Virtual Supply Chains and Their Enemies: From Static Object Architecture to Dynamic Regulation

Virtual supply chains are increasingly popular because they offer a company greater flexibility than the alternatives. Although it may not be difficult to design and implement such a chain, there are several natural organizational phenomena that over time render the supply chain less virtual. We trace the conceptual origins of virtual supply chain architecture to object orientation in software and hardware design, and use this information to suggest means for dynamic regulation of supply chains that increases their chance of remaining virtual by militating against the 'organizational enemies' of virtuality.

Introduction

Supply chains are of strategic importance to firms in the modern global business environment (Christopher, 1998). They come in all shapes and forms with architecture that is presumably designed for best strategic fit (Chandler, 1962). One popular way to characterize them is on a continuum ranging from the highly integrated architecture of a firm that produces all of its key components to a market-based architecture in which goods and services are exchanged on a transactional arm’s-length basis. Evolution of computer technology and generally accepted standards has resulted in a market-based form that evolves even further, to the point that the terms ‘virtual organization’ or ‘virtual supply chain’ are increasingly used (Chandrashekar & Schary, 1999; Frigant & Talbot, 2005; Hagel, 2002; Hoogeweezen et al., 1999; Rahman & Bhattachryya, 2002; van Hoek, 1998; Walker, 2006; Watson et al., 2004).

Each form has its advantages and shortcomings, and there is elaborate literature on selecting and building a supply chain with the right architecture to support a specific corporate strategy in a given context. It is not the purpose of this paper to comprehensively review this literature, but we include a summary in Table 1. The choice of the right strategy is dependent on characteristics of the environment and on the business model adopted by the firm (Hagel, 2002; Lajili & Mahoney, 2006; Peck & Juttner, 2000; Qingyu et al., 2006; Shi & Gregory, 2005). For example, in environments characterized by high uncertainty, integration leads to lower risks and transaction costs (Blois, 1972; Mahoney, 1992). A company in a more stable and technologically mature business may want to focus its strategy on branding and distribution, acquiring products flexibly from a...
wide array of suppliers (Sturgeon, 2002; van Hoek & Weken, 1998). Many companies adopt a hybrid architecture, using different strategies in different parts of their business (Boddy et al., 2000; Hon et al., 2000; IBM, 2007; Lau & Yam, 2005; Parmigiani, 2003).

As illustrated in Table 1, there is extensive knowledge on properly architecting the supply chain, given corporate strategy and environmental constraints. There is an equally impressive body of literature on the difficulties encountered in implementing the chosen architecture (Anon., 2005b, 2006; Bask & Juga, 2001; Boddy et al., 2000; Christopher, 1998; Dekkers & Van Luttervelt, 2006; Doran, 2005; Graman & Magazine, 2006; Holweg et al., 2005; Cousineau et al., 2004; Moller, 2005; Williamson, 2005). But there is a paucity of research on how to maintain architecture over time, once it is implemented and faced with the challenges of withstanding the winds of organizational and environmental dynamics. This is the subject of this paper, focusing particularly on the challenges of maintaining supply chain architecture close to the virtual end of the continuum.

Indeed, emergence of virtual supply chain concepts was encouraged not only by the development of communication and information processing technology that make it possible, but also by ideas about product design in some key industrial sectors, particularly computing and electronics, centered around the notion of 'object-oriented architecture' (Baldwin & Clark, 1997). Object orientation is a set of design principles (Romme, 2003; Romme & Endenburg, 2006) for creating complex systems as loosely coupled assemblies of autonomous subsystems or modules that each can be designed and manufactured independently of each other and with only minimal reference to the whole, and which in turn can be further decomposed so that the process of hierarchical decomposition continues until a manageable level of complexity is reached. At each level the designer need not know anything about the lower level subsystems, except how to interface with them and get them to perform their function. They are the proverbial 'black boxes', or in the object orientation parlance, they are encapsulated. In principle it should be possible to substitute one module for another without affecting the performance of the system as a whole, provided that the two modules respect the same interface conventions and perform the same function.

Object orientation may often play the role of a leading design principle. In organization design, an example of such an approach is demonstrated by component business modeling, a method conceived by IBM Global Business Services. Component business modeling aims to model the company as a set of loosely coupled components defined by their business purposes, model of governance, activities performed, resources owned, and business services provided and received (Pohle et al., 2004a). The method allows firms to evaluate their goals and strategies and to take full advantage of internal and external specialization.

In a supply chain context object orientation often drives the architecture of the entire supply chain. For example, it is natural that industries with object-oriented products impose the same philosophy on their supply chain, favoring commoditization of subassemblies (Hagel, 2002; Hon et al., 2000; Magretta, 1998) and arm’s-length supplier relationships, usually mediated by impersonal computers (Watson et al., 2004; Welker & Vries, 2005). Thus object orientation as a design approach has implicitly carried over to the area of managing supply chains, and has given rise to the virtual supply chain.

The problem that is further explored in this paper is that there are limits to the transferability of ideas and design principles rooted

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Advantages and Shortcomings of Different Supply Chain Architectures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional Characteristic</strong></td>
<td><strong>Supply Chain Architecture</strong></td>
</tr>
<tr>
<td>Alignment of goals and operations</td>
<td>+</td>
</tr>
<tr>
<td>Control over inputs and transactions</td>
<td>++</td>
</tr>
<tr>
<td>Economics of specialization</td>
<td>-</td>
</tr>
<tr>
<td>Transaction cost economics</td>
<td>+</td>
</tr>
<tr>
<td>Management cost economics</td>
<td>-</td>
</tr>
<tr>
<td>Simplification of transactions</td>
<td>-</td>
</tr>
<tr>
<td>Organizational flexibility</td>
<td>--</td>
</tr>
<tr>
<td>Knowledge transfer and sharing</td>
<td>+</td>
</tr>
<tr>
<td>Risk reduction</td>
<td>+</td>
</tr>
</tbody>
</table>
in object-oriented architecture. Products are inanimate, and any competent manufacturing process will produce identical exemplars by the thousands. But supply chains are living organisms, likely to continually change. What may start as a supply chain with a virtual architecture may evolve over time towards a more integrated form. The problem that we will explore is how to apply the object-oriented design principles to virtual supply chain design to avoid that unwanted evolution towards more integrated forms. Indeed, as we will argue in this paper, there are many natural organizational processes that militate against the integrity of virtual supply chains. We call them ‘enemies’, inspired by Churchman (1979). The principles of object-oriented product architecture are static in nature. Supply chains are dynamic constructs and thus the object-oriented principles need to be revisited and adapted to the dynamic nature of virtual supply chains.

