Suppliers and Environmental Innovation: The Automotive Paint Process

Published in *International Journal of Operations and Production Management.* Volume 20, No. 20, 2000. pp. 166-186

Dr. Charlette A. Geffen
Associate Director
Strategic Planning
Pacific Northwest National Laboratory
902 Battelle Blvd., MSIN: K1-50
Richland, WA 99352
(509) 375-3646
ca.geffen@pnl.gov

Dr. Sandra Rothenberg
Assistant Professor
Rochester Inst. of Technology
College of Business
108 Lomb Memorial Drive
Rochester, NY 14623
(716) 475-6032
slrbbu@rit.edu

ABSTRACT

Automobile assembly plants worldwide face increasing pressures in the environmental arena. How a plant responds to these issues has significant implications for the cost and quality of plant operations. This paper uses three case studies of U.S. assembly plants to examine the role of partnerships between original equipment manufacturers (OEMs) and their suppliers in improving the environmental performance of manufacturing operations. We find that strong partnerships with suppliers, supported by appropriate incentive systems, were a significant element of the successful application of innovative environmental technologies. Supplier staff members were an important part of achieving environmental performance improvements while maintaining production quality and cost goals. The management factors influencing the extent and nature of supplier involvement are identified. The results of this work point to the importance of suppliers in addressing the manufacturing challenges of the future.

Introduction

In automobile manufacturing, environmental issues and strategic investment decisions about technological change have become critical management issues. One potential path for achieving environmental performance improvements while maintaining production quality and cost goals at the plant level is through unique partnerships with suppliers. Our research, based on case studies of environmental management and performance at automotive assembly plants, explores the extent to which suppliers are a primary source of product and process innovation in bringing environmental improvements to the plant. The paper begins with a discussion of the problem context, followed by a review of emerging evidence on the changing roles of suppliers in manufacturing operations. Next, the research method used and the case study data is presented. The paper ends with a discussion of results and conclusions.

The Environmental Challenge

Most automotive companies and customers are concerned about the environmental and safety impacts generated through the use of automobiles. The environmental impacts of the automobile manufacturing process, however, are also of significance (Keoleian et al., 1997; Graedel and Allenby, 1997). The primary source of air emissions and hazardous wastes at an automotive assembly plant can be traced to a single unit operation: automotive painting (AAMA, 1997). Over 80% of the environmental concerns at these facilities stem from the paint shop and related operations (Lowell et al., 1993). The painting process is a complex, multistage operation that is extremely energy intensive. It is also the primary source for air emissions of regulated chemicals, including volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). These emissions place General Motors (GM), for instance, among the top ten companies in the United States with the largest total chemical releases as reported by the U.S. Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI) (U.S. EPA, 1998). The painting process is also a major cost of production, with large capital investments and high material costs (Nallicheri, 1993).

Over the last decade, there has been a consistent trend toward the reduction of environmental releases in the automotive manufacturing sector, as measured by the EPA's toxic release inventory data. This is primarily in response to increasingly stringent regulatory limits on allowable levels of emissions at the plants (Praschan, 1994). Most automotive assembly plants today achieve these results through the use of abatement equipment, rather than material substitution. Yet, the capital and operating costs of traditional environmental control technologies are significant. For example, more than 60% of General Motor's annual pollution control costs (which in 1996 were over $110 million for their U.S. automotive operations) are devoted to air emissions control (General Motors Corporation, 1997). U.S. industrial investments in pollution control and abatement were more than $100 billion annually in 1992; these costs were expected to double by the year 2000 (Sheridan, 1992). Increasing costs of compliance coupled with advances in materials and process technology are now driving some companies to consider more innovative approaches to solving environmental problems (Porter and van der Linde, 1995).

Supplier Involvement: Emerging Evidence

Most research to date on supplier involvement in manufacturing has focused on the influence of suppliers on traditional measures of manufacturing performance, such as product quality or cost. This research shows that one of the benefits to manufacturers from stronger relationships with suppliers is that suppliers often serve several customers within related industries and thus have greater access to external information and experience with different technologies (Clark and Fujimoto, 1991). From the supplier's perspective, being closer to the technology and processes in use and building closer relationships with their customers can also lead to increased levels of innovation (Tyre and von Hippel, 1997; von Hippel, 1988). Many innovations require the development of complementary assets before they can be successfully adopted in practice (Teece, 1986). These assets may include related technology or know-how that is not necessarily housed within the boundaries of a single company. Teece (1986) points out the importance of collaboration among companies who contribute different elements of a technologically interdependent system, where strong coordination and information flows across company boundaries are required for successful implementation. Suppliers, by broadening the diversity and span of existing knowledge in the manufacturing process, can increase the ability of a manufacturing firm to recognize, access, and utilize new external knowledge.

