Servicizing the Chemical Supply Chain

Edward D. Reiskin
Allen L. White
Tellus Institute
Boston, MA USA

Jill Kauffman Johnson
California Environmental Associates
San Francisco, CA USA

Thomas J. Votta
Tellus Institute
Boston, MA USA

Keywords

chemical management services (CMS)
dematerialization
environmental cost accounting
greening the supply chain
outsourcing
product-to-service

Summary

Servicizing the transformation from product- to service-based enterprise is a major force in changing how firms manage material input, throughput, and output. Redefinition of the firm as a service provider instead of a product manufacturer means that function, not form, is the source of added value delivered to the customer. To realize the dematerialization benefits of such a transformation requires a fundamental realignment of the supplier-customer relationship. Instead of the traditional incentives to maximize the volume of physical product sold, servicizing requires a partnership wherein the financial rewards of reduced material consumption are shared between supplier and customer. We illustrate this partnership concept with the example of chemical management services (CMS), an approach that is gaining momentum in the automobile and electronics sector. Compensation and gain-sharing based on chemical efficiency and chemical use reduction, often tied to fixed price mechanisms, lie at the core of the CMS model. Diffusion of the servicizing model holds much promise for driving dematerialization while reducing the environmental burden of product manufacturers.

Address correspondence to:
Allen L. White
Tellus Institute
11 Arlington Street
Boston, MA 02116 USA
awhite@tellus.org
http//:www.tellus.org

Volume 3, Number 2 & 3

Introduction

The shift from a product-focus to a service-focus enterprise in the manufacturing sector—a transformation we call "servicizing"—has potentially profound implications for the theory and practice of industrial ecology (IE). Looking back over ten years of organizational change in traditional manufacturing firms, servicizing emerges as a major thrust in industrial organizations during the last two decades. It appears in both incipient and mature forms across a broad array of traditionally product-based firms: XEROX moving from a photocopy machine maker to the "Document Company"; IBM from a mainframe and PC maker to an information services company; Herman Miller from an office furniture maker to an office furnishings service provider; Electrolux from an appliance manufacturer to an industrial cleaning service firm; and a unit of Castrol from an industrial lubricants vendor to an industrial lubricants services supplier. (White, Stoughton, and Feng 1999)

How far firms have moved, and plan to move, toward a service-based enterprise varies widely. But all such transformations—whether incipient or mature, partial or comprehensive—share a common theme: the realization that value is linked to the function of a product rather than the product itself. That is, customers, be they industrial, commercial, or final consumer, have less interest in the physical product (the office carpet, the photocopier, the PC, the chemical solvent) than in the service delivered by such products (comfort/aesthetics, document reproduction, information processing, and a clean metal surface) (Stahel 1994).

Looking at servicizing during the past decade and envisioning its evolution in the next 10–20 years, this deceptively simple concept portends a major shift in how companies view materials flows, choices, and management. While the pivotal role of services at all stages of the value chain has been analyzed by many (Dyer 1996; Heskett, Sasser, and Hart 1990; Lewis 1995; Margetta 1998), the connection between servicizing and materials use is only recently emerging as an identifiable theme in the business/environment literature (Axt 1994; Hinterberger 1994; Meijkamp 1994; Esty and Porter 1998). Insofar as products ultimately are nothing more than agents of service delivery, making such products durable, repairable, transportable, upgradable, and disassemblable increasingly will become standard practice for a manufacturer whose rewards are tied to customer satisfaction, not product quantity. And, insofar as servicizing means ownership of products in perpetuity for the producer while extracting maximum service value during a product's useful life, servicizing will contribute to transforming the volume-based incentive structure that undergirds the modern manufacturing corporation.

Decoupling volume from profitability represents a fundamental shift in how companies select, design, and manage materials. Extending the product life through innovative engineering and materials choices, building in flexibility to adopt new technology without discarding the entire product, enhancing transportability through lightweighting and miniaturization, and facilitating repair and disassembly through modularization—all these attributes point to lower material and energy inputs over the product life cycle. However, while servicizing stands as a potent driver for dematerializing industrial systems, translating this vision into the real world will require major change in corporate behavior. Servicizing challenges managers to rethink what business they are in and how materials serve, or fail to serve, that new vision.

Servicizing requires a transformation of traditional incentive structures from "more is more" to "less is more." It is a transformation that has some of the characteristics of normal outsourcing decisions, but it runs much deeper. Today, outsourcing is coming to mean long-term contracts for activities that could be performed in-house. In its most developed form, outsourcing involves a basic redefinition of the corporation around core competencies and outside relationships (Dunn 1999). Traditional outsourcing of activities such as component manufacturing, facilities management, and travel services fall short of this redefinition standard. In contrast, outsourcing of critical functions (such as chemical applications in production processes) is more strategic in nature because they impinge upon core competency of the firm. Moreover, the outsourcing of critical functions may lead to rethinking of an activity, shifting its focus from physical product output to a service-based orientation in which value is defined by functionality, not material content. It is the combination of these two attributes—strategic content and shift to functionality—which distinguishes servicizing from traditional outsourcing.

Servicizing requires a shared vision of seller and customer as allies in search of mutual benefit through maximization of resource efficiency. Managers face the formidable challenge of finding concrete ways to capture the benefits of this new incentive structure. This challenge, in turn, requires an information-rich environment in which firms clearly articulate exactly what "functions" customers really want, the true costs of delivering a unit of such function, and, finally, building an information system which sends signals to both service provider and customer that services delivered in a quality and timely fashion yield economic rewards to both parties. These are some of the lessons we learned during an experiment in servicizing the chemical supply chain at three U.S. manufacturing facilities.