The paper begins by setting the stage for virtual supply chain considerations and introducing an imaginary company, Xybelle, whose supply chain we will be examining further. The following section explores the organizational enemies of virtual supply chains, as illustrated by Xybelle’s case. Object-oriented architecture is then introduced as a method for dynamic regulation of virtual supply chains. The paper concludes with a translation of object-oriented principles into guidelines for organization design and an illustration of merits of object orientation in a battle against virtual supply chain enemies.

Evaluating Supply Chains

A company’s choice of its organizational structure is a fundamental step towards building a supply chain. This choice experiences tensions from two opposing trends, one towards a market-based transactional model and the other towards a model of close collaboration and supplier integration. This highly polarized view seems to be a result of an unresolved dispute about the nature of the firm, initiated by Coase’s seminal article (1937) and elaborated on by Williamson (1971, 1973, 1979, 1985, 1993, 1996) and numerous other theorists (Alchian & Demsetz, 1972; Demsetz, 1968, 1988; Klein et al., 1978). In one of his last works, Drucker (1999) points out that a modern firm can no longer be thought of in terms of the span of control; present-day managers are increasingly called upon to produce results with resources over which they have no hierarchical control, for example, in project teams or in supply chains. Nevertheless, the conventional view of a firm is akin to an army that has a tightly structured control hierarchy that is difficult to root out.

We created a hypothetical and highly simplified case of a company named Xybelle that sells a branded line of radio clocks with novelty features, mostly in external appearance, for example, a radio clock with a statuette of a fantasy character glued on top of it, destined for children’s bedrooms. The company sells to a niche. Its strategy is to purchase all elements in the open market, globally, from a wide and ever-changing set of suppliers, driving for the lowest possible cost. The assembly of the elements is manual, with a few simple tools and some glue, farmed out in small batches to local inhabitants who see this as an opportunity to earn some extra income on weekends or during after-work hours. The company uses a prototypical virtual supply chain, owning no specialized assets, relying on a variety of suppliers in the global marketplace to ensure the variety of its own products and communicating with the suppliers through electronic channels (email and fax). Xybelle is organized into the following departments: purchasing, production, sales and marketing, finance and administration, all headed by a president. There is no development department, although the company produces many different products, all of them in smallish batches and marketed as limited editions. The R&D function results from coordination between the purchasing department, which scouts the global market for novelty items that could be integrated into new products (e.g., new statuettes), and the sales and marketing department, which has a feel for fashion and other consumer trends. It helps that the managers of the two departments are twin brother and sister, and that the president is their uncle.

Xybelle’s supply chain architectures can be evaluated based on four key characteristics of transactions that arise within it: cost, risk, asset specificity, and frequency.

There are four kinds of costs related to transactions (Dyer, 2000): search, cost-the cost of gathering information, supplier identification, and evaluation; contracting cost-the cost of negotiating and writing a contract; monitoring cost-the cost associated with monitoring the fulfillment of a contract; and enforcement cost-which is associated with ex-post bargaining and conflict resolution.

Xybelle has a low cost of acquiring the radio clock components, using for that highly developed business-to-business electronic commerce boards. It buys only components that fit its rather broad range of specifications on weight and physical dimensions, and it has a policy of buying only products that have third-party certification in terms of safety, reliability, and quality. It does not acquire from major manufacturers because it attempts to keep the cost down, but it checks the references of the suppliers and requires some kind of bank guarantees on deliveries. It maintains a diverse group of suppliers, with frequent additions and substitutions. Every purchase transaction is separate, although the same suppliers may be used repetitively. The company extensively uses electronic channels to communicate with its suppliers. Even though no form of electronic data interchange is available, Xybelle keeps search and monitoring costs down.
avoids long-term supply relationships on the grounds that what it will gain in lower component costs, it may lose in flexibility and added management complexity. It also avoids a warranty relationship for after-sales service, and sells its products with a 'satisfied or we will replace it with a comparable (but not identical) product' policy.

Buying the novelty components is more haphazard, but also a lot more fun for the purchasing manager and her team, who go to industrial and art exhibitions all over the world to scout for items available for integration into Xybelle’s product line. They favor less developed countries where the cost of acquisition is low and artistic variety high, but they cannot avoid relatively high transaction costs. Indeed, it is hard to obtain information about suppliers and difficult to assess their capacity to produce their items consistently, on time, and in sufficient quantity. Many of the more talented producers with the aesthetically most appealing items do not have the capacity to get their act together for a larger run, or are simply not trustworthy. Xybelle’s team has to navigate through these complexities with the help of a lot of intuition. They are also helped by two corporate policies: they will not purchase from any one supplier more than a very small portion of the total, reducing thus the disruptive effects of a problematic delivery, and they promote to their sales channel a general concept of a product line with guaranteed functionality and price range rather than specific product characteristics, allowing thus for last-minute substitutions in case of need.

Williamson (1973, 1979) assumes risk resulting from uncertainty to be a critical factor affecting transactions and identifies two types of uncertainty: exogenous and behavioral. Exogenous uncertainty stems from the impossibility of accurately predicting future states of the environment and behavioral uncertainty results from the impossibility of hedging against 'self-interest seeking with guile' of the contracting parties.