Recent research by Florida (1996) indicates a positive relationship between advanced manufacturing innovations and environmental performance, suggesting that supplier involvement is an important mechanism in this relationship. Emerging evidence in the automobile industry suggests that suppliers are a source of innovative ideas for environmental improvements (Geffen, 1997 and Rothenberg, 1999) and can have a significant influence on the introduction and successful implementation of environmental innovations at the plant level. Little empirical work has been done in this area, however. The set of case studies presented in this paper addresses that gap. The links between material use, production process and environmental impacts in manufacturing facilities suggest that the important role of suppliers in acquiring and assimilating external information, extending the capacity of a firm to implement innovation, may also hold in the area of environmental innovation.

Method

Our research was based on case studies of the application of innovative paint materials at three U.S. automotive assembly plants from different automotive companies, representing a variety of supplier/OEM relationships. All three plants exhibited strong commitments to leadership in environmental performance and technological innovation. Investments in innovative technologies that reduce or eliminate regulated materials were an important part of their environmental strategies. These plants were all relatively early adopters of revolutionary new paint materials and technologies. The primary difference among these plants was their approach to supplier involvement in plant operations and environmental improvement.

Primary data were collected through site visits and extensive interviews with corporate and plant management at each assembly plant. Multiple on-site interviews were conducted at each site by two interviewers over a 3-month period. The most extensive interviews were conducted with the environmental staff at the plant and the suppliers and operations staff in the paint department. In addition, telephone interviews were conducted with the research and management staff involved in paint and related chemicals product and process decisions at each automotive manufacturer's and major supplier's corporate headquarters.

Quantitative and qualitative data related to the operation of the plant, the paint process, management styles, supplier roles, and environmental practices were collected. Data on environmental performance was obtained from an analysis of the EPA Toxic Release Inventory (TRI) database for the years 1989 through 1995 (U.S. EPA, 1998). This data was used in conjunction with data provided by the plants on environmental releases and chemicals and materials inventories. Production data for each plant were collected to allow comparisons among plants on a per-vehicle basis.

Case Studies

Plant A

Plant A, an older plant, produced high-quality luxury cars (about 1,100 per day during full production) until 1993 using high-solvent paints. The management approach at the facility was relatively open and flexible, encouraging workers to provide input to management and supporting integrated work teams. The plant has a history of worker involvement in process improvement. In 1990, the plant extended the team concept to the supplier of solvents and cleaning chemicals, appointing a single supplier located in-house to manage the needs across the facility and to help establish environmental goals. In 1993, the facility shifted production to a new vehicle type and underwent a number of major process and management system changes. As part of its technology shift, waterborne paints were introduced to reduce VOC emissions. Management also implemented a new partnership with the paint suppliers, extending the approach that had earlier been developed for the solvent suppliers. The new program gave suppliers greater responsibility for key production chemicals and elements of the paint process, involving them more heavily in the operation of the plant. These suppliers were paid based on a set fee per vehicle painted rather than volume of materials sold. They were also given an incentive for meeting environmental goals. Suppliers received a percentage of any savings achieved, as long as a high-quality finished vehicle was produced. By 1994, a single supplier was providing all paint shop-related chemicals and coating materials, as well as those chemicals needed for the rest of the plant operations.

As a result of implementing the partnership program, suppliers now play a very important role at Plant A, both in productivity improvements and environmental performance. In the first full year of operation under the new partnership program (1994), the supplier saved over $1 million for the plant in improved efficiencies and reduced waste. The automaker now relies heavily upon suppliers to provide innovative products and process control, in addition to helping meet environmental goals at the plant.

The partnership arrangement with paint and chemical suppliers at Plant A is relatively unique in the industry. First, a single supplier is used for the entire paint system, including cleaning and treatment chemicals. Under this approach, cost and environmental tradeoffs can be made effectively across the plant, at a facility level, rather than simply focusing on elements of the paint shop unit operations.

Second, contracts with suppliers are managed through the environmental organization and include requirements to meet plant environmental goals. This contractual and organizational arrangement encourages the introduction of new products with lower VOC content and process improvement suggestions that reduce emissions and waste. Under this arrangement, suppliers have a broader role in the environmental management of the plant, utilizing their technical expertise in partnership with plant personnel to accomplish business and environmental goals.

