資料７

ケミカル・マネージメントサービスについて

化学物質の使用量削減が産業の活性化にも資することを示したものに「ケミカル・マネージメントサービス（Chemical Management Service)」（※）がある。

これは、化学物質の製造者と使用者の間での契約を、従来の化学物質の使用量に基づいた契約から、サービスの質・量に基づいた契約（例えば、単位車体あたりに必要な塗装金額）にすることにより、製造過程における継続的な化学物質の費用・リスクの削減が可能となることを示している。

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出典文献：

Implementing service-based chemical procurement: lessons and results (M. Stoughton and T. Votta, Journal of Cleaner Production, Vol.11)

出典文献の要約：

化学物質の使用量削減は環境や公的福祉の観点から強く求められており、企業間経済におけるより持続可能性の高い消費に向けた動きを考える上で重要な要素となっている。しかしながら、化学物質の供給者と顧客との経済関係は、基本的に供給者側の主導によっており、化学物質の使用量増加をもたらしている。ケミカル・マネージメントサービス（CMS）は、化学物質の量よりもむしろサービスに供給者側の報酬の基盤を与えることにより、従来の供給者－顧客間の関係に化学物質の使用量削減に向かう経済的インセンティブを与えるビジネスモデルである。このように、CMS は、化学物質の供給連鎖（supply chain）を提供し、潜在的に大きな環境便益を有した製品サービスシステムである。CMS は、アメリカの自動車や半導体部門において広く浸透しており、他部門にも広がりつつある。本論文は、15 の化学物質使用工場において、５年以上にわたり CMS プログラムを実践していく中で得られたあらゆる教訓をまとめたものである。重要なことは、コスト計算や化学物質の情報管理に対する理解の乏しさが、CMS によるビジネスケースを行い、理解し、評価する上での主要な障壁となっている点である。契約における報酬構造の詳細が、実際に CMS モデルによって潜在的な環境便益を達成する上で極めて重要である。

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Product Service Systems and Sustainable Consumption

Implementing service-based chemical procurement: lessons and results

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Abstract

Chemical use reduction is strongly desirable for environmental and public welfare reasons, and is a critical element of moving towards more sustainable consumption in the business-to-business economy. However, the fundamental economic relationship between chemical supplier and chemical customer creates supply side incentives for increased chemical use. Chemical management services (CMS) is a business model that aligns economic incentives in the chemical supplier–customer relationship towards *reduced* chemical use by making chemical services rather than chemical volume the basis of supplier compensation. CMS thus 'servicizes' the chemical supply chain and is a Product Service System with significant potential environmental benefits. CMS enjoys high penetration in the US auto and semiconductor sectors, and is emergent in other sectors. The paper synthesizes lessons learned from hands-on work with 15 chemical-using firms over 5 years in all aspects of CMS program implementation. Key points are that poor cost accounting and chemical information management form significant barriers to making, understanding and evaluating the CMS business case. The details of contractual compensation mechanisms are critical to achieving in practice the potential environmental benefits of the CMS model.

Author Keywords: Chemical management services; Product service system; Total cost accounting; Chemical use reduction; Supply chain management; Chemical strategies partnership

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Article Outline

1. Chemicals, society and a problematic supplier–customer model

For most products, *chemicals* are a significant production input to manufacturing, and a very significant source of the upstream, direct, and downstream environmental impacts of the manufacturing process. Chemicals function as lubricants, coolants, hydraulic fluids, suspension solvents, cleaners, catalysts, and reactants. They may be *indirect*—chemicals used in production processes or machinery, but which do not become part of the product (e.g. cleaners and catalysts). Or they may be *direct*—chemicals that become physically incorporated in the products themselves (e.g. paints, resins, or pigments). Regardless of their role in production, they are ubiquitous.[1]

Chemicals as a class have a number of troubling environmental characteristics, ranging from traditional acute toxic effects to carcinogenic and developmental disruption effects. Often dispersive in use and comingled in industrial waste streams, chemicals can combine long environmental persistence with bioreactivity. These and other characteristics have led to heavy regulation in all the wealthy industrial economies—regulations regarding registration, labeling, health screening, handling, tracking, disposal and reporting, to name only the most basic elements of current regulatory regimes. These regulations have undoubtedly averted a large number of serious environmental and public health impacts. However, increasing evidence regarding pervasive and serious effects of chemicals—e.g. the subtle and serious developmental and endocrine-disruption effects of persistent bioaccumulative toxins (PBTs) and other compounds—suggests that chemicals are anything but a `solved' environmental problem.