Xybelle does business in the third world, but not in places where the institutional and business environments are unstable. For the purchasing of the radio clock components it never encounters any significant problems, except an occasional lateness of delivery that it factors into its production scheduling. A significant proportion of purchases of the novelty components go sour in one way or another, but thanks to the good intuition of the purchasing team it is kept within the bounds of about 5%. This is largely compensated by the low cost of acquiring fine products, and is considered to be an acceptable cost of doing business.

**Asset specificity** develops when the transacting parties make investments that are not reusable in other transactions, thus creating sunk costs (Williamson, 1996). What is more, writing and negotiating contracts for transactions which are highly asset specific and costly (Williamson, 1981).

Xybelle shies away from any asset specificity. It is frequently tempting to have the novelty item modified to produce a more attractive product - for example, having the eye of the figurine light up when the alarm goes off - but the company resists and limits its purchases to that which can be integrated into its products as originally conceived.

Irregularities in the frequency when a transaction is renewed are induced by fluctuations either on the demand or supply side. According to Hon et al. (2000, p. 23) 'even when the customer demand is relatively stable, institutional and random factors tend to make the demand expressed at each subsequent stage upstream in the supply chain more cyclical and extreme in variation', a phenomenon otherwise known as the bullwhip effect (Lee et al., 1997). Irregularities in transaction frequency apply to the supply side as well, especially when the number of suppliers on the market is large (Dobriša et al., 1998).

Xybelle experiences significant fluctuations on the demand side, in part similar to any fashion-driven business, in part because of random shifts in customer moods, but mostly because of the rapid and continuous reconfiguration of its distribution channels caught up in the turmoil of consolidations and cross-border mergers that are characteristic of the global marketplace. But with no significant fixed assets and a flexible production workforce, the company is agile, capable of expanding and contracting with demand. The supply chain is short and dependent on markets with abundant supply. Furthermore, the value added produced by the firm stems from its creative capabilities and the distribution system, the cost of supplies and manufacturing labor being kept at a relatively low proportion of the total. Therefore, the firm is capable of absorbing some fluctuation in direct costs, such as those that may occasionally arise from a shortage in transportation means.

This is the portrait of Xybelle as we start our journey. The company has a near-perfect virtual supply chain, and this is clearly a critical feature of its strategy. This is what allows it to function with low capital outlays and to remain flexible, protecting itself from the ups and downs of the market. As we shall see in the next section, however, it takes a lot of discipline to defend this kind of supply chain from the myriad organizational enemies that are ready to attack and budge it in the direction of higher integration.

**Organizational Enemies of Virtual Supply Chains**

There was a pleasant feel to the kind of hospitality shown in the third world countries where the purchasing manager did her shopping for the novelty items. Suppliers frequently invited her to sumptuous meals and some offered junkets on the pretext that she...
should visit the remote places where the items were made. Somehow production tended to be concentrated around beautiful beaches and mountain retreats; she was never invited to any ordinary, poverty-filled places. She accepted a few such invitations to kill time during the weekends that she had to spend away from home. But she did not feel good about it, detecting a touch of corruption in those practices, and imposed on herself a strict code of conduct that excluded socializing with suppliers. Later, when her staff grew, she noticed that a young buyer tended to purchase a lot of products from one particular place in Venezuela. She watched the situation a little bit more closely and discovered that the buyer took his family to vacation in that place annually. She also noticed that the cost of the items bought went up and the variety decreased. She made an example of the buyer by firing him, and used the occasion to explicitly formulate as policy the code of conduct that she imposed on herself.

This story illustrates corruption, the first organizational enemy of virtual supply chains. It is natural for people who repeatedly transact with each other to develop social relationships, and because the decision to purchase by a buyer may be perceived by the seller as a favor, it is only natural to reciprocate. At what point is the line of acceptable behavior crossed and becomes corrupted? The answer is largely a matter of personal decision, and will vary significantly from one culture to another. But for a virtual supply chain to stay virtual it is essential that each transaction be approached independently with only a narrow focus on the best interest of the firm.

The seller may not intend to corrupt the buyer, but merely pursue a legitimate strategy of developing customer loyalty. This can be done through means that are somewhat compatible with the virtual supply chain philosophy, for example, volume discounts cumulated a posteriori over a period of time. When this is done, the buyer need not decide to commit to a higher volume of purchasing, having the option to forego in the future the opportunity to buy from the same purchaser. However, if volume discounts require prior commitment or some form of down payment, and therefore a longer term contract, there is a de-virtualization of the supply chain, with increased transaction costs and risks. This is tempting for the buyer, because the decrease in unit costs may be significant. But the virtual supply chain philosophy imposes the obligation to consider the totality of costs, including a monetized value of risk and of intangibles such as the management attention required to work the deal.

In recent years it has become fashionable for companies faced with intense competitive pressures and commoditization of their wares to transform themselves from product into service firms by marketing their goods as part of a complete package that includes consulting or R&D services for the client, after-sales services, economic and technological intelligence, training, and so on. This approach requires a close and sustained relationship, and therefore clients that accept it forego the virtuality of their supply chain. To entice their customers, sellers tend to adopt a transparency philosophy, revealing features of their operations to the buyers, with factory or laboratory tours, product improvement conferences, sharing of strategic information, and so on. This otherwise positive attitude removes the relationship even further from the transactional mode. The buyer can no longer treat the seller as a black box that delivers by whatever means needed; it must now acquire the competencies and the knowledge to make sense of the seller’s operations.

In the early days Xybelle used to have a dozen transactions yearly for the purchase of the radio clock components. Every month it bought what was needed for the month after. It used a population of a few hundred suppliers, and for every purchase could efficiently negotiate good terms. But now that its business has grown, only about a dozen suppliers have the capability of delivering reliably out of their inventory the required monthly amount. Another couple dozen could do this, but only with six months’ notice to allow them to gear their production up. A few smaller but quality suppliers approached Xybelle with a proposal for a stable relationship, indicating their willingness to expand their production capacity to meet Xybelle’s demand. Now the company was faced with a choice of continuing its purchasing practices but increasing the number of transactions to supply from the entire field; to continue ad hoc purchasing twelve times yearly, but reduce the number of potential suppliers and thus accept the potential for less competitive pricing; or to change strategy and enter into a strategic alliance with a supplier. It opted for the second option, thus avoiding the increase in the internal complexity of its purchasing process and hoping that a dozen suppliers’ competitive pressures would be sufficient to maintain low costs. This illustrates that size is an enemy of virtual supply chains.