Plant B

Plant B is a relatively new facility, producing about 1,100 mid-size vehicles per day. This plant was designed to accommodate the use of waterborne paints. A powder anti-chip coating is also used for additional durability and replaces a high-VOC-containing liquid solvent, reducing

VOC emissions from the manufacturing process. The management approach at the plant is relatively open and flexible, with workers encouraged to provide suggestions to management and to work in teams to solve problems. The organizational structure at Plant B is built around business units that are comprised of teams dedicated to specific tasks.

An environmental manager coordinates environmental information among the different units. Management at Plant B has experimented with a number of programs for improving their environmental performance, although they have not (to date) explicitly involved suppliers in improving plant performance across business units. They have tried to encourage innovation and change at the level of the business unit, however. Although the environmental staff say they have good support from leadership on environmental issues, the importance of financial measures at the plant often results in cost reduction as the primary motivation for environmental projects.

Suppliers at this facility are viewed as team members, but report directly to the unit operation they supply. Different suppliers provide each of the primary materials and related chemicals for the painting process, with the process integration performed by the paint department manager. These suppliers are paid for sales, based on product volume, but are not paid an incentive for meeting environmental goals. No one supplier has responsibility for chemicals or materials across the various departments at Plant B. In the paint shop, up to six different suppliers provide the many materials needed. A single supplier was commissioned in 1992 to provide cleaning chemicals and solvents to the plant, and to provide new product ideas to improve efficiencies of various business units (including environmental performance). This supplier has been working to identify ways to reduce the VOC content of and emissions from these materials and invests in its own research and development to try to bring new products to the facility. This supplier also initiated a solvent reclamation program at Plant B. About 70% of all purge solvents are now reclaimed through this program. The solvent supplier, however, is not in a position to identify broader improvements across different unit operations, at the facility level, with respect to the other sources of emissions and wastes from the plant.

Plant C

Plant C is an older plant that was built to produce large-sized, luxury vehicles (about 1,000 per day) using high-solvent paints. In 1990, new materials, including waterborne paints and a non-solvent purge, were introduced to the painting process, primarily to lower the VOC emissions from the plant. The plant management approach is relatively traditional, with hierarchical reporting arrangements and managers and supervisors clearly identified by their white shirts and ties. Management priorities are on specific production goals and quality measures, with progress posted on signs throughout the facility. Ideas from workers for improvements are submitted through a formal suggestion program. Suppliers have well-defined roles in providing materials for the paint shop, and a number of different suppliers serve the needs of the facility. Suppliers are not invited to be a part of setting or achieving environmental performance goals.

Plant C has two environmental engineers, both of whom report to the manager for Central Engineering. In interviews with these staff members, they reported that about 75% of their time was focused on environmental matters, most of which dealt with reporting and compliance requirements. As a result, environmental staff at Plant C had much less involvement with the production process or with suppliers than staff at Plants A and B.

The relationship with suppliers in the paint shop is limited primarily to the provision of materials and equipment. The suppliers have much more of an arms-length relationship than observed at the other facilities. While paint shop management and staff said that they place a high value on supplier expertise for help in optimizing the process and monitoring the quality of the coating process, the suppliers do not have an avenue at this facility to easily supply that expertise. They are paid based on volume of high-quality material provided, and there are no other financial incentives related to improving paint processes or environmental performance. The large number of different suppliers and the highly competitive nature of the business preclude a view of process improvements at the department level or the introduction of innovative materials that might cut across unit operations.

Changes Over Time in Environmental Performance

The baseline performance of the assembly plants, as measured by TRI emissions in 1989 (1991 for Plant B, its first full year of operation) is shown in Table I. Despite the use of waterborne paint technology and a flexible, team-oriented management approach, Plant B generated the highest level of emissions among these facilities. Plant A, with a relatively open management approach, had similar levels of emissions to Plant C (about eight pounds or more TRI emissions per vehicle produced). At that time, all three plants utilized traditional arms-length contracting approaches with their suppliers and each had a variety of vendors providing the materials and chemicals used in the paint shop and other areas of the plant.

See Table I

Differences in the environmental performance of the plants began to emerge as changes in relationships with suppliers occurred over time. Table II shows the performance of these facilities in 1992. By this point in time, Plants A and B had begun to move toward more of a partnership arrangement with key suppliers. Plant C, while retaining a more traditional approach to supplier relationships, had shifted to the new waterborne paint technology in 1990. Yet, without the expertise of the suppliers, the plant had a difficult time integrating the new materials into its process. According to an engineer who worked in the paint shop at that time, “the first year was hell—we couldn’t figure out how to properly apply the stuff and get all the process parameters right.” Emissions from Plant C in 1990 increased by almost 40% over 1989 as it attempted to implement the waterborne technology. Interestingly, the best performer in 1992 was Plant A, which was using a solvent-based paint technology but beginning to develop a stronger partnership with suppliers. The solvent supplier at Plant A succeeded in achieving efficiencies in material use and reductions in the VOC and regulated chemical content of the cleaners used at the facility.

