REPORT OF FIELD RESEARCH ON ENVIRONMENTALLY-CONSCIOUS MANUFACTURING IN THE UNITED STATES

Dr. Richard Florida
Mark Atlas

H. John Heinz III School of Public Policy and Management
Carnegie Mellon University
Pittsburgh, PA

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EXECUTIVE SUMMARY

INTRODUCTION

This report describes the findings of field research conducted to assess whether there is a relationship between U.S. industrial facilities' environmentally conscious manufacturing ("ECM") practices (e.g., source reduction, recycling, green product design, etc.) and their efforts to adopt advanced technological and organizational approaches to manufacturing. These new and innovative manufacturing systems are distinguished by a blend of technological and organizational changes inside the facility (e.g., self-directed work teams, worker rotation, total quality management, and continuous process improvement) and by close and interdependent relationships across the production chain, particularly between end-users and suppliers.

It has often been argued that there is a trade-off between industrial and environmental performance, with environmental quality coming at the expense of industrial competitiveness. A number of studies have recently argued that efforts to reduce wastes and waste management costs need not negatively affect business performance, and at times may actually improve it. They have labeled this apparent confrontation between environmental values and economic success as a "false dichotomy," arguing that the innovative workplace practices that improve facilities' overall efficiency and innovation can be applied to environmental management. These efforts can lower waste management and compliance costs, thereby improving facilities' overall competitiveness, while reducing pollution, thereby benefiting the environment.

While prior studies have explored the motivations for and components of ECM, apparently no research has been conducted focusing on whether facilities' general efforts to be innovative and adopt advanced manufacturing practices motivates them to also pursue ECM, thereby achieving this best of both worlds. This was the specific intent of this study, which was implemented by conducting on-site interviews of over 100 managers and line workers at 11 industrial facilities around the country that were specially selected to represent facilities at opposite ends of the spectrum of ECM adoption.

FIELD RESEARCH METHODOLOGY

The small number of facilities that could be visited were selected to maximize the information generated. By focusing on facilities at the ends of the spectrum of ECM adoption, we expected to be better able to assess what factors facilitated or obstructed its adoption. Therefore, our strategy was to identify "high adopters" and "low adopters" of such practices. Furthermore, to try to control for the effects upon ECM adoption of being in different industries, pairs of facilities were selected representing a high and low adopter within a particular industry. Within these constraints, a diverse sample was sought with respect to industry, size, and geographical location.

High adopters of ECM practices were identified by using several U.S. Environmental Protection Agency ("EPA") databases. Some were initially identified in laudatory ECM case

studies made available by EPA. All potential high adopter facilities' waste management activities were checked in EPA databases to ensure that they had consistently engaged in pollution prevention over the past several years. The greater the depth, breadth, and tenure of a facility's pollution prevention efforts, the higher it was rated with respect to ECM. Low adopters of ECM were selected by identifying facilities that had not engaged in pollution prevention over the past several years, despite their managing relatively large amounts of wastes or chemicals. For both the high and low adopters, these criteria were clearly rigorous because they eliminated all but a few percent of the facilities within any industry.

The industries within which high and low adopter facilities were desired were selected to reflect a diversity of U.S. manufacturing industries with significant environmental concerns. These industries were industrial organic chemicals, electroplating, motor vehicle parts, aircraft, and industrial machinery. For the 11 facilities that were visited, interviews of 30 to 60 minutes each were typically held with the facility managers who were responsible for the following functional areas: overall plant management, production operations, environmental compliance, financial affairs, procurement, and human resources. In addition, facilities' production workers were interviewed and brief tours of the facilities were conducted. The visits to facilities in Alabama (two facilities), California (three facilities), Connecticut, Louisiana (two facilities), Michigan, Pennsylvania, and Texas were conducted from July through November 1996.

OVERALL FINDINGS

There was substantial adoption of both innovative workplace practices and ECM techniques by the 11 facilities that were visited. Naturally, it was assumed that the seven facilities that were selected because they were identified as high adopters of ECM would confirm their statuses. What was obviously unknown prior to visiting the facilities, and was a primary purpose of visiting them, was the extent to which they had adopted innovative workplace practices. What was found was a high degree of use of such practices. Figure 1 provides a graphic display of the extent to which various of these practices appeared to be present at each facility, as well as other descriptive information about each facility. The more of a pie chart that is filled in, the more that the practice or characteristic is associated with the facility in question.

"Mission Statements" indicates whether the facility possessed and disseminated a formally-adopted, written, facility- or corporate-level overall policy expressing the organization's basic principles, objectives, and operating style. "Explicit Quality Management Systems" reflects the extent to which the facility has a formal and reasonably comprehensive management system designed to monitor and ensure the quality of its production operations. "ISO-Certified" refers to whether the facility's management systems have been officially certified as satisfying the quality control requirements of International Organization of Standardization ("ISO") 9000. "Supplier Quality Assurance" measures the degree to which the facility has a formal and consistent procedure for evaluating the quality of its suppliers, both before and after they become suppliers of the facility. "Supplier Partnerships" denotes whether the facility has an explicit program to encourage cooperative agreements with some of its suppliers to act as partners in the development and production of the facility's products, rather than simply functioning as suppliers and customers. "Just-in-Time Inventory" means whether the facility has formal procedures to minimize its inventory by only ordering supplies when they will be needed imminently.

FIGURE 1

WORKPLACE MANAGEMENT PRACTICES

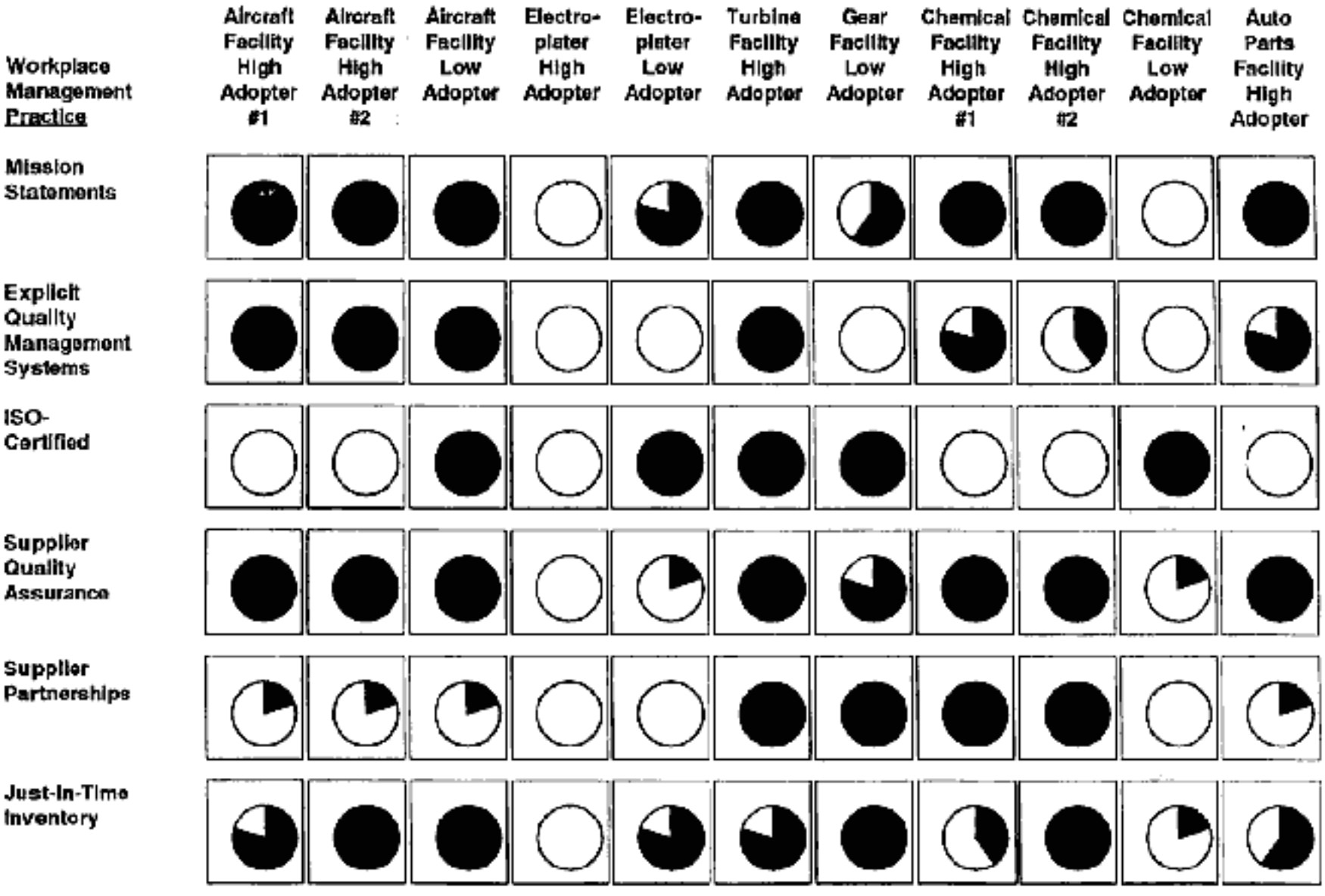
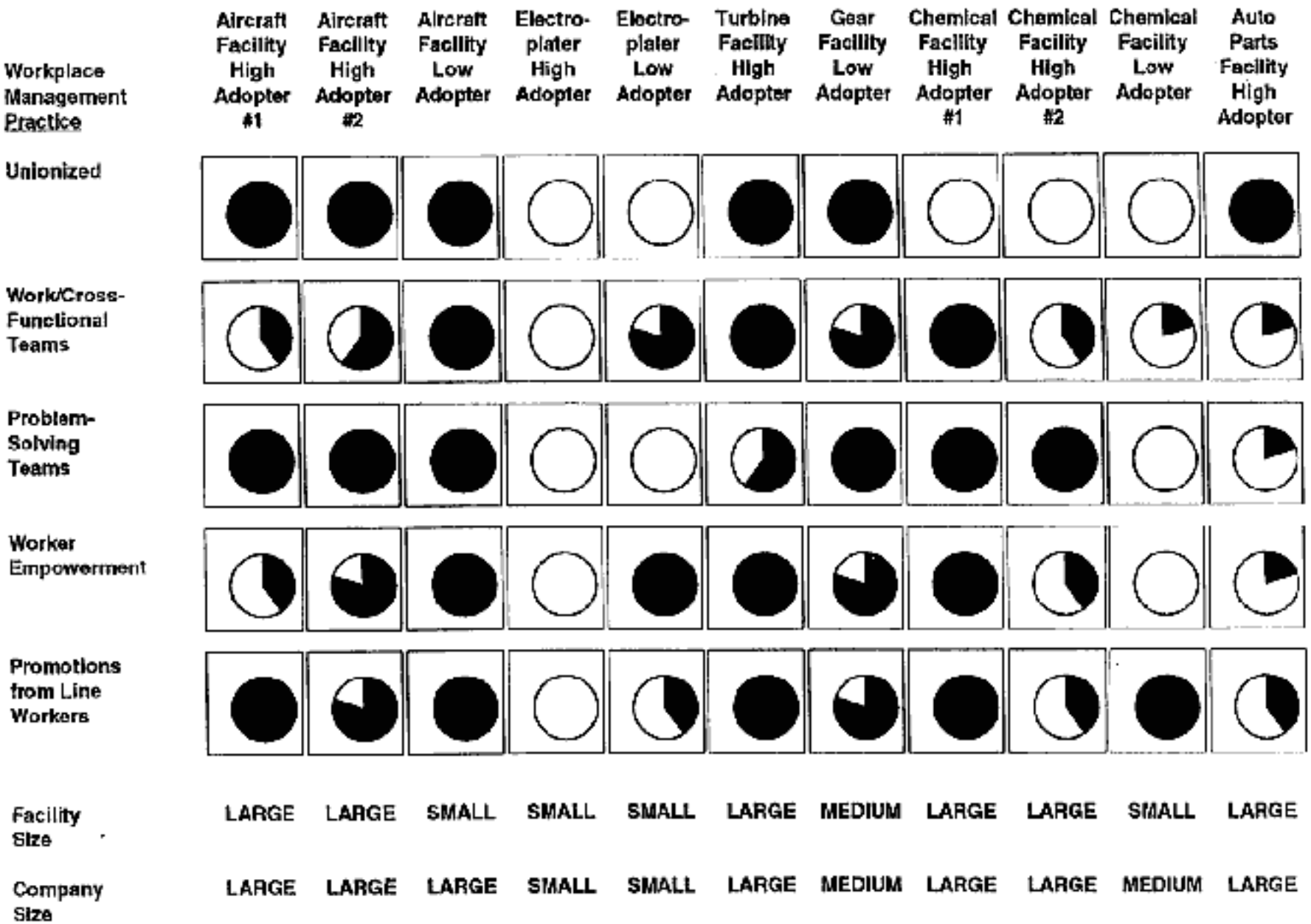


FIGURE 1 (cont.)

WORKPLACE MANAGEMENT PRACTICES



"Unionized" simply indicates whether the facility's line workers are unionized. "Work/Cross-Functional Teams" reflects the extent to which the facility has structured its workforce into team-like units, centered around certain products or production operations, or has created various cross-functional teams bringing together workers from different departments within the facility to address continuing operational issues. "Problem-Solving Teams" refers to whether the facility creates special teams of workers to address particular operational issues that sporadically arise requiring attention. "Worker Empowerment" measures the extent to which line workers have been given the authority to control the work practices and production processes within their assigned areas of responsibility. Finally, "Promotions from Line Workers" denotes how likely it is that production operations supervisors were promoted to their positions after first having been line workers.

