Sourcing Concepts: Matching Product Architecture, Task Interface, Supplier Competence and Supplier Relationship

Roman Boutellier, Stephan M. Wagner

1 Introduction

Three trends have changed the competitive landscape for producers of physical goods:

- Complexity
- Miniaturization
- Globalization

Complexity stems, among others, from a greater variety of technologies contained in one product that drives up innovation and logistics costs. A modern watch contains not only mechanics, but electronics and software as well.

Miniaturization has made dramatic progress. The first mobile telephone had a volume of 30 liters. Today, mobile phones are restrained by the size of our fingertips and the entire device requires less volume than 2-3 credit cards. Miniaturization allows physical products to be split up into modules that are more or less independent of one another and are defined by their functionality. The power supply of PCs, for example, is defined by its input, output and physical dimension. The PC assembler buys a functional unit and the power supply provider can sell its product not only in the PC market, but also in numerous other market segments as well. Miniaturization has increased the economy of scale.

The last trend, *globalization*, builds a bridge between product complexity and miniaturization. Product complexity pushes companies towards outsourcing. They can only manage their multitude of technologies with the help of suppliers who, due to globalization, can be found anywhere in the world.

Thus, currently sourcing is very often sourcing of functional units defined by their interfaces with the overall system, i.e. the product sold to the customer.

The discussion in this article elaborates on *sourcing concepts* that, for the moment, we describe as the degree to which sourcing objects are broken up into smaller parts or are aggregated to larger units, and the way in which the development, manufacturing and assembly of these objects are divided between the buying firm and its suppliers. As such, the notion of the sourcing concept enlarges Arnold's [Arnold, 1996] strategic sourcing dimensions.

Besides the three major trends, there are three more reasons why sourcing concepts need more elaboration. First of all, Arnold's [Arnold, 1996] other sourcing dimensions have already been researched in great depth. For example, there is a great deal of research on the desired number of alternative suppliers [e.g. Homburg, 1995; Swift, 1995], a significant number of articles on sourcing time [e.g. Chapman/Carter, 1990; Çetinkaya/Lee, 2000], and some research on the sourcing subject [e.g. Hendrick, 1997; Essig, 2000] as well as on the sourcing area [e.g. Frear/Metcalf/Alguire, 1992; Petersen/Frayer/Scannell, 2000]. The degree of vertical integration has attracted the attention of well-known academics from numerous disciplines for several decades [e.g. Williamson, 1985; Grossman/Hart, 1986; Barney, 1999].

When we look at sourcing concepts, however, we face a general lack of well-grounded literature. The small body of literature on sourcing concepts is frequently anecdotal and predominantly examines them with examples drawn from the automotive industry.

The second reason is that for several years firms have focused business activities on their core competencies [Prahalad/Hamel, 1990], and as a result, increasingly favored the buy decision over the make decision [Quinn/Hilmer, 1995]. It is not uncommon for companies in various industries to source from their suppliers at 50 to 60 or even up to 80 percent of the value that they deliver to their customers. If these firms would not aggregate sourcing objects to a higher level, i.e. source modules, black boxes, and systems instead of single parts, the number of parts, suppliers, and sourcing transactions that they had to handle would result in a very high complexity. Changing the sourcing concepts has become vital. Hence, more knowledge about sourcing concepts and recommendations for their implementation in practice are needed.

Third, empirical studies – conducted time and again in the automotive industry – have indicated that many firms in Western Europe and in the United States have frequently approached outsourcing inappropriately [e.g. Womack/Jones/Roos, 1990; Lamming, 1993]. For a long time now companies have lacked lean supply abilities, i.e. partnering approaches, with a smaller number of selected suppliers. They have not been able to implement the right sourcing concept in conjunction with other situational factors. Taking situational factors into consideration is often referred to as a contingency approach [Appelbaum, 1997]. We argue that the decision for and implementation of archetypical sourcing concepts should follow the contingency approach. All archetypical sourcing concepts are useful and effective, in different situations, however.

Last but not least, some research has investigated the link between sourcing concepts and the change in supplier relationship dynamics and structures, the change of entire industry structures, the advent of new logistics and supply chain management concepts, as well as product configuration and modularization [e.g. Womack/Jones/Roos, 1990; Hsuan, 1999; Cousins, 1999; Sobrero/Roberts, 2002]. However, there is a tendency to discuss modular, black-box and system sourcing either from the relationship management or the technology management perspective. Consistent with this thinking, a broadened view of modular and system sourcing is needed. We argue that firms must match several important aspects, such as the architecture of the product being sourced, the interface with the supplier in the innovation process, the supplier's competence and the supplier relationship in order to be able to exploit the potential benefits of specific sourcing concepts.

The goals of the analyses and discussions in this article are threefold. First, we intend to provide a clear definition of the sourcing concepts of modular, black-box and system sourcing. What do they have in common, what distinguishes them, and what are their essentials? Second, we want to explore four major constructs that should be considered in companies' decisions for one or the other sourcing concept in depth. Third, we will argue that each sourcing concept is characterized by a certain combination of parameters that firms should strive to match in order to be successful in their implementation.

In achieving these goals and deriving the necessary arguments, the article builds on knowledge from research on innovation management, inter-firm relationship management, and supply management.

The article consists of six remaining sections. In the second through the fifth section, we discuss the four generic constructs and their parameters that should determine the decision for one or the other sourcing concept. Subsequently, the four constructs will be put together into a comprehensive frame of reference. From this we will derive the notions of traditional, modular, black-box and system sourcing. In section seven, we will draw some important management implications regarding the sourcing concepts and close with remarks on their future.

2 Product Architecture

"Complexity is more and more acknowledged to be a key characteristic of the world we live in and of the systems that cohabit our world." The Nobel laureate Herbert A. Simon [Simon, 1996, pp. 181ff.] has argued that our complex world is half empty and most systems are almost deconstructible. In a modern airplane, the tail is connected to the cockpit through data links and no longer through hydraulics. The two, cockpit and tail, can be designed and assembled independently, which was not the case in earlier times. A larger tail needed larger hydraulics and more power in the cockpit. A disadvantage was, for example, that due to the strong connection, the cockpit got crowded. The very general notion of almost decomposable systems has tremendous power to reduce complexity and lies at the heart of modern sourcing concepts.

2.1 Basic Product Architectures

Product architecture – a key driver of manufacturing firms' performance – can be defined as "the scheme by which the function of a product is allocated to physical components." [Ulrich, 1995, p. 419] The basic beliefs are that any component of a comprehensive system has a role to play in the functionality of the entire system in which it is included, and that any component is part of the physical structure of the comprehensive system. Ulrich divides the implementation of the product architecture into three steps:

1. Arrangement of the functional elements:
   At the beginning, functions of the product must be described before they can be translated into physical product features. It has proved helpful to create diagrams consisting of verbally expressed functional elements. Functions can be described at different levels of abstraction. Ulrich uses the example of a trailer to illustrate his concepts. A trailer might either consist of the single function "expand cargo capacity" or, on a more detailed level, of a collection of functional elements, such as "protect cargo from weather, connect to vehicle, minimize drag, support cargo loads, suspend trailer structure, and transfer loads to road".

