requirements in the chemical industry (Loos 1997; Kallrath 2002a), detailed scheduling models especially for batch production (Blömer 1999; Neumann et al. 2000; Trautmann 2001; Neumann et al. 2002) and in some cases continuous production (Zhou et al. 2000) or hierarchical production planning (Hauth 1998) or multi-site production and supply network planning problems in complex company networks providing production synchronization planning methods (Timpe/Kallrath 2000; Berning et al. 2002; Kallrath 2003; Grunow et al. 2003a; Grunow et al. 2003b; Berning et al. 2004; Levis/Papageorgiou 2004; Yang 2005; Timpe/Kallrath 2000). Integrated production and distribution network design and planning are addressed by Grunow (2001) and Timpe/Kallrath (2000). While production and distribution are intensively investigated due to the complexity and cost-importance of capital-intensive production assets in the chemical industry, procurement and demand management in the chemical industry value chain are less investigated. An example for a procurement model is a spot and contract procurement planning model by Reiner/Jammernegg (2005). Demand-oriented models investigating demand and classical forecasting of demand quantities in the chemical industry can be found for example in practice-oriented industry cases (Franke 2004).

Commodity models are traditionally related to natural resource commodities such as agricultural products e.g. sugar, coffee, metals or crude oil. Economists investigated pricing and market mechanisms for these commodity markets especially during the 1970s and 1980s during the oil crisis from a macro-economic perspective (Meadows 1970; Labys 1973; Labys 1975; Hallwood 1979; Guvenen 1988). From a micro-economic perspective, commodities are considered in financial market research (Roche 1995, Clark et al. 2001; Geman 2005). These models focus on commodities traded on international exchanges. Regular analysis and research are conducted to analyze the development of demand, supply and prices for natural resources but also for industry commodity products (Commodity Research Bureau 2005). Planning commodities in the chemical industry has to deal with demand volatility and uncertainty in volumes and prices as with sales quantity flexibility. Several authors proposed models to handle demand uncertainty in general focusing on quantities (Cheng et al. 2003; Gupta/Maranas 2003; Cheng et al. 2004; Chen/Lee 2004). Uncertainty is reflected by demand quantity scenarios and/or probabilities. Proposed models maximize expected or robust profit. Process industry-specific models use simulation to address demand uncertainty and to determine optimal inventory levels (Jung et al. 2004).

1.2 Research Gaps and Questions

The first research field overview reveals that management research disciplines are specialized focusing on either supply, demand or values. Porter was the first to recognize the anatomy of a value chain with the interdependencies between functional units to create value. However, he did not provide a structured management framework helping companies to translate the value chain anatomy into integrated management processes. Supply chain management research made great progress towards this goal but was still limited to the integration of production and distribution decision making with focus on volumes and costs neglecting price and volume decision making in procurement and sales.

The purpose of this work is to contribute to taking supply chain management to the next level and to complete Porter's value chain mission of integrating decision making in management processes throughout the value chain overcoming separation into demand, supply and value-orientation. For that reason we believe that this work is new. The chemical industry and specifically with its price-volatile commodities is the perfect application field given the complexity in the industry value chain as well as the volatility in volumes and values. The benefits of integrated value chain management will get transparent when demonstrated in an industry case. Summarizing, the specific research gaps so far are:

- there is lack of integrated value chain management framework to integrate demand, supply and value decisions in the value chain; specifically, the integration of sales price and volume decisions with supply chain and procurement decisions is excluded in so far specialized research areas focusing either on demand, supply or values
- the specific problem to plan a monthly global commodity value chain network end-to-end is not covered so far; research is specialized on parts of the problem such as production planning and scheduling, value-based management or revenue management without providing an inte-

grated model for integrating sales prices and volumes with supply volume and value decisions

The following research questions are formulated to close the gaps:

> Research question 1: How can volumes and values within the value chain be managed in an integrated way?

The work's first objective is to combine specialized research to a value chain management framework for managing a value chain end-to-end by volumes and values.

> Research question 2: How can a global commodity value chain be optimally planned by volumes and values?

Developed frameworks are applied to the specific industry problem to monthly plan a global chemical commodity value chain by volumes and values. Sub-objectives are to elaborate characteristics and planning requirements for a global commodity value chain in the chemical industry and to develop, implement and evaluate the respective model. Research question 2 is directed to a real industry case study demonstrating the real existence of formulated requirements, showing the applicability of the developed model in reality and evaluating the model using industry data.