While the next section of this Executive Summary describes the findings with respect to ECM practices, Figure 2 provides a graphic display, similar to Figure 1, of the extent to which various of these practices appeared to be present at each facility, as well as other descriptive information about each facility. "Catalyzing Incident" indicates whether the facility or parent company was subjected to some extreme incident or set of occurrences that largely prompted it to reevaluate its environmental practices. "Management Commitment" reflects the extent to which the senior management of the facility and parent company are overtly supportive of efforts to adopt ECM. "Explicit Environmental Objectives" refers to whether the facility has set specific and quantifiable objectives to be attained through its environmental practices and publicized these to its workers. "Environmental Performance Monitoring" measures the degree to which the facility has established formal, structured procedures through which its environmental activities are monitored and assessed. "Providing Environmental Information to Workers" denotes the effort the facility expends in consistently disseminating information about its environmental practices and performance to its workers. "Identification of Environmental Costs" means the ability that the facility has to track its environmental costs back to specific products or production processes.

"Size of Environmental Staff" indicates the adequacy of the number of environmental personnel at the facility, given the variety and nature of the environmental issues that it faces. "Experienced Environmental Staff" reflects the amount of experience solely in environmental matters possessed by the facility's environmental staff. "Long-Tenured Environmental Staff" refers to the typical length of time that the key environmental personnel have been at the facility, regardless of the specific positions that they may have previously worked at there. "Environmental Staff with Production Background" measures the frequency with which the primary environmental staff have some prior training or employment in the production operations relevant to their facility. "Chemical Control Processes" denotes the degree to which the facility has formal management and recordkeeping procedures in place to safeguard, monitor, and track the usage of its chemicals by workers. "Environmental Inspections" means the frequency with which the facility is audited for environmental purposes by its own staff, by corporate staff, by retained consultants, or by government agencies. Finally, "Audits of Suppliers" indicates the frequency with which the facility's suppliers are audited for environmental purposes by facility or corporate personnel.

By comparing the ratings of each facility on the two figures, there does appear to be a positive relationship between facilities that have implemented innovative workplace practices and those that have adopted ECM. The correlation is imperfect, partly because, due to their size

FIGURE 2
ENVIRONMENTAL MANAGEMENT PRACTICES

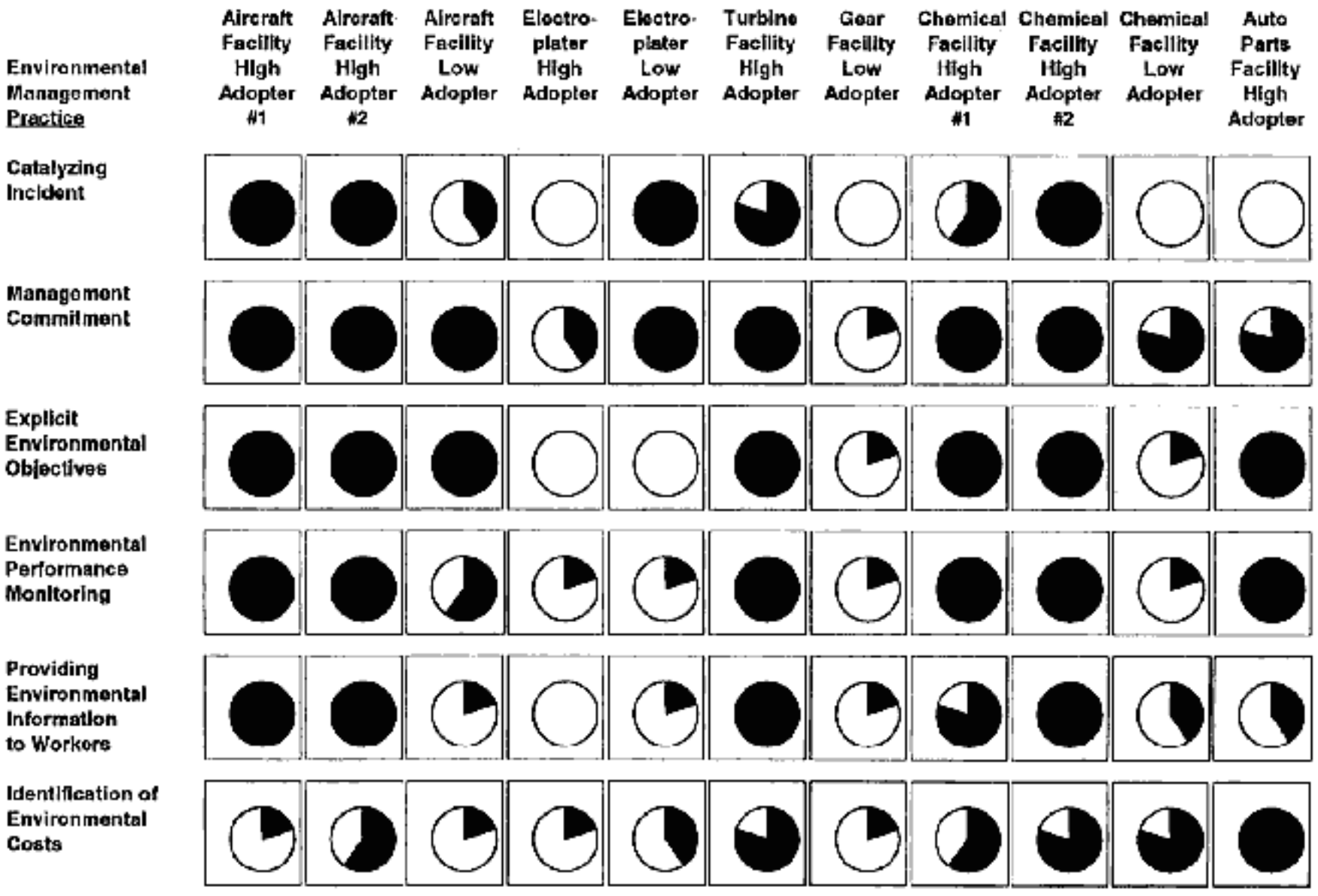
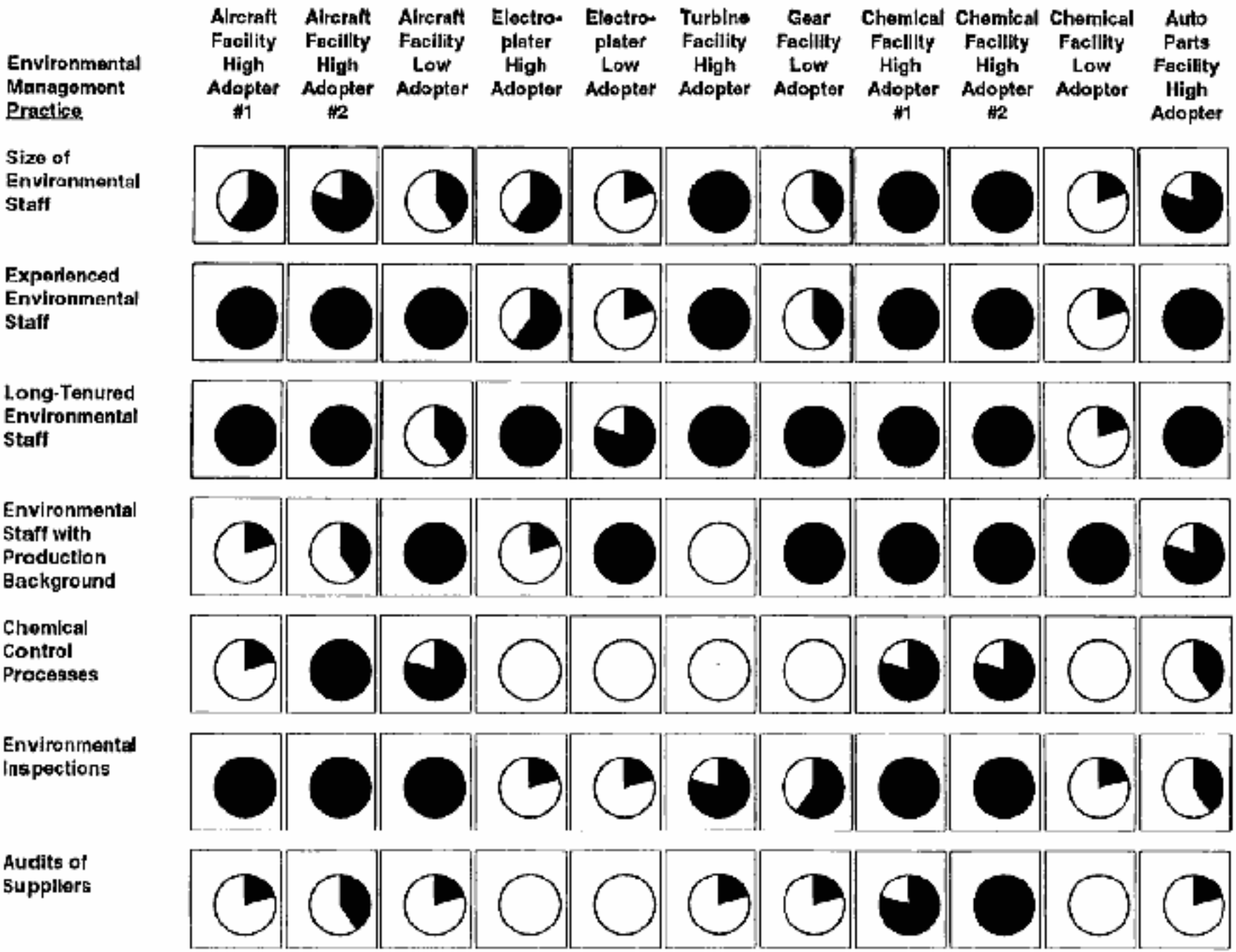


FIGURE 2 (cont.)
ENVIRONMENTAL MANAGEMENT PRACTICES



and/or environmental characteristics, some workplace and/or environmental practices are not particularly applicable to some facilities. Thus, confined only to those practices that are truly relevant to a particular facility, the comparison would show an even stronger relationship.

SUMMARY OF DETAILED FINDINGS

The following are the major findings from the field research with respect to environmental management practices. These findings are grouped into four basic areas: outside influences on ECM adoption and implementation, organizational influences on ECM adoption and implementation, individual influences on ECM adoption and implementation, and the mechanics of ECM adoption and implementation.

OUTSIDE INFLUENCES ON ECM ADOPTION AND IMPLEMENTATION

- Single incidents (e.g., chemical spills, government enforcement actions, new environmental reporting requirements, etc.) can lead to such substantial adverse consequences (e.g., widespread negative publicity, large penalties, community hostility, etc.) that the company and/or facility reevaluates and improves its entire approach to environmental concerns. Sometimes less serious incidents can still motivate change when they occur while the facility is in the throes of reevaluating all of its operations due to difficult business conditions.

- Some diffusion of ECM practices occurs through supplier chains (both up and down such chains), but it does not appear to be substantial. The opportunity appears to exist, however, for more such diffusion. This diffusion process is likely inhibited by the geographical distance between many suppliers and their customers.

- At least some facilities perceive that at least some environmental agency personnel are more motivated by a desire to find and fine violations, even if they are unintentional and inconsequential, rather than to predict and prevent potential problems and propose pollution prevention solutions.

- Pressures created by environmental laws can motivate facilities to adopt ECM practices that exceed the laws' requirements. This may be due to a desire to reduce materials use and/or waste generation to levels that exempt a facility from those laws, to pollution prevention opportunities identified as a result of considering process changes necessary to comply with laws, to public concerns over perceived environmental dangers from the facility, or to facilities' better understanding of their processes' inputs and outputs due to increased monitoring and record-keeping requirements.

- Some facilities expressed dissatisfaction with the apparent irrationality or irrelevance of some environmental requirements (e.g., requiring reporting of spills for some quantities of chemicals that were too low to pose any meaningful risk or managing some common household materials as hazardous wastes). Such requirements imposed costs upon them, without any, or any comparable, environmental benefit.

- Obtaining accurate, timely, and understandable information on environmental requirements is a barrier to ECM practices. Some facilities reported difficulty in obtaining such information from either their higher corporate level environmental groups or from government entities.

- The fear of potential liabilities from sending wastes off-site for disposal has motivated facilities to engage in pollution prevention, on-site waste treatment or disposal, or off-site recycling.

ORGANIZATIONAL INFLUENCES ON ECM ADOPTION AND IMPLEMENTATION

- The explicit commitment of top corporate and facility management to ECM practices provides leverage and support to lower-level managers to promote such practices at the facility level.

- Barriers to the diffusion of environmentally conscious practices exist between corporate sibling facilities, even despite the expressed commitment of overall corporate management to such practices. Thus, corporate-level analyses may not indicate the true extent of ECM practices, nor would corporate-level policies necessarily ensure the adoption of such practices throughout all facilities.

- Some facilities did not obtain the assistance that they desired in developing ECM practices from intermediate corporate levels (e.g., divisional headquarters staff). Thus, the overall corporate and individual facility environmental goals were not always being facilitated by all levels of the organization.

- Setting lower financial return thresholds for approving environmentally-beneficial projects can encourage their adoption.

INDIVIDUAL INFLUENCES ON ECM ADOPTION AND IMPLEMENTATION

- Individual environmental managers behaving proactively and innovatively can push a facility into more ECM practices, even in the initial or continued absence of a noteworthy overall facility or corporate support of such practices.