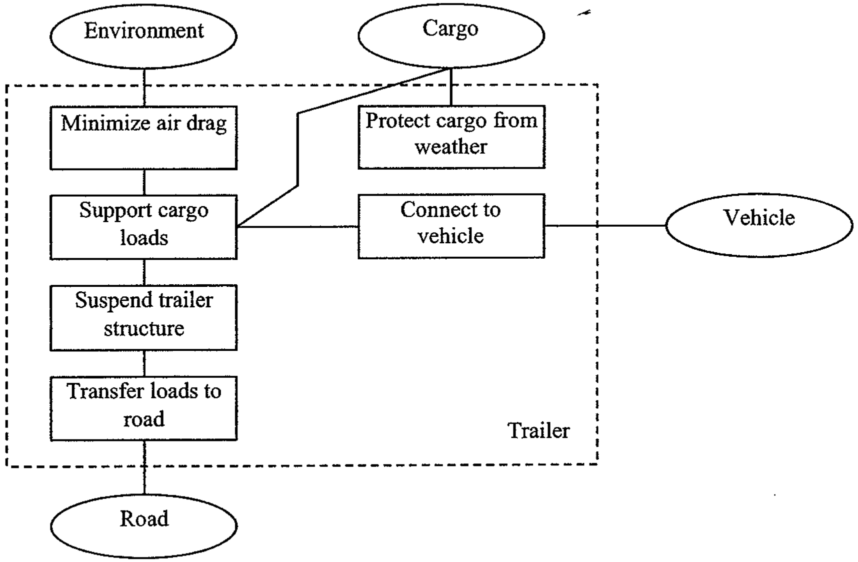

Figure 1: Function structure for a trailer
[Ulrich, 1995, p. 420]

2. Mapping of functional elements to physical components:
   According to Ulrich, the mapping of functional elements to physical components determines the basic architecture of the product. Two basic product architectures with different consequences for the other elements in the supply chain, such as suppliers, inbound logistics, procurement, manufacturing, assembly, outbound logistics and customers, may result: modular architecture or integral architecture.

   A *modular product architecture* implies a one-to-one mapping from functional elements to physical components.

   In this case, each functionality of the product resides in only one product component and each product component only relates to one functionality. SMART, the miniature car from DaimlerChrysler's subsidiary Micro Compact Car (MCC), was modularly designed from the beginning. The frame with its function of providing stability has well defined interfaces with the drive-module consisting of engine, gearbox and rear axis. These three had to be put into one module, since the gearbox and rear axis change when SMART uses a diesel engine instead of a gas engine. The other modules, and the frame do not change.

   Modular architecture speeds up design, since the design can easily be divided between different suppliers. The upgrade of components causes few problems. The main caveat is the tolerance that has to be built into the interfaces – the product becomes heavier.

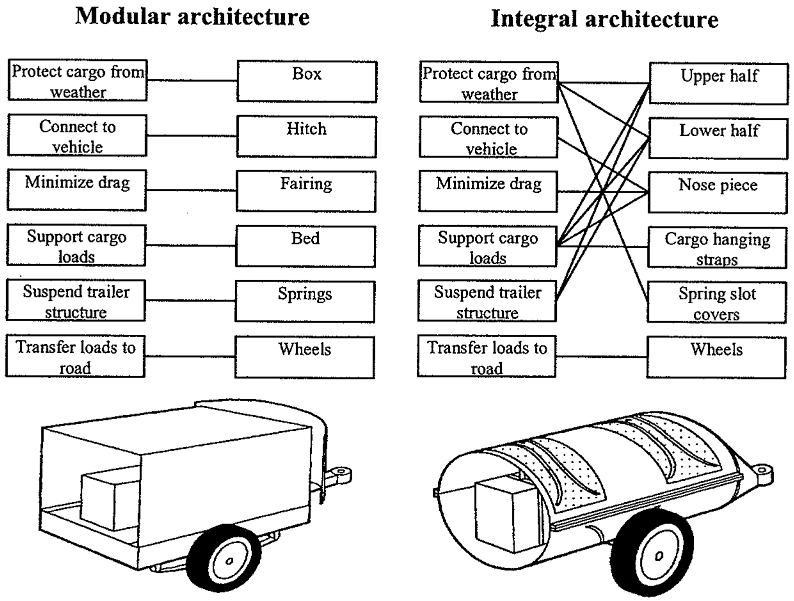

Figure 2: Modular and integral trailer architecture
[Ulrich, 1995, pp. 421f.]

Conversely, *integral product architectures* are much more complex as the mapping is not one-to-one. Instead, many functional elements are implemented by more than one physical component and several physical components implement more than one functional element. The instrument panel of a car, as described by Robertson and Ulrich [1998, p. 21], provides another good example of an integral product architecture. “It provides structural support for heating, ventilation, and air conditioning (HVAC) ducts; components; switches; gauges; audio components; storage areas (such as the glove compartment); airbags; and tubing and wiring. The instrument panel also must help absorb the shock of a front or side collision and help the car body from twisting during normal driving. Finally, the instrument panel plays an aesthetic role: the look, feel, and even smell of an instrument panel can affect the appeal of the car and distinguish one car from another.”

Integral design is used whenever top efficiency is sought. A Formula One car is an integral design. All interfaces are stripped down to the actual component, and weight is reduced to the physical limits of the materials used.

3. Specification of the interfaces among interacting physical components:
   The third step when implementing a product architecture, deals with the interfaces among the physical components.

   Modular product architectures build on standardized interfaces between different components within a product. Hence, the substitution of components can be easily done. Product configuration is flexible and allows a large degree of variation. The physical components and their interfaces are de-coupled.

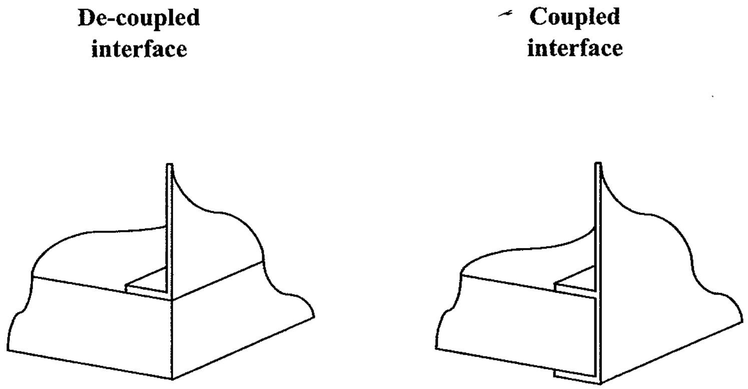

Figure 3: Versions of interface coupling [Ulrich, 1995, p. 423]

   Interfaces in modular product architectures are frequently specified according to industry standards or standard protocols, such as DIN/ISO or SCSI interfaces. The more software becomes important in products, the easier it is to define standardized interfaces.

   In *integral product architectures*, interfaces between physical components are coupled. When one physical component is changed, coupled interfaces require other physical components to be changed as well.

The ability to quickly provide customers with customized products can be a vital source of competitive advantage. Customers’ demand for product variety has increased considerably and will continue to increase in future [Pine, 1992]. In many markets customization may require the ability to “mass customize” products within a very short time. Customization or even mass customization is possible when the interfaces shared by components in a system are standardized and permit the configuration of a wide range of variations. Product components can be easily substituted. This is essentially what flexible and modular product architectures are about. On the other hand, integral product designs can result in enhanced functional solutions, because fewer compromises are required. Solutions can be tailored to solve highly complex problems.

Figure 4 summarizes goals that can be predominantly achieved either through integral or modular product architectures.