Reducing chemical use clearly provides significant environmental and public welfare benefits, and is a critical element of moving towards more sustainable consumption in the business-to-business economy. Given the importance of such reduction—and the significant public and private resources dedicated to implementing chemical regulatory regimes which appear increasingly inadequate in the light of new environmental problems—it is ironic and troubling that the *fundamental economic relationship between chemical supplier and chemical customer creates supply side incentives for increased chemical use.*

Consider the stylized depiction of the traditional chemical supplier–customer relationship (Fig. 1). In this relationship, the supplier's profit is directly dependent on

[1] Consider the case of retail trade (excluding restaurants) and financial services, two sectors for which chemical inputs are, at first thought, minimal. Each US$ 1 million of goods purchased by these sectors involves US$ 60,000 and US$ 40,000, respectively, in chemical inputs to their supply chains. (Calculated from US Bureau of Economic Analysis Input–Output Benchmark Tables [1]; chemicals are defined to include industrial inorganic and organic chemicals, gum and wood chemicals, adhesive and sealants, paints and allied products, and lubricating oils and greases. Fuels and agricultural chemicals are excluded.)

volume of chemicals sold. The customer has a clear incentive to reduce cost; negotiations between the two parties focus on unit cost, and volume-based discounting. Volume-based discounting (e.g. the more liters or kilograms of chemicals bought, the cheaper the per kilogram or per liter price is) is particularly problematic from an environmental perspective because additional increments of chemical consumption cost the buyer less. Thus, at the margin, volume-based discounting reduces cost penalties of increased consumption for the buyer while requiring the supplier to sell increasing volumes to offset the decreased profit per unit of chemical sold.

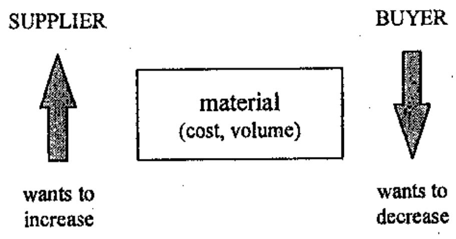

Fig. 1. Conflicting incentives in the traditional chemical supplier–chemical customer relationship.

The environmentally perverse incentives at work can be illustrated with the following example: An automobile manufacturer has 100 car doors to paint each hour. Each car door requires roughly 4 l of paint; therefore, the manufacturer needs to purchase 400 l, 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 US$ 1 per liter and it is sold at US$ 1.25 per liter, the manufacturer pays the supplier US$ 500 for the paint, while simultaneously incurring the many hidden and indirect costs of managing and applying the paint (e.g. inventory, transport on-site, cleaning application equipment, collection and disposal of waste). The supplier profits US$ 100 in the initial transaction and sees additional sales from every management problem that results in increased paint use. Though the supplier may make occasional suggestions to improve process efficiency in order to maintain customer loyalty, it essentially is not in the supplier's interest to see the buyer improve the efficiency of the painting process.

2. Chemical management services: a service-based alternative

From an environmental perspective, and at the level of basic principle, a supplier–customer model that aligns economic incentives towards *reduced* (and thus more sustainable) chemical consumption is clearly preferable. In such a model, the chemical supplier would principally be compensated on the basis of chemical services delivered, not on chemical volume sold. This basis for compensation is possible because manufacturers that purchase chemicals—particularly for indirect use—generally see little intrinsic value in the chemicals per se. Instead, the real value of a chemical resides in the function it performs; e.g. cleaning, cooling, lubricating, coating. If the supplier can assure that these functions are delivered by managing certain aspects of chemical use and handling in the plant, then a move to service-based compensation is possible. Consider again the car door example above, this time under a service-based compensation model wherein the supplier is responsible for delivering painted car doors that meet the auto manufacturer's specifications. Since the auto manufacturer in this case derives revenue from each car that leaves the facility, it is sensible, then, to compensate the supplier on that same basis. If, as a baseline, it costs the supplier