Servicizing is premised on two key preconditions that must be present in the business enterprise. The first is that there is potential to increase the function-to-volume[1] ratio of a material; i.e., to increase the material's functionality relative to the amount that is used to deliver such a function. The second is that the producer of the material can recreate its core competency from product to service in an economically viable and technically competent fashion. These two critical conditions are by no means present in all industries. For example, a raw materials producer may have significantly less opportunity to capitalize on servicizing than, say, an automobile manufacturer. Further, some materials used in manufacturing processes, especially those that do not become part of the end product and those that can be reclaimed, have been at the front line of this transformation. Chemicals represent one such class of materials. And many, though not all segments of the chemical industry have substantial potential to increase the function-to-volume ratio of the materials they produce. These two pre-conditions translate into still limited but telling reinvention among selected chemical manufacturers and, equally important, formation and growth among a new breed of chemical services enterprises that never were in the business of product manufacture.

Servicizing in the Chemical Context

Servicizing is beginning to redefine the way chemicals are purchased, managed, and used (Bierma and Waterstraat 1997; Kauffman Johnson, White, and Hearne 1997). At a time when businesses are looking to environmental improvements as integral to competitive advantage, the chemical version of servicizing—chemical management services (CMS)—provides a vehicle for some manufacturers to simultaneously reduce chemical throughput and reduce chemical costs.

The concept directly parallels that used by the manufacturers of carpets, photocopiers, and PCs that redefine their businesses along service lines, that is, as providers of office aesthetics and comfort, document production, and information services. In the CMS case, companies that purchase chemicals for indirect use (versus direct use as constituents of final products) generally see little intrinsic value of the chemicals per se. Instead, the real value of a chemical resides in the function it performs; e.g., cleaning, coating, lubricating. The CMS model is the vehicle for transforming chemical suppliers into service providers, and along the way creating mutual incentives to reduce costs, chemical use, and waste generation while improving overall resource efficiency.

To be sure, not all chemical suppliers are poised for this transformation. Reducing chemical throughput poses an obvious conflict for a supplier that traditionally profits through volume sales. Also, the skills and resources to manage chemicals are not entirely the same as those required to produce and market chemicals. Other issues relating to corporate strategy, time commitment, and business risk may also give chemical suppliers pause. For suppliers that are moving in the service direction, motives are mixed. Some use CMS as a vehicle for expanding their product line into the facility. When they provide a value-added service such as chemical management, they build knowledge about the needs of the customer. By doing so, they may be able to replace existing brands with their products and develop new chemistries for the customer. The ability to meet, or even create, new customer demands is a competitive advantage at this early stage of CMS development. Over time, as chemical customers realize chemical-use efficiency as a business imperative, traditional seller-buyer relationships begin to reconfigure as the customer sees the supplier more as a resource than a vendor. This, in turn, leads to a continuous search for arrangements that yield joint gains under the new partnership-based business relationship.

Why Should Managers Care?

Improving chemical management merits attention simply because managing chemicals is costly—far more costly than most managers recognize. The cost of a chemical reaches far beyond the purchase price paid to the chemical supplier. How large is this cost? Certainly it varies from facility to facility and industry to industry, but for few chemical users is it insignificant. Some attempts have been made to estimate its relative magnitude. Taking into account only the direct costs of labor, materials, equipment, land, and service fees, every dollar spent to purchase a chemical may require another dollar to support its use.[2] Estimates[3] by auto manufacturers and the Department of Defense have put the ratio of chemical management costs to chemical purchase costs in the range of 5:1 to 10:1 (Votta et al. 1998).

Like any purchased materials, chemicals generate costs associated with procurement, delivery, inspection, and inventory. But, because of the specialized and heavily regulated nature of chemicals, these costs are high relative to other material inputs. Many industrial processes require chemicals with sophisticated properties—such as purity and heat resistance properties—that demand more attention and expertise by procurement staff. Similarly, chemicals typically demand special and costly delivery and storage requirements. Transportation is subject to stringent regulations; storage often requires incoming inspection, climate control, shelf-life management, labeling, and safety precautions. Each of these requirements has a cost. And such costs, more often than not, are recorded across a wide array of accounts in the firm or facility.

Unlike most other purchased materials, chemicals also require substantial resources for monitoring, tracking, reporting, training, and disposal, not to mention the less tangible but real costs of liability and, sometimes, public communications and corporate reputation assurance. Even after a chemical has been procured, delivered, and received into inventory, another wave of resources is put into motion as it is drawn from inventory and brought into use. Chemicals require special handling to move them within a facility, and chemical handlers require special training and equipment. Once delivered to the point of use, temporary storage locations scattered throughout the facility (except in plants using materials on a just-in-time basis) may generate many of the same costs as warehouse storage. When the chemical is put into use, the workers must have training and protective equipment. The process continues as some of the chemical is converted into non-product output that must be managed as waste, with all the attendant handling, transport, and disposal costs.

As the number of storage locations and points of use increase, the resource burden increases as well. Emissions of constituent chemicals, waste management activities, storage of chemicals, and other pieces of information must be routinely gathered for regulatory reporting. Collectively, these requirements place a significant burden on environmental, health, and safety (EH&S) staff. For example, procurement systems are rarely linked to the environmental management systems that contain information needed for reporting. Therefore, determining the volume of any specific chemical component released from a facility requires manual data gathering and manipulation. EH&S managers are all too familiar with the annual deluge of activity that precedes regulatory reporting deadlines.