An ecclesiastic from Xybelle’s home market was elected Pope, and he announced a pilgrimage to his place of birth in a few months. The country went into a frenzy of anticipation and preparations, with urban renewal projects quickly launched for beautification before the visit. Xybelle’s marketing department determined that there would be a huge demand for memorabilia in anticipation, during, and after the visit. Furthermore, it feared that other kinds of novelty items would not be selling for the next few months, because all of the retail shelf space would be taken with papal memorabilia. It was decided that the company needed to quickly put on the market items with a papal theme. The purchasing manager went to the Philippines and bought a batch of ceramic statuettes...
representing the new Pope. The plan was to glue them on top of the clock radios. The product sold well, but not as well as Xybelle had hoped for. The marketing team determined that customers wanted something to put in their living rooms, not bedrooms, to signify to their kin and friends their attachment to the Pope and to have an object that would lead the conversation towards that subject. A clock-radio is not something ordinarily seen in the living room. The marketing team suggested a product innovation: a clock that will mark every hour with a sound simulating church bells. This made sense and the purchasing manager was entrusted with the task of finding the right electronic component.

There were no such components available off the shelf, but several radio clock makers indicated that it would not be very difficult to redesign their products to meet the new specifications. The unit cost would not have to be higher, because the radio component would be replaced by a much simpler contraption to produce the bell sound. But, the manufacturers had to justify the upfront cost of redesigning and retooling their production, so they required a long-term delivery contract. Alternatively, some of them offered to deliver product on an ad hoc basis and at a low unit cost, but demanded that Xybelle absorb the upfront cost through a one-time payment. Xybelle went for the second option, figuring that with the papal mania it would be able to recoup its investment through higher unit pricing and higher sales volume. Management made this decision reluctantly, realizing that this was a radical departure from the virtual supply chain philosophy, but reasoned that this was a one-time exception for a limited duration. This illustrates that product innovation may lead to asset specificity, which is an enemy of virtuality in supply chains.

The product sold beyond expectations. Surprisingly, the sales continued well after the papal visit. Tourists and pilgrims identified the country, and especially the home town, with the Pope and bought the item as a souvenir. Furthermore the Pope was a popular figure worldwide and made a lot of pastoral visits. Retailers from all around the world were eager to carry Xybelle's papal clock, and the company became a small multinational, not only in its supply chain, but also as a global supplier. What was initially a one-time project became a permanent fixture in Xybelle's business. The Malaysian supplier of the clock component had to again expand capacity, but this time Xybelle did not make an upfront investment, limiting itself to a long-term guaranteed contract. Xybelle's president visited the Malaysian partner, and a return visit was arranged. Soon the two families became friendly, exchanging their children during vacations. But the Malaysian firm had a hard time managing its expansion, and some quality problems surfaced. Xybelle had to intervene, insisting that its partner implement standard industry quality procedures. Xybelle had to hire manufacturing experts and clock gurus to supervise the quality of its supplier. It soon found out that it was not easy to transfer specific nuances of clock manufacturing knowledge to the Malaysian supplier and the experts had to take intensive courses in Malaysian language and culture. What is more, a team of Malaysian engineers was taken for a tour abroad to familiarize themselves with standard quality assurance practices. This illustrates how transfer of tacit knowledge inevitably turns the transactional relations into collaborative ones.

Surreptitiously Xybelle started to co-manage the manufacturing operations of its partner. One of the Xybelle engineers in charge of the process subsequently developed complex reporting and control procedures, which required the hiring of additional personnel and installation of information technology. It also added complexity and cost to the supplier operations, and Xybelle had to agree to an increase in transfer prices. It resisted at first, but when the owner of the Malaysian firm made a personal appeal, Xybelle's president relented, not wanting to be responsible for the financial difficulties of his friend and partner. This illustrates how control of supplier operations and quality militates against virtuality of supply chains. It also illustrates the moral hazard resulting from relations that are not at arm's length.

Similarly, the Filipino supplier of papal statuettes had to expand capacity and hire a new workforce. The company had grown to a size sufficient to hire a young, professional marketing manager with an American MBA. He worked hard on developing ideas for the improvement of Xybelle's product. He was approached by a university colleague who was now working for a Taiwanese company specializing in Christmas tree lights. The marketing manager got soon convinced that incorporating blinking lights into the statuettes was a great idea. The thrill of innovation encouraged by the Christmas lights supplier made him ignore the need to do a cost-benefit analysis, which he had learned so much about in his MBA classes. Had he done it, he would have discovered that the cost of the innovation far outweighed the market demand for statuettes clad in multicolored blinking lights. This illustrates how supplier opportunism in the form of encouragement for customization of the product is an enemy of the virtual supply chain. Fortunately, Xybelle was sensitive to this issue and rejected the idea.

But then the Filipino marketing manager became excited by the notion of placing in the head of the statuette a blue light that would project a halo for the duration of the hourly bell sounds. This was simple enough, involving a slight modification to the mold to produce a indentation in the head into which the light could be mounted and embedding wires within the body that would run to the base and connect to a switch
inside that was controlled by the clock. Xybelle embraced the idea enthusiastically, the Malaysian supplier modified the clock mechanism without difficulty and at a low cost, and the people to whom Xybelle farmed out the assembly of the final product could be trained in less than thirty minutes to perform the new operation. However, and without having thought through the implications, Xybelle has significantly altered product complexity. At the beginning it could glue any statuette onto any radio clock; now it had to purchase the statuettes from the Filipino supplier and the clock component from the Malaysian partner. Furthermore, the two components had to be carefully coordinated: the hole in the top of the clock base to pass the wire through had to be exactly where the hole at the bottom of the statuette was, and the length of the wire out of the figurine had to be sufficient for successful connection. Getting this settled took a lot of management resources and additional quality controls were needed to keep it that way.

