MARKUS FRICKE

INFORMATION LOGISTICS IN SUPPLY CHAIN NETWORKS

CONCEPT, EMPIRICAL ANALYSIS, AND DESIGN

With 94 Figures
and 26 Tables

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To my wife Tina and my parents

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The present thesis originated from the research on inter-organizational cooperation's and supply chain management at the Institute for Information Systems at the Johann Wolfgang Goethe University in Frankfurt. During discussions about the coordination of economic activities in supply chains and the use of information technology, questions about the interdependencies between the use of information technology and the efficient form of coordination arose. This was the starting point for an empirical analysis and the development of a theoretical approach to analyze these questions.

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Markus Fricke

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INFORMATION LOGISTICS

IN SUPPLY CHAIN NETWORKS

CONCEPT, EMPIRICAL ANALYSIS, AND DESIGN

1 Introduction

Information-logistical competence is already a
competitive-decisive factor today.
(Augustin 2000, 200)

For the planning and optimization of information and goods flow an efficient use of information technology (IT) as well as the organizational willingness to undertake networking must be considered (Swaminathan, Smith et al. 1998). Whereas technological factors relate to the use of communication standards, information systems and the information flows between them, organizational problems lie in the different interests of the communication partners and the asymmetric accruement of costs and benefits in the network. In both areas a trend from closed, enterprise-internal to open inter-organizational strategies and thus to networks can be found (Klaus 1998).

Inter-organizational cooperation is of importance, when common objectives, synergies and externalities link otherwise independent agents with each other. Cooperation in the sense of participating in networks can lead to an improvement of the competitive position of single agents as well as for a whole network against agents that are not part of the network as well as against other networks in the same industry (Porter 1980). Furthermore, participation in networks potentially enables a neutralization of competitive pressure against other agents that are also involved in the same network. This results because of stronger dependencies between these entities and the strategic importance of cooperation (Rupprecht-Däullary 1994).

Especially because of economics of scale and economics of scope, costs reductions can be achieved; and by cooperating development costs, risks and time can be reduced, quality can be increased, capacity can be balanced more flexibly and bottlenecks become bridgeable (Fleisch 2001). The advantages make evident the potential of optimizing whole networks consisting of different agents working together to achieve a common goal.

In the literature, these networks are frequently defined as supply chains. A supply chain is a network of organizations and their associated activities that work together, usually in a sequential manner, to produce value for the customer (Christopher 1998). Supply chains have existed ever since business has been organized to bring goods and services to customers. The silk route between China, India, and west Asia; the flourishing sea-trade links between ancient Indochina and south India; and the English and Dutch East India companies are but a few examples of global supply chains (Kumar 2001). Today's most popular examples of supply chains might be found in the automotive industry, where a

large number of entities are involved in the development and manufacturing of vehicles. Because agents are frequently involved in different supply chains and supply chains in general do not have a linear form, the term supply chain network is often used to describe industry networks and/or the relation between agents involved (Franks 2000; Knolmayer and Mertens et al. 2001; Samaranayake 2002).

In contrast to the traditional point of view, where enterprise-individual decisions related to procurement, production and distribution have been the focus of consideration, the total network optimum is in the center of integrated approaches. Based on integrated system thinking (Isermann 1998), supply chain management has been developed. The concept of supply chain management can be described as the integrated planning, control, realization and monitoring of goods and information flows. Supply chain management differs significantly from traditional approaches in four essential respects (Oliver and Webber 1992):

- The supply chain and/or the network is viewed as a single entity rather than as relegated fragmented responsibilities for various segments in the supply chain related to functional areas.
- SCM stresses the need for strategic decision making
- SCM provides a different perspective on inventories, which are used as a balancing mechanism of last, not first, resort
- SCM requires a new approach to information systems and IT infrastructures.

Because each supply chain can only be as competitive as its weakest member, SCM addresses coordination and design problems (e.g. decisions about the use of different information technologies and the kind of integration of business partners) in networks.

The concept of information logistics is closely connected to supply chain management. Information logistics focuses on the integrated planning of information flows and IT-infrastructures to minimize the costs of communication and/or transactions in networks (Klein 1996). As in supply chain management, the objective of information logistics is to find the optimal IT configuration of networks that will lead to the minimal overall costs. This includes the logistical tasks Information allocation, decision about technologies to be used in the network and the use of intermediaries as well as the selection of communication paths and channels (Voß and Gutenschwager 2001). Information logistics can consequently be described as the area of SCM that is concerned with the design of necessary IT-infrastructures and information flows.