- The involvement of line workers can be very beneficial in developing ECM practices, because most pollution prevention improvements require relatively simple and inexpensive changes that may be most obvious to the line workers directly involved with the process in question.

- Possessing personnel in-house with environmental expertise is important in identifying, implementing, and monitoring ECM practices. Due to the complexity of environmental law, such expertise is important in understanding the legal implications of possible changes in production process inputs and outputs. Larger facilities, or facilities that are part of larger companies, are more likely to have that expertise immediately and relatively

inexpensively available.

- Most facilities indicated that unionized workers would be less receptive than other workers to efforts by management to seek their ideas in developing and implementing ECM practices.

- The continuity of environmental managers in their positions appears to be important in facilitating adoption of ECM practices. This could be explained by the fact that some ECM practices require relatively long lead times to implement, that line workers may be more likely to offer ideas to managers whom they have known for some time, that some ECM practices require a detailed understanding of the facility's production and labor practices that only develops with tenure, and that more senior managers may have more influence on upper management's decisions.

- The geographical proximity of suppliers and customers to facilities appears to have no substantial impact upon the diffusion of ECM practices among these entities.

MECHANICS OF ECM ADOPTION AND IMPLEMENTATION

- Using measurements of environmentally-related activities and outcomes (e.g., materials use, environmental costs, wastes generated, spills, etc.) is an important tool for determining progress, evaluating efforts' effectiveness, motivating further initiatives, and identifying opportunities for new ECM practices. Most facilities, however, have not attempted or succeeded in assigning environmental costs to specific products or operations, thereby undermining efforts to identify and justify possibilities for environmental and efficiency improvements.

- Most pollution prevention improvements involve relatively simple and inexpensive source reduction efforts, such as materials substitution, waste segregation, equipment monitoring, and minimization of materials inputs.

- In many situations, facilities adopted practices that ultimately were environmentally conscious, but did so primarily to reduce costs or improve their production processes. Thus, environmental benefits often were fortuitous byproducts of changes motivated by other reasons.

- The setting of explicit, ambitious, and quantitative environmental improvement goals at the corporate and facility levels helps to motivate and direct facilities to meet and exceed those goals.

- Frequent inspections of facilities can provide the continual pressure to be attentive to environmental concerns. Such inspections can be by internal facility staff, corporate level staff, outside consultants, customers, environmental agency personnel, or other government inspectors (i.e., when the facility is working on government contracts).

- Including environmental performance as part of workers' and facilities' overall

performance evaluations can help to sensitize everyone to the importance and benefits of taking environmental considerations into account. In addition, providing financial incentives for waste reduction or other environmental ideas can be desirable.

- Most facilities' environmental managers had a background in the production aspects of their facilities, typically by having come into their environmental positions directly from a production-related function.

- Line workers are more receptive to environmental requirements when the purposes behind them are made clear.

- Facilities that had adopted ECM practices were more likely to communicate their environmental objectives and progress to their workers.

INTRODUCTION

RESEARCH QUESTION

This report describes the findings of field research conducted to assess whether there is a relationship between U.S. industrial facilities' environmentally conscious manufacturing ("ECM") practices (e.g., source reduction, recycling, green product design, etc.) and their efforts to adopt advanced technological and organizational approaches to manufacturing. These new and innovative manufacturing systems have been referred to variously as lean production, agile manufacturing, and high-performance production.[1] These systems are distinguished by a blend of technological and organizational changes inside the facility (e.g., self-directed work teams, worker rotation, total quality management, and continuous process improvement) and by close and interdependent relationships across the production chain, particularly between end-users and suppliers.

It has often been argued that there is a trade-off between industrial and environmental performance, with environmental quality coming at the expense of industrial competitiveness. A number of studies have recently argued that efforts to reduce wastes and waste management costs need not negatively affect business performance, and at times may actually improve it. They have labeled this apparent confrontation between environmental values and economic success as a "false dichotomy," arguing that the innovative workplace practices that improve facilities' overall efficiency and innovation can be applied to environmental management. These efforts can lower waste management and compliance costs, thereby improving facilities' overall competitiveness, while reducing pollution, thereby benefiting the environment.

As described in the following section, prior studies have explored the motivations for and components of ECM. Apparently no research has been conducted, however, focusing on whether facilities' general efforts to be innovative and adopt advanced manufacturing practices motivates them to also pursue ECM, thereby achieving this best of both worlds. This was the specific intent of this study. As described in detail in the "Field Research Methodology" section of this report, this study was implemented by conducting on-site interviews of over 100 managers and line workers at 11 industrial facilities around the country that were specially selected to represent facilities at opposite ends of the spectrum of ECM adoption.

LITERATURE REVIEW

There is considerable literature documenting the shift to new and innovative manufacturing systems at facilities. An influential Massachusetts Institute of Technology study

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[1] *See, e.g.*, James Womack, Daniel Jones, and Daniel Roos, *The Machine that Changed the World* (New York, NY: Rawson and Associates, 1990); Paul Osterman, "How Common Is Workplace Transformation and Who Adopts It?," *Industrial and Labor Relations Review*, 47/2 (January 1994).

documented the transition from mass production to lean production in the automotive industry.[2] A survey of U.S. manufacturing establishments by Osterman found evidence of significant adoption of innovative work organizations in a large and representative sample of U.S. plants.[3] Survey research by Florida and Jenkins found a significant rate of adoption of innovative manufacturing practices by Japanese transplant manufacturers in the U.S.[4]

There also is considerable literature documenting the shift to ECM at facilities.[5] In particular, some literature has found aspects of or motivations for ECM that explicitly incorporate some fundamental concepts of advanced manufacturing systems. Nearly half of the U.S. manufacturers responding to a 1994 survey stated that they had implemented a total quality environmental management program, similar to the total quality management concept for general manufacturing purposes.[6] Nearly two-thirds of the companies surveyed stated that line workers were key contributors to their pollution prevention efforts and almost half said the same of their suppliers, the same type of worker and supplier involvement desired in high performance production.

Consistent with the latter, a study in Denmark concluded that the quality of the interaction processes between facilities and their suppliers and customers was critically important

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[2] Womack, Jones, and Roos, op. cit.

[3] Osterman, op. cit.

[4] Richard Florida, *The Japanese Transplants Project: Final Report to the Sloan Foundation* (Pittsburgh, PA: Carnegie Mellon University, Center for Economic Development, 1995); Paul Davis Jenkins, *The Japanese Transplants and the Work System Revolution in U.S. Manufacturing*, unpublished Ph.D. dissertation (Pittsburgh, PA: Carnegie Mellon University, 1995).

[5] Richard Florida, "Lean and Green: The Move to Environmentally Conscious Manufacturing," *California Management Review*, 39/1 (Fall 1996), pp. 80-105; Michael Porter and Claas van der Linde, "Green and Competitive: Ending the Stalemate," *Harvard Business Review* (September-October 1995), pp. 120-134; Michael Porter and Claas van der Linde, "Toward a New Conception of the Environment-Competitiveness Relationship," *Journal of Economic Perspectives*, 9/1 (Fall 1995), pp. 97-118; D. Keith Denton, *Enviro-Management: How Smart Companies Turn Environmental Costs Into Profits* (Englewood Cliffs, N.J.: Prentice Hall, 1994); Office of Technology Assessment, *Industry, Technology, and the Environment: Competitive Challenges and Business Opportunities* (Washington, D.C.: U.S. Government Printing Office, 1994); Joel Makower, *The e Factor: The Bottom-Line Approach to Environmentally Responsible Business* (New York, NY: Times Books, 1993); Klaus North, *Environmental Business Management: An Introduction* (Geneva: International Labour Office, 1992); Office of Technology Assessment, *Green Products by Design: Choices for a Cleaner Environment* (Washington, D.C.: U.S. Government Printing Office, 1992); Stephan Schmidheiny, *Changing Course: A Global Business Perspective on Development and the Environment* (Cambridge, MA: The MIT Press, 1992); Bruce Smart (ed.), *Beyond Compliance: A New Industry View of the Environment* (Washington, D.C.: World Resources Institute, 1992).

[6] Florida, op. cit. 5.

in whether facilities adopted pollution prevention.[7] A Dutch study of large multinational corporations also found that interactions with suppliers, as well as just-in-time inventories, were key components of ECM.[8] A U.S. study determined that facilities with a team-orientation were more likely to voluntarily adopt environmentally beneficial policies.[9] A survey of British companies determined that the most important requirements for projects leading to environmentally friendly products were collaboration with suppliers and customers.[10] Finally, some field research on U.S. chemical companies concluded that environmentally superior companies tended to have explicit objectives, long-range planning, performance-based evaluations for employees, pro-active corporate cultures, and formalized control, measurement, and reward programs.[11]

Thus, research has been done on the existence of both sets of workplace management practices individually, and some results indicate that there is overlap and synergy between the sets of practices. Most of these latter results, however, were after-the-fact conclusions of the research, rather than explicit, well-defined hypotheses upon which the research was based. The purpose of the field research in this project was to expressly select these hypotheses beforehand and to then thoroughly explore them.

REPORT STRUCTURE

This report is structured in the following manner. First is a detailed description of the methodology by which the sample of facilities was selected to participate in this research. The strategy behind the selection criteria used is explained, as well as the specific information extracted about prospective participants that was compared to those criteria and the bases for those comparisons.

Next, this report provides summaries of the interviews conducted at each of the participating facilities. Each of these summaries is composed of two sections, one describing the general background, management structure, and workplace management practices of the facility

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[7] Susse Georg, Inge Ropke, and Ulrik Jorgensen, "Clean Technology -- Innovation and Environmental Regulation," *Environmental and Resource Economics*, 2 (1992), pp. 533-549.

[8] Johan Schot, "Credibility and Markets as Greening Forces for the Chemical Industry," *Business Strategy and the Environment* 1/1 (Spring 1992).

[9] Tom Suraphol Apaiwongse, "Voluntary Reaction to Green Policies Among Market-Mavens: An Application of the Parallel-Political Marketplace Conceptualization," in Michael Polonsky and Alma Mintv-Wimscott (eds.), *Environmental Marketing: Strategies, Practice, Theories and Research* (Binghamton, NY: Haworth Press, 1995).

[10] Kenneth Green, Andrew McMeekin, and Alan Irwin, "Technological Trajectories and R&D for Environmental Innovation in UK Firms," *Futures*, 26/10 (1994), pp. 1047-1059.

[11] Patricia S. Dillon and Kurt Fischer, *Environmental Management in Corporations: Methods and Motivations* (Medford, MA: Tufts University, 1992).

and the other detailing its environmental management practices. Though numerous individuals were interviewed at each facility, their responses have been woven together to provide a combined, coherent discussion of specific points. The depth and breadth of the summaries vary by facility, due to the amount of time the facility personnel were able to spend with our researchers and to the level of detail in which it was relevant to delve to address our research questions. Small facilities with relatively rudimentary workplace and/or environmental management practices would, by definition, have less details to provide than large, complex facilities with numerous relevant practices. Each of the participating facilities had the opportunity to review a draft version of its summary and to correct any misunderstandings or erroneous recollections.

The next section of this report discusses the basic research question of whether facilities that have adopted innovative workplace practices also are more likely to have adopted ECM. Our conclusions based upon this field research are described, as well as the reasons why any such relationship should be expected.

The final section of this report describes the detailed findings of this field research specifically with respect to environmental management practices. These findings are grouped into four basic areas: outside influences on ECM adoption and implementation, organizational influences on ECM adoption and implementation, individual influences on ECM adoption and implementation, and the mechanics of ECM adoption and implementation.

ACKNOWLEDGEMENTS

Research funding was provided by grants from the National Science Foundation's Environmentally Conscious Manufacturing Program and Division of Geography and Regional Science, the Alfred P. Sloan Foundation, and the Great Lakes Protection Fund. Parag Shah and Christopher Bell provided research assistance with various aspects of this project.

FIELD RESEARCH METHODOLOGY

FIELD RESEARCH SAMPLE SELECTION: STRATEGY

Given the small number of facilities that could be visited within the project's travel budget, a sample selection strategy had to be devised for this field research that could maximize the information generated. The objective of this research was to better understand the processes by which some facilities adopt ECM while others do not. Thus, we believed that these processes might best be revealed by selecting facilities that presented the extremes of ECM practices -- those that had an unusual propensity to adopt ECM practices and those with a special propensity to ignore them.

By focusing on facilities at the ends of this spectrum, we expected to be better able to assess what factors facilitated or obstructed the adoption of ECM practices. Therefore, our guiding sample selection strategy was to identify "high adopters" and "low adopters" of such practices. Furthermore, to try to control for the effects upon ECM practice adoption of being in different industries, we decided to select pairs of facilities representing a high and low adopter within a particular industry. Within these constraints, we also sought to obtain a diverse sample with respect to industry, size, and geographical location.

FIELD RESEARCH SAMPLE SELECTION: HIGH ADOPTERS

To operationalize the concept of high adopters of ECM practices, we decided first to try to identify manufacturing facilities that had been the subjects of laudatory published case studies of their ECM practices. Clearly, facilities about whom such case studies had been published were more likely to be ECM high adopters, given the nature of those case studies. In addition, it was believed that facilities that allowed their experiences to be publicized through such studies would be more likely to agree to participate in our research, which would further publicize their practices, though not reveal their identities.