An obscure layer of costs underlies the more visible EH&S costs. These hidden costs are those that are connected less to specific chemicals than to supporting the facility's overall capacity to manage chemicals. For example, most of the aforementioned activities are supported by information systems. However, while it is rare that a facility's information systems exist solely to manage chemical information, chemical management may well be their primary function. The development and maintenance of these systems has its own resource requirements. Similarly, facilities using chemicals require emergency response procedures and equipment in case of a chemical spill, explosion, or accident, though such procedures and equipment at the same time may support fuel storage and waste oils.

Chemical use also demands some level of legal expertise and creates various types of liability. From the time the ownership of a chemical is transferred to a company until long past the time it leaves the facility, potential liabilities from both human and environmental exposure must be managed. Finally, the use of chemicals often requires—either by company policy or government regulation—public communications efforts such as meeting with concerned neighbors, talking with the media, negotiating with local authorities, and providing information to shareholders. These demands, too, add to the long list of less tangible costs associated with chemical use.

Uncovering "True" Costs

The lower on the visibility spectrum, the more uncertain the costs and the more difficult it is to manage them (figure 1). As costs move down the spectrum they are less direct and more dispersed throughout a firm's functional groups, making them more difficult to identify and attribute to specific materials or activities. Moreover, in most chemical-using manufacturing companies, none of the activities indicated are part of the core business. Chemical users typically are focused on making product; that is the activity toward which their resources are rightfully directed. Of course, no company willfully employs an inefficient chemical management system. But because it is outside its core business and because the costs may be perceived to be relatively small, chemical management may not be as carefully managed or continuously upgraded as production processes. Poor visibility leads to deficient management, despite the substantial costs of such practices.

Some of the chemical management costs shown in figure 1 vary with the volume of chemical use, others vary with the chemicals' toxicity or other characteristics, still others vary

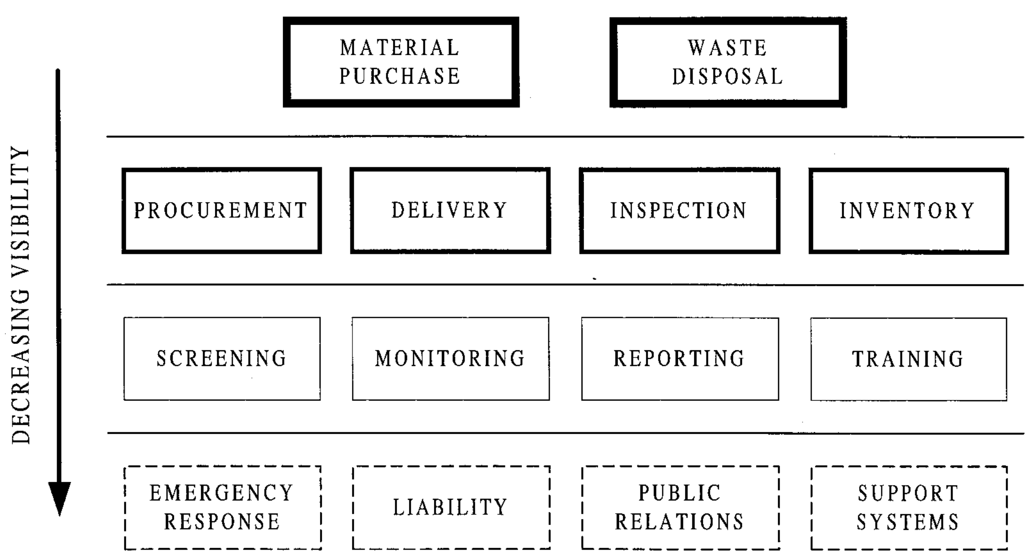

Figure 1 Chemical management cost visibility. Boxes represent cost generating activities and are grouped horizontally by the relative visibility within the company.

with the number of different chemicals used. Of course, there are also chemical management costs that are fixed; costs that essentially will not change significantly with changes in volume used. For example, because of the U.S. liability law, some liability associated with using even small volumes of chemicals and the legal staff needed to manage them may be nearly impossible to eliminate regardless of how successful chemical use reduction efforts are. Nevertheless, better cost characterization is a prerequisite to undertaking better cost management.

Cost reductions may occur in essentially two ways. One is to manage chemicals more efficiently. Simply put, improvements in chemical management activities—more efficient purchasing, reduced inventory, better data management—reduce chemical management costs. The second, and more potent, way to reduce costs is to reduce the volume of chemicals used. When the volume of chemicals is reduced, the result is savings in both chemical purchase costs *and* in many of the variable, hidden, and less visible costs. Exposing the nature and magnitude of chemical management costs therefore will create an incentive to increase management efficiency and reduce chemical use.

How best can chemicals—and their costs—be managed? To answer this question, consider three reasons chemicals are not managed well:

- lack of management focus;
- lack of internal expertise; and
- conflicting buyer-supplier incentives.

First, as we noted earlier, chemicals simply are not the focus of management attention. Typically, these activities are considered ancillary or marginal, secondary to the primary concern of maximizing throughput and accelerating a product's time-to-market. Given finite internal resources, this lack of attention may be a rational decision; after all, chemical costs, even if underestimated, may be a small fraction of operating costs.