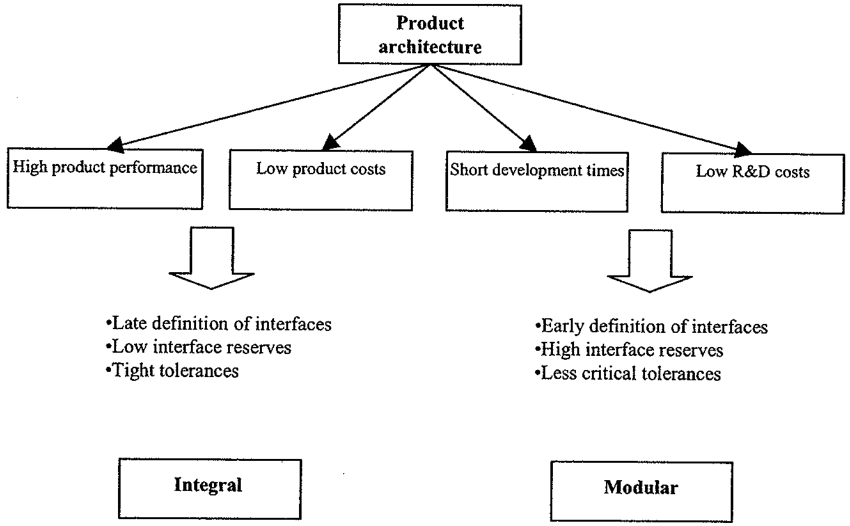

Figure 4: Consequences of fundamental R&D goals on modular and integral product architectures

2.2 From Architecture to Innovation

Change is inevitable in our business life. Throughout the life cycle of a (successful) product, change occurs due to technological upgrades, add-ons, adaptations to new environments, wear, consumption or flexibility of use [Ulrich, 1995]. In all of these cases, the changes can be more easily executed when the architecture of the product is modularized. Modularization introduces a "change hierarchy". In an HP printer, for example, a change in the exterior design does not affect other functions. But a change in the generic ink-jet technology affects most other modules. The ink-jet technology is at the heart of printers. With integral product architectures, changes in one single function can have an effect on a large number of other functions. When the lamps in an Audi change, the bumper will change as well. In 1997 Audi had more than 800 different bumper designs.

Besides the product architecture itself, the type of product innovation has a considerable impact on the ability to alter the product and the opportunity to cooperate with suppliers. *Autonomous innovations* in a modular environment can be pursued independently from other innovations, consequently, the product innovation can be done in a more decentralized manner than compared to product innovations of a systemic nature. *Systemic innovations*, most suited to integral designs, can only realize their full potential in combination with related, complementary innovations and should be organized in a more centralized manner [Chesbrough/Teece, 1996]. In essence, while autonomous product innovations can simultaneously be successfully developed with an independent supplier, systemic innovations require a tighter and more integrated organization of the innovation process, i.e. a very strong link between the firms involved in the innovation, or even strong links within an integrated enterprise.

One can identify several differences in three of the four main stages in a product development process – depending on whether a modular or integral product architecture has been chosen. The stages are: concept development, system-level design, detailed design, and product test and refinement. Product architecture "has implications for the effectiveness of approaches to the three development phases following concept development." [Ulrich, 1995, p. 434] Some differences have an impact on purchasing. In the *system-level design* stage, modular architecture is by comparison more demanding of the process than an integral architecture, because interface definition and the specification of standards will largely influence whether the modular architecture can be implemented successfully.

In the case of a modular architecture, the *detailed design* of each individual component can proceed almost independently and in parallel. Hence, every module supplier can work more or less independently from all other suppliers. Integral product architectures usually require a great deal of interaction between development activities and all parties involved in the development process for the entire product. Hence, it is necessary, that all component designers – whether in-house or external – "form a 'core team' and interact continually in order to analyze performance of the subsystem to which their component belongs and to manage changes required because of component interface coupling." [Ulrich, 1995, p. 435] *Product testing and refinement*, in the case of a modular architecture, is a "checking activity", whereas for the integral architecture it is a "tuning activity". If changes are necessary in the integral case, they are likely to affect numerous other components [Ulrich, 1995, p. 435].

The types and processes of product innovation lead us to the second generic construct – the external innovation task interface, i.e. the problem-solving interdependence. During the design of product architectures, companies' interest is mainly in technical and technological subjects. When putting together appropriate innovation task interfaces, however, firms have to focus even more on process and innovation management aspects.

3 External Innovation Task Interface

After the decision for a product architecture has been taken, i.e. after functional elements have been arranged and mapped to physical components and interfaces have been defined, the allocation of tasks to the people, departments and organizations involved in the innovation process must be tackled. The allocation goes either to the focal firm or to the supplier. This (external) task allocation will be looked at from two angles: the partitioning of design tasks between the focal firm and suppliers and the partitioning of designing/building tasks between these two actors.

3.1 Interfaces between Innovation Tasks

Von Hippel [1990] discusses the partitioning of an innovation (R&D) project into tasks and subtasks and their assignment to a number of organizational units – either within or across firm boundaries. We can find the latter situation when innovation tasks are divided between buying firms and their suppliers. Tasks can either be solely assigned to the buyer, or to the supplier, or the task network can cross firm boundaries.

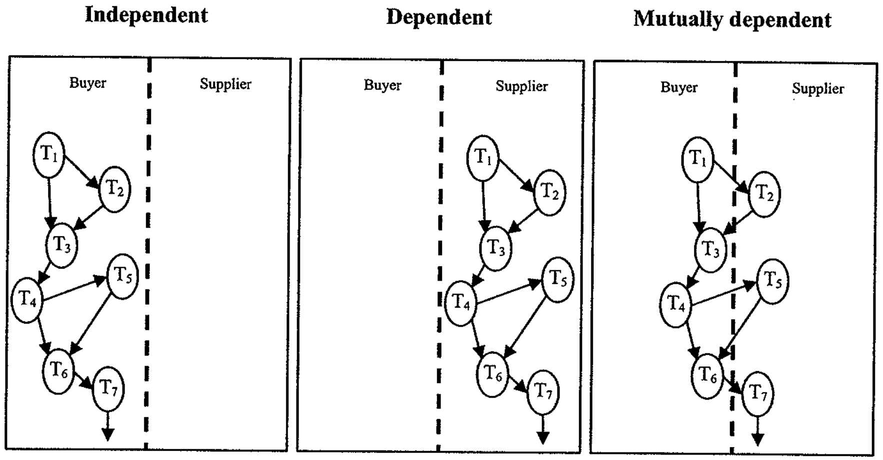

Figure 5: Innovation task network partitioning

Outputs of some tasks may be inputs to other tasks. In the case of cross-organizational task allocation, task coordination is, as a rule, more difficult, because R&D tasks are prone to opportunistic behavior.

Companies increasingly shift R&D tasks to other firms [Tao/Wu, 1997; Fritsch/Lukas, 2001]. When innovation tasks are allocated to suppliers, firms are likely to strive for a better utilization of their suppliers' know-how and a reduction or sharing of R&D costs. However, the required effort to coordinate the tasks might offset some of the benefits. If the focal firm is able to convince suppliers that interfaces will remain constant and that the product will be sold over a longer period, the suppliers will start investing in R&D for their modules. This is one of the best ways of reducing R&D expenditures. Compaq does not invest in R&D for hard disks or CPUs. But the company does keep the interfaces constant.

The interface between any two innovation tasks can be defined with respect to problem-solving interdependence among them, i.e. it is likely "that efforts to perform one of the tasks to specification will require related problem-solving in the other." [von Hippel, 1990, p. 409] Ceteris paribus, the cost of interrelated and partitioned innovation tasks will be lower, if they are arranged in a manner so that problem-solving interdependence among them is low [von Hippel, 1990].

If all innovation tasks are performed within a company's boundaries, task interfaces are *independent*. If the supplier takes over the R&D responsibility (system-level design, detailed design) problem solving is more *dependent*. The supplier might, at the very least, require functional specifications and the focal firm's requirements regarding handling of the product by the supplier. A typical example is the power supply of a notebook. The supplier might rely on clarifications or further details. We define *mutual dependence* as a third type of external task interface. Here, the actual responsibilities for task execution are split between the buyer and the supplier, as shown in Figure 5. Neither of the firms could complete a product innovation without the support of the other. The drive module of the SMART can be considered a typical example.