Sales were growing at a nice pace, although costs were also higher. Unexpectedly, a novel problem that resulted in a significant increase in the number of returns began plaguing Xybelle. The returns were caused by the burning out of the blue diode responsible for the halo effect. It turned out that several batches of electric transformers purchased by the Malaysian partner from one of its suppliers were faulty and caused the diodes to fail prematurely. Xybelle has observed earlier problems with suppliers of inexpensive electric transformers, and generally did not trust them. It forced the Malaysian partner to choose one supplier, monitoring transactions closely and collecting evidence for legal actions in case of problems. This resulted in closer relations with the supplier and increased transaction costs through monitoring and enforcement, which illustrates how lack of trust negatively affects virtual supply chains.

Profits grew and Xybelle had a cash surplus that it decided to reinvest into the business. The owner-president wondered whether he should diversify, considering among others an attractive offer to invest in multimedia Christmas tree decorations. But he admired and was fascinated by Henry Ford who had built a self-sufficient, vertically integrated company producing everything from steel and tires through engines to cars. He fancied becoming a powerful entrepreneur exerting reign over his empire, and he eventually decided to begin integrating his supply chain by acquiring his Malaysian partner. This shows how drive to empire building may become an enemy of virtual supply chains.

Unlike many comparable ventures, the post-acquisition integration went quite smoothly, perhaps due to an already high degree of collaboration between the companies. Nevertheless, the company lost in the eyes of the financial community, exhibiting a much lower return on invested capital than before, which delayed the plans for an initial public offering at the local stock exchange. In the meantime, Xybelle was excited about the prospects of an announced visit of the Pope to the United States, a huge market known for the ease with which people buy trivial gizmos. That is when disaster struck. Church groups in the United States were very concerned about the country being deluged by third world products manufactured by labor working in slave-like conditions. One of the groups decided to audit the papal memorabilia coming into the market. Retailers responded quickly, adopting a corporate social responsibility chart that required all products to be certified as being produced in fair and humane conditions. Xybelle was not worried at first, knowing that it farmed the assembly work at fair conditions, and its paternalistic policies towards the local workforce were regarded as a model. But then it learned that the American certifiers wanted to look

at the entire supply chain. Xybelle knew that the Malaysian factories it had just acquired were good by local standards, but had only a vague idea on how the Filipino statuettes were made. A hastily arranged visit revealed that the Filipino partner was himself farming the work out to small companies that made the statuettes in extremely rudimentary conditions. Many of the workers were children, paid for their labor with substandard food ratios, developing skin rashes from unprotected contact with wet ceramic paste and lung diseases from working without masks. The inspectors were appalled and the word leaked out, with a major television network airing a report on ‘Xybelle’s slave camps’. Now that the company was in the public eye it also surfaced that in the past the Malaysian company suppressed quite brutally an attempt to unionize its workforce. Xybelle was now the symbol of nasty global capitalism. Orders were cancelled, at first from the United States, and later from all around the world. This illustrates how social and political pressures militate against the virtual supply chain philosophy. Indeed, if the supplier is treated like a black box, then it is impossible to be responsible for what happens inside.

The use of a hypothetical and highly simplified case does not, of course, provide any empirical evidence about the occurrence and the frequency of the phenomena that we collectively label as enemies of virtual supply chains. It is merely a didactic device to facilitate narration of complex concepts. But the case has been constructed from evidence reported in the literature, which clearly points towards difficulties of consistently maintaining virtual supply chain architecture over time. The way in which Xybelle gradually and surreptitiously moved in the direction of a more integrated supply chain is not atypical. Table 2 provides a summary description of the
enemies of virtual supply chains, of their impact, and provides references to supporting literature.

In the next section we switch gears and consider the basic tenants of object-oriented architecture as it developed in the computer and electronic industries, then move to the discussion of how this approach can be translated into dynamic principles for designing virtual supply chains and keeping them such over time under the constant assault from its enemies.

Object-Oriented Architecture for Dynamically Regulated Virtual Supply Chains

Origins in Product Architecture

Most of the modern computer software is based on a paradigm known as object-oriented programming. To understand in simple terms the essence of this approach consider the ways in which you designate a file stored on the personal computer to retrieve its contents into a program such as a word processor, a spreadsheet program, a presentation maker, or a graphic processor. Even with programs that come from different vendors, the popup dialog box for identifying the file is the same. This is because the task is performed by a module-an object in computer terms-that is independent of the program and in fact resides outside its boundaries. The program knows of the existence of the module, knows what it does, and knows how to communicate with it in a mutually understandable fashion, called a protocol. In our example the program sends a message asking the file designating module