A second reason for deficient chemical management is that facilities may lack expertise in various aspects of chemical management such as inventory control, chemical tracking, chemical processes, and even chemistry itself. Without knowledge of the availability of, say, less toxic adhesives or more efficient cleaners, facilities have little chance of making improvements. Similarly, firms with ad hoc ordering processes that require multiple iterations between the user, the buyer, and the supplier, are spending resources on an inefficient system that directly diverts money from the bottom line. When these costs are relatively small it may not make sense to hire procurement experts and full-time chemists. Nonetheless, the need for that type of expertise and the potential benefits remains and its absence is sure to create wasted materials and human resources.

A third reason—and one that is most central to our discussion—is that under a traditional chemical buyer-supplier relationship, the supplier's profitability is a function of volume, which provides an incentive to *increase* the amount of product sold. Meanwhile, the buyer has the opposite incentive—to reduce costs by *reducing* the amount of chemicals purchased. Not surprisingly, internal efforts to reduce chemical use often face an uninterested or reluctant supplier. As long as the supplier increases its profits when chemical use increases, the buyer and supplier face conflicting incentives. This, in turn, is likely to retard chemical management improvements, especially those linked to chemical use reduction such as process efficiencies and systems optimization.

How Servicizing Works

Using an outside chemical service provider is the cornerstone of CMS. A CMS provider assumes the responsibility for managing chemicals over some or—in its most comprehensive version—all stages of the material cycle (Bierma and Waterstraat 1997). It is a form of outsourcing, but with added complexity because of its highly integrated nature and the challenge of striking the right balance to achieve an effective seller-buyer partnership. The model rests on two key premises: (1) the service provider has the necessary focus and expertise to both reduce the absolute use of chemicals and the inefficiencies associated with their management; and (2) the service provider will pursue such improvements if the proper incentives are in place. The linchpin of CMS is compensation of suppliers

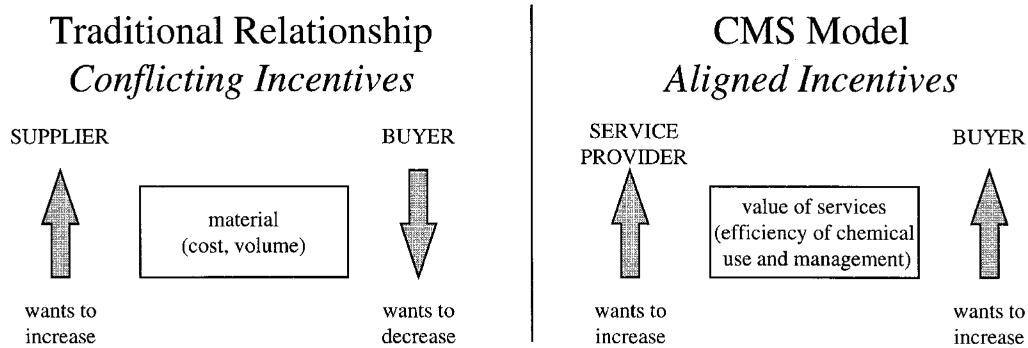

Figure 2 Incentives in traditional relationship versus CMS model.

for services provided, *not* volume delivered. The rationale for this arrangement is the one we earlier examined—chemical users require the function of the chemicals, not the chemicals themselves. In this way, CMS decouples profit from volume sales, and replaces it by linking profits to quantity and quality of service. Ultimately, this compensation scheme harmonizes the incentives so that both parties work towards the common goal of efficiently creating value (figure 2). In other words, dematerialization becomes a shared objective.

To illustrate, consider the following example. An automobile manufacturer has 100 car doors to paint each hour. Each car door requires roughly one gallon of paint; therefore, the manufacturer needs to purchase 100 gallons, assuming no wasted inventory (expired shelf-life, contamination), application mistakes (over-applied paint, wrong paint used), or unintended overuse (spills, accidents). If the paint costs the supplier $4 per gallon and it is sold at $5 per gallon, the manufacturer pays the supplier $500 under a traditional arrangement and also incurs the many hidden and indirect costs of managing the paint, e.g., inventory, transport on-site, cleaning application equipment, collection and disposal of waste. The supplier profits $100 and benefits in this scenario from every management problem that results in increased paint use. Though the supplier may make occasional suggestions to improve process efficiency to maintain customer loyalty, it essentially is not in the supplier's interest to see the buyer's chemical management processes improve the painting process.

Now, compare this example to the CMS scenario where the supplier faces the same incentives as the buyer—lower materials throughput, higher process efficiency. The buyer in this case is compensated for each painted car door that leaves the facility. It is sensible, then, to compensate the supplier on that same basis. If, as a baseline, it costs the supplier $4 for each door painted and the supplier receives $5, the supplier still profits $100, but the incentives are completely reversed. Instead of profiting by *increased* paint use, the supplier stands to gain by *decreased* paint use. For example, if the supplier increases the paint application efficiency and reduces the amount of paint required for each car door by 25%, the supplier only needs .75 gallon to paint a door and his costs are reduced to $3.00 per door. Thus, the supplier's profit rises to $200. The supplier now has an incentive to work with the buyer to seek more efficient ways to apply paint to the car doors and to be sure that as much of the paint purchased as possible coats the product instead of the waste drum. If, by making improvements in chemical use and management processes, the supplier can lower paint usage, both parties benefit: the supplier provides less raw material, and the buyer needs to manage less material. Systems costs—including both direct procurement and indirect management costs—are reduced. Further, under a gain-sharing arrangement, savings can be shared to further incentivize both buyer and supplier. Under this scenario, it makes sense for the supplier to manage more of the process; in effect, become a service provider. The service provider has a direct financial incentive to ensure that chemical use is minimized through both material management and process efficiency improvements. With this unit pricing arrangement, less material and higher efficiency simultaneously yield greater margins for the supplier and cost savings for the auto manufacturer.