To locate such case studies, we used the "Enviroene" computer bulletin board system ("BBS") operated by the U.S. Environmental Protection Agency ("EPA"). Enviroene is a free, publicly-accessible BBS in which EPA makes available a variety of about 3,000 pollution prevention documents. Among these documents are many case studies of facilities that implemented ECM practices. EPA has made a conscious effort to gather such studies from many sources (e.g., EPA offices, state environmental agencies, industry reports, etc.) to centralize their availability. While other sources of these studies exist, none are likely to be as voluminous or accessible as Enviroene.

While Enviroene is a well-structured compilation of documents, it does not clearly isolate those containing facility case studies. Thus, the first step in identifying such studies was to review the thumbnail descriptions provided in Enviroene of the approximately 3,000 documents that it contains. Of those documents, 620 were believed to potentially contain facility-specific case studies. These documents were then downloaded from Enviroene for thorough examination.

These 620 documents produced the names and locations of 184 facilities that had engaged in noteworthy ECM practices. Because ultimately we would be selecting facilities within certain Standard Industrial Classification ("SIC") codes and with certain minimum environmental characteristics, two EPA databases were used to obtain more information about the identified facilities. The primary database was EPA's Biennial Reporting System ("BRS"), which contains information about facilities that are large quantity generators of hazardous waste. The secondary database was EPA's Toxic Release Inventory ("TRI"), which contains information about facilities that use substantial amounts of toxic chemicals.

Among the information that these databases contain is the four-digit SIC codes of facilities in them. The names and addresses of the 184 Enviroene-derived facilities were then used in searches of BRS. For those 114 facilities that were BRS facilities, their BRS-reported SIC codes were noted. The remaining 70 facilities not in BRS were then used in searches of TRI. For those 36 facilities that were TRI facilities, their TRI-reported SIC codes were noted.

Thus, of the 184 Enviroene-derived facilities, SIC codes were found for all but 34 of them.[12] Those facilities not in BRS or TRI were eliminated from further consideration. This was because being in BRS or TRI indicated that a facility had substantial amounts of hazardous wastes or chemicals. We wanted to ensure that our high adopter facilities were those that faced, and successfully surmounted, the challenges of implementing ECM practices when confronted with, volumetrically, a large task. Thus, we wanted to exclude facilities whose high adopter statuses might have been earned with relatively minor efforts directed against relatively small amounts of wastes or chemicals.

The 150 surviving facilities were then separated into groups with identical SIC codes. Each facility was then rated for the extent of its ECM activity, based upon the available information. This information was the nature, extent, and longevity of its pollution prevention efforts, as described in the applicable Enviroene document(s), and its history of source reduction and recycling activities, as reflected in BRS and TRI. Among the BRS information on each facility is whether it began or expanded source reduction or recycling efforts for its hazardous wastes in 1989, 1991, and 1993.[13] Among the TRI information on each facility is whether it engaged in source reduction or recycling efforts for certain of its chemicals in 1991

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[12] The fact that over 80 percent of the facilities about whom pollution prevention case studies were found are BRS or TRI facilities is a significant finding by itself. Less than 40,000 facilities nationwide are BRS and/or TRI facilities, a small fraction of all U.S. manufacturing facilities. This extreme over-representation of BRS and TRI facilities among pollution prevention case studies indicates that such studies are concentrated among facilities with large amounts of waste or chemicals. Because it may be easier for such facilities to engage in a pollution prevention activity, given their greater opportunities to do so, such studies may be providing a misleading impression of the ability of facilities in general to accomplish pollution prevention. Thus, such studies may be reflecting the "low-hanging fruit" of pollution prevention possibilities.

[13] As its name implies, BRS data are gathered biennially, in odd-numbered years, beginning in 1989 and with the most recent available data from 1993.

through 1993.[14] The greater the depth, breadth, and tenure of a facility's pollution prevention efforts, the higher it was rated with respect to ECM practices. This process ensured that a facility would not be selected that was the basis of a laudatory case study many years ago, but which had not recently consistently engaged in ECM practices. Of the four high adopters ultimately visited during this research that were chosen through this methodology, all were rated "A" or "A+" on a scale of from "A+" to "E."

Because of the small number of high adopters identified in some desired SIC codes and either their disinclination to participate in this research or the excessive expense of travelling to them, the high adopters for two SIC codes were selected through a slightly different methodology. These facilities were initially identified not from published pollution prevention case studies, but rather solely on the basis of their BRS and TRI information. These facilities all were ones which, according to their BRS and TRI information, had engaged in source reduction and recycling in each reporting year since 1989. Thus, while no case studies had been posted on EnviroSenSe regarding them, these facilities were clearly superior with respect to ECM activities since only a few percent of all U.S. facilities within each SIC code met these criteria.

FIELD RESEARCH SAMPLE SELECTION: LOW ADOPTERS

To operationalize the concept of low adopters of ECM practices, we relied upon BRS and TRI information. Within the SIC codes in which high adopters were identified, we identified facilities that had not reported source reduction or recycling activities in any of their BRS or TRI reports from 1989 to 1993. These facilities were clearly inferior with respect to ECM activities because only a couple of percent of all U.S. facilities within each SIC code met these criteria.[15] Furthermore, we excluded facilities which handled relatively small amounts of wastes or chemicals. We wanted to ensure that our low adopter facilities were those that faced the challenges of implementing ECM practices when confronted with, volumetrically, a large task. Thus, we wanted to exclude facilities whose low adopter statuses might have been due to the relative unimportance of implementing pollution prevention when facing minor amounts of wastes or chemicals. Finally, each of the surviving facilities was checked against the list of EnviroSenSe-derived facilities to ensure that no pollution prevention case study existed concerning them.

FIELD RESEARCH SAMPLE SELECTION: SIC CODES

The SIC codes within which high and low adopter facilities were desired were selected to

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[14] While TRI data were reported beginning in 1987, this pollution prevention information became required only in 1991. The most recent available TRI data were from 1993.

[15] The fact that only a couple of percent of all BRS facilities within these SIC codes had engaged in neither source reduction nor recycling during these years is a significant finding by itself. This obviously indicates that pollution prevention is almost completely diffused among facilities handling large amounts of wastes or chemicals. The depth of these activities, however, still is uncertain.

reflect a diversity of U.S. manufacturing industries with significant environmental concerns. The SIC codes selected were the following:

- SIC code 2869: Industrial Organic Chemicals
- SIC code 3471: Electroplating, Plating, Polishing, Anodizing, and Coloring
- SIC code 3714: Motor Vehicle Parts and Accessories
- SIC code 3728: Aircraft Parts and Auxiliary Equipment
- SIC code 3511: Steam, Gas, and Hydraulic Turbines, and Turbine Generator Set Units
- SIC code 3566: Speed Changers, Industrial High-Speed, Drives and Gears

Due to the inability to identify a suitable low adopter facility for SIC code 3714, only a high adopter facility was included for that SIC code. Due to the inability to identify suitable high and low adopter facilities with the same four-digit SIC code in SIC code 35, the facilities selected were those in that two-digit SIC code and which manufactured related products.[16]

FIELD RESEARCH SAMPLE SELECTION: SPECIFIC FACILITIES

Once the facilities meeting our criteria were identified, we prioritized them by their geographical locations and our prior contact, if any, with them. We attempted to maximize the overall geographical dispersion of the facilities, while choosing pairs of facilities that were close enough together to enable efficiencies in our travel budget.[17] In a few cases, the parent companies of some facilities had participated in prior studies conducted by our researchers, and thus we prioritized these facilities more highly because we believed that their cooperation was more likely to be forthcoming.

The plant or corporate managers of a few of the priority high and low adopters within each SIC code were then sent letters informing them of our research and seeking their facilities' participation. These letters were followed up by telephone calls from our researchers. If facilities declined to participate, lower priority facilities were selected in their place. This process continued from June through September 1996.

Of the 17 facilities whose participation was sought, 11 agreed. We requested interviews of 30 to 60 minutes with the facility managers who were responsible for the following functional areas:

- Overall plant management
- Production operations
- Environmental compliance
- Financial affairs

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[16] In fact, we discovered during our facility visits that the low adopter in SIC code 3566 had obtained advice on managing its operations from the high adopter in SIC code 3511.

[17] Though the travel budget was based upon visiting the originally proposed 5 to 7 facilities, a total of 11 were ultimately visited.

- Procurement
- Human resources

In addition, we asked to interview some of the facilities' production workers and for a brief tour of the facilities.

Due to the difficulties of scheduling times when most of a facility's senior management would be available for interviews during a one or two day period, the facility visits continued from late July through early November 1996. The facilities visited were located in Alabama (two facilities), California (three facilities), Connecticut, Louisiana (two facilities), Michigan, Pennsylvania, and Texas.

The facilities visited were all promised confidentiality with respect to their identities, and thus the following names will be used to identify them in this report:

- Aircraft facility high adopter #1
- Aircraft facility high adopter #2[18]
- Aircraft facility low adopter
- Chemical facility high adopter #1
- Chemical facility high adopter #2
- Chemical facility low adopter
- Electroplater high adopter
- Electroplater low adopter
- Turbine facility high adopter
- Gear facility low adopter
- Auto parts facility high adopter

The information which was used to designate facilities as high or low adopters was sometimes a few years old, particularly with respect to the low adopters, who were chosen on the basis of BRS and TRI data that were no more recent than 1993. Thus, we realized that it was possible that some facilities might have recently changed their practices sufficiently to fail the criteria that we had set. We believed, however, that even if this became obvious during our facility visit, the resulting information still would be useful as it might best provide an understanding of the process by which facilities evolve from low to high adopters or vice versa.

Among the facilities that we visited, two of the low adopters (in SIC codes 3471 and 3728) had recently significantly improved their environmental practices such that they would no longer completely fit our stringent criteria for low adopters. In addition, a high adopter (in SIC code 3471), while still meeting our criteria, did not, on the basis of our visit there, appear to be as much of a high adopter as its case study and BRS data indicated.

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[18] The two Aircraft Facility High Adopters were in the same company. When our researchers contacted one of them, the company recommended that we visit both facilities.

FIELD RESEARCH INSTRUMENTS AND BACKGROUND INFORMATION

Prior to visiting the facilities, we prepared a detailed list of questions to serve as starting points for our interviews of each of the types of facility personnel. Given the relatively short amount of time available for each interview, these questions were designed to focus on the subjects most within the purview of the applicable interviewee. Naturally, all of the questions were directed at the purpose of this research -- exploring facilities' adoption of innovative workplace practices in general and ECM practices in particular, and the relationships between these sets of practices. While it was not always possible or necessary to ask interviewees all of these questions, they served as a guide in our discussions.

In addition to preparing the research instruments, we also reviewed extensive environmental information about the facilities prior to our visits. This enabled us to better understand the environmental context within which these facilities operated. The following EPA databases were checked for information about the facilities from as early as 1983 to date:

- **Accidental Release Information Program**: chemical releases from facilities
- **Biennial Reporting System**: facilities' hazardous waste generation and management practices
- **Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA") Information System**: possible hazardous substance contamination at facilities
- **Toxic Substances Control Act Inventory of Chemical Production**: chemicals produced at facilities
- **DOCKET**: EPA civil litigation and administrative actions against facilities
- **Emergency Response Notification System**: chemical and oil releases from facilities
- **National Priorities List**: CERCLA sites at facilities
- **Permit Compliance System**: permitted wastewater discharges by facilities
- **Toxic Release Inventory**: chemical releases, transfers, and management practices at facilities

Finally, for most of the high adopter facilities, we also had the Enviroene case studies which originally led to the facilities' selection.

SUMMARIES OF FACILITY INTERVIEWS

AIRCRAFT FACILITY HIGH ADOPTER #1

GENERAL BACKGROUND

Aircraft Facility High Adopter #1 is an aircraft maintenance and refurbishment facility in California. The facility leases a large site. Almost all of the facility's work involves U.S. military aircraft, with some foreign military aircraft also done. The facility has existed for nearly 50 years, though it plans to close soon to consolidate its operations with Aircraft Facility High Adopter #2. The facility owner is a wholly-owned subsidiary of a Fortune 50 corporation which has been a prominent member of the aviation industry for decades.

The facility's work involves repairing aircraft that have been damaged (e.g., through accidents or hostile fire) or worn out, and refurbishing aircraft with upgraded avionics or other equipment. This work involves the stripping and reapplication of paint on the aircraft, replacement and cleaning of mechanical and electrical parts, and other such repair work. The parts produced at this facility are built only a few at a time, given their sophistication and special purpose, and thus there is not a traditional production line. In a typical year, the facility works on 10 to 12 aircraft, requiring an average of 8 to 10 months of work apiece.

Since 1993, the facility has been using an "Integrated Product Development" approach in its production operations, forming teams from all levels of the facility to address work projects. When a problem is identified, the facility management nominates a team, with someone from management as the team leader. The team leader selects the team members, though input on the problem is sought from everyone. Each team then sets the cost, scheduling, and quality objectives for its project. This general approach, however, had been the norm at the facility before it was formally called "Integrated Product Development" (previously, it was referred to as quality circles). The facility also is using a continuous quality improvement philosophy -- focused on reducing quality, scheduling, and cost defects -- combined with a management by objectives process that requires it to set objectives annually. These philosophies were adopted to emphasize what the facility believed it needed to accomplish to retain its competitiveness.