3.2 Design/build Task Interfaces

It is not sufficient to take interfaces between innovation tasks into consideration. Interfaces between design and build tasks are equally important, i.e. the interface between product design and process design. In the course of simultaneous engineering – within firm boundaries or with external participation – much has been written about enhanced efficiency due to the bridging of design and building responsibilities [e.g. O'Neal, 1993].

If a component should be produced by a supplier upon start of production, it is, on the one hand, advantageous to allocate the design responsibility for this component to the supplier. Design/build interaction for the component would be simplified. Partitioning tasks in such a way would, on the other hand, complicate the interaction with design activities of other components as performed within the focal firm. Companies must decide between a close proximity of design tasks, or a close proximity of design/build tasks.

If the design for component B is shifted from the firm that designs component A in conjunction with entire product, i.e. the Original Equipment Manufacturer OEM, to the firm that manufactures component B, i.e. the supplier, the design/build interface is improved. At the same time, the design interface between component A and component B is weaker [von Hippel, 1990].

The importance of these interdependencies ("Which interdependence is more important for the success of the product?") will determine the actual task partitioning.

When products are designed in-house and built in-house with materials sourced from suppliers, the design/build interface can be considered *independent*. Companies that design components themselves and outsource their manufacturing and assembly are faced with strong design interfaces, but weak design/build interfaces. If design is outsourced to suppliers as well, design interfaces are weak, however, the design/build interface is strong. In these two cases the tasks *depend* on external coordination. Strong, *mutual dependence* would occur when design as well as build tasks are divided among the OEM and its suppliers.

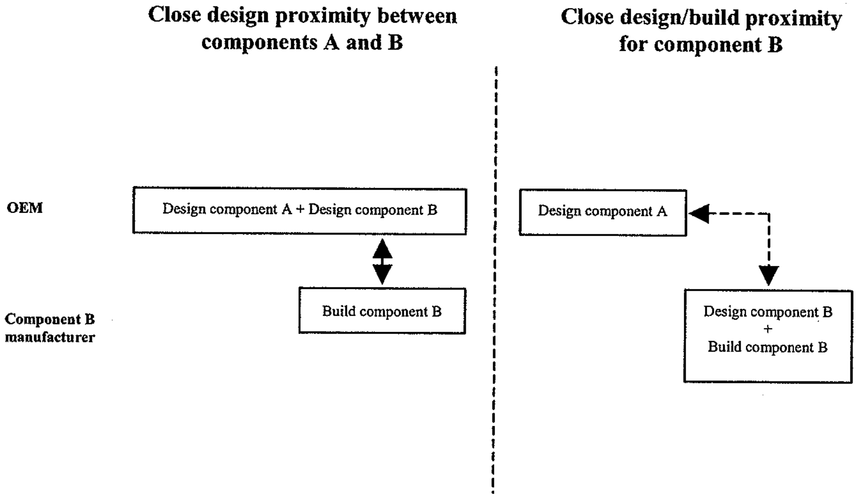

Figure 6: Design/build task partitioning
[von Hippel, 1990, p. 415]

4 Supplier Competence

Outsourcing possibilities always depend on the potential that the market is offering in terms of manufacturing resources, assembly and logistics capabilities as well as innovation and design capabilities on component or product level.

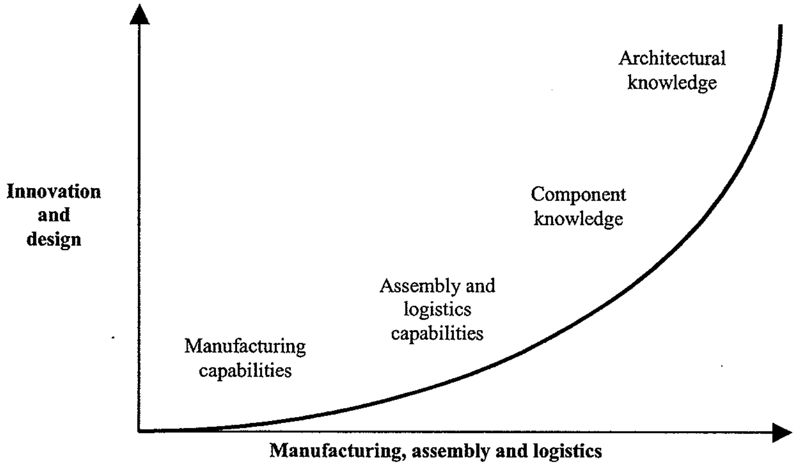

Figure 7: Potential supplier competencies

By exploiting core competencies and specific investments, suppliers might be able to economize on scope and scale. The buying firm as well as the supplier is then able to benefit from enhanced efficiency and effectiveness.

4.1 Operational Capabilities

Suppliers must possess at least some specific *manufacturing capabilities* in order to be able to produce and deliver even simple parts, components or products with the required standards of quality. These capabilities may include the ability to ramp up production rapidly, to respond quickly to customers' orders and to utilize economies of scale.

However, due to technological and environmental changes, maintaining and building up manufacturing capabilities is not risk-free. Semiconductor device manufacturers, for example, face large investment risks. These are derived from Gordon Moore's Law, which states that device complexity doubles about every 18 months. Feature size reduction, increased wafer diameter, increased chip size, ultra-clean processing, and defect reduction, among others, are manifestations that have a direct impact on the cost and quality of products, factory flexibility in responding to changing technology or business conditions, and on the timelines of product delivery to customers. Today a CPU manufacturing unit costs between one and two Billion US Dollars. It has to be financed in advance and nobody knows whether the products will bear the depreciation. During the crisis of 2001 Intel went ahead with large investments to be ready for the recovery after the crisis. After the previous crisis, Intel had lost a large market share to its main competitors because the company had not been ready for the recovery. Thus, chip manufacturers have to be independent of banks and need a very strong balance sheet to protect themselves from liquidity bottlenecks during the typical dramatic downturns in this industry.

The next parameter according to which a supplier's capabilities can be measured is the ability to manufacture not only parts, but to assemble more complex sub-assemblies. This often involves the coordination of sub-suppliers and the management of the upstream supply chain. These *assembly capabilities* need *logistics capabilities*. The latter materialize in concepts such as just-in-time or just-in-sequence delivery, or the ability for complex, expensive and manufactured-to-order products and kanban systems for mass products.

Another dimension must be added if operational capabilities are to be controlled on a global scale [Flaherty, 1986]. With concentration in many industries, firms become larger and more global. Hence, their suppliers should be capable of manufacturing, assembling and delivering products just-in-time and globally as well. Whenever the OEM globalizes, the suppliers should be able to globalize as well.

4.2 Technological Knowledge

Henderson and Clark [1990] distinguish between component knowledge and architectural knowledge – a classification that is indeed helpful for our purpose. These two types of knowledge explain why some suppliers are able to take on certain R&D responsibilities while others are not.

A component is a physically distinct portion of a product that represents a core design and performs a defined function [Clark, 1985]. Several components put together shape a product, such as an automobile. Some firms might be able to design and manufacture one component for a product, but not the product itself. All they require is R&D and design knowledge about the component they manufacture – *component knowledge*. Other firms might have sufficient knowledge about the entire product and assume more comprehensive responsibilities. To this very day car manufactures (OEM) still keep the architectural knowledge with which to design and assemble the final product – the car – in-house. From the entire car perspective, the only design and innovation responsibilities assigned to automotive suppliers are component responsibilities. From the perspective of selected portions of a car, such as the engine, OEMs even transfer the responsibility for architectural innovation to suppliers. Engine manufacturers for North American truck manufacturers, such as Freightliner or Paccar, are responsible for innovations around the engine while the truck manufacturers source engines as "black boxes".