See Table II

Table III shows the performance of the plants in 1994. Plant A, which introduced waterborne paints in 1993, continued to outperform the other two facilities. According to both the paint department manager and the environmental coordinator at the plant, the presence of the paint supplier as a major partner facilitated the plant’s success in integrating the waterborne materials into the painting process. “We realize that the supplier is the technical expert—and we depend on them for that," said the environmental coordinator. He continued, “One of the things I really enjoy is that every month we have a meeting to discuss key technical issues. The supplier brings in folks from their other plants or their research labs.” The combination of innovative materials and process improvements implemented through a strong relationship with the suppliers resulted in Plant A's environmental performance in 1994 exceeding that of either Plant B or Plant C.

See Table III

Analysis of Management and Performance

The plants evaluated in this study all ultimately utilized new technology (e.g., waterborne paints) for their painting operations, but they had different approaches to their relationships with suppliers. The similarities among these operations in terms of the use of new technology and management's environmental priorities suggest that supplier involvement is a key differentiating factor in their level of environmental performance. While all three plants have emission levels at or below industry averages, Plant A showed the greatest reductions and, over time, demonstrated improved performance in both total emissions and those normalized by vehicle production. Plant A's initial reductions in emissions, from 1989 to 1993, occurred without the implementation of the innovative waterborne paint technology. Plant management had, however, implemented a partnership with their solvent supplier that included environmental performance goals. Once waterborne paints were introduced to the plant, they achieved additional improvements in environmental performance. The partnership arrangement with their paint supplier was instrumental to the success of waterborne technology at Plant A. The presence of suppliers in the facility, with responsibility for materials and process results, helped the plant personnel obtain better and more timely data and facilitated problem solving. The supplier was also able to bring additional innovative products and process ideas to the facility for other parts of the manufacturing operation. Managing the supplier contract through the environmental coordinator reinforced environmental priorities and the importance of pollution prevention.

Plant B also utilized advanced paint technology and had an overall management style that encouraged and supported innovation. However, they did not involve the suppliers in the implementation of the waterborne paint system and did not initially achieve the expected environmental performance. While the plant had an open relationship with suppliers and tried to involve them in process decisions that related to their products, they had a large number of suppliers with whom they were working. This plant underutilized the expertise of suppliers by focusing them too narrowly on the specific needs of a single department. Paint materials were supplied by a set of competitors who had little incentive to collaborate on improvements. This approach limited the ability of the paint shop suppliers to identify and implement new products to achieve cost and environmental efficiencies facility-wide. Significant improvements in environmental performance were achieved when the plant implemented a partnership with the solvent supplier.

Plant C, while utilizing advanced paint technology, never developed a relationship with suppliers that capitalized on the competencies they had in understanding how to use the new materials most effectively to achieve environmental improvements. The environmental engineers at Plant C relied on the paint suppliers for data on paint toxicity and emerging regulatory requirements, but suppliers were not encouraged to take the initiative in thinking about changes to the painting process. Process problems often generated arguments between supplier and automaker staff, rather than leading to constructive working sessions about potential solutions. The lack of a partnership with the suppliers also limited Plant C's ability to gain the anticipated environmental benefits from the use of the waterborne paint technology.

Discussion and Conclusions

These case studies suggest that closer supplier-manufacturer relations, where the relevant product expertise resides in the supplier, can contribute to improved environmental performance through the implementation of innovative materials and related processes. As suppliers learn more about the manufacturing operation, they are better able to understand the kinds of products that best serve the customer's needs. Within the protection and trust of a partnership with the manufacturer, they are more willing to share their innovative ideas.

The results of this research also reinforce the importance of suppliers as sources of expertise in implementing innovative technology in a complex manufacturing environment. Plant A, which had a strong partnership with its primary supplier when it implemented waterborne paints, did so effectively and with the intended reductions in environmental emissions from the plant. Plant C, on the other hand, while adopting the waterborne technology, was unable to integrate it into the manufacturing operation on its own. Instead of the expected improvements in environmental performance, the plant experienced increases in emissions and frustrations with getting the new technology to work. The integrated nature of the materials and application process of automotive painting requires that suppliers and OEMs work together to achieve successful results. This suggests that the importance of cospecialized assets, as described by Teece (1986), and the challenges in transferring tacit knowledge, particularly across company boundaries, extend to environmental innovations.