Most of the raw materials used at the facility are aluminum and steel stock, electronic components, and chemicals. Most of its supplies are commercial off-the-shelf parts, and thus there is little customization needed. Sometimes, however, it does need to work with suppliers -- typically, metal fabrication shops -- to determine the specifications or design of unique parts. Thus, the location of such suppliers is important in procurement decisions because the facility's engineering and procurement staff tend to visit them often and sometimes require quick turnaround of work. In addition, the facility tries to maintain a very low inventory. Consequently, about 35 to 40 percent of the facility's nearly 1,000 suppliers are in the surrounding area.

Prospective suppliers are evaluated through a "Supplier Quality Assurance" program in which the facility determines whether the processes and procedures of the suppliers satisfy specifications. Part of this process is an evaluation survey of prospective suppliers, but the survey does not include environmental considerations. Suppliers that are approved are placed on the facility's "Quality Product List." Requisitions for raw materials and capital equipment must be

reviewed by the environmental staff, and those for supplies of a hazardous nature must be stamped with the environmental staff's approval. Suppliers typically are the source of innovations only when they are trying to sell something new.

The facility has about 1500 employees, about one-third of which are engineers who are unionized and with all line workers unionized. There are five major categories of non-managerial employees: supervisors, manufacturing engineers, lead people, part makers, and technical assistants, the latter three groups being the hourly workers. About 70 to 80 percent of the facility's supervisors were promoted from line worker positions. Most of the line workers are ex-military personnel with one or two years of college. Line workers are ordinarily hired already possessing the skills needed for the particular vacant position, and thus there is no need to train them in their skill areas.

ENVIRONMENTAL MANAGEMENT

In the early 1990's, another of the parent corporation's facilities in a nearby city was closed largely due to environmental concerns. The contamination around that facility has resulted in lawsuits and government enforcement actions against it seeking hundreds of millions of dollars for contamination cleanup costs, property damage, and personal injury. This legacy has motivated the corporation and facility to be conscientious in their environmental efforts. Now this facility is considered to have one of the better environmental programs in the state. Recently, the facility received several awards for pollution prevention, including one from the state environmental agency. The facility's efforts in pollution prevention are considered to have set the standard for Aircraft Facility High Adopter #2.

The environmental manager is perceived by other managers as the "cop on the beat" who warns them of the consequences of potential violations and motivates them to focus on concerns other than the product. According to the production operations managers, however, the facility's environmental efforts can help, rather than constrain, production and the environmental staff serves as consultants on proposed process changes at the facility. In their view, such efforts can lower costs and increase productivity. For example, recycling its wastewater not only reduces the facility's water consumption, it reduces its reliance on and expenditures for city-supplied water.

Similarly, sometimes efforts undertaken to improve product quality or production efficiency have desirable environmental impacts. For example, at one time military specifications required five separate paintings of certain electrical parts, which led to difficulty in their performance. The facility developed, with the approval of the customer, a new process that required only one application of paint. This process, which was subsequently incorporated into the formal specifications, not only improved product quality and cut costs (by eliminating the need for one painter), it reduced the paint used and thus emissions and waste.

The facility also has switched from using solvents to remove paint from aircraft to using plastic media blasting ("PMB"). The PMB equipment shoots small plastic pellets at a surface to scrape off paint and reduce it to residual dust. The facility actually leases these pellets and, after they are of no more use, transfers them back to the lessor, who recycles them into tiles. Using the PMB equipment allowed the facility to eliminate this prior source of solvent air emissions.

The facility, however, began considering using this technology only because the time required for paint removal using solvents was creating a production bottleneck. While the facility incurred some cost working with the PMB equipment manufacturer to develop this application of the technology, it has resulted in halving the process time and labor cost for this function. While using PMB requires substantial electricity, the facility also has obtained a pollution prevention rebate on its bill from the utility company. Furthermore, this innovation aided worker satisfaction, as it is more comfortable working inside with PMB than outside with solvents. The facility has subsequently trained other facilities in using PMB.

The facility is the subject of frequent environmental audits, including biweekly audits by facility staff, audits by corporate staff every other year, military customer visits, and state and federal environmental agency inspections. At least monthly the facility is audited by some government agency. In addition, the performance appraisals for managers includes their efforts on environmental concerns.

The environmental staff uses a variety of means with which to communicate the facility's environmental performance, including bulletin boards, monthly presentations, bulletins, and newsletters. The workers are kept informed of various performance measures, including the amounts of waste disposed, recycled, and landfilled.

Environmental costs are included in the facility's overall manufacturing overhead costs and thus are allocated over all work through the common overhead rate, rather than being charged to the particular work that generated the costs. Speculative environmental liabilities are estimated by the environmental manager and forwarded to the facility's financial staff. In 1996, the facility spent about $1,000,000 on environmental compliance and waste costs.

The environmental manager has been with the facility for nearly 10 years and is assisted by a few other environmental staff. They are not formally trained in production operations, but rather have learned what they need on their own. The environmental staff obtains information from local university and corporate seminars, from corporate sibling facilities, and from quarterly environmental regulatory updates from corporate staff.

Each year the environmental manager prepares a strategic plan stating environmental goals for the upcoming year. The goals depend upon the current focus of applicable environmental regulations and the corporate interests involved, and the corporation is involved in setting those goals. An executive-level team meets monthly to review the facility's environmental performance. The availability of reliable pollution prevention or control technology, logistical difficulties, and the adequacy of substitutes for undesirable chemicals are key barriers to achieving some environmental objectives.

Some ideas for environmental improvements also come from line workers, primarily involving ways to eliminate scrap parts. The facility, however, has no formal employee suggestion process. How proposed environmental projects are evaluated to determine whether they should be implemented depends upon their magnitude. Consideration of small projects can be done informally and sometimes on the spot. The facility estimated that 60 to 70 percent of its environmentally beneficial projects were non-resource intensive common sense solutions. Medium-sized projects can be evaluated informally or by a team. Large projects would be evaluated through a more formal approach, using a team of up to several people.

For major proposed environmentally-related projects, the key criteria are whether the technology is proven, what are the costs and benefits, whether a change will enhance the facility's production efficiency, and what goals, legal requirements, and/or issues of concern they address. Ordinarily, a two to five year return on investment period on environmental projects is desired, and a two to three year period is usually achieved. The facility's underlying goal is to initiate cost-effective projects, not to attain a level of zero emissions.

AIRCRAFT FACILITY HIGH ADOPTER #2

GENERAL BACKGROUND

Aircraft Facility High Adopter #2 is an aerospace research and development facility on a large site in California. The facility maintains and develops prototype and limited production combat and surveillance aircraft and spacecraft for U.S. military and intelligence agencies and the National Aeronautics and Space Administration. The facility has existed for about 30 years, though in the last 10 years it has expanded to incorporate functions from corporate sibling facilities that have closed or are about to do so, including Aircraft Facility High Adopter #1. The facility owner is a wholly-owned subsidiary of a Fortune 50 corporation which has been a prominent member of the aviation industry for decades.

Since 1993, the facility has been using an "Integrated Product Development" approach to its production operations, forming teams from all levels of the facility to address work projects. When a problem is identified, the facility management nominates a team, with someone from management as the team leader. The team leader selects the team members, though input on the problem is sought from anyone. Each team then sets the cost, scheduling, and quality objectives for its project. This general approach, however, had been the norm at the facility before it was formally called "Integrated Product Development" (previously, it was referred to as quality circles).

Process certified teams are used, though not extensively because production activities at the facility are limited. Such teams are typically used only when there is expected to be a repeated need for certain functions. Worker teams, quality circles, and continuous quality improvement philosophies have been tried previously.

The facility is comprised of a number of separate buildings for different processes. Since 1990, each building has been assigned a building manager. Each building manager is responsible for all operations, including their environmental implications, within his building. This program was in part a reaction to the environmental problems that previously arose at a corporate sibling facility. Each building manager audits his building monthly and a checklist of objectives for each building manager is evaluated monthly. The program has instilled self-awareness and the motivation for self-inspection and self-policing. If a problem is discovered, a correction notice is issued and entered into a database, with this information subsequently reviewed by senior management.

Most of the raw materials used at the facility are metal stock, resins, glues, composite materials, and chemicals. Sometimes the facility needs to work with suppliers -- typically, metal fabrication shops -- to determine the specifications or design of unique parts. Thus, the location of such suppliers is important in some procurement decisions because the facility's engineering and procurement staff tend to visit them often and sometimes require quick turnaround of work. In addition, since about 1990, the facility has tried to manage its supplies using a "just-in-time" inventory system. Consequently, nearly half of the facility's suppliers are in the surrounding area.

The facility's quality assurance department inspects suppliers and their processes. A

checklist, which includes environmental issues, is used in this approval process and the approval of suppliers must be renewed every few years. Product quality is the main criterion used to select suppliers, with delivery time and cost secondary concerns, but often there is only one supplier available for certain needs. The facility and its corporate siblings are developing a common supplier database that uses a rating system for suppliers. This is expected to reduce the duplication of effort in certifying suppliers and the number of suppliers used.

The facility has about 5,000 employees, most of whom are unionized. The major categories of employees are managers, supervisors, and hourly workers (either engineers or manual laborers). About 50 to 80 percent of the supervisors were promoted from line worker positions. Line workers are ordinarily hired already possessing the skills needed for the particular vacant position, and thus there is no need to train them in their skill area. Voluntary turnover is very low, with an average seniority of over 20 years.

ENVIRONMENTAL MANAGEMENT

In the early 1990's, another of the parent corporation's facilities in a nearby city was closed largely due to environmental concerns. The contamination around that facility has resulted in lawsuits and government enforcement actions against it seeking hundreds of millions of dollars for contamination cleanup costs, property damage, and personal injury. This legacy has motivated the corporation and facility to be conscientious in their environmental efforts.

Since 1990, there have been no environmental notices of violations issued against the facility. The facility has reduced its releases of certain toxic chemicals by 97 percent since 1988 and reduced its hazardous waste disposal tonnage by 77 percent since 1991. Now this facility is considered to have one of the better environmental programs in the state and has received several awards for pollution prevention, including ones from the state and federal environmental agencies. The facility also participates in the U.S. Environmental Protection Agency's 33/50 toxic chemical reduction program and "Green Lights" energy efficiency program.

Because so much of the facility is new, the facility has had more opportunity to adopt an ambitious environmental goal of zero, rather than just reduced, emissions. To meet this emissions goal, the facility has installed thermal oxidizer, carbon absorption, acid scrubber, nitrogen oxide, wastewater treatment, and ultra-violet oxidation systems. In one building, the air control system traps all of the air, thereby enabling the use of certain chemicals without needing a variance from air pollution laws. Also, the wastewater treatment system for its metal finishing operations was redesigned to collect, treat, and recycle all of its wastewater, thus discharging nothing to the sewer system. During just the early 1990's, the facility has invested over $22 million in air and water emissions controls.

The facility has engaged in many source reduction projects involving substituting more environmentally benign products and processes for less desirable ones. For example, substitutes were found for a certain class of ozone-depleting substances and water-soluble dye was substituted for turpentine dye. Scrap aluminum also is being recycled and sold.

Until a few years ago, the environmental staff was perceived of as the "cops on the beat"

who warned of the consequences of potential violations, and environmental requirements were viewed as threats to jobs. Sensitivities towards environmental concerns were not absorbed into the organizational culture. The environmental staff now is perceived to be engaged in proactive efforts to find cost-effective ways to change processes and working with the building managers to provide the resources and expertise that they need. To change their image, they have emphasized the cost savings resulting from their efforts, which now are viewed as essentially paying for themselves.

According to the production operations managers, the facility's environmental efforts can help, rather than constrain, production and the environmental managers serve as consultants on proposed process changes at the facility. Such efforts can lower costs and increase productivity. While pollution prevention may not produce profits, it has improved the facility's competitiveness and skills. Environmental requirements are seen as a catalyst to thinking about ways to enhance the facility's competitiveness.

To meet facility waste minimization goals and objectives, Process Action Teams ("PATs") are formed to characterize specific waste streams, define alternative reduction measures, and develop action plans for implementing solutions. PATs which have resulted in significant reductions in the generation and disposal of hazardous waste include those working on ozone depleting chemicals elimination, perishable materials, chromium reduction, carbon filter regeneration, wastewater treatment, and vapor degreasing replacement.

An internal facility "Chemical Control Board" maintains a catalog of allowable products for the facility. If the purchase of a new chemical is requested, it must be reviewed and approved by this board. The facility also has a control system over all of its chemicals that requires containers of them to be checked out by workers from centralized locations, known as "chemical cribs," around the facility. The weight of each container is measured before workers take it and after they return it. This enables the facility to closely monitor chemical use on a daily basis and to be aware if any significant amounts are spilled. This system was implemented as a way of meeting local environmental agency monitoring requirements for use of air pollutants, but it was expanded to cover all chemicals. The facility believes that this tracking and control procedure has reduced waste and produced cost savings.

The facility is the subject of frequent environmental audits, including monthly inspections by building managers, biannual audits by facility environmental staff, audits by corporate staff every other year, military customer visits, and federal, state, and local environmental agency inspections. The facility is subjected to environmental audits by staff from corporate sibling facilities, and its own environmental staff do similar audits at these other facilities. This practice was begun relatively recently as a way of replacing the use of expensive consultants with internal experts.

The environmental manager comes from a production operations background and has been in his position only a few years. He is supported, however, by a number of people with specific environmental backgrounds who also have been with the facility for many years. The environmental staff includes environmental and safety engineers, toxicologists, and industrial hygienists. The facility's environmental efforts are overseen by an "Environmental Policy Action Committee," an executive-level decision-making body that directs environmental policy, reviews the facility's compliance, measures pollution prevention progress, and tracks relevant legal

changes.