1.3 Research Approach

The study is structured into three parts framed by an introductory chapter and a summary, conclusions and outlook chapter at the end as shown in fig. 2.

- Chapter 2 defines the theoretical background of the work. Related research areas around the central terms *value chain* and *value chain management* are identified. Definitions, classification schemes and concepts are presented as a whole.
- Chapter 3 and 4 introduce the specific global value chain planning problem to be solved in the work. The problem is determined by the industry specifics. This part has two functions: first formalizing the problem and sharpening the work's scope; secondly, define value chain planning requirements as basis for a state of the art analysis to identify specific research gaps in the current literature.
- Thirdly, a value chain planning model is elaborated in chapter 5 and 6 to support postulated requirements and to fill identified research gaps.

Finally, the model needs to prove its applicability in reality and its performance in an industry case study. The model is evaluated with comprehensive industry case data and the relevance of the end-to-end value chain planning approach is evaluated. Opportunities for model extensions are outlined at the end.

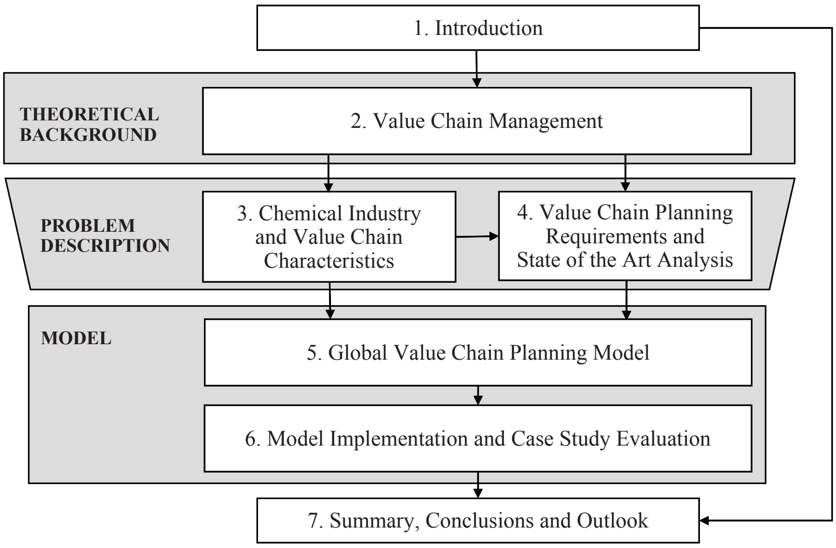

Fig. 2 Study structure and approach

The research results are summarized in chapter 7 and compared to the research questions and objectives formulated in chapter 1. A concluding outlook outlines open and potential new areas, where future research is required.

This approach combines deductive and inductive research steps (Popper 1959, pp. 27-33) and complies with the process proposed by Ulrich/Hill (1976). This process includes cases studies as one mean of deductive research. A case study serves as one basis for the definition of industry requirements existing in reality in chapter 4 as well as a test bed for the model evaluation in chapter 6. A mapping of each chapter to the research process of Ulrich and Hill (1976), p. 348 is summarized in table 1.

Table 1 Study chapters mapped to research process

Research process	Chapter	Chapter function in research process
A. Terminological-descriptive	Value Chain Management	Define the research field and basic terms
	Chemical Industry and Value Chain Characteristics	Use of descriptive studies to narrow problem area investigated within research field Definition of types and relevant dimensions in the scope
B. Empirical-inductive	Global Value Chain Planning Requirements and State of the Art Analysis	Identify planning requirements based on case studies and literature Analyze requirements coverage by state of the art research and further specify research gaps
C. Analytical-deductive	Global Value Chain Planning Model	Model development for formulated requirements
D. Empirical-deductive	Model Implementation and Case Study Evaluation	Validate applicability and requirements coverage of model in industry case

Research field and basic terms are now introduced in chapter 2.

2 Value Chain Management

The theoretical background is defined around the central term *value chain*. Chapter 2 presents research concept*s to manage the value chain* structured by their area of specialization either on supply, demand or values. Secondly, within an integrated framework, the results of the specialized disciplines are combined with the objective to manage sales and supply by values and volume. *Value chain management* is defined and positioned with respect to other authors' definitions. A *value chain management framework* is established with a strategy process on the strategic level, a planning process on the tactical level and operations processes on the operational level. These management levels are detailed and interfaces between the levels are defined. Since the considered problem is a planning problem, the framework serves for structuring planning requirements as well as the model development in the following chapters.