References

American Automotive Manufacturers Association (AAMA) (1997), "Progress measurements" in US Automotive Pollution Prevention Project, www.aama.com\environment\

Clark, K. and Fujimoto, T. (1991), *Product Development Performance: Strategy, Organization and Management in the World Automobile Industry*, Harvard Business School Press, Boston.

Florida, R. (1996), *The Environment and the New Industrial Revolution*, Presented at the annual meeting of the Association of American Geographers, April 1996.

Geffen, C. (1997), *Innovative Environmental Technologies in Automotive Painting: the Role of Suppliers*. Doctoral Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts.

General Motors Corporation (1997), *General Motors Environmental, Health and Safety Report*, Detroit.

Graedel, T. and Allenby, B. (1997), *Industrial Ecology and the Automobile*. Prentice Hall, Upper Saddle River, New Jersey.

Keoleian, G., Kar, K., Manion, M. and Bulkley, J. (1997), *Industrial Ecology of the Automobile: A Life Cycle Perspective.* SAE, International, Warrendale, Pennsylvania.

Lowell, J., Plumb, S., Sorge, M. and Winter, D. (1993), "Hazardous waste: the auto industry's $500 billion mess?" *WARD's Auto World*, July 1993, pp. 34-47.

Porter, M. and van der Linde, C. (1995), "Green and competitive: ending the stalemate." *Harvard Business Review*, Vol. 73, No.5, pp. 120-134.

Praschan, E. (1994), "What the clean air act means to the auto industry." *Automotive Body Painting Proceedings of the International Body Engineering Conference*. Warren, Michigan, IBEC Ltd. Publications, pp. 78-81.

Rothenberg, S. (1999), *Is Lean Green? The Relationship Between Manufacturing Processes and Environmental Performance within Different Regulatory Contexts*. Doctoral Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts.
Sheridan, J. (1992), "The environment: straightening our priorities," *Industry Week*, January 6, pp. 36.
Teece, D. (1986), "Profiting from technological innovation: implications for integration, collaboration, licensing, and public policy," *Research Policy*, Vol. 15, pp. 285-305.
Tyre, M. and von Hippel, E. (1997). "The situated nature of adaptive learning in organizations." *Organization Science*, Vol. 8, No. 1, pp.71-83.
U.S. Environmental Protection Agency (1998), *1996 Toxic Release Inventory*, EPA-745-R-98-005, Office of Pollution Prevention and Toxics, Washington, D.C.
Von Hippel, E. (1988), *The Sources of Innovation*, New York, Oxford University Press.

Table I. 1989 Comparative Environmental Performance: Baseline

	Plant A	Plant B [b]	Plant C
Annual Production (vehicles)	256,600	95,821	189,500
Total TRI Emissions (lbs)	1,979,274	1,036,399	1,623,300
Normalized TRI Emissions (lbs/vehicle) [a]	7.74	10.82	8.57
Paint Technology	Solvent-based	Waterborne	Solvent-based
Supplier Responsible for Environmental Performance	No	No	No

(a) The industry average in 1989 was about 9 pounds per vehicle.
(b) Baseline data is for 1991, first full year of production.

Table II. 1992 Comparative Environmental Performance: Differences Among Plants Emerge

	Plant A	Plant B	Plant C
Annual Production (vehicles)	152,649	212,112	157,335
Total TRI Emissions (lbs)	567,497	859,676	1,108,205
Normalized TRI Emissions (lbs/vehicle) [a]	3.72	4.05	7.04
Paint Technology	Solvent-based	Waterborne	Waterborne
Supplier Responsible for Environmental Performance	Yes, limited	Yes, limited	No

(a) The industry average in 1992 was 6.5 pounds per vehicle.

Table III. 1994 Comparative Environmental Performance: Plant A Shows the Greatest Improvement

	Plant A	Plant B	Plant C[b]
Annual Production (vehicles)	242,822	280,002	161,669
Total TRI Emissions (lbs)	361,426	1,072,482	871,844
Normalized TRI Emissions (lbs/vehicle) [a]	1.49	3.83	5.39
Paint Technology	Waterborne	Waterborne	Waterborne
Supplier Responsible for Environmental Performance	Yes	Yes, limited	No

(a) The industry average in 1994 was about 5 pounds per vehicle. The range of performance varied widely, however, from about 1.5 to 14 pounds. Over 60% of plants emitted over 4 pounds per vehicle.

(b) 1993 data