In this work, an economic model of information logistics which finds the optimal information flow and IT configuration for information networks is developed. The optimization is meant to improve the exchange of information and business documents between enterprises and so the coordination of processes and transactions in relatively stable supply chains and/or supply chain networks.

1.1 Motivation and research questions

The theoretical relevance of information logistics is fundamental in that it addresses the general coordination and design problems in networks. The synchronization of operations involved in supply chain processes across multiple firms of different kinds is much more difficult than it is within a single firm (Oliver and Webber 1992) and is one of the major problems in today's supply chains. The principal reason for this is the information sharing required to perform supply chain operations. Therefore efficient information logistics becomes essential.

Economic theory asserts that firms will choose transactions that economize on coordination costs (Wigand and Benjamin 1993). *Malone et al.* argue that IT reduces the cost of a transaction. It follows that the use of IT influences the mode of coordination (Malone, Yates et al. 1987). Because different information technologies have different investment costs and different effects on the costs of communication, the problem of deciding how to find the efficient form of IT and/or coordination that will minimize the costs of coordination and/or communication arises.

The overall goal of this research is thus to acquire a more subtle understanding of information logistics in supply chains and supply chain networks, analyze individual as well as overall efficiency and derive solution proposals.

The main theoretical goal is to develop an analytical approach for the planning and optimization of information-logistical infrastructures and information flows and to corresponding search strategy for obtaining the optimal solution. The main practical goal is to develop an instrument that will be applicable and provide some guidance in deciding on network and information flow design problems.

In particular, the following research questions form the scope of the work:

- What are the determinants of information logistics in information networks (section 2)?
- How are information logistics and physical goods logistics connected (section 2)?
- How do selected economic theories contribute to the understanding of networks and/or information logistics (section 3).

- What do business relations in corporate reality look like, what information technologies and concepts are used and planned to store, manipulate and exchange information and what effects on the transaction costs result from IT-usage (section 4).
- What is the optimal IT based form of coordination in supply chains (section 5)?
- Can vertical e-markets effect the exchange of information in supply chains and how (section 5 and section 6)?
- How can theoretical implications from information-logistics be taken over to close-to-reality networks (section 5 and 6)?
- Which differences result from a supply chain network perspective as against a perspective where only a single supply chain is regarded (section 6)?

1.2 Methodology

This work is theoretical as well as empirical and uses computer-based optimization and simulations to understand the complexity of the design of information-logistical infrastructures and information flows in information networks. It draws on the implications of transaction costs theory and network effect theory. All calculation results were generated using self-developed Lisp applications.

Based on the empirical findings on information logistics in the automotive industry, an analytical model is developed. With the model different sample networks are optimized. After that the model is applied to supply chains and supply chain networks derived from the empirical data.

Examining questions of managing information logistics in and between enterprises, the Institute of Information Systems and the PA Consulting Group conducted a survey in the summer of 2001. A questionnaire containing 45 questions on 9 pages was sent to 800 suppliers and manufacturers in the European automotive industry. Prior to mailing the questionnaire, each company was contacted by phone to identify the responsible managers to whom the questionnaire was then directly addressed. 125 questionnaires from 9 countries were returned (15%). On the one hand, the study was designed to provide an insight into the determinants of information-logistical and information management issues like the software solutions used by the automotive companies. On the other hand, more detailed questions were asked in the selected categories e-business strategies, EDI, e-procurement, e-markets and organizational changes resulting from the use of e-business solutions. The results presented in chapter 4 on a general level were complemented by other empirical data and case studies which give examples demonstrating the specific

behavior of individual companies and technological concepts in the automotive industry. For data analysis MS EXCEL and SPSS 9.0 were used.

1.3 Structure of the thesis

The structure of this thesis is as follows: Chapter 2 offers a brief overview of the terms information and logistics (section 2.1), followed by a classification and discussion of information-logistical conceptions and areas of application. In particular, this includes the connection of information logistics to (physical) goods logistics (section 2.2) and the relation of information logistics to information management (section 2.3). We also identify a set of information-logistical requirements, tasks and their factors of influence (section 2.5) that enter into the economic model developed in chapter 5.

In chapter 3 we analyze the meaning of economic theories in terms of the concept of information logistics and/or the design of information logistical infrastructures in networks. In so doing we focus particularly on transaction costs theory (section 3.1) and network effect theory (section 3.2). The implications derived from both theories for the design of information-logistical infrastructures serve as a further foundation for the model of information logistics developed in section 5.1 and the general framework used for analysis and discussion of close-to-reality supply chains in the automotive industry in section 6.1.