CMS is an operational expression of life-cycle management with the added capability of driving suppliers and users toward joint efforts to squeeze waste out of each step in the product cycle. From the time a chemical enters a facility until the time it leaves, it passes through numerous stages which, from the user's viewpoint, collectively comprise the chemical's life cycle (figure 3) . Each stage requires resources in the form of labor, materials, equipment, management systems, and time. For each facility, the relative size and resource intensity of each stage varies. The extent to which it makes business sense to transfer the management responsibilities of any one stage to a CMS provider also varies. For this reason, the CMS model covers a spectrum of service levels from procurement only to comprehensive life-cycle coverage. The more comprehensive the system, the greater its potential for realizing gains in reduced material throughput. Whatever the contractual specifics, the linchpin of any CMS relationship is that compensation is divorced from volume.

Notwithstanding its potential to achieve resource efficiency gains, a few words of caution concerning the implementation of a CMS program are in order. First, managing chemicals requires managing a complex set of activities. Transferring the management of this system to a supplier can be a daunting task because of its many linkages with other management and manufacturing systems such as procurement, material management, production engineering, and waste management. Second, as with any change process, implementing a CMS program is subject to individual and organizational resistance, system inertia, and risk aversion, especially when potential gains do not directly accrue to the parties essential to implementation. Third, CMS creates increased interdependency between supplier and customer that requires high levels of confidence and trust. In contrast to the traditional seller-buyer relationship, CMS requires longer-term, continuous, and multi-faceted interaction. Fourth, CMS, like any form of outsourcing, can evoke resistance immediately from personnel, especially union personnel who may view CMS as a trigger to job dislocation.

A thoughtful implementation program can effectively respond to all of these challenges. In the real world, CMS does not shift all chemical management tasks from a manufacturer to a supplier, but rather transforms the way the two work together. While CMS does therefore require considerable leadership and receptivity across numerous staff functions, the transition does not have to occur overnight. Roll-out may occur gradually and sequentially in different parts of the facility or company, by incorporating different classes of chemicals, and by phasing in different stages of the life cycle. As the following sections demonstrate, despite these formidable challenges, successful CMS implementation is evident and increasing.

From Concept to Practice

Experiences in various industries in the past decade demonstrate CMS's promise. After all, the CMS model, like servicizing itself, is not really new. On the heels of the quality revolution of the 1970s and 1980s came a realization that suppliers can be a strategic resource. Rather than treat suppliers simply as product vendors, leading companies found that through strategic alliances they can draw on the substantial expertise of

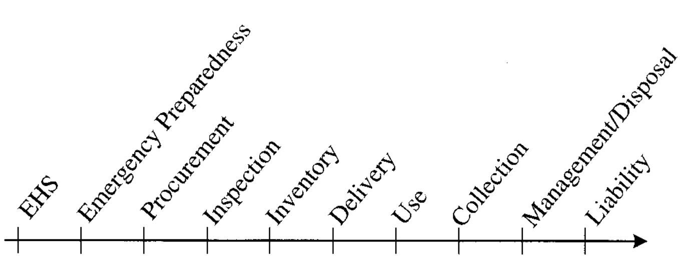

Figure 3 The chemical life cycle as seen from the user's perspective. Adapted from the chemical life-cycle framework proposed by the Intel corporation.

their suppliers (Lewis 1995). By rethinking the role of the supply chain and the integrated manner in which its resources can be leveraged to maximize value added, suppliers began to redefine themselves into service providers. This initial, quality-driven transformation signaled the beginning of what we now identify as servicizing. CMS is one manifestation of this evolution.

The automotive industry, learning the hard lessons of quality management, was among the first to seize the opportunity to leverage supplier resources (Dyer 1996). Not surprisingly, the industry was among the first to expand the concept to chemical suppliers. General Motors (GM) has been a leader in chemical management for over a decade (Reid 1997). Cautiously, the world's largest automaker experimented with partnering with chemical suppliers and transferring, facility by facility, pieces of chemical management to them. Over the years, GM has refined and increasingly standardized its program while reaping significant benefits. In various forms, CMS is in place in over 80% of GM's North American plants, and the company is now deploying its CMS program to its facilities worldwide.

GM is not alone in realizing economic and environmental benefits from CMS. Navistar, a leading producer of truck engines, has partnered with Castrol Chemical since 1987 at one of its Illinois facilities (Bierma and Waterstraat 1997). Castrol is responsible for the supply and management of all of the plant's coolants, cleaners, and associated additives. Working in partnership with Navistar, Castrol has reduced coolant use by over 50% and coolant waste by over 90%. In the process, production downtime has been reduced, as have the number of reworks. Concurrently inventory management has been improved, thus reducing inventory costs. The reduction in chemical use and improved handling has led to an improvement in both environmental and personnel protection. Through its knowledge of Navistar's facility and its own coolant systems, Castrol has been able to identify tens of thousands of dollars worth of saving opportunities. These are opportunities that most likely would have remained untapped. After all, Navistar is an engine producer, not a coolant system manager.