Some companies already started using system suppliers a few years ago. But the start was difficult. In 1996, no supplier in the world could deliver a complete car door. Car doors are highly complex. They contain heating, loudspeakers, motors, air conditioning channels and air bags. Thus their interface is a complex one as well. When MCC set up its factory in Hambach, the single most important criterium for appointing suppliers was their willingness to become a system supplier. Not many suppliers passed this test.

If a firm in a supply chain possesses *architectural knowledge*, it has the ability to integrate and coordinate knowledge, innovation, capabilities, activities or products from other firms. When deciding on a sourcing concept, a crucial question is whether the focal firm or the supplier is in the best position to develop, maintain and contribute architectural knowledge. Above all, architectural knowledge requires "a different kind of organization and people with different skills" [Henderson/Clark, 1990, p. 281]. Larger, more advanced, innovative, and well-organized firms are more likely to possess architectural knowledge. Hence, only a limited number of (mostly large) suppliers with sufficient financial, human and technical resources will be able to contribute architectural knowledge to an outsourcing process. In future, SMEs will have more problems serving complex products. The supplier's organization and its employees must be able to work in cross-functional teams within the supplier's various companies and together with the sub-suppliers and customers of these companies.

Integrative knowledge is "in part a firm-level analogue to architectural knowledge" [Helfat/Raubitschek, 2000, p. 964]. Although codified knowledge is generally easier to coordinate across a supply chain, Helfat and Raubitschek propose and underline that integrative knowledge, i.e. architectural knowledge, "is required not only for coordination of tacit knowledge, but also for complex coordination of codified knowledge, within and across vertical chains." For example, an integral product architecture is difficult to codify.

There are good reasons for suppliers to specialize. Suppliers can build on manufacturing, assembly and logistics, component development or architectural knowledge. All of these specializations can occur on part, component, module or system level. It is necessary to point out, however, that some capabilities are necessary to build and maintain others [Morris/Ferguson, 1993]. This line of argument relates to the arguments regarding the design/build interface put forward in the previous chapter. As such, the capability to manufacture a component or module is often required for its development and design.

5 Supplier Relationship

For the purpose of this article we will elaborate on the characteristics of contrasting supplier relationships. It is not important, however, to what degree these relationships are different – only the fact, that they follow different rules. We will ground our discussion on three theories: Ian R. Macneil's relational contracting theory, Oliver E. Williamson's transaction cost theory, and Oliver D. Hart's incomplete contract theory.

5.1 Contractual Relationships

Relational contracting theory distinguishes between discrete and relational contractual relationships [Macneil, 1978 & 1980].

Discrete contractual relationships assume that all transactions between the contracting parties, both past and future, are independent of one another, involving a one-time granting of rights of disposal. Dwyer, Schurr, and Oh [1987] put forward one example which comes very close to a discrete contractual relationship: "A one-time purchase of unbranded gasoline out-of-town at an independent station paid for with cash …". With discrete contractual relationships, the individual contracting parties involved remain independent of one another, strive to enforce their interests emphatically, and can call on extensive financial and legal sanctions if contracts have to be enforced. Or they simply rely on the power of the free market as in the case of the gasoline. With simple, low-tech products, or commodities, spot market contracts may be advisable – provided there are enough suppliers in the market. Other examples are the purchase of property or consulting services, although these are already in the gray zone between one-time and ongoing business. The main goal here is to buy cheaply. Arm's-length buyer-supplier relationships are typical for discrete exchanges.

Relational contractual relationships differ mainly in the time and processes involved, the emphasis is on an on-going concern. Each transaction has a past and a future, and the transaction partners are involved in complex social relationships. Both sides set out what they will do and what they are to receive in return, openly, in advance and continuously. Conflicts are mostly resolved without resorting to the courts. Correctly understood, relational contracts provide the basis for ongoing partnerships or even strategic partnerships between customers and suppliers in today's supply management practice. The relationships involved are highly intensive and, above all, recurrent. Opportunistic behavior has no chance, since there is another opportunity in the future where the other party might fight back. Outsourcing of R&D inevitably leads to a relational contract, at least for the duration of the design phase. It is almost impossible to achieve the intended result without ambiguities and the design proceeds step by step – from milestone to milestone. There is usually no free market and price comparisons are very difficult to make.

5.2 Transaction Costs

Transaction cost theory adds another aspect to relational contracting theory, as it tries to combine legal with macro-economic and organizational theory [Williamson, 1975 & 1985]. Transactions occur when transaction objects such as goods, services and/or rights, pass from one transaction partner, the supplier, to another, the customer. Transaction costs arise when setting up, agreeing, monitoring and, if necessary, modifying transactions. They are governed by the specific investments involved in a transaction, the level of uncertainty and transaction frequency; and they are higher if decisions have to be made in an environment which is marked by a high level of uncertainty and complexity, or a small number of possible transaction partners.

The exchange of transaction objects between transaction partners follows specific organizational rules. Originally, the theory only considered two institutional arrangements: the market and the hierarchy. Hierarchy (vertical integration) was better than a market arrangement if factor specificity and uncertainty were important. But, as transaction cost theory progressed, this dichotomy faded, and it was suggested that relationships between independent firms could, under certain conditions, provide similar or even higher benefits than outright integration. Besides vertical integration, market arrangements (arm's-length) and hybrid arrangements (partnerships) are the two remaining institutional arrangements.

Transaction cost theory recommends using *market*-like forms of organization, that is, arm's-length supplier relationships, where specific investments and uncertainty are low and transactions less frequent. In such cases, measurability of quality should be high, whereas the goal congruence of the two parties is rather low [Ouchi, 1980].

Partnerships or strategic partnerships also aim at minimizing transaction costs, although in different situations. Relationships should be *hybrid*, where the specific investment and uncertainty levels involved are high and transactions are frequent. Partnerships or strategic partnerships can then help minimize transaction costs. Contrary to market arrangements, measurability of quality is generally low, whereas the goal congruence of the two parties should be high [Ouchi, 1980].

5.3 Completeness of Contracts

Incomplete contracts, that is, contracts which do not specify and regulate the subject matter down to the last detail, and leave much uncertain [Hart, 1988; Hart/Moore, 1988], are typical of agreements between strategic partners. The subject of the contract in partnership-like relationships is often complex or risky. Activities between a buying firm and its supplier, which cannot be specified in detail up-front, are characterized by high investments, high levels of technical and commercial risks, and highly uncertain outcomes – typical situations for incomplete contracts. The entire situation is somewhat 'fuzzy' at the time the two firms begin to team up. This is, for example, the case in many new joint product development projects. During the execution of the project, a good partner does not merely abide by the letter of the contract, but does whatever is necessary for the benefit of both parties. A survey among German and Swiss suppliers of R&D showed that four topics have to be managed when outsourcing R&D [Boutellier/Völker, 1997]:

- Specific targets to be achieved
- Milestones in the process
- Key persons (project leaders)
- Exit strategies (if one party wants to retreat from the project)

The incompleteness is dealt with through key persons and the exit strategy.

Trust plays an important role where incomplete contracts are concerned. The level of trust should be the level at which partners and strategic partners actually work together. Hence, trust matters more than mere written contracts. If trust resides in a long-term business relationship, the relationship is more likely to be mutually advantageous and hence successful [Morgan/Hunt, 1994]. As a rule, trust has a lot to do with being able to plan and predict, i.e. with predictability [Fukuyama, 1999]. In partnerships, and even more so in strategic partnerships, both parties should know how the other side is likely to behave in any given situation. If the two companies trust each other, they behave according to rules implicitly defined in a contract or explicitly assumed. Consequently, no major surprises should crop up.