Next, in chapter 4, empirical data about information-logistical parameters and infrastructures in the automotive industry is presented. We identify the status quo and the future of various IT solutions and IT-based scenarios used to support business processes and relations in the automotive industry. We especially focus on the areas of Electronic Data Interchange and/or the exchange of business documents (section 4.3), business software (section 4.4), e-procurement (section 4.5), electronic markets (4.7.) and IT-based supply chain management (4.8). For selected technologies we show how the use of IT can affect the costs of transaction and purchasing conditions. We also identify barriers to and/or problems with the use of IT-based solutions and concepts in automotive companies. Moreover we present an overview of organizational changes resulting from the use of e-business technologies (section 4.9). On the one hand the findings provide a set of further determinants to be considered in the information-logistical model developed in chapter 5. On the other hand, the results are used as the data foundation for the application of the theoretical findings on automotive networks in chapter 6.

Based upon the findings outlined in the previous chapters, in chapter 5 a formal economic model of information logistics aimed at finding the optimal IT-configuration and information flows in information networks is developed (section 5.1). The optimization is meant to improve the exchange of information and business documents between enterprises and

thus the coordination of supply chain processes and transactions. We introduce a search strategy for obtaining an optimal solution implemented in a Lisp application and discuss the characteristics of the optimal solution based on the example of an abstract information network (section 5.3). We also look at the quality versus computation time of the application and/or the search strategy (section 5.4). The chapter ends with the practical applicability of the model-approach and its meaning to supply chain management (section 5.5).

Subsequently in chapter 6, the theoretical findings about the optimal information-logistical infrastructure and the optimum information flows outlined in chapter 5 are applied to the example of supply chains and/or a network of supply chains using the example of the automotive industry. To make the adaptation of the analytical findings to real live networks possible, in section 6.1 a general framework (section 6.2) for automotive supply chain networks as a foundation for analysis and discussion is developed, based on the empirical data outlined in chapter 4. We show the number of possible configurations and thus the complexity of the design of information-logistical infrastructures in automotive supply chains and supply chain networks. Moreover we calculate the total network costs of close-to-reality supply chains and discuss various effects resulting from changes in configuration. Subsequently in section 6.4 the same is done for an intermeshed supply chain network to outline potential differences from the case where only a single supply chain is regarded.

Finally, chapter 7 includes a summary and discussion of the results as well as an outlook.

2 The Concept of Information Logistics

"Efficient information logistics is the foundation
of distributed work in networks"
(Klein 1997, 45)

At the beginning of a scientific treatise a definition of the terms used in the discussion has to be made. In providing a topology of the information-logistical landscape a confusing profusion of overlapping terminology and meanings can be found in the literature. As a consequence, different labels are used to describe information logistics. This chapter sets out, not to review the information-logistical literature per se, but rather to present a critical theory debate and categorization of the literature linked to information logistics. In order to ensure a better understanding of the two components of the term information logistics, in section 2.1 basic aspects of information and logistics will be outlined. Section 2.2 deals with the connection between information logistics and goods logistics, followed by the connection between information logistics and information management in section 2.3. Next, in section 2.4 further information-logistical conceptions and areas of application will be presented. Last, section 2.5 is concerned with information-logistical tasks and problems.

2.1 Basic aspects of information and logistics

2.1.1 About the term information

In common linguistic usage, information is understood in the sense of messages which can accessed using several media (e.g. radio, newspaper, Internet etc.). Therefore information, which can be characterized by the three dimensions relevance, novelty and practical usability, designates mediated knowledge about facts (Capurro 1978).[1] Unlike common linguistic usage, different conceptions and definitions of the term information exist in the literature. For a detailed review see for example (Capurro 1978; Hopf 1983; Bode

[1] For the scientific and philosophic definition of the term information c.f. (Capurro (1978). The beginning of the scientific term information is grounded in the exchange technologies of the 1930s. Based on an improved ability to deal with signals in physical systems a mathematical and statistical definition has been made (c.f. (Capurro 1978) and (Gebauer 1996)).

1993).[2] The different aspects of the term information can however be illustrated using the typology provided by *Bode*. As illustrated in Figure 1, the different aspects of the term information can be represented graphically by the dimensions semiotics, time-orientation, truth, novelty and carrier of information (Bode 1993; Bode 1997).