Another area where CMS has gained a foothold is in the intensely competitive and cost-conscious semiconductor industry. Intel and Motorola have led the way in bringing chemical managers into their facilities to improve efficiency, increase quality, reduce chemical use, and cut costs. In this highly specialized manufacturing process, chemicals play a critical role in the production of every batch. Even in this industry where management attention is strongly oriented to chemical design and processes, many semiconductor fabrication facilities have realized significant benefits from engaging a CMS provider. The success of CMS throughout the industry is most clearly manifested by the trend among all new semiconductor facilities to incorporate comprehensive CMS programs from day one of operations.

In some cases where a CMS program has been implemented, the initial large reductions in chemical use and costs have been followed by more modest improvements as the program progressed. It is to be expected that shifting attention to the chemical management system—where attention had not previously been directed—will expose some immediate opportunities for improvement. But by creating a partnership with a service provider where both sides of the partnership have direct incentives to seek improvements, the gains from a CMS program are not limited to the initial, readily achievable gains. More comprehensive and mature CMS programs, such as those in the semiconductor industry, can create a decision-making context in which continuous improvement is institutionalized.

The Chemical Strategies Partnership

Recognizing the joint business and environmental potential of CMS, the Chemical Strategies Partnership (CSP) was formed in 1996 to promote CMS as a business model to reduce chemical use and integrate environmental considerations into strategic business decision-making processes. A project of the Tides Center, CSP was launched in 1996 with funding from the Pew Charitable Trusts, and subsequently the Heinz Endowments. CSP seeks to disseminate CMS as an innovative, cost-effective means of achieving chemical use reduction. Pew and Heinz had one overarching goal in creating CSP—to reduce use of persistent and bioaccumulative chemicals. Yet

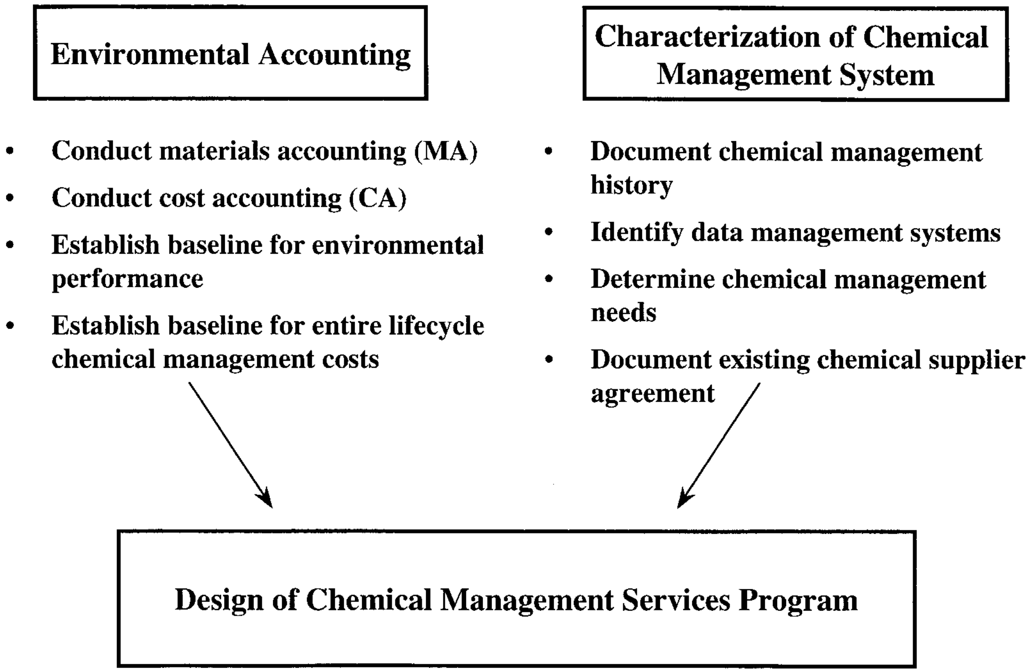

Figure 4 Two-pronged approach to CMS program development.

both recognized that without a strong business case for CMS, this goal would go unrealized.

CSP teamed with three corporations in the electronics industry: Raytheon Systems Company, Northern Telecom (Nortel), and AMP, Incorporated. CSP is currently working with these manufacturers to adapt the chemical management services model to achieve environmental, financial, and operational performance improvements through reduced chemical use. Its longer-term goal is to promote deployment of CMS throughout the electronics and other sectors.

Because each partner company and each facility faced different technical, management, and competitive challenges, and because each was at a different stage of CMS program development, CSP tailored its general approach to meet individual needs. Underlying all activities, however, is a common premise: through an understanding of the costs and processes associated with the chemical life-cycle stages, an effective CMS program can be designed to achieve cost-effective chemical use reduction.

Each firm formed a cross-functional team comprising representatives from operations, procurement, engineering, waste management, EH&S, information systems, and other functional areas. This team helped define the facility's chemical management needs and assessed the potential for a CMS program to meet those needs. The teams employed the tools of environmental accounting at both a process and facility level, as shown in figure 4, to: 1) estimate the true, life-cycle financial costs of current chemical management practices; 2) uncover savings opportunities within each facility that could result from improved chemical management; and 3) provide a baseline of chemical costs and usage (Votta et al. 1998).