In incomplete contract situations, suppliers might only be willing to make investments that have not been contractually specified in sufficient detail up-front, if their investment is secured through a partnership which is based on mutual trust. Such suppliers would adopt an active role above and beyond short-term contractual performance.

To summarize, when suppliers are willing to engage in extra-contractual investments to the benefit of the customer, the customer is better off with a small number of partners, instead of a larger number of suppliers at arm's-length. This tends to hold true for the purchase of more complex products and for complex inter-organizational processes. On the other hand, if suppliers cannot manage the quality of their production without exception, the focal firm needs several suppliers. For example, food retailers cannot rely on one apple producer in Europe, since apple crops can be ruined by hail, something the former does not have under his control.

6 Archetypical Sourcing Concepts

Based on the hitherto analyses and discussions, we are now able to provide definitions for four distinct sourcing concepts. We argue that the parameters which describe a sourcing concept must match in a balanced manner.

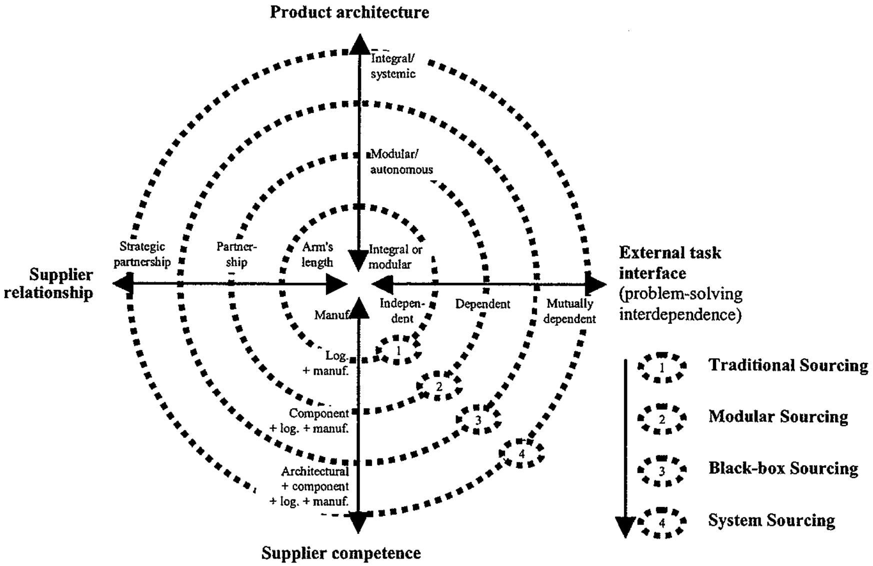

Figure 8: Archetypical sourcing concepts: matching, product architecture, task interface, supplier competence and supplier relationship

6.1 Traditional Sourcing (1)

In traditional sourcing situations – already understood in the name – the focal firm controls and carries out all R&D activities for the final product and, in a very "traditional" manner, only buys materials, parts or components from its suppliers. The materials, parts or components sourced are usually of lower complexity and they are frequently in the supplier's standard product portfolio, such as wiring for computers.

In this sourcing concept it does not matter whether the architecture of the final product is either integral or modular, because everything is done in-house. In the case of integral product designs, the complexity resides inside the firm boundaries. Also, the focal firm can solve problems independently, as all R&D activities and the assembly work for the final product are performed in-house. Only the manufacturing tasks for outsourced materials, parts or components reside with the supplier. From the buyer's perspective, traditional sourcing merely requires the supplier to have good manufacturing competencies. In situations with no design interfaces, problem-solving independence and non-critical supplier competencies, suppliers can be kept at arm's length and changed frequently, if this is favorable.

6.2 Modular Sourcing (2)

Firms strive to operate with low assets, reduced product costs, increased flexibility and swifter throughput times, i.e. customer responsiveness. The modular sourcing concept can help to support these goals. This is why modular sourcing has become very popular in today's business world. Although, R&D activities for the final product are still under the control of and performed by the focal firms, the firms source not only simple parts but often highly complex and comprehensive "modules" from their suppliers. The modules are assembled from parts and materials that the module supplier has previously sourced from sub-suppliers. Due to the higher value of modules, they are often delivered just-in-time or just-in-sequence to the production or assembly facility of the final product.

In order to be able to outsource complex modules, the architecture of the final product has to be modular. Although, R&D is done in-house, the task interface with the supplier is somewhat dependent, because the supplier is responsible for more complex assembly and manufacturing tasks. And more complex tasks, such as the coordination of manufacturing master plans or delivery schedules, cause some dependence. Suppliers must have strong manufacturing as well as assembly and logistics capabilities. Complex modules, operational supplier integration and some problem-solving dependence can be best managed with a partnership-like supplier relationship.

6.3 Black-box Sourcing (3)

On an even higher outsourcing level, suppliers do more than assume the responsibility to manufacture, assemble and deliver complex modules. In effect, they develop and design a module – which does not have to be a standard item in the supplier's product portfolio. The product is designed according to specifications of the functional requirements and the interfaces within the final product. Examples are a specific hard-disk drive for a computer, where the computer manufacturer does not dive into the electronics and electro-mechanics of the parts that make up the hard-disk drive. A large office building can be broken up into 20 to 30 crafts and each of them is defined by the function and the interfaces with other crafts. The ins and outs of the building's heating, for example, must be designed by the supplier. Matters such as the maximum energy consumption, heat values or the radiator locations, will be defined by the architect or the construction engineer.

Black-box sourcing requires modular product architectures and autonomous innovation. Each party must be able to design its contribution to the whole without massive interaction. Some collaboration during the R&D phase is still necessary. The interface of the tasks with the suppliers can be classified as 'dependent' as R&D is done by the suppliers after receiving specification of the module. Even after the best specifications, the supplier usually has to obtain more detailed information from the OEM and has to have problems clarified. Since the suppliers also perform complex assembly and manufacturing tasks in order to manufacture the module, they need strong manufacturing, assembly and logistics competencies. The suppliers' R&D tasks focus on the module, not on the entire product. Hence, the suppliers must have component knowledge, while the architectural knowledge is located in the focal firm. An even stronger form of partnership is therefore required in black-box sourcing situations.

6.4 System Sourcing (4)

Last but not least, the most challenging sourcing concept, system sourcing, can be defined as the joint (buying and supplying firms) development of complex modules which compose a final product and which are sourced from suppliers. Take the braking system of an automobile. The braking system (including ABS) is a complex module that utilizes mechanical, hydraulic, electro-mechanical and electronic technologies and affects and is affected by the car's entire layout, e.g. the chassis.

System sourcing is extremely difficult to manage, because the product architecture is integral and the innovation is of a systemic nature. In solving problems, the OEM and the supplier strongly depend on each other. Frequent and open communication is imperative. Some R&D is done by suppliers without prior and detailed specification by buyers. The comprehensive R&D tasks and complex assembly and manufacturing tasks of the supplier not only require strong competence in manufacturing and logistics, but also strong component knowledge and architectural knowledge. The supplier needs to understand the particulars of the final product. Only strategic partnerships will result in successful project execution.

7 Management Implications and Outlook

Based on the analyses and discussions presented in this article, several implications for supply management and R&D can be outlined.