The environmental staff obtains information from corporate seminars, from corporate sibling facilities, and from quarterly environmental regulatory updates from corporate staff. There is an annual environmental task force meeting with environmental staff from corporate sibling facilities. This helps reduce duplication of effort, such as in finding product substitutions.

Information on environmental performance is provided in a monthly meeting with building managers, who then disseminate it to workers. Quarterly meetings are held to disseminate information on all of the areas of the facility. There are weekly staff meetings, use of e-mail, and company newspaper articles and brochures for sharing environmental information. In addition, Material Safety Data Sheets on the chemicals in products used at the facility are available to any worker via an automated system. Also, for a long time, the facility has produced written documents of lessons learned in confronting problems, including pollution prevention. Production personnel may also become involved in environmental decision-making through PATs, and employees can achieve recognition and monetary awards for making suggestions for environmental projects.

Proposed environmental objectives for the facility are submitted by the environmental staff to its management, tied to costs and customer demands. Because of concerns about long-term liabilities, the estimated payback periods for environmental projects are not severely scrutinized, even when they are not directly required by law or when they do not cut costs. No formal maximum return on investment period on environmental projects is desired. Only projects with sensible costs, however, are proposed. The environmental staff manages all wastes and thus is aware of all environmental costs.

AIRCRAFT FACILITY LOW ADOPTER

GENERAL BACKGROUND

The Aircraft Facility Low Adopter is an aircraft maintenance and refurbishment facility in Alabama. Almost all of the facility's work involves U.S. military aircraft, with some foreign military aircraft also done. The facility has been located in Alabama for about ten years, having been attracted to the area primarily due to economic development financial incentives offered by the state. The facility owner is a wholly-owned subsidiary of a corporation which has been a prominent member of the aviation industry for decades. That corporation is in turn a subsidiary of a Fortune 50 corporation with a long history of involvement in the aviation and other technology-related industries. The facility's major competitors are a few other maintenance and refurbishment firms, most of which send their workers to military bases to conduct the repairs contracted for, rather than having the aircraft delivered to their facilities, as is primarily the case here. The facility has been consistently profitable over the years.

The facility's work involves repairing aircraft that have been damaged (e.g., through accidents or hostile fire) or worn out, and refurbishing aircraft with upgraded avionics or other equipment. This work involves the stripping and reapplication of paint on the aircraft, replacement and cleaning of mechanical and electrical parts, and other such repair work. Ordinarily there are no more than a handful of aircraft awaiting maintenance at any one time and the work can take several months apiece. The facility has separate bays for its electronic, mechanical, and assembly work. Sometimes the facility sends teams of its workers to customers' facilities to do the necessary modifications there.

A Total Quality Management ("TQM") system was initiated at the facility in 1994. The impetus for the system came at least partly from its parent corporation, which was seeking to spread the TQM concept throughout its facilities, but the facility's managers developed the specific system in use there. The driving force for initiating the specific system in the facility was that it was violating government standards through inadequate control of information and product quality. Prior to this system, the facility had essentially no tools to manage its operations.

The system has now been so successful that its corporate sibling facilities want to imitate it. A key component is a completely paper-less process at the facility floor level, with all aspects of the management of operations conducted through computer systems. The facility had almost a complete shutdown for three months while all line workers were trained with the system. An initial barrier was that they were concerned that if their efficiency increased, their jobs might be lost as less workers would be needed. This initial concern, however, has since dissipated and the line workers have not resisted the system. Rather, the system has succeeded in giving the line workers a greater sense of ownership of the production process.

Recently, the facility became certified under ISO 9000. Its U.S. military customers encouraged this certification because it enables them to standardize their quality standards across all of their contractors. Thus, rather than having potentially inconsistent and convoluted government standards for different contractors, a contractor's ISO 9000 certification acts as a

contractor's ISO 9000 certification acts as a proxy indicator of its satisfaction of government requirements. The facility also believed that being ISO-certified would enhance its global competitiveness.

The facility manages about 80 to 90 percent of its supplies on a "just-in-time" inventory system, supported by a "Material Resource Planning" system. It is implementing bar-coding of shipments and work-orders, so that relevant information can easily be entered into computers to facilitate tracking of the arrival and use of materials. About 65 percent of its supplies are obtained from a corporate sibling facility in the northeast U.S., with the remainder from suppliers across the country. Location of suppliers is not important in its procurement decisions.

Prospective suppliers are evaluated through the use of a structured questionnaire, as well as visits to their facilities if they would produce critical parts for the facility. About 70 suppliers are evaluated by the facility, while others have been previously approved by its corporate parents. Periodic audits are done of some suppliers, and employees also provide feedback directly to materials managers if supplies are defective. Environmental and safety records are not part of the supplier inquiry. Most of the supplies are commercial off-the-shelf parts, and thus there is little customization needed. Consequently, ordinarily it does not need to work with suppliers to determine the specifications for or design of parts.

The facility has about 100 to 150 employees, about 75 to 100 of which are line workers who are unionized. Both the managers and line workers stated that the union-management relationship is good. There are five major categories of line workers --maintenance, mechanic, inspector, lead mechanic, and materials manager. These employees work in what were termed "Natural Work Teams." These teams were part of the TQM system instituted in 1994, to use supervisors less and to encourage employees to feel a sense of ownership of the product.

Depending on the task, there is flexibility in the size and structure of teams. Each team has a working leader, with typically four to five mechanics under him and a foreman over him. All of these workers are involved in determining the composition of the team. Line workers are ordinarily hired already possessing the skills needed for the particular vacant position, and thus there is no need to train them in their skill areas. While the mechanics are thus expected to have an area of expertise, they also must learn, and receive cross-training in, other areas so that they can work on different tasks as needed. There is formalized training of some kind for workers about every week. When deciding on issues or problems, teams are supposed to make a communal decision based on all team members' opinions. Every morning there is a team meeting at which suggestions can be offered.

A team is evaluated on, among other criteria, the time that it takes to complete its work on an aircraft versus the time that was budgeted. These time budgets are developed by a team's mechanics prior to beginning the work and thus become the team's objective. This ratio between projected and actual time budgets is calculated weekly for each team and is posted for everyone to see. If the projected and actual time budgets are substantially different, managers will do a root cause analysis by talking to the line workers and foreman to try to determine the problem. Previously, the ratio had been examined only at the end of a year to identify any issues. This new system has been much more effective in making timely corrections because under the prior system money would have already been lost throughout the year before a problem was known.

For some issues, the facility organizes a "Process Action Team" ("PAT"). A PAT includes a few people who are familiar with the problem or who have been part of the problematic process, as well as a few other people to offer fresh perspectives. Before the facility's TQM system was implemented, there was a tendency for a difficulty to be mentioned to a supervisor, with a solution informally taking its own course. PATs provide a formalized system to handle most problems. In addition, there is a weekly "Quality Management Team" meeting of the managers where they can raise ideas for possible projects.

The facility has a formal suggestion system for employees. Furthermore, if a suggestion is implemented, some portion of the resulting annual costs savings to the facility is given to the employee(s) who made the suggestion. Also, the name of an employee of the month, quarter, and year is posted on the bulletin board outside of the facility as an incentive to do good work. Furthermore, all managers are required to walk around the facility floor for at least one hour a day to encourage interaction with line workers.

There is a weekly meeting to inform line workers of any changed procedures, so they know these not only for their own purposes, but also if government inspectors arrive. In addition, each morning a team's foreman provides a breakdown of relevant issues to the team. Also, about once every three weeks, the facility's management holds a meeting with all employees, sharing with them information including the facility's general business outlook.

ENVIRONMENTAL MANAGEMENT

The facility's stated commitment to environmental protection is memorialized in a formal "Environmental, Safety, and Health Policy," which was signed by the facility manager and is posted on numerous walls around the facility. The policy, however, was dated January 1996, which may reflect the relative recency of some of the facility's initiatives about environmental management. In addition, any employee has the authority, as confirmed by a letter sent to them by the facility manager, to stop a process if s/he believes that it poses safety or environmental problems. Also, the environmental manager is authorized to give out driving ticket-like notices to employees for violations that he discovers. A carbon copy of the notice goes to the facility manager, thus alerting the latter on a daily basis to any environmental concerns.

In the past few years, the facility's corporate parents were fined million of dollars for environmental violations. This legacy has motivated the corporations and facility to be conscientious in their environmental efforts. Now the facility is considered to have one of the best environmental programs in the state, leading the state environmental agency to show the facility's environmental program to other companies as an example. Since 1993, the state's five environmental audits of the facility have uncovered no deficiencies and the facility has reduced its barrels of hazardous waste by over 80 percent. Its sibling facilities around the country have been so impressed with the facility's progress that they have been seeking to emulate its efforts.

Much of the credit for effectively implementing the facility's greater attention to environmental concerns is due to the environmental manager, who took over the position a few years ago. The prior environmental manager did not have much experience in the area and was reportedly overwhelmed by his duties. The new manager had 20 years of experience as an

environmental officer with the military. He reinforces his skills by meeting annual corporate and government environmental and safety training requirements and by taking up to several company-paid environmental training courses annually.

In October of each year, all managers meet to set goals for the upcoming year. With respect to the environment, goals are set for waste minimization, accident prevention, and recycling opportunities. Included are numerical goals for the number and weight of barrels of hazardous waste generated. The environmental manager develops a written environmental plan which is circulated to the other managers for comments. Ultimately, the facility manager reviews it and balances its goals against the goals of the facility's overall business plan. The facility also develops a five-year environmental business plan. For this plan, the overall goals come from the facility's corporate parents and the environmental manager of each facility determines how these goals are relevant for his/her facility.

According to the environmental manager, at least some senior managers perceive that some environmental laws violate common sense and they might be willing to risk violating some requirements. The environmental manager is thus perceived by such managers as the "cop on the beat" who warns them of the penalties for potential violations. According to the production operations managers, however, the facility's environmental efforts help, rather than constrain, production. Such efforts can lower costs and increase productivity. For example, rather than mixing large batches of paint primer, some of which inevitably was not used and thus had to be disposed of as waste, the facility now buys pre-mixed primer and allows employees to take small cups of it adequate for their needs. This saves the time of mixing and reduces the primer wastes.

Many ideas for environmental improvements come from line workers. For example, a line worker originated the idea of providing small cups, rather than buckets, of paint to workers doing small paint jobs, thereby reducing the leftover paint and thus wastes. Line workers originated simple ideas for using smaller rags with which to clean parts, substantially reducing waste generation, and for compacting wastes, greatly increasing the amount fitting in each waste container, thereby dramatically cutting waste disposal costs based on each container. On a daily basis, the facility's environmental manager emphasizes to employees the need for waste minimization, thus encouraging such ideas. Twice annually, during a safety and environmental training course, the environmental manager provides employees with a status report of how much waste was generated in the past and what were its disposal costs.

The facility estimated that 85 to 90 percent of its environmentally beneficial projects were non-resource intensive common sense solutions. For example, the earlier cited use of smaller rags, waste compaction, and smaller containers for paint and primer were all technically simple efforts with little, if any, start-up costs. In addition, the facility replaced much of its solvent used for cleaning purposes with a readily available non-toxic household cleaner.

The facility makes a concerted effort to maintain a very clean and uncluttered working environment, and it has succeeded. Though there are undoubted potential environmental benefits from doing so (e.g., reduced chances of chemical spills), the facility's primary motivations for doing so are to enhance worker safety and quality control. With respect to the latter, a key consideration in the facility's housekeeping practices is to minimize "foreign object damage" to the aircraft -- damage due to chemicals or tools coming into inappropriate contact with the aircraft. Given the sensitivity and cost of some parts of the aircraft (e.g., avionics), such damage

could have serious consequences. In addition, the facility believes that its customers are impressed with its efforts at providing a clean working environment for their aircraft. This is especially important because, largely due to being a military contractor, it is inspected on average every two weeks by some government entity.

As part of its overall materials control procedures, the facility has what it calls "Materials Pharmacies." This is similar to Aircraft Facility High Adopter #2's chemical cribs. These are restricted areas where most materials in the facility are logged in when they arrive, are stored, and are logged out when they are dispensed to employees in the necessary amounts. This enables the facility to manage and monitor the usage of materials, thereby enhancing its inventory control and, when chemicals are involved, its environmental and safety performance.

Environmental costs are included in the facility's overall manufacturing overhead costs and thus are allocated over all work through the common overhead rate, rather than being charged to the particular work that generated the costs. Speculative environmental liabilities are considered at the corporate, rather than facility, level. In the past few years, the facility has spent $400,000 to $500,000 annually on environmental costs, though this has been decreasing over time.

For major proposed environmentally-related projects, the key criteria are who will implement it, whether facility space is available, whether permits are necessary, and what are the financial and personnel resource requirements. Ordinarily, a two to three year payback period on environmental projects is desired. The environmental manager has the authority to spend up to $100,000 a year on environmental matters without upper management approval and he has never had a proposed environmental project disapproved.

ELECTROPLATER HIGH ADOPTER

GENERAL BACKGROUND

The Electroplater High Adopter is a medium-sized electroplating facility in Connecticut, with about 40 non-union employees. The facility's work includes cadmium, cyanide, and zinc electroplating. Its customers are spread across many different industries, which has buffered it against recessions in particular industries. The facility has existed for nearly forty years and its sales volume has remained stable in recent years.