<table>
<thead>
<tr>
<th>Enemy</th>
<th>Outcome</th>
<th>Sample References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corruption of buyers by sellers</td>
<td>Increased costs and loss of bargaining power</td>
<td>Millington et al. (2005); Steidlmeier (1999)</td>
</tr>
<tr>
<td>Customer loyalty tactics by suppliers</td>
<td>Increase in transaction costs and risks</td>
<td>Piercy and Lane (2007)</td>
</tr>
<tr>
<td>Bundling of products with associated services</td>
<td>Increased dependence on specific suppliers and loss of strategic independence</td>
<td>Wilson et al. (1990); Heide and John (1988)</td>
</tr>
<tr>
<td>Supply chain transparency</td>
<td>Need to acquire capabilities to evaluate supplier operations</td>
<td>Gunasekaran and Ngai (2004)</td>
</tr>
<tr>
<td>Interference with supplier operations</td>
<td>Increase of overhead and management costs, development of emotional ties with the supplier leading to moral hazard.</td>
<td>Williamson and Ouchi (1981)</td>
</tr>
<tr>
<td>Product innovation</td>
<td>Disturbance of standardized module interfaces, loss of benefits from commoditization leading to asset specificity</td>
<td>Ernst (2005); Sturgeon (2002)</td>
</tr>
<tr>
<td>Product complexity</td>
<td>Increase in coordination costs</td>
<td>Baldwin and Clark (1997); Burkett (2006); Ernst (2005), Wilson et al. (2006)</td>
</tr>
<tr>
<td>Encouragement to procure customized products</td>
<td>Increased supplier dependency, increased buying costs with potentially marginal customization payoffs</td>
<td>Ganesan (1994); Gassenheimer and Manolis (2001); Gassenheimer et al. (1998); Heide and Miner (1992)</td>
</tr>
<tr>
<td>Intensive tacit knowledge content</td>
<td>Successful tacit knowledge transfer requires close collaboration</td>
<td>Bao (2000)</td>
</tr>
<tr>
<td>Lack of trust</td>
<td>Monitoring of unreliable suppliers increases transaction costs</td>
<td>Chu and Fang (2006); Myhr (2001); Ratnasingam and Phan (2003); Violino (2002)</td>
</tr>
<tr>
<td>Size/scale of production</td>
<td>Increased supplier dependency</td>
<td>Jacobs (1974)</td>
</tr>
<tr>
<td>Empire building</td>
<td>Loss of supply chain flexibility, increased management costs (possible company undervaluation on stock exchange)</td>
<td>Avery et al. (1998); Gaughan (2004); Trautwein (1990)</td>
</tr>
<tr>
<td>Social and political pressures</td>
<td>Increased transaction cost and possibly management costs</td>
<td>Anon (2005a); Barlett et al. (2006); Littlefield (1996); Winstanley et al. (2002)</td>
</tr>
</tbody>
</table>
to return a file name. When the user makes a choice, the module sends back a message to the program, indicating the file location or the fact that the user cancelled the operation. This may take a while, because the user may be scratching her head, answering a phone call, or going on a walk. If the program needs to know where things stand, it can read a status indicator displayed by the module, which will generally show 'busy' while the user is deciding. But when waiting for user input, the computer need not be killing time; it can perform some other task and count on being interrupted when the file-designation task is concluded.

The module is encapsulated, which is a fancy term for the popular notion of a black box. The designers of the module decided what it will do (functionality) and how it will communicate with the programs wishing to use it (interface), which includes means for the program to indicate its wishes (e.g., designate a file, but only from those ending in '.doc') and to receive an outcome (e.g., the user designated 'myfile.doc'). That is all the program knows and needs to know. The rest is none of the program's business. The module takes care of getting the resources necessary for the accomplishment of its task (memory, for example) and figuring out how to perform it.

The introduction of encapsulated modules was a major revolution in computer programming. Readers old enough to have used personal computers in the eighties might recall that each program handled a task such as designating a file differently. Sometimes the user simply had to know where the file was and how it was called, supplying the program with complicated strings such as 'c:/myfiles/mydocs/reports/jan/myfile.doc'. More importantly, developers of each program had to have fairly specialized knowledge of file storage systems and they had to invent from scratch a way of interfacing with the user. This had to be done for dozens of operations, leading to unreliable bug-laden programs, which were hard to fix and modernize. Encapsulated modules can evolve independently of the program, and in fact are frequently updated without the user realizing it during system software patches or when installing new software that is not necessarily related to the original program. One of the key design principles of encapsulation is upward compatibility. New versions of the module can have enhanced functionality, and therefore substantially modify interfaces, but they must be able to perform the functions of the older versions in exactly the same way. In this manner the program using the module does not have to be modified and continues getting the services based on the way in which it was designed. For example, with time the file-designation module evolved to be able to identify items stored elsewhere than on the personal computer, such as on a network disk. The program using the module did not need to know about this.

This approach to product design carried over to other fields. For example, modern automobiles are made with a slot to receive a car radio. The dimensions are standard, as are the interfaces (the wiring to the car electrical system) and therefore any make can be substituted for any other. Some car owners may elect to have something else than a radio in the slot, which is fine as long as the physical dimensions and the electrical wiring are the same. But in some cars the radio interacts with the dashboard screen that displays the name of the radio station in addition to other information about the car and its environment. This obviously requires a more sophisticated interface, with wires that transmit the words to be displayed on the screen. But the encapsulation principle requires that the interface be compatible with a simpler radio that is not capable of displaying to the central screen. Xybelles's original products can be viewed as consisting of two encapsulated modules: the clock-radio base and the figurine glued onto it. The interfacing was trivial at first, allowing for mixing of modules from a wide variety of sources. The first product innovation consisted of radically changing one module, the base, without affecting the other. The second product innovation required a complex interface between the two modules: the clock base had to pass an electric current to the papal figurine at the right time and for the right duration, and the holes drilled in the two modules for passing the wires had to be physically coordinated.

The object-oriented architecture is based on four fundamental design principles (Booch, 1998):

1. **Modularity** refers to the notion that a complex system should be designed as an assemblage of loosely coupled constituents, each of which is capable of independent evolution.

2. **Abstraction** refers to the notion that component modules are viewed in terms of their functionality and interfaces, not as concrete objects that have a specific physical or software implementation.

3. **Encapsulation** refers to the opacity of the module, or its treatment as a 'black box', forbidding the system architect to assume anything about it other than what is in the 'contractual' specification of its functionality and interface.

4. **Hierarchy** refers to the idea that complexity is best handled by decomposing processes into relatively few loosely coupled and opaque modules, which in turn can be further decomposed into other such modules, and so on, until one arrives at simple operations.

Because the objects used by the overall system reside outside its boundaries, and may be installed or upgraded independently, the analogy with a virtual supply chain is immediately apparent. Indeed, the modules may be viewed as suppliers of services that are orchestrated by the main program to achieve the desired effect. Modules that themselves are complex programs can be seen as suppliers of subassemblies with...
their own supply chains and orchestration processes.