First, firms should thoroughly and in advance *evaluate the four constructs* – product architecture, external task interface, supplier competence and supplier relationship – in the sense of a contingency approach. Only if they understand these constructs and if they *align them with the sourcing concept*, can they fully exploit the outsourcing potential. A mismatch might result in a high risk for the buyer and the supplier. For example, if the supplier does not possess the development know-how – whether component or architectural – to assume the R&D responsibility under black-box or system sourcing conditions, the OEM is better off sourcing on a lower level, i.e. through modular or traditional sourcing, and assume all R&D responsibilities. System sourcing, and to a lesser degree also black-box and modular sourcing, have to be associated with partnership-like supplier relationships. Partnerships and strategic partnerships are difficult to manage and require a substantial amount of financial and management resources [Wagner/Boutellier, 2002]. If the focal firm does not have the necessary skills to build and manage such supplier relationships, system sourcing, black-box sourcing and even modular sourcing will often not be successful.

Second, on an industry level we observed, that the sourcing concepts of traditional, modular, black-box and system sourcing are *of importance to managers from all industries*. Table 1 provides a few examples. Time and again the automotive and computer industries lead, but other industries are following this trend.

	Automotive	**Computer**	**Construction**	**Machinery**
Traditional Sourcing (1)	Battery	Cables	Ground excavation	Ball bearings
Modular sourcing (2)	Door	Case (e.g. Macintosh)	Bare brickwork	Metal frame
Black-box sourcing (3)	Radio	Hard disc drive	Elevator	Application specific electro motor
System sourcing (4)	Breaking system	Operating system (for specific application)	Fire protection system	Plastic body of drilling machine

Table 1: Examples for sourcing concepts from different industries

Finally, many firms have increasingly *favored "buy" over "make"*, hence they try to outsource manufacturing as well as R&D tasks to suppliers.

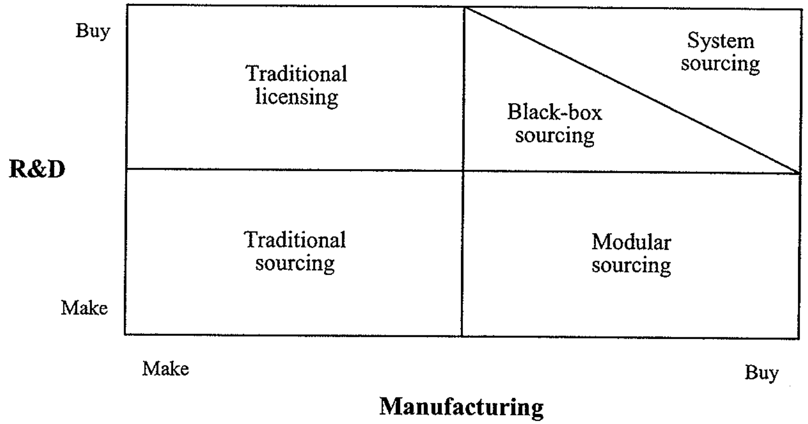

Figure 9: Sourcing concepts from the make-or-buy perspective

They have increasingly recognized that their suppliers' manufacturing and R&D competencies are vital and that traditional sourcing concepts should no longer be the predominant mode of value creation. If firms consider R&D as well as manufacturing as their own core competence, they would source traditionally. Supported by the increase in complexity, miniaturization and globalization, firms source in modular, black-box and system modes instead. Traditional licensing does not mean buying of materials, parts or components, but buying of R&D. This is the case, for example, in the pharmaceutical or biotech industries, or when firms buy the design of furniture and manufacture the furniture themselves.

8 Literature

[Appelbaum, 1997]
Appelbaum, Steven H.: Socio-technical systems theory: An invention strategy for organizational development, in: Management Decision, Vol. 35, No. 6, pp. 452-463, 1997

[Arnold, 1996]
Arnold, Ulli: Sourcing-Konzepte, in: Kern, Werner/Schröder, Hans-Horst/Weber, Jürgen (eds.): Handwörterbuch der Produktionswirtschaft, 2nd ed., Stuttgart: Schäffer-Poeschel, col. 1861-1874, 1996

[Barney, 1999]
Barney, Jay B.: How a firm's capabilities affect boundary decisions, in: Sloan Management Review, Vol. 40, No. 3, pp. 137-146, Spring 1999

[Boutellier/Völker, 1997]
Boutellier, Roman & Völker, Rainer: Erfolg durch innovative Produkte, München: Carl Hanser Verlag, 1997

[Çetinkaya/Lee, 2000]
Çetinkaya, Sila & Lee, Chung-Yee: Stock replenishment and shipment scheduling for vendor-managed inventory systems, in: Management Science, Vol. 46, No. 2, pp. 217-232, February 2000

[Chapman/Carter, 1990]
Chapman, Stephen N. & Carter, Phillip L.: Supplier/customer inventory relationships under just-in-time, in: Decision Sciences, Vol. 21, No. 1, pp. 35-51, Winter 1990

[Chesbrough/Teece, 1996]
Chesbrough, Henry & Teece, David J.: When is virtual virtuous? Organizing for innovation, in: Harvard Business Review, Vol. 74, No. 1, pp. 65-73, January-February 1996

[Clark, 1985]
Clark, Kim B.: The interaction of design hierarchies and market concepts in technological evolution, in: Research Policy, Vol. 14, No. 5, pp. 235-251, October 1985

[Cousins, 1999]
Cousins, Paul D.: Supply base rationalization: Myth or reality?, in: European Journal of Purchasing & Supply Management, Vol. 5, No. 3/4, pp. 143-155, September/December 1999

[Dwyer/Schurr/Oh, 1987]
Dwyer, F. Robert/Schurr, Paul H./Oh, Sejo: Developing buyer-supplier relationships, in: Journal of Marketing, Vol. 51, No. 2, pp. 11-27, April 1987

[Eßig, 2000]
Eßig, Michael: Purchasing consortia as symbiotic relationships: Developing the concept of "consortium sourcing", in: European Journal of Purchasing & Supply Management, Vol. 6, No. 1, pp. 13-22, March 2000

[Flaherty, 1986]
Flaherty, M. Therese: Coordinating international manufacturing and technology, in: Porter, Michael E. (ed.): Competition in global industries, Boston: Harvard Business School Press, pp. 83-109, 1986

[Frear/Metcalf/Alguire, 1992]
Frear, Carl R./Metcalf, Lynn E./Alguire, Mary S.: Offshore sourcing: Its nature and scope, in: International Journal of Purchasing and Materials Management, Vol. 28, No. 3, pp. 2-11, Summer 1992

[Fritsch/Lukas, 2001]
Fritsch, Michael & Lukas, Rolf: Who cooperates on R&D?, in: Research Policy, Vol. 30, No. 2, pp. 297-312, February 2001

[Fukuyama, 1999]
Fukuyama, Francis: The great disruption: Human nature and the reconstitution of social order, New York: Simon & Schuster, 1999

[Grossman/Hart, 1986]
Grossman, Sanford J. & Hart, Oliver D.: The costs and benefits of ownership: A theory of vertical and lateral integration, in: Journal of Political Economy, Vol. 94, No. 4, pp. 691-719, August 1986

[Hart, 1988]
Hart, Oliver D.: Incomplete contracts and the theory of the firm, in: Journal of Law, Economics and Organization, Vol. 4, No. 1, pp. 119-139, Spring 1988

[Hart/Moore, 1988]
Hart, Oliver D. & Moore, John: Incomplete contracts and renegotiation, in: Econometrica, Vol. 56, No. 4, pp. 755-785, July 1988

[Helfat/Raubitschek, 2000]
Helfat, Constance E. & Raubitschek, Ruth S.: Product sequencing: Co-evolution of knowledge, capabilities, and products, in: Strategic Management Journal, Vol. 21, No. 10-11, pp. 961-679, October-November 2000