US$ 4 for each door painted and the supplier receives US$ 5, the supplier still profits US$ 100, but the incentives with respect to chemical consumption are completely reversed. Instead of profiting more by *increased* paint use, the supplier stands to gain more 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 3 l to paint a door and his costs are reduced to US$ 3.00 per door. Thus, the supplier's profit has doubled to US$ 200 per hour. The supplier now has an incentive to work with the manufacturer 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 materials while making more money, and the manufacturer needs to manage less material. System 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 a gain-sharing scenario, it makes sense for the supplier to manage more of the process; in effect, to become a provider of services. The service provider has a direct financial incentive to ensure that chemical use is minimized through both material management and process efficiency improvements. In making the transition from product to service, less material and higher efficiency simultaneously yield greater margins for the supplier and cost savings for the auto manufacturer *if the right incentives are in place*.

This example illustrates a fundamental revision of the chemical supplier–customer relationship, one in which the incentives facing both parties are aligned to favor reduced chemical consumption, and in which service rather than chemical volume is the basis of supplier compensation (Fig. 2).

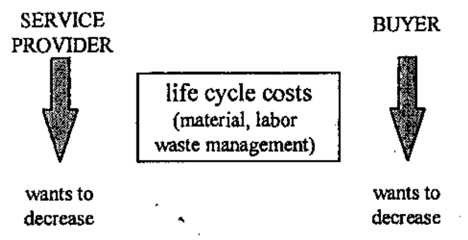

Fig. 2. Aligned incentives in a servicized chemical supply relationship.

Such a chemical services business model is in widespread use within the US auto and semiconductor sectors; it is emergent in several others. We refer to the model as *chemical management services (CMS)*, and define it as follows:

Chemical management services is a business model in which a customer engages with a service provider in a strategic, long-term contract to supply and manage the customer's chemicals and related services.

As the definition indicates, using an outside chemical service provider is the cornerstone of CMS. In its most mature form—illustrated by the door painting example above—CMS is characterized by the service provider taking a direct role in or holding responsibility for chemical application and use in the production process, deriving profit directly from decreases in unit production costs [2]. Less mature or extensive programs may be limited to only a few key chemical management areas such as procurement and inventory control. As discussed below, the exact scope and compensation mechanisms within a CMS program play a critical role in realizing the potential environmental benefits of the model.

Note that CMS should not be confused with the term *chemical leasing*. Chemical leasing may be an element of some CMS programs. However, the term 'leasing' implies a transfer of liability from manufacturer to supplier that is often not possible in the US regulatory context.

3. History and documented results

Since the implementation of the CMS model is still in its early stages, no comprehensive statistics exist regarding cost and chemical use reduction that have occurred under CMS programs. A survey of both CMS providers and CMS customers conducted by the Chemical Strategies Partnership (CSP) for the first CMS Industry Report [3] revealed that many CMS contracts contained guaranteed continuous annual cost reductions, usually in the order of 3–5% in real terms on a production-adjusted baseline. The large majority of customers surveyed reported cost reductions in the order of 10% per year over the first 3 years of the program.

Chemical use reduction is an oft cited economic and environmental benefit of CMS programs but statistics are not tracked consistently enough to report with confidence on average percent reductions. However, as Fig. 3 shows, customers who have adopted the model see strong environmental benefits: 80% of respondents saw a reduction of chemical use and 50% eliminated some hazardous materials from their operations. In the absence of an average estimate of chemical use reduction for all CMS programs, it is necessary to rely on current CMS penetration and growth trends (Table 1), in combination with individual program results to evaluate CMS's environmental potential. The following discussion provides such program results in the context of a general history of the CMS business model.