The facility is run under an informal management style, with no explicit capital budget or cost accounting system. The facility has three, albeit very informal, layers of management: the president, a few managers, and the line workers. The president had worked at the facility under the prior owner, and then purchased the business nearly 10 years ago. Most of the line workers are not well-educated and many do not speak English well. None of the line workers are perceived of as helpful in suggesting ways to improve processes, as they do not really care about the facility.

ENVIRONMENTAL MANAGEMENT

The facility's recent approach to environmental management is undoubtedly influenced by past contentious relations with some units of the state environmental agency. In the view of the facility, while the air and water pollution offices of the state agency have been somewhat helpful, the hazardous waste office has had no interest in being cooperative and has created a very antagonistic relationship from the start. The facility believes that it has genuinely tried to comply with the regulations, though the environmental manager stated that they are very difficult to keep up with and that she did require some help from the state agency.

In her view, however, the state agency has been unwilling to work cooperatively and instead has "harassed" and fined the facility for relatively minor problems. The facility is apprehensive about seeking assistance from the state agency, because it may simply result in a violation being discovered that leads to another fine. The facility has obtained some advice on environmental issues from a state technical assistance program, but it is afraid to use the program too much due to concerns that the program might report this to the state environmental agency, which will then scrutinize the facility further.

The state agency's alleged harassment may be due to the facility's prior owner's practice of barring state agency inspectors from the facility when he believed that they were exceeding their authority. In addition, the facility has a contaminated waste site in its backyard because, long ago when it was legally allowed, it used to place chemicals there in a lagoon area.

The facility has an environmental consultant that does periodic compliance audits to check its paperwork and operations. The consultant, however, often needs instruction from facility personnel as to what an electroplater does, as do most other consultants. This ignorance also extends to state agency inspectors. They see the large chemical baths, and the mist rising

from them, and believe that there must be many problems in such a place, even though the mist is not noxious and the indoor air quality meets the applicable standards. Also, one inspector might ask the facility to do something one way, and then a subsequent inspector claims that it is wrong and demands changes or imposes a fine.

The facility's environmental manager has been around the facility for about 30 years (a parent also has worked there), and assumed her environmental functions as the need arose over the years. She has not been specifically trained in the facility's production operations nor has she an academic background in environmental matters, but she has completed many environmental courses at local universities and received state-run environmental training. She is assisted by a chemical engineer, who works primarily on water-related processes, including environmental issues, waste treatment, government reporting, and managing consultants. In addition, the facility has two people responsible for its wastewater treatment system.

Quarterly environmental audits are conducted by the facility, driven by state requirements. The environmental manager also does annual safety training for employees and has posted bulletin boards containing information on proper handling of different drums of hazardous materials. She believes that others at the facility view her role in negative terms because she often is the bearer of bad news about the additional costs and efforts needed for the facility to satisfy environmental requirements. In her view, most of the line workers do not know or care about environmental issues. Even in terms of worker safety, the line workers often do not make an effort to follow the rules.

The facility believes that environmentally beneficial projects have never saved it money in the long run or provided any economic benefit or competitive advantage. The only possible exception might be technology that it installed to reduce the amount of waste that it sends to landfills. The technology was suggested by a salesman, and other local plating shops were known to be using it, so that helped convince the facility to install it. Environmental projects not required by law are rarely done and only if they simultaneously improve other aspects of the overall facility (e.g., safety), as well as provide some monetary benefit. One exception is the facility's participation in EPA's 33/50 toxic emissions reduction program. The facility feels under such pressure from the state agency that it believes that if it tries anything new or creative that may benefit the environment, it may result in penalties from the state agency because it unknowingly did not follow the law that may apply to the new process. Consequently, the facility ordinarily only does what is required.

Environmental costs, which are about 10 to 15 percent of sales, are placed in the facility's overhead. The primary criteria used in prioritizing possible environmental projects are financial liability, environmental liability (e.g., will it help prevent spills), the reputation of the facility, and pride in the way the facility looks.

In terms of general housekeeping, the facility was somewhat cluttered, with pervasive vapors and stains that would not necessarily be unexpected for an electroplater of its tenure. Some customers do inquire about its environmental record, including sending staff to inspect the facility. Most of the time, prospective customers just send a form for the facility to complete, with the form mostly concerned with whether the facility has any chlorofluorocarbon-related emissions or problems. Some of its large customers also were concerned for a time about the use of cyanide and thus the facility started a non-cyanide plating line. In addition, the facility

switched from cadmium plating baths to caustic baths on one of its lines because it believed that some of its customers wanted to avoid cadmium due to its overall perception as very hazardous.

ELECTROPLATER LOW ADOPTER

GENERAL BACKGROUND

The Electroplater Low Adopter is a medium-sized electroplating facility in Alabama, with about 30 non-union employees working on one shift. The facility's work includes cadmium, copper, gold, nickel, silver, and zinc electroplating and electroless nickel, anodizing, passivation, black oxide, and alodine finishing. Its nearly 200 customers, including some Fortune 50 firms, are predominantly in the southeastern U.S., though about ten percent of its sales are to international customers. The facility services the aerospace, automotive, defense, home appliance, electronics, and medical industries. The facility has existed for nearly ten years and its sales volume increased by over one-third in the preceding three years.

The facility was founded when it was becoming increasingly difficult for some electroplaters to adapt to more stringent environmental requirements. The facility's president, who was not in the electroplating business at the time, believed that constructing a facility from the ground up would enable him to incorporate the necessary equipment and practices to meet environmental requirements and still be profitable. He also believed that he could develop a process that was reliable and provided predictably high quality products to customers -- unlike many electroplaters who treated it as an art that sometimes worked and sometimes did not. He also wanted to develop an assembly line-like process that could cope with any product without much delay.

In 1995, the facility was named as the outstanding small manufacturer by its county's Chamber of Commerce. That same year it became the first U.S. job shop electroplater to receive ISO 9002 certification. Though none of its customers required such certification, it decided to seek it because it believed that ISO 9002 contains good business standards, being certified attracts more business,[19] and it wants to stay ahead of competitors.

The facility's overhead is substantial for this size of facility, largely because it includes a quality manager, a vice president, and a very experienced supervisor. The facility believes, however, that this structure better ensures a high quality product and future growth because it will have an effective operating system. Environmental costs, which are about 15 to 20 percent of sales, also are placed in the facility's overhead and have led to price increases and thus some lost customers. For liability reasons, however, it considers its environmental efforts necessary.

The facility aggressively pursues seemingly difficult or unusual work. About 40 percent of its jobs taken in the preceding year were somewhat unusual and needed creativity to accomplish. It is a very diverse electroplating facility in terms of the types of products that it will process. Other electroplating facilities do a substantial amount of only one or a few different parts. In contrast, this facility's acceptance of unusual requests allows and forces it to be constantly learning. The research that it engages in for new products often helps it increase its process

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[19] One such customer acquired after its certification is a corporate sibling facility of the Aircraft Facility High Adopters.

efficiency for old products and future new processes. This also enables it to be well-informed on different types of products and industries.

The facility encourages the philosophy that its workforce operates as a team. Line workers are trained in all areas so that they can operate different processes. The facility emphasizes this cross-training, but if employees do not want to perform different functions, they are not required to. Some of the senior line workers are operators and they also act as inspectors to check on the quality of plating runs.

The line workers are empowered and are given the right to speak freely to supervisors and managers. They feel no inhibition to discuss matters and make suggestions. In fact, some line workers make changes without asking for permission and then show the managers the results. Everyone can offer improvements to the facility's processes, with such ideas usually first brought up with a supervisor and then considered in meetings of the president and his key staff. There are weekly production meetings between the president, vice-president, maintenance engineer, and supervisor, with senior line workers sometimes sitting in. This provides an opportunity for everyone to generate new ideas.

The main supplies procured by the facility are its raw materials -- generic chemicals, such as acids and caustics; proprietary chemicals, such as brighteners; and metals, such as cadmium, zinc, gold, and silver. It generally subscribes to a "just-in-time" inventory approach, but it stocks enough chemicals to ensure that it will never be caught short even if a delivery is missed. Prospective suppliers of chemicals are largely evaluated on their price and service, especially the latter because the cost of supplies comprises only about 10 to 12 percent of the facility's charges to customers. The facility also requires that its chemical suppliers have liability and environmental insurance.

It does not, however, check on the environmental or safety records of suppliers, nor does audits of them. The facility believes that prospective suppliers would be unlikely to agree to such audits and that it would be unnecessary, given that these facilities' practices are regulated and monitored by environmental agencies. For metal suppliers, the facilities select whomever is least expensive. The location of suppliers is generally unimportant, though its generic chemicals are primarily from local suppliers. The facility sometimes is visited by suppliers' technical staff who examine its processes to offer suggestions for improvements.

The primary criteria used in prioritizing possible capital projects are the cash flow and payback period associated with the projects. Projects are preferred that better position the facility competitively in the future and that have substantial positive short- and long-term effects on sales.

ENVIRONMENTAL MANAGEMENT

The facility's recent approach to environmental management is undoubtedly influenced by past contentious relations with the state environmental agency. The agency had initiated an enforcement action against the facility for an alleged violation denied by the facility. Ultimately, the facility prevailed after a long and expensive court battle. In the perception of the facility, the

agency then began suspiciously frequent and nitpicking inspections of the facility.

The facility's environmental manager has been with the facility for seven years, though only assumed his environmental functions in the past five years. The environmental duties are in addition to his duties as a plating supervisor. He is presently completing a college degree in chemistry, attends numerous environmental compliance seminars, and obtains environmental information from trade periodicals and environmental managers in other companies. He is assisted in some efforts by an environmental engineering consultant retained by the facility, but feels especially overwhelmed by the paperwork requirements.

He believes that others at the facility view his role in negative terms because he often is the bearer of bad news about the additional costs and efforts for employees to satisfy environmental requirements. The facility believes that occasionally environmentally beneficial efforts have led to production efficiency gains as well. Usually, however, environmental requirements force it to act inefficiently. In addition, at times production has to be slowed to meet environmental requirements.

Sometimes, however, efforts to improve production efficiencies have led to environmental benefits. For example, compared to before his becoming environmental manager, the facility has cut its chemical use in half. The environmental manager led an initiative to tighten the control processes, leading to reductions in input materials. The motivation for this initiative was to improve production efficiency, but it generated environmental benefits as well. The facility has the ability to break down the environmental costs for each of its processes, but does not have the time or need to actually do so.

In terms of general housekeeping, the facility was extremely clean. The shop foreman noted that he has been in the electroplating business for 15 years and that the facility is the cleanest electroplating shop he has been in. The environmental manager does a quarterly audit of the facility's environmental and safety conditions. The facility urges new customers to visit it because it is certain that once customers see its organization and cleanliness, they will be convinced that it is a first-rate facility. Some customers do inquire about its environmental record. The facility was subjected to an intensive environmental audit by a large customer before it agreed to use the facility extensively, due to a past problem the customer had with another electroplater in which the customer was held liable for that electroplater's contamination.

The facility management has been receptive to doing some environmentally-related projects each year as long as they fit within the year's projected budget. The environmental manager periodically brings a "wish-list" of projects to the management, most of which require a minimum investment of $500,000. Because the technology in the marketplace is currently improving and the cost of acquiring it is decreasing, it has not made sense for the facility to pursue many of these projects unless it is legally required to do so. In the environmental manager's opinion, the main barrier to improving environmental quality at the facility is the equipment it uses, with newer, better technology being highly desired.

About 60 percent of the facility's environmental initiatives are non-resource intensive common sense solutions, while the remaining tend to require substantial funds and technical efforts. An example of the former is a drying technology which has reduced the weight of its solid waste by 80 to 90 percent, thereby saving recycling and disposal costs. An example of the

latter is a closed-loop reclamation/disposal system that enables the facility to recover a large percentage of the chemicals used in its plating, to discharge no industrial water into the sewer system, and to reduce its solid waste by 80 percent. This system was installed because it costs less than discharging wastewater to the sewer, obtaining the necessary permit, and dealing with uncooperative state regulators. This system was a substantial factor in the facility's Chamber of Commerce award and resulted in a commendation from the state's legislature.

In the past few years, the facility also began sending its sludge waste to an off-site recycling facility, rather than a hazardous waste landfill. This change was initiated by the environmental manager, who researched 25 different options for the sludge and determined that recycling technology had become sufficiently reliable for its type of material. Although there are no immediate cost savings, it believes that it eliminates any future liability concerns by sending the waste to a recycler, rather than to a landfill that could conceivably become a contaminated waste site. In addition, customers prefer that an electroplater does not have such liability concerns and is managing its wastes in a responsible manner.

TURBINE FACILITY HIGH ADOPTER

GENERAL BACKGROUND

Turbine Facility High Adopter is a manufacturer of mid-range industrial gas turbine systems in California. The turbines are packaged in a system with compressors, pumps, and electrical generators. These turbine systems use natural gas or liquid fuel and are applied to a wide range of heavy duty industrial applications, such as cogeneration, standby power sources, or offshore platforms in the petroleum and natural gas industries. This facility is primarily responsible for the engineering and manufacturing of components, while a nearby corporate sibling facility does the assembly and testing. About 75 percent of the facility's sales are to foreign buyers. In addition to manufacturing turbines, the corporation provides field service, parts, and maintenance support. The facility has been in its current location for nearly 70 years. The facility owner is about a billion dollar corporation in its own right, and about 15 years ago became a wholly-owned subsidiary of a Fortune 50 corporation which itself has been a prominent member of the industrial machinery sector for decades.