At each collaborating facility, the team measured or estimated the costs incurred for each stage of the chemical life cycle. This activity sheds light on the potential for chemical management savings. The first step was to map the flow of chemicals through the facility including all information systems and departments involved in chemical use and management. Although most manufacturing facilities do not view chemical use from a systems perspective, every facility has evolved, typically in ad hoc fashion, all the elements of a chemical management system. Characterizing the system provides an understanding of all resources used to manage chemicals throughout their life cycle. It identifies the people, functions, and activities required to shepherd chemicals through the facility. Through this exercise, the teams were able to highlight specific data deficiencies and management information system needs.

Each life-cycle stage was broken down into its component activities. The resulting output is the total cost each facility incurs for its internal chemical management system. This information identifies areas for potential savings and provides a baseline for valuing chemical management services, whether provided by an external or internal CMS provider. In tandem, these two dimensions of chemical use—the physical and the cost—form the critical baseline information for revamping chemical management at a facility. They give both supplier and user the requisite information for restructuring their contractual relationship into a form that ensures material benefits for reducing chemical use and a common data set for negotiating an equitable compensation arrangement.

A second analysis conducted at each facility was the evaluation of one process through a materials accounting exercise. This exercise involves mapping the chemicals that flow into, through, and out of the process. Where possible, the team assigned costs to these material flows. The materials accounting by itself was instructive on two counts. First, the analysis often presents a striking picture of how much of the chemicals purchased used in a process become waste. Second, the difficulty of gathering the necessary data for the analysis illuminated accounting systems deficiencies that obscure key information from decision makers. Facility personnel immediately recognized specific areas of potential process improvement. These improvement opportunities, extrapolated throughout the facilities' other processes, demonstrated the savings potential from a better understanding of chemical use, process, and waste revealed by a focused chemical management.

The Raytheon Example

CSP began work with a Raytheon (formerly Hughes Electronics) manufacturing facility in Arizona. At the Arizona facility, the cross-functional team conducted materials accounting analyses in two process areas that identified opportunities for reducing chemical use. In this instance, simply measuring materials flows revealed ample opportunities for efficiency gains, a clear indication of the potential value-added of a CMS provider that might focus on such activities in the future.

Following the first round of materials accounting, the facility took steps to improve its paint application efficiency in its main painting area, resulting in an estimated 71% decrease in paint waste. Subsequently, it planned to install a system that will virtually eliminate solvent use and VOC generation for many products. In the same area, efforts are under way to eliminate redundant inks and paints that often result in needless waste generation. The company plans to replicate the accounting activities that preceded these changes at all other paint shops in the facility. Where appropriate, similar changes will be made to further reduce resource inefficiencies tied to wasted chemicals. The power of sound materials accounting was persuasively demonstrated.

With CSP, Raytheon subsequently conducted a materials and cost accounting analysis in its printed wiring board (PWB) production area. The analyses revealed that management attention had traditionally been focused on reducing the more hazardous waste streams but overlooked the facility's high volume general industrial waste stream, an under-managed cost driver as well. Following these analyses, significant changes were proposed to the facility's waste treatment processes to result in reductions in energy use, treatment chemical use, and hazardous waste generation. Conservative estimates suggest annual operating savings of $400,000 with minimal capital investment. (These changes were not implemented due to the merger with Raytheon and the transition of PWB production away from Tucson.)

At the facility-wide level, CSP worked to estimate total costs of chemical management. Gathering this data entailed interviews with staff members from various functions throughout the organization. The goal was two-fold: (1) to characterize the stages of the chemical life cycle at the facility (i.e., what departments are involved in each stage of chemical management); and (2) to determine chemical management cost at each stage. This investigation identified six different information systems and more than twenty discrete organizational functions supporting chemical management, revealing once again the diffuse, complex, and surprisingly costly nature of chemical use in production processes. Including only hard, measurable costs (and therefore excluding some of the lower-level costs pictured in figure 1), a conservative estimate is that the facility incurs management costs nearly equal to the purchase costs of the chemicals themselves. In other words, for every dollar the facility spends to purchase a chemical, it spends another dollar to manage it. This multiplier is critical to making the CMS business case to upper management.

With insight into the true costs of chemical management and the potential for reductions in chemical use throughout the facility, interest in developing a CMS program gained momentum, encompassing virtually every aspect of chemical management, procurement, inventory management, delivery waste disposal, process optimization, data management, and environment, health, and safety support. At that juncture, the merger of Hughes with Raytheon occurred. This spurred activity at a corporate level to combine systems and increase efficiency for the new, larger company. The pilot program at the Arizona facility was recognized for its potential economic and environmental value in transforming chemical management corporation-wide. Based on the success of the approach at the Arizona facility, CSP was invited to assist a corporation-wide team to develop a CMS program for the company's U.S. operations. A team composed of representatives of many of the major Raytheon sites proceeded to develop a CMS program and select a nationwide service provider. In February 1999, a five-year $200 million contract was awarded to Radian International to purchase, manage and dispose of chemicals and gases for more than 50 of Raytheon's facilities. In terms of scope and magnitude, it ranks among the most ambitious CMS programs ever launched in the United States. Included in the contract are strong incentives for reducing chemical use, reducing the unit price of chemicals, and improving process efficiency. Most notably, the compensation system is heavily weighted toward process efficiency and largely decoupled from waste volume.