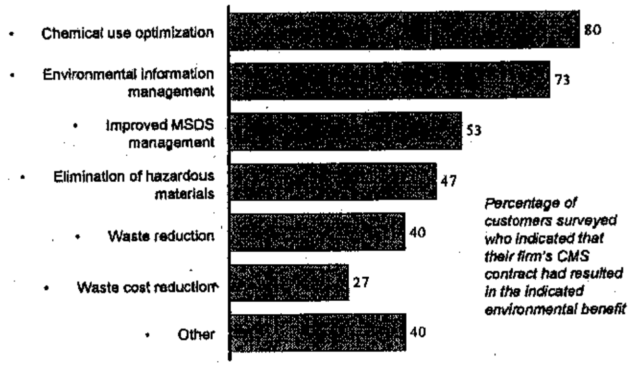

Fig. 3. Environmental benefits of CMS according to customer survey. Source: CMS Industry Report 2000 [3].

Table 1. Estimated CMS penetration, selected US industrial sectors

US Sector	Estimated 1998 chemical purchases (US$ millions)	Provider estimates of CMS penetration (%)
Automotive	4944	50–80
Metalworking	1478	15—25
Aerospace manufacturing	252	5–15
Airline	65	10–20
Electronics	1684	30—40

Source: CMS Industry Report 2000 [3].

The CMS model is not 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 could draw on the substantial expertise of their suppliers [4]. The automotive industry, learning the hard lessons of quality management, was among the first to seize the opportunity to leverage supplier resources [5]. 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 [6]. Cautiously, the world's largest automaker experimented with partnering with chemical suppliers and transferring elements of overall chemical management to them on a facility-by-facility basis. 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 estimates that total chemical use reduction averages 30% for facilities implementing chemical management [7]. Total cost savings are well above 30%, because savings are not limited to chemical purchase costs alone. Reductions in chemical use directly reduce associated chemical management costs as well. GM groups environmental benefits of its chemical management programs into four categories [8]:

- Reduction in the number of chemicals. This has occurred across a large number of chemical classes (including detergents, lubricants, and coolants). By simplifying the complexity of chemical management, this benefit has set the stage for the remaining three benefit categories.
- Reduction in the amount of chemicals used. For example, purge solvent used per vehicle in their painting operations has been reduced significantly.
- Elimination of chemicals. For example, a CMS provider designed a system to use water as a die release in place of a chemical that was widely used.
- Reduction in the toxicity of chemicals used. In a number of cases, GM has been able to use less toxic chemicals in place of the more toxic chemicals they were previously using.

GM is not alone in realizing economic and environmental benefits from CMS. Navistar, a leading producer of truck engines, has partnered with a CMS provider since 1987 at one of its Illinois facilities [2]. The provider is responsible for the supply and management of all of the plant's coolants, cleaners, and associated additives. Under the CMS program, coolant use has been reduced by over 50% and coolant waste by over 90%. In the process, production downtime as well as the number of reworks has been reduced. 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 protection and occupational health and safety. Through its knowledge of Navistar's facility and its own coolant systems, the provider has been able to identify tens of thousands of dollars worth of saving opportunities. These are opportunities that most likely would have remained untapped; Navistar's core competency is engine production, not coolant system management.

The second industrial sector in which CMS has high penetration is the US semiconductor sector. Intel and Motorola 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, chemical purity and application consistency are critical factors in determining reject rates, and thus competitiveness. 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 during the building phase to take advantage of CMS provider expertise and ensure they can start on day one of operations [3].

Results of one such program—which are not atypical—were the following: Under the CMS program, on-site chemical inventory was reduced by 50%, and annual chemical consumption was reduced by 50% over 2 years. Hazardous waste generation was reduced 8% over 2 years (resulting in this case in a savings of US$ 24,000). Chemical substitutions resulted in savings of US$ 120,000/year, and changes to chemical container sizes resulted in savings of US$ 55,000/year.