[Henderson/Clark, 1990]
Henderson, Rebecca M. & Clark, Kim B.: Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms, in: Administrative Science Quarterly, Vol. 35, No. 1, pp. 9-30, March 1990

[Hendrick, 1997]
Hendrick, Thomas E.: Purchasing consortiums: Horizontal alliances among firms buying common goods and services, Tempe: Center for Advanced Purchasing Studies (CAPS), 1997

[Homburg, 1995]
Homburg, Christian: Single Sourcing, Double Sourcing, Multiple Sourcing … ?, in: ZfB – Zeitschrift für Betriebswirtschaft, Vol. 65, No. 8, pp. 813-834, August 1995

[Hsuan, 1999]
Hsuan, Juliana: Impact of supplier-buyer relationships on modularization in new product development, in: European Journal of Purchasing & Supply Management, Vol. 5, No. 3/4, pp. 197-209, September/December 1999

[Lamming, 1993]
Lamming, Richard: Beyond partnership: Strategies for innovation and lean supply, Hemel Hempstead: Prentice Hall International (UK) Ltd., 1993

[Macneil, 1978]
Macneil, Ian R.: Contracts: adjustment of long-term economic relations under classical, neoclassical and relational contract law, in: Northwestern University Law Review, Vol. 72, No. 6, pp. 854-905, 1978

[Macneil, 1980]
Macneil, Ian R.: The new social contract: An inquiry into modern contractual relations, New Haven: Yale University Press, 1980

[Morgan/Hunt, 1994]
Morgan, Robert M. & Hunt, Shelby D.: The commitment-trust theory of relationship marketing, in: Journal of Marketing, Vol. 58, No. 3, pp. 20-38, July 1994

[Morris/Ferguson, 1993]
Morris, Charles R. & Ferguson, Charles H.: How architecture wins technology wars, in: Harvard Business Review, Vol. 71, No. 2, pp. 86-96, March-April 1993

[O'Neal, 1993]
O'Neal, Charles: Concurrent engineering with early supplier involvement: A cross functional challenge, in: International Journal of Purchasing and Materials Management, Vol. 29, No. 2, pp. 3-9, Spring 1993

[Ouchi, 1980]
Ouchi, William G.: Markets, bureaucracies, and clans, in: Administrative Science Quarterly, Vol. 25, No. 1, pp. 129-141, March 1980

[Petersen/Frayer/Scannell, 2000]
Petersen, Kenneth J./Frayer, David J./Scannell, Thomas V.: An empirical investigation of global sourcing strategy effectiveness, in: The Journal of Supply Chain Management, Vol. 36, No. 2, pp. 29-38, Spring 2000

[Pine, 1992]
Pine, B. Joseph II: Mass customization: The new frontier in business competition, Boston: Harvard Business School Press, 1992

[Prahalad/Hamel, 1990]
Prahalad, C. K. & Hamel, Gary: The core competence of the corporation, in: Harvard Business Review, Vol. 68, No. 3, pp. 79-91, May-June 1990

[Quinn/Hilmer, 1995]
Quinn, James B. & Hilmer, Frederick G.: Strategic outsourcing, in: The McKinsey Quarterly, Vol. 32, No. 1, pp. 48–70, 1995

[Robertson/Ulrich, 1998]
Robertson, David & Ulrich, Karl T.: Planning for product platforms, in: Sloan Management Review, Vol. 39, No. 4, pp. 19-31, Summer 1998

[Simon, 1996]
Simon, Herbert A.: The science of the artificial, 3rd ed., Cambridge, MA: MIT Press, 1996

[Sobrero & Roberts, 2002]
Sobrero, Maurizio & Roberts, Edward B.: Strategic management of supplier-manufacturer relations in new product development, in: Research Policy, Vol. 31, No. 1, pp. 159-182, January 2002

[Swift, 1995]
Swift, Cathy Owens: Preferences for single sourcing and supplier selection criteria, in: Journal of Business Research, Vol. 32, No. 2, pp. 105-111, February 1995

[Tao/Wu, 1997]
Tao, Zhigang & Wu, Changqi: On the organization of cooperative research and development: theory and evidence, in: International Journal of Industrial Organization, Vol. 15, No. 5, pp. 573-596, August 1997

[Ulrich, 1995]
Ulrich, Karl T.: The role of product architecture in the manufacturing firm, in: Research Policy, Vol. 24, No. 3, pp. 419-440, May 1995

[Von Hippel, 1990]
Von Hippel, Eric: Task partitioning: an innovation process variable, in: Research Policy, Vol. 19, No. 5, pp. 407-418, October 1990

[Wagner/Boutellier, 2002]
Wagner, Stephan M. & Boutellier, Roman: Capabilities for managing a portfolio of supplier relationships, in: Business Horizons, Vol. 45, No. 6, pp. 79-88, November-December 2002

[Williamson, 1975]
Williamson, Oliver E.: Markets and hierarchies, analysis and antitrust implications, New York: The Free Press, 1975

[Williamson, 1985]
Williamson, Oliver E.: The economic institutions of capitalism, New York: The Free Press, 1985

[Womack/Jones/Roos, 1990]
Womack, James/Jones, Daniel/Roos, Daniel: The machine that changed the world, New York: Rawson Associates, 1990

Hubert Österle · Robert Winter
Herausgeber

Business Engineering

Auf dem Weg zum Unternehmen des Informationszeitalters

Zweite, vollständig neu bearbeitete
und erweiterte Auflage

Mit 106 Abbildungen

Springer

Prof. Dr. Hubert Österle
Prof. Dr. Robert Winter
Universität St. Gallen
Institut für Wirtschaftsinformatik
Müller-Friedberg-Straße 8
CH-9000 St. Gallen
www.iwi.unisg.ch

ISSN 1616-0002
ISBN 3-540-00049-6 Springer-Verlag Berlin Heidelberg New York
ISBN 3-540-67258-3 1. Aufl. Springer-Verlag Berlin Heidelberg New York

Bibliografische Information Der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.ddb.de> abrufbar.

Dieses Werk ist urheberrechtlich geschützt. Die dadurch begründeten Rechte, insbesondere die der Übersetzung, des Nachdrucks, des Vortrags, der Entnahme von Abbildungen und Tabellen, der Funksendung, der Mikroverfilmung oder der Vervielfältigung auf anderen Wegen und der Speicherung in Datenverarbeitungsanlagen, bleiben, auch bei nur auszugsweiser Verwertung, vorbehalten. Eine Vervielfältigung dieses Werkes oder von Teilen dieses Werkes ist auch im Einzelfall nur in den Grenzen der gesetzlichen Bestimmungen des Urheberrechtsgesetzes der Bundesrepublik Deutschland vom 9. September 1965 in der jeweils geltenden Fassung zulässig. Sie ist grundsätzlich vergütungspflichtig. Zuwiderhandlungen unterliegen den Strafbestimmungen des Urheberrechtsgesetzes.

Springer-Verlag Berlin Heidelberg New York
ein Unternehmen der BertelsmannSpringer Science+Business Media GmbH

http://www.springer.de

© Springer-Verlag Berlin Heidelberg 2000, 2003

Printed in Germany

Die Wiedergabe von Gebrauchsnamen, Handelsnamen, Warenbezeichnungen usw. in diesem Werk berechtigt auch ohne besondere Kennzeichnung nicht zu der Annahme, dass solche Namen im Sinne der Warenzeichen- und Markenschutz-Gesetzgebung als frei zu betrachten wären und daher von jedermann benutzt werden dürften.

SPIN 10895634 42/3130/DK – 5 4 3 2 1 0 – Gedruckt auf säurefreiem Papier