Conclusions

CMS, rooted in the idea of function over form and service in lieu of product, exemplifies an emerging trend observable in a variety of manufacturing sectors. Rooted in the quality movement of the past two decades, servicizing presents a rich opportunity to bring operational expression to many of the key underpinnings of IE: a life-cycle approach to product design; dematerialization of production systems; and closed-loop manufacturing processes. Servicizing facilitates all of these, but it does something even grander. It prompts business organizations to rethink the very nature of their enterprise, to ask: What business are we in? What do our customers really want? What organizational configuration will best allow us to meet customer needs?

But realizing the environmental benefits of servicizing requires more than good intentions. It requires concrete steps to align the incentives of participants at each step of the value chain. Final consumers need to see value in functionality, and less in products per se. They must see that clothes cleaning and voice communications are what they really seek, not washing machines and answering machines. Manufacturers must understand that success in the future global economy will depend less on physical inputs and more on the ability to generate, receive, process, and act upon information pertaining to consumer preferences. Products in the future will be valued more as service delivery agents and less for their physical attributes per se. And suppliers to industry must be prepared to sharpen their responsiveness to rapidly changing customer needs where such needs are increasingly tied to information, not physical content.

Indeed, information is the lubricant of this service transition. We have seen it in the specific case of CMS, where activities such as materials and cost accounting, inventory control, and continuous replenishment of process-improvement information are tasks that enable

CMS providers to effectively partner with their manufacturing customers. Structuring the right incentives, and packaging them into a workable contractual arrangement that delivers concurrent benefits to suppliers and product makers, and to product makers and their consumers, is a critical stepping stone to tapping the environmental benefits achievable through the servicizing model.

Acknowledgments

Funding for the Chemical Strategies Partnership (CSP), under which this research was conducted, was provided by The Pew Charitable Trusts and The Heinz Endowments, and administered by the Tides Center. Our thanks to Joshua Reichert and Shelley Hearne of The Trusts, and Andrew MacElwaine of Heinz, for their many insights in the course of designing and implementing CSP. Our appreciation also to Raj Mishra and Bruce Reid of General Motors and Tom Bierma of Illinois State University for their generous sharing of experiences and resources. Finally, thanks to our three CSP partner companies—AMP, Northern Telecom, and Raytheon—for teaming with us to refine the chemical services model described herein.

Notes

1. "Volume" throughout this paper refers to the quantity or amount of chemical.
2. The studies from which these conclusions were drawn were conducted by the Chemical Strategies Partnership, described later in the paper.
3. These estimates are based on conversations with representatives from General Motors and Hughes Electronics during 1996–1997.

References

Axt, P., S. Jauch, K. Hockerts, and A. Petmecky. 1994. Eco-efficient services. Paper presented at the seminar on Eco-Efficient services, Wuppertal Institute, 18–19 September.

Bierma, T. and F. L. Waterstraat. 1997. Innovative chemical supply contracts: a source of competitive advantage. Illinois Waste Management and Research Center; Illinois Dept. of Natural Resources.

Dunn, R. L. 1999. Exploring outsourcing. *Plant Engineering* 53(3): 123–133.

Dyer, J. H. 1996. How Chrysler created an American keiretsu. *Harvard Business Review* (July–August): 42–56.

Esty, D. C. and M. E. Porter. 1998. Industrial ecology and competitiveness: Strategic implications for the firm. *Journal of Industrial Ecology* 2(1): 35–43.

Heskett, J., W. E. Sasser, and C. Hart. 1990. *Service breakthroughs*. New York: The Free Press.

Hinterberger, F., S. Kranendonk, M. Welfens, and F. Schmidt-Bleek. 1994. Increasing resource productivity through eco-efficient services. Paper presented at Eco-Efficient Services Seminar, Wuppertal Institute, 18–19 September.

Kauffman Johnson, J., A. White, and S. Hearne. 1997. From solvents to services: Restructuring chemical supplier relationships to achieve environmental excellence. Proceedings, Annual Meeting of Institute of Electrical and Electronics Engineers. New York: IEEE.

Kauffman Johnson, J. T. Votta, E. Reiskin, and J. Claussen. 1999. *Tools for optimizing chemical management: Strategies for reducing chemical use and cost*. San Francisco: Chemical Strategies Partnership. http//:chemicalstrategies.org

Lewis, J. D. 1995. *The connected corporation: How leading companies win through customer-supplier alliance*. New York: The Free Press

Margetta, J. 1998. Fast, global and entrepreneurial: Supply chain management, Hong Kong style: An interview with Victor Fung. *Harvard Business Review* 122: 103–114.

Meijkamp, R. 1994. Service-products, a sustainable approach? A case study of Call-a-car in the Netherlands. Presented at Eco-Efficient Services Seminar, Wuppertal Institute, 18–19 September.

Reid, B. 1997. Chemical management services at General Motors. Presentation at Globe Environmental Conference, Vancouver. March.

Stahel, W. 1994. The utilization-focused service economy: Resource efficiency and product-life extension. In *The greening of industrial ecosystems*, edited by B. R. Allenby and D. J. Richards, 178–190. Washington: National Academy Press.

Votta, T., R. Broe, A. White, and J. Kauffman Johnson. 1998. Using environmental accounting to green chemical supplier contracts. *Pollution Prevention Review* (Spring): 67–78.

White, A., M. Stoughton, and L. Feng. 1999. *Servicizing: The quiet transition to extended product responsibility*. Report prepared for U.S. EPA, Office of Solid Waste. Boston: Tellus Institute.