Outside the semiconductor and auto sectors, CMS is best described as emergent, and concrete examples of program performance in these sectors are scarcer (Table 1). In February 1999, a 5-year US$ 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 US. 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. Given the scope of the program, the focus of the first year was implementation at the many facilities. Savings from the program paid for all CMS program costs within the first 6 months and has resulted in streamlined management and improved data (chemical gate keeping, MSDS management, and environmental data for record keeping and regulatory reporting); improved service and quality (improved delivery, acceptance rate of material); reduced costs (based on year one savings, total savings over 5 years are expected to be in excess of 30%); and reduced waste (consolidating regional inventories and higher inventory turn rates has resulted in lower scrap rates of chemicals). In its second year, the CMS provider identified several continuous improvement initiatives; second-year results are not yet available [9].

As evidenced by the Raytheon example, CMS programs typically result in initial reductions in chemical use and costs resulting from more focused management. Once the program is established, continuing improvements come from more fundamental changes to chemical use and management. As we argue later, continuous improvement under CMS depends significantly on the use of appropriate compensation mechanisms in CMS contracts.

4. CMS in business and theoretical context

The evolution of CMS as a strategic service-based alternative to chemical procurement was described above. It is one of a class of such practices whose distinguishing characteristic is performance-based contracting. Under performance-based contracting, the performance of a supplier in delivering a service is the basis of supplier compensation, rather than per-unit payment for delivery of a commodity. Thus, under CMS, fulfillment of chemical services replaces unit of delivered chemical product as the basis of compensation. Under *Resource Management*, solid waste management services replace ton of waste hauled, and under performance-based energy contracting, provision of light, heat or other energy services replaces Kilowatt-hours and British thermal units (BTUs) as the basis for compensation [10 and 11].

CMS also clearly falls under what Tellus Institute and others have termed *servicizing*—the emergence of a class of product-based services in which physical product per se is no longer the basis of compensation, but rather the vehicle to deliver service or function [12 and 13]. In servicizing the chemical supply chain, CMS clearly constitutes a product service system (PSS), under any of several definitions that have been proposed [14]. Because chemical management activities may, on the surface, change little under CMS—the same or very similar chemicals must still be procured, received, stored, quality-assured, distributed to point-of-use, etc.—CMS, like many 'servicized' business models, raises questions regarding the distinction between products and services. Ehrenfeld and Brezet [15] have argued that the principle distinction between products and services is temporal in nature: products are acquired and held in stock for later consumption; services, by their nature, are consumed almost immediately. We believe in this case that the relevant distinction between products and services is the basis of compensation.

CMS is one of the few active, business-to-business PSS examples of which the authors are aware which is experiencing growth purely on the basis of its business merits (Table 1) [3, 10, 11 and 16]. This said, there are significant obstacles both within chemical customer and some chemical supplier organizations to adopting the CMS model and to assuring that the environmental potential of the model is realized. These are addressed later in this paper.

5. Piloting environmentally beneficial CMS

In the mid-1990s, the environmental and cost benefits realized by initial CMS programs in the auto sector raised two questions: is the CMS model applicable outside the auto sector—and, if so, how can its environmental benefits be maximized? In 1996, the non-profit CSP was founded by the Pew Charitable Trusts to explore these issues—to investigate, through demonstration and application, the utility of CMS as a business model for continuously reducing chemical use and waste in a variety of industrial sectors. Tellus Institute coordinates CSP's technical and research program; the organization is staffed by Tellus and California Research Associates, which provides overall management.

With initial funding from the Pew Charitable Trusts and the Heinz endowments, CSP has collaborated in-depth with 15 companies to help develop their CMS programs, among them Nortel, Raytheon Company, AMP, Inc., Seagate, Analog Devices, the Stanford Linear Accelerator Center, and a coalition of small and medium-sized enterprises in Western Pennsylvania. Involvement has ranged from chemical cost baselining and benchmarking to RFP (Request For Proposal) development, proposal evaluation, and implementation tracking.
The following discussion synthesizes the insights and lessons from this applied experimentation, and provides insight into the dynamics of an emerging PSS. Key points are that poor cost accounting and information management form significant barriers to making, understanding and evaluating the CMS business case. The details of contractual compensation mechanisms are critical to achieving in practice the potential environmental benefits of the CMS model. Specific examples are provided where possible; however, confidentiality requirements limit the extent to which we can attribute