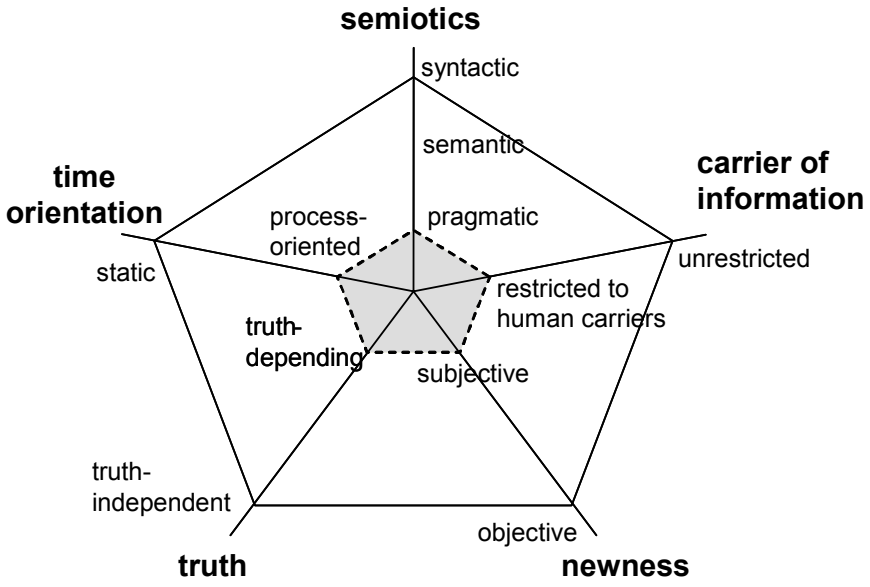

Figure 1: Topology of information terms (Bode 1997)[3]

From a *semiotics* point of view, the characterization of information can follow three different conceptions:[4] in the *syntactical* conception, information is a sequence of tokens which are concatenated based on a set of rules to form a message. In contrast, from a *semantic* perspective, information is only what we understood (Morris 1960). This means that a syntactic understanding requires the recipient to be able to distinguish between the tokens used in the alphabet (relation between character strings and their significance). *Pragmatic* information results in an effect on the recipient (Morris 1960). This expresses the fact that pragmatic information always has to have a consequence for the recipient, and that the pragmatic conception is closely connected to prior experience. This differs from the semantic interpretation, because it implicitly requires the active utilization of information by the recipient (Morris 1960).

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[2] C.f. also (Bode 1997), (Krcmar 1992) and (Krcmar 2000).

[3] The line outside determines a wide, the inner line a tight information term. The further a characteristic is from the center, as larger is the field of the term included.

[4] For the fundaments of semiotics c.f. (Morris 1960), (Gebauer 1996), (Bode 1997) and (Krcmar 2000).

From a time-oriented perspective *process-oriented* and *static* conceptions can be distinguished. Whereas the process-oriented point of view argues that information is a process, from a static perspective information is viewed as a state (König, Syben et al. 1990).

With regard to the truth-content of an item of information, truth-dependent and truth-independent approaches can be divided. While the truth-dependent perspective postulates that information needs to be true, at least in the view of the sender of the information (Wittmann 1979), the truth of an item of information is unimportant in the truth-independent conceptions.

In terms of newness, the information state of the particular recipient of information is used for classification. Individual-subjective perspectives arrogate that information must be new for its receiver (Szyperski 1980; Kloth 1999). Objective perspectives, on the other hand, do not view information as dependent in the personal state of its recipient (Kosiol 1972).

Different approaches to the carrier of information are distinguished in the literature. The conceptions differ between approaches where only humans are accepted as the carrier of information, and unrestricted ones, where in principle anything can be the carrier of information (e.g. an information system) (König, Syben et al. 1990; Voß and Domschke 1999).

As a result of the above considerations, in the following the term information is to be understood as a truth (information must be new for the receiver) and time-oriented message that has significance for a recipient system which can be human or technological (e.g. an Enterprise Resource Planning system).

In the context of economics, information is frequently regarded as decision- and/or activity-oriented and, based on *Wittman's* pragmatic point of view, defined as purpose-oriented knowledge (Wittmann 1959).[5] The definition makes clear that that only the knowledge relevant for an agent in a certain situation for the solution of a specific task represents information and that the term knowledge can not be used interchangeably with information (Picot and Maier 1993). Within the scope of a decision-oriented context, information is used to reduce uncertainty, to trigger activities and to enable monitoring and control (Gebauer 1996). On the one hand information is needed for planning and control of processes, on the other hand information initiates these processes evenly, pointing out risks and opportunities (Horváth 1988). Because of its increasing importance in economics, especially in the context of inter-organizational cooperation and supply chain man-

[5] C.f. (Bode 1997) for a critical reaction to this definition.