2.1 Value Chain

Value chain as a term was created by Porter (1985), pp. 33-40. A value chain "disaggregates a firm into its strategically relevant activities in order to understand the behavior of costs and the existing and potential sources of differentiation". Porter's value chain consists of a "set of activities that are performed to design, produce and market, deliver and support its product". Porter distinguishes between

- *primary activities*: inbound logistics, operations, outbound logistics, marketing and sales, service in the core value chain creating directly value
- *support activities*: procurement, technology development, human resource management, firm infrastructure supporting the value creation in the core value chain

Fig. 3 illustrates Porter's value chain.

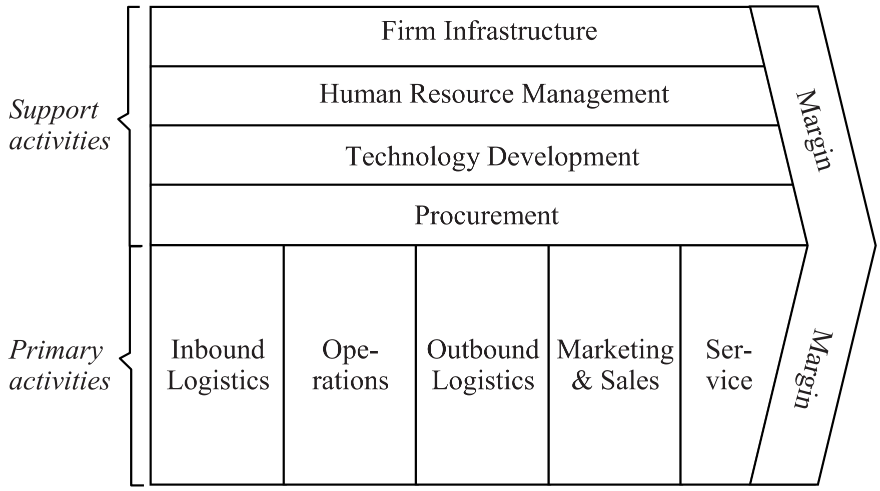

Fig. 3 Value chain by Porter

Porter formulates the general strategies for the value chain of *cost leadership* and *differentiation* to reach competitive advantage (Porter 1985, pp. 62-163). These cross-value chain strategies established a principle that competitive advantage can be reached only by managing the entire value chain as a whole including all involved functions.

Some authors argue that Porter's value chain is characterized by classical functional separation and thinking in organizational units instead of processes, since not processes but activities are listed by organizational function (Corsten 2001, p. 93). Over the years, the value chain was further enhanced towards

- cross-company-orientation defined in the term *supply chain*
- network-orientation defined by the term supply chain network

Supply Chain and Supply Chain Network

Porter's value chain is one basis for the development of the *supply chain*. The term *supply chain* was created by consultant Keith Oliver in 1982 according to Heckmann et al. (2003). Compared to the company-internal focus of Porter's value chain, the supply chain extends the scope towards intra-company material and information flows from raw materials to the end-consumer reflected in the definition of Christopher (1992): "*a supply chain is a network of organizations that are involved through upstream and downstream linkages in different processes and activities that product value in the form of products and services in the hand of the ultimate consumer"*. Core ideas of the supply chain concept are:

- a better collaboration between companies in the same supply chain will help to improve delivery service, better manage utilization and save costs particular for holding inventories (Alicke 2003)
- individual businesses can no longer compete as solely autonomous entities, but rather as supply chains (Christopher 1998)

Various illustrations and definitions for the supply chain exist as shown in fig. 4.