Indeed, the computer industry led to supply chains whose architecture is heavily influenced by the object-oriented approach, promoting competition, customization, and innovation. Every encapsulated module can have a life of its own and can be substituted with any other module with a compatible interface, without the involvement of the program. A totalitarian state might substitute the standard file-designation module with one that will hide from the populace all but approved content, and parents can use similar contraptions to control the good taste of their offspring’s viewing. The popular Adobe program makes itself look to other programs like it were a printing module; it then intercepts messages sent to the printer to produce a fax-like output in a portable document format (pdf). Developers working on encapsulated modules are not dependent on those developing the main products and concentrate their talent and resources on the narrow specialty of their module.

Again, this idea carried into other fields of industrial activity. For example, makers of sophisticated modern weapons define themselves as system integrators, which establish the overall architecture and then integrate third party encapsulated modules into a complex whole. When principles of encapsulation are broken, the approach may produce absurd results, as in the famous case of the toilet seat for a NASA space shuttle designed by a committee to be so special that its cost became astronomical, whereas an ordinary seat would have been fine.

**Extending Object-Oriented Principles to Virtual Supply Chains**

Although there is an obvious intuitive appeal to extending the object-oriented design philosophy to virtual supply chains, it is difficult to do so. As already noted previously, this difficulty resides in the **dynamic nature of supply chains**. What may start in a virtual supply chain as a simple extension of the object-based design of a product will be subject over time to some of the same pressures experienced by Xybelle. Therefore, an object-oriented design philosophy for supply chains must include principles for dynamic regulation that ensure persistence of the four basic characteristics-modularity, abstraction, encapsulation, and hierarchy. In this subsection we reflect on how this can be accomplished.

To ensure **modularity** supply chain considerations must play a central role in product design decisions. What may appear as a simple enhancement in a product development laboratory may in fact significantly increase the complexity of the supply chain, mitigating against the requirement that modules be loosely coupled. There is nothing inherently very complex about embedding a blue diode in the head of the papal figure or having a car radio use the dashboard computer of a car. The problem becomes complex only when one takes into consideration that this requires much tighter coordination between suppliers and processes to ensure much higher quality control, and that those in turn make it more difficult to substitute one supplier for another. Thus every product design and every design modification must be subject to a rigorous assessment of impact on supply chain operations.

To ensure the principle of **abstraction** all alternative suppliers of a specified class of modules must be treated the same: standard requirements, standard contracts, standard transaction rules, and no exceptions. It is probably a good idea in product development to design prototypes with modules supplied by alternative suppliers, mixed and matched, to test that the abstraction principle can indeed be applied. No assumptions about any module should be made beyond those contractually specified, and it is a good practice to test exemplars that barely satisfy the contractual requirements rather than test only good performers.

The principle of **encapsulation** is probably the least intuitive. It implies no involvement with the suppliers, other than for transacting business: no socializing, no site visits, no monitoring of strategic and financial performance, only simple transactions, preferably mediated through a computer network or a third party. When information about the suppliers is needed, for example about financial reliability, quality, or fulfillment of ethical standards, use of third-party certification is recommended.

The **hierarchy** principle states that the supply chain should favor purchasing subassemblies rather than more elementary components.

We now can define a **virtual supply chain** as one that obeys in its operations the aforementioned four principles. What remains is to show how the object-oriented principles translate into organizational design and how their enforcement militates against the enemies identified earlier.

**Translating Object-Oriented Principles into Organizational Design**

In order to implement the object-oriented principles in a supply chain, we first have to translate them into actionable guidelines for design. The principles are translated into four organizational design components to construct an object-oriented organization design model. The model builds on rules, roles, control mechanisms, and supporting technology (see Figure 1). This idea is further elaborated as follows.

Rules represent the policy an organization and its employees must adhere to in order to retain virtuality of the supply chain. The object-oriented principles translate into the following rules:

- **Treat every class of suppliers with standard contracts and requirements.** Each class of
supplier is given a standard contract and transaction rules, thus limiting the opportunities to 'negotiate' corrupt deals. This rule implements the abstraction principle.

- **Treat every transaction on a stand-alone basis**—Every transaction is treated on a stand-alone basis with no a priori spreading of the total cost over guaranteed future transactions. This provides guidelines for assessing bundled and loyalty-dependent supplier offers. This rule implements the abstraction principle.

- **Develop and sustain modular product architecture over the entire product lifecycle**—Every product should be developed with a modular architecture, which should be sustained over its lifecycle. This provides guidelines for dealing with product innovation, customization, and growing complexity. This rule implements the modularity principle.

- **Use third-party certifications whenever possible**—Use third-party certificates extensively in order to minimize the need to monitor quality and specifications of supplies. This rule implements the encapsulation principle.

- **Use third-party intermediaries for transaction mediation**—Use transaction mediation through a party external to the purchasing, marketing, and R&D departments in order to avoid the development of social relations and minimize the opportunity of negotiating corrupt or otherwise harmful deals. This rule implements the encapsulation principle.

- **Avoid buyer-seller dependency**—Avoid any kind of dependency between the buyer and the supplier by ensuring that transactions with a certain partner do not constitute a too significant portion of total supplies of a certain good or this partner’s total output of this good. Steer clear of developing specificity of either tangible (e.g., machinery) or intangible assets (e.g., knowledge and competencies for dealing with a certain partner). This helps to maintain a healthy supplier base even with a large scale of production. This rule implements the encapsulation principle.

- **Benefit from a supply chain hierarchy whenever possible**—Take advantage of a supply chain hierarchy by delegating problematic transactions to first tier suppliers, thus lowering the transaction and production costs in case of limited supplier trust or high product complexity. This rule implements the hierarchy principle.

Roles represent job functions that should be created in order to help retain the virtuality of the supply chain. The object-oriented principles translate into the following roles:

- **Supply chain integrity analyst role**—Responsible for analysis of strategic impact and cost-benefits of all strategic supply chain decisions to ensure that they are well informed and consciously taken. This role implements all of the object-oriented principles.

- **Supply chain transaction mediator role**—Either internal or external party responsible for mediating and monitoring transactions. This role should have most of its key performance indicators (KPIs) conflicting with purchasing department KPIs but at least one in common in order to avoid organizational paralysis. Creation of this role implements the encapsulation principle to the greatest degree as well as supports the other principles.

An organization must have control systems that help to keep its supply chains on track. Proposed mechanisms ensure that strategic supply chain decisions are taken consciously and as such safeguard from the violation of all of the object-oriented principles. We propose the following control mechanisms:

- **A priori transaction reviews**—Every transaction of significant value should be a priori analyzed against the object-oriented rules for the potential impact it bears on supply chain strategy and for the totality of costs and benefits it causes.

- **Periodic supply chain audits (a posteriori)**—Regular a posteriori reviews of the integrity of the virtual supply chain, to ensure that it still remains on track of virtuality.

**Supporting technology** is an IT communication and coordination platform that helps to establish and sustain certain rules and behaviors that are beneficial for retaining virtuality of the supply chain. The IT platform is to be used for negotiations, information exchange, and transaction monitoring in order to...
Table 3
How Object-Oriented Organization Design Defends Virtuality

<table>
<thead>
<tr>
<th>Enemy</th>
<th>Rules</th>
<th>Roles</th>
<th>Control systems</th>
<th>Supporting technology</th>
<th>Comment/Context</th>
</tr>
</thead>
</table>
| Corruption of buyers by sellers           | - Treat every class of suppliers with standard contracts and requirements  
- Use third-party intermediaries for transaction mediation | Supply chain transaction mediator                                  |                 |                       | Limiting opportunities to negotiate 'negotiate' corrupt deals.                |
| Customer loyalty tactics by suppliers     | - Treat every transaction on a stand-alone basis  
- Use third-party intermediaries for transaction mediation | Supply chain transaction mediator                                  |                 |                       | Every transaction is treated on a stand-alone basis with no a priori spreading of the total cost over guaranteed future transactions. Mediation through a third-party and IT platform for information exchange. |
| Bundling of products with associated services | - Avoid buyer-supplier dependency                                  | Supply chain integrity analyst                                    |                 |                       | Unbundling and explicit assessment of supplier dependency if the sub-components are not modular. Third-party mediation to avoid supplier frazzleness with R&D and marketing departments. |
| Supply chain transparency                 | - Avoid buyer-supplier dependency                                  | Supply chain integrity analyst                                    |                 |                       | Contrast the benefits of a relationship with the costs of de-encapsulation.   |
| Interference with supplier operations     | - Use third party certification whenever possible  
- Benefit from supply chain hierarchy whenever possible | Supply chain integrity analyst                                    |                 |                       | Contrast the benefits of an interference with the costs of de-encapsulation. If possible transfer relations with the problematic party to a lower organizational level. |
| Product innovation                        | - Avoid buyer-supplier dependency                                  | Supply chain integrity analyst                                    |                 |                       | Assess the impact of innovation on standardized module interfaces, the potential asset specificity arising from product innovation (supplier) and resulting supplier dependency. |
| Product complexity                        | - Develop and sustain modular product architecture over the entire product lifecycle  
- Use third party certification whenever possible | Supply chain integrity analyst                                    |                 |                       | Use third parties to certify that the products comply with specifications. |
| Encouragement to procure customized products | - Develop and sustain modular product architecture over the entire product lifecycle  
- Avoid buyer-supplier dependency               | Supply chain integrity analyst                                    |                 |                       | Assess benefits of the relationship vs. potential costs of de-encapsulation. |
| Intensive tacit knowledge content         | - Treat every class of suppliers with standard contracts and requirements  
- Avoid buyer-supplier dependency            | Supply chain integrity analyst                                    |                 |                       | Assess the extent to which the contract and the relationship need to be modified for the transfer of tacit knowledge to happen. Assess benefits of the relationship vs. potential costs of de-encapsulation. |
| Lack of trust                             | - Benefit from supply chain hierarchy whenever possible            | Supply chain integrity analyst                                    |                 |                       | Delegate problematic relationships to lower organizational levels.           |
| Size/scale of production                  | - Avoid buyer-supplier dependency                                  | Supply chain integrity analyst                                    |                 |                       | Avoid supplier dependency and avoid making suppliers dependent.             |
| Empire building                           |                                                                       | Supply chain integrity analyst                                    |                 |                       | Assess benefits of the relationship vs. potential costs of de-encapsulation. |
| Social and political pressures            |                                                                       | Supply chain integrity analyst                                    |                 |                       | Analyze if the relationship is worth getting into, taking into account the potential need to manage the social and political pressures. |

ensure a higher degree of buyer and supplier encapsulation and lower transaction costs. Numerous modern information technologies and systems support object-oriented principles, for example, systems assisting the handling of requests for information and proposals (RFI, RFP), Internet-based auction systems, or the use of RFID for tracking of goods within the supply chain.
Concluding Remarks

The concept of object orientation applied to organization design in a virtual supply chain context has yet to be empirically tested and improved, but it already holds a promise of providing a comprehensive framework for architecting virtual supply chains that stand the ground to their enemies regardless of their provenance.

References


Manufacturing Technology Management Review

Journal of Logistics Management

dynamics of supply chains.


About the authors

Ksawery MULINSKI, MSc pursues a PhD in Supply Chain Strategy on Amsterdam Business School, The Netherlands and holds a Master’s degree in Information Management from Cracow University of Economics, Poland. He is a management consultant within a global professional services company. He specialises in process optimisation, performance management and strategy implementation. His main research interests are supply chain strategy and organisational design with focus on supply chains.

Wladimir M. SACHS was an Associate Dean of Research at ESC Rennes School of Business. Previously on the Faculty of Wharton School, Rotterdam School of Management, CERAM and Reims Management School. He was a high-tech entrepreneur, manager and management consultant to companies and other organizations in the United States, Latin America and Europe. He held a PhD in management from the Wharton School and a DEA (advanced post-masters degree) in mathematics from the University of Paris at Orsay. Dr. Sachs lived in seven countries, spoke six natural languages and several computer dialects.