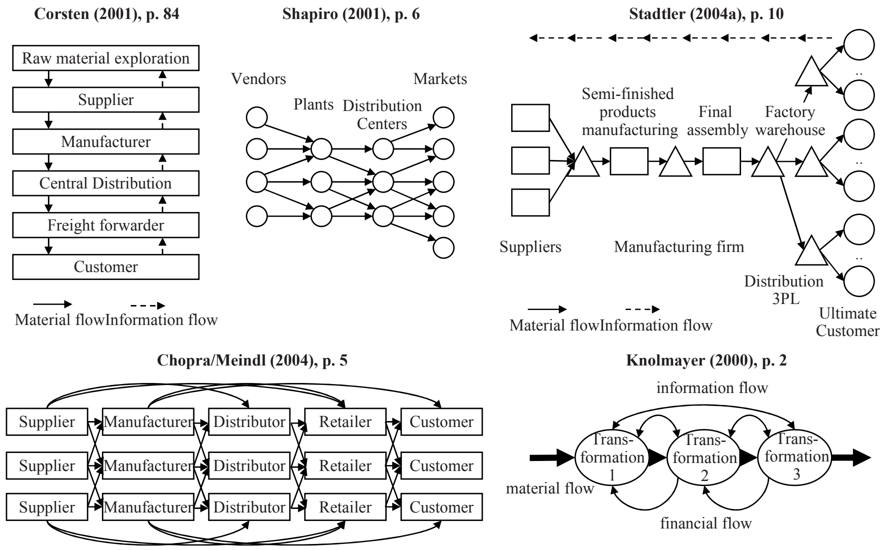

Fig. 4 Supply chain illustrations in literature

Corsten points out that a supply chain is a special type of network composed of multi-level logistic chains owned by legally separated companies. The focus in the supply chain is the coordination of flows of materials and information between these companies. Corsten's examples show the supply chain structure starting with raw materials up to the final consumer (Corsten/Gössinger 2001).

The network aspect in supply chains is illustrated by Shapiro where supply chain networks are composed by notes connected by transportation networks (Shapiro 2001, p. 6). Compared to Corsten, Shapiro extends the supply chain including many-to-many-relations between vendors, plants, distribution centers and markets.

Stadtler addresses the aspect of multi-level manufacturing of semi-finished and final assembly products as well as multi-level distribution steps. He also introduces different node types for procurement, production, distribution and sales and confirms the one-directional flow of material and the one-directional flow of information similar to Corsten. Stadtler emphasizes the difference between intra-organizational and inter-organizational supply chains (Stadtler 2004a, p. 10).

Chopra and Meindl support the aspect of many-to-many relations and a supply chain network. Additionally, they add the aspect of direct relations between partners in the supply chain across several supply chain steps. The primary purpose of the supply chain is to satisfy customer needs, in the process generating profit for itself (Chopra/Meindl 2004, p. 5).

The review of Knolmayer supports the cross-node communication to ensure collaboration across the chain. Additionally, communication is not only one-directional but bi-directional as well as supply chain does not only cover material and information but also monetary flows (Knolmayer/Mertens et al. 2000, p. 2).

While the previous illustrations are focused on the *intra-company* supply chain structures, *inter-company* structures of the supply chain are related to Porter's value chain as shown in fig. 5 (Meyr/Wagner et al. 2004, p. 113 based on Rohde/Meyr et al. 2000).

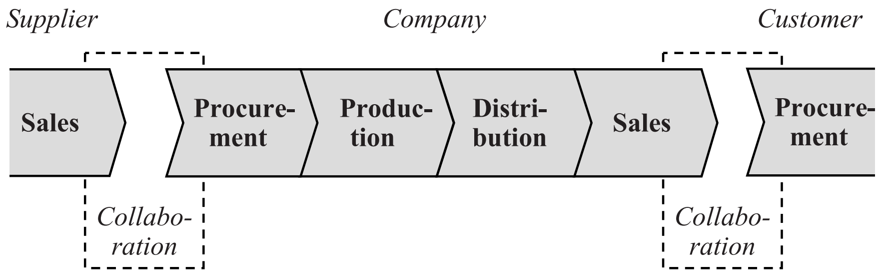

Fig. 5 Company-internal supply chain structures

Here, the focus is on the primary value-creating activities influencing directly the bottom line of the company. Different to Porter,

- *procurement* is a primary value-creating activity and core element in the supply chain and not a support function,
- market-facing activities are combined into *sales* including customer services
- inbound and outbound logistics activities are combined in *distribution*,
- operation in Porter's value chain is more specified with the term *production*.

Concluding, the supply chain and supply chain network concept extends Porter's value chain concept towards cross-company networks in order to improve efficiency and delivery service, minimize costs and inventories based on a given demand across the chain. The focus shifted from value creation within a company towards ensured supply for a given demand and cross-company material flow and information management.

This approach requires a cross-company coordination and information exchange platform in order to create transparency and accurate information about material flows in the chain as basis for decisions. In addition, full collaboration and trust rather than the competition between different companies is required. These assumptions are similar to approaches in planned economies with a central planning office trying to optimize complete industries composed by state-owned companies.

In market economies, however, companies are confronted with competition when selling to customers and they use the market competition when purchasing from suppliers. On the other hand, market constellations can change, when many customers compete for limited resources or raw materials provided by few large suppliers. In these situations, prices, values as well as ensured profitability within each company are decisive for the sustainable survival of the business. While the supply chain emphasizes the supply aspects including ensured supply and availability (Corsten 2001, p. 94), an essence of Porter's value chain underlining the value focus and the supply chain concept is required as basis for the study.

Value Chain and Value Chain NetworkUsed in the Study

The value chain in the study focuses on the company internal value creation in the primary activities consistent to the company-internal supply chain structures by Meyr et al. (2004) and Rohde et al. (2000) as illustrated in fig. 6.

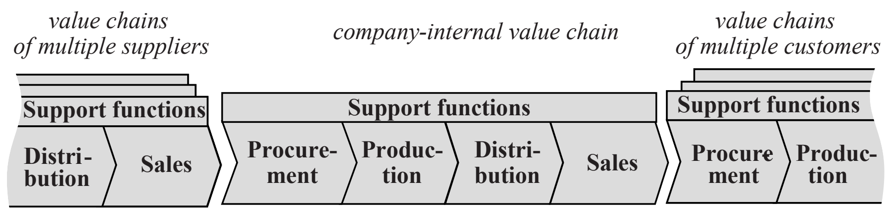

Fig. 6 Value chain considered in the study

The considered value chain is characterized by

- the primary functions of sales, distribution, production and procurement as well as the support function consistent to Porter's support functions excluding procurement

- *sales* covers besides core sales activities also marketing and sales-related service function
- *distribution* covers inbound and outbound logistics with warehousing and transportation
- *production* covers Porter's operations functions; production is not a mandatory function e.g. in case of retailers in the consumer goods industry
- *procurement* is a primary function directly impacting volumes and values

- the value chain has clear interfaces with the procurement functions of multiple customer and the sales functions of multiple supplier interfaces
- the functional structure is consistent with the value creation process and supports the definition of cross-functional management processes

The company-internal value chain is basis for end-to-end volume and value management as well as collaboration and negotiation between other value chains.

The value chain network combines illustrations of the different supply chain network (see fig. 7).

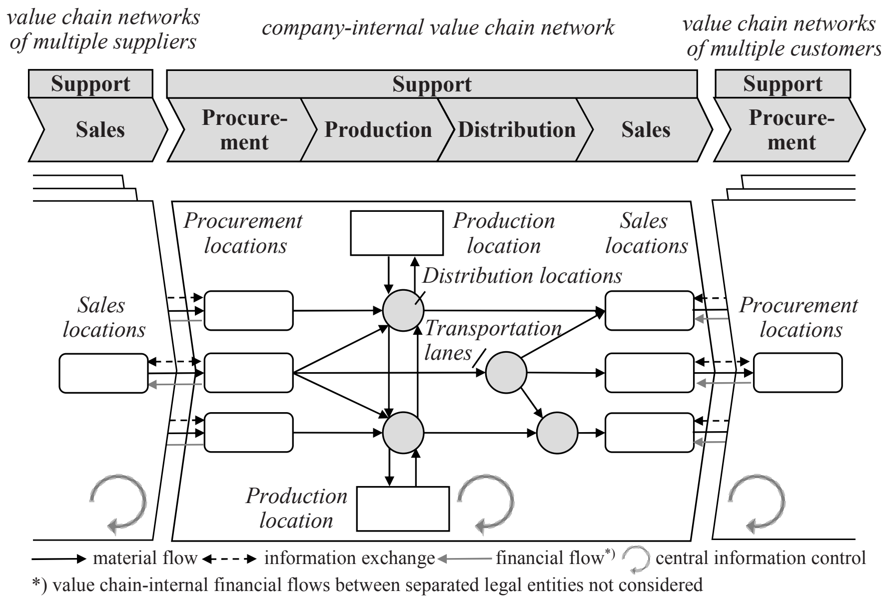

Fig. 7 Value chain network structures

The network is composed by locations and transportation lanes between these locations consistent to supply network structure definitions e.g. in