In the mid-1980's, the facility was anticipating the downturn in the petroleum industry, which was one of its major markets, and was feeling pressured by its parent corporation to improve its profitability. In addition, around the same time, due to pressures from perceived oppressive state taxes and laws, the facility's owner began considering relocating operations out of state. Also, it was around this time that a union strike resulted in a reevaluation of the facility's practices.

All of these major events occurring within a relatively short time period combined together to produce dramatic changes at the facility. During the latter half of the 1980's, the facility attempted to reorient itself and institute changes that would produce a greater sense of purpose. In response, the facility reduced the number and levels of its employees and dramatically restructured its management and procedures and brought in new managers who instituted various new programs. These programs included organizing production operations and line workers into teams for each logical subassembly unit of the turbines. These teams are called "Certified Assembly Manufacturing" units ("CAMs"). The CAMs at the facility are the Rotor CAM for producing rotating parts, such as turbine disks, blades, and shafts; the Hot CAM for producing internal combustion parts and injector nozzles; and the Cold CAM for producing external turbine housings and casings.

Workers producing these subassemblies are in various stages of becoming full-fledged self-directed work teams. The CAM teams are designed to be autonomous, self-directed work units with employees rotating as leaders. The Hot and Cold CAMs, created in 1994, are at the second of five stages in this development and the Rotor CAM, created in 1992, is at stage four. Workers in the Rotor CAM apparently are completely involved and enthusiastic about teams, while workers in the other CAMs have been more resistant to the change.

A fully developed CAM team will control its own schedules, pay, overtime, and production processes within parameters set by the facility. CAMs are individually responsible for their own capital expenditures and manage their budgets, internal return on investment, and

depreciation. CAM teams meet twice daily, and problems are solved within the CAM unit, unless they are safety-related. Initially, team leaders are selected by the management but, after a couple of years, team leaders are then nominated by the team members. The team members are assigned to particular CAMs when the CAMs are created or as the workers are hired. Workers are being cross-trained, but this has been hampered by time constraints due to production demands. The facility also has a learning center, partly funded by the state, that offers education in a broad range of topics to the facility's workers and to those of other companies.

The facility also has adopted the practices and procedures of ISO 9000. It began the ISO 9000 certification process in 1990, before it was widely accepted. Management had foreseen that certification could become a purchasing criterion in Europe and was concerned about being disadvantaged in that market. There were initially significant doubts about its usefulness and difficulties in communicating to employees the global utility of obtaining certification. The latter problem was addressed by formulating ISO 9000 tenets in a basic way as a framework for documenting what employees do and then holding them accountable for it. This helped dispel the notion that ISO 9000 prescribed production processes. The facility considers ISO 9000 to be an excellent tool for enabling it to fully understand and to identify gaps in its practices. As part of its institutionalization of planning functions for purposes of ISO 9000 certification, the facility also adopted a "material resource planning" system.

In addition, the facility is beginning to use statistical process control techniques to improve quality. The facility also has used the "kaizen" process to determine desirable changes in its production methods, including eight times just in the last year. The facility tries to adhere to the Deming model of management -- plan, do, check, and act. It focuses on the process, rather than on the functional organization.

The results of all of these changes are reflected in the facility's production efficiency -- it is now producing five times as much as in 1984, but with the same number of workers. Half of this increased efficiency is believed to be due to improved equipment and processes and the other half to the increased efforts of more motivated employees.

The facility also has aggressively begun planning new products, with three new turbines expected by the end of the decade. This is a significant increase in new products in a short time for this industry and especially for the facility. In contrast, only one new product had been introduced in the preceding two years. Historically the facility had developed a base-size turbine that was then incrementally modified to produce new products. The facility now is pursuing entirely new models, metallurgy, components, and designs.

An annual meeting establishes "Critical Success Factors" for the upcoming year, which are a handful of goals that need to be focused on the most. One such criterion is whether a finished turbine works on its first try. The facility measures its defect rate on a monthly basis by product and engine model, aiming for as close to a zero defect goal due to mechanical failures as possible. When subassemblies reach the turbine assembly stage, defects that are discovered are documented and evaluated on a weekly basis under its downstream defects program. In analyzing defects, rather than seeing them as isolated incidents, the facility takes a systemic view by determining what went wrong with the applicable process. When the facility's turbines are returned by customers for overhauls, the time that the turbine had been in use is recorded and evaluated against the goal that had been set for that type of turbine. This elapsed running time

is important because the facility justifies the relatively high price of its turbines by their superior durability.

The facility has about 100 suppliers providing about 80 percent of its product-related material, compared to about 800 several years ago. The primary supplies that it uses are sand castings, forgings, investment castings, nozzles, injectors, and machining supplies. Presently, sourcing managers are responsible for using strategic criteria to select suppliers as part of the facility's "Certified Supplier Program." One strategy that they use is to deal with a small number of suppliers who can do the most for the facility, thereby maximizing its financial leverage with those suppliers.

Its relationships with suppliers take three possible forms. With the majority of suppliers, it has a traditional buy-sell relationship with a fixed contract. With some suppliers it has a teaming relationship, in which both companies have a mutual strategic intent, and with a few suppliers it has a partnering relationship, in which both companies act as if they were part of the same organization. Suppliers of castings and forgings are the ones with whom the facility usually has closer working relationships, and sole source suppliers are often brought into the product design process. On some occasions, the facility has sent its staff to improve suppliers' processes and train their workers, in an effort to forestall supplier price increases, and sometimes suppliers have shown the facility how to better use their products.

Prospective suppliers are evaluated primarily from the facility's business perspective. The criteria used are a prospective supplier's quality control systems and procedures, technology, training, personnel expertise, compatible management philosophies, financial soundness, and relations with competitors. Information requested from suppliers includes their defect rates for finished products, internal failure rates, and annual quality improvement indicators. The facility prefers suppliers in its geographic area, or at least west of the Mississippi River, but only about 10 to 20 percent are located within a 50 mile radius.

Sourcing managers inspect some of the suppliers, but do not technically evaluate their manufacturing processes. Similarly, while environmental issues are considered (e.g., environmental fines against a supplier would indicate poor management), there is no checklist or systematic procedure for doing so. Rather, the sourcing manager focuses on the prospective supplier's cleanliness and only if something appeared environmentally questionable might the facility's environmental staff do a more thorough inspection.

Inventory management at the facility is decentralized, using a "point of view" storage philosophy that places inventory around the individual CAMs. The facility has a general goal of reducing its inventories, but has not adopted a "just-in-time" inventory philosophy. Typically, there are a few days of inventory immediately on hand for a CAM.

The facility has about 3,000 employees and has been unionized for over 50 years. Until a union strike in 1987, general layoffs occurred consistent with the business cycle. After the strike, management decided to welcome workers back and improve their relationship. There was no signed labor agreement for four years, and thus during that period the facility tried to avoid doing anything that might be perceived of as unfriendly to the workers.

The facility's new management initiated explicit efforts to value workers more and thereby

established a management credibility that was previously lacking. During the negotiations over those years, the labor agreement was rewritten to reflect management's new philosophy, including work teams. The facility's policy became that if certain work is unavailable, other work should be found for the affected employees. A special department was created for surplus workers, which gave them the work of salaried employees. The facility also is more careful to avoid overhiring. Fortunately, however, the facility's business situation has been sufficiently good that there has not been much cause to consider layoffs and there have been none since 1989. About 80 percent of the facility's supervisors and area coordinators were promoted from being line workers. Line workers believe that there is opportunity for everyone to advance, and cited examples of cafeteria and gardening workers being encouraged to take production positions when their hard work impressed managers.

On a monthly basis, the corporation's president gives a presentation to employees describing their goals, future projects, and opportunities. There are quarterly meetings of all employees to inform them of significant developments, such as business performance. The production operations manager has monthly meetings with the overall workforce, holds regularly scheduled staff meetings, and tries to be available for ad hoc meetings. An annual employee survey is conducted to get feedback, and financial awards are available to contributors of ideas for improvement. The facility also believes in tracking plans and objectives using easels, bulletin boards, and other accessible ways on the facility floor, rather than burying information in computers.

ENVIRONMENTAL MANAGEMENT

Before 1990, the facility's environmental efforts were largely end-of-pipe pollution control reactions to regulations, with particular issues arising from its use of solvents, warnings required by state law to be published in newspapers about potential cancer risks at the facility, and wastewater treatment deficiencies. The role of the environmental staff at this time was primarily to respond to problems and bring the facility into at least temporary compliance. Large environmental fines, the need for those cancer warnings, and the negative publicity arising from both motivated the facility to rethink its approach to environmental issues. Consistent with and integrated into the overall managerial changes that were occurring at the facility, the environmental staff decided to shift to a proactive strategy. This strategy emphasized pollution prevention and its associated cost savings, rather than just compliance, and set measurable goals and mobilized support for them at all levels of the facility.

The facility's environmental goals are now articulated in its mission and business statements and in its core business principles, including a zero-emissions vision. In keeping with this strategy, the facility line managers assumed responsibility for the environmental impacts of their activities, with the environmental staff providing consulting, technical expertise, and contacts with the relevant environmental agencies. Thus, it was a major shift in attitude for the line managers, rather than just the environmental staff, to accept responsibility for these concerns. The production and environmental staffs now make decisions in concert, such as installing new machines or changing processes. The environmental manager has an equal voice in meetings in which manufacturing decisions are made. The environmental staff was no longer forced into a policing mode or adversarial relationships.

In addition, the environmental staff was increased from just one person to over ten and a facility "Environmental Council" was established composed of upper level managers who address facility and product environmental concerns. All environmental results are reviewed in a monthly sales and operation planning meeting of the top managers. Because the facility's new culture emphasized quality, learning, continuous improvement, and human resources, the environmental efforts are a natural part of it.

The facility believes that the desire for excellence in production spills over to other functions, including environmental matters. The environmental staff helps the production staff think about the environmental consequences of their actions (e.g., identifying more environmentally benign cutting fluids, rust-inhibiting processes, and methods for containing water runoff). According to the production operations manager, the environmental staff's efforts have saved the facility money and have demonstrated that environmentally sound manufacturing does not necessarily increase costs.

The environmental performance of the facility since these changes reflects the efficacy of its approach. During the last few years while turbine production has doubled, hazardous waste generation was halved. The facility has reduced toxic metal emissions by 99 percent and eliminated the need for newspaper warnings about potential cancer risks. Environmental fines have declined from about $250,000 a year to $250, and the facility has established a high level of credibility and integrity with environmental agencies. The wastewater treatment facility has been upgraded; recycling of wastewater, machine coolant, and solid waste has begun; and water and energy conservation programs were initiated. It is phasing out its solvent degreaser and instead using a water-based parts washing system.

These environmental efforts have resulted in annual quality improvement corporate awards for hazardous waste reduction, an award from the corporate parent for pollution prevention accomplishments, an award from the city, and an award for environmental excellence from a local trade association. In addition, the facility estimates that it has saved millions of dollars due to hazardous waste reduction and eliminated government fines. The key components of these accomplishments are management commitment, employee involvement, managing issues as strategic business concerns, explicit and measurable goals, and using training, teaming, and continuous improvement.

To enable workers to be responsible for the environmental impacts of their jobs, extensive training has been provided in a number of ways. For example, environmental issues have been added to the facility's monthly safety meetings. There is a program to provide managers with the knowledge and skills to successfully handle the safety and environmental issues in their CAMs. The environmental staff uses newsletters, brochures, and videos to communicate information to workers. Cross-functional teams have been used to address environmental issues, such as recycling, solid waste reduction, and integrating environmental considerations into product design.

Environmental costs are discretely forecast and reported as a cost category. These costs are planned in advance and become part of the expense for the product. Maintenance costs of certain pollution control equipment would be assigned to a particular CAM. Operating groups track the costs associated with their areas, but not all costs can be directly tracked to a product or process. The environmental staff, however, keeps track of how much hazardous waste is

generated by each CAM so that its cost can be charged to that unit. An external auditor reviews all contingencies, including environmental risk, on a quarterly basis.

Environmental projects are evaluated just like other projects. For a new program or project, the facility finance staff evaluates the net present value and the internal rate of return on investment under the parent corporation's guidelines. There is no required payback period, but the typical time period is three years.

Some ideas for environmental improvements come from line workers and the facility depends upon such workers to drive the incorporation of such considerations in production operations. Also, the facility estimated that most of its environmentally beneficial projects were non-resource intensive common sense solutions. For example, the facility began sifting out grinding grit for recycling. It also combined sewers and water collection points to reduce the cost of sampling and analyzing water. It also began refining oil on site for reuse. After hiring a company to analyze the composition of its trash, it began separating out certain wastes to reduce its disposal costs. To maximize the return from its recycling of scrap metals, its line workers use different containers to catch scraps from the different metals on which they work. Before, scraps from all metals were caught in the same container and the facility was paid by its recycler only the price per pound of the least expensive metal in the container. By sorting the metals, the facility gets paid the price per pound for whatever metal is in a particular container. The facility has reduced a three-step paint process to two steps, reducing paint wastes. Even the water treatment system improvements were low technology solutions, though they were relatively expensive.

The environmental staff audits the entire facility monthly. The production staff now welcomes regular environmental audits because it helps them to meet their goals. In addition, the parent corporation audits the facility annually and state environmental agency inspectors come somewhat often.

GEAR FACILITY LOW ADOPTER

GENERAL BACKGROUND

The Gear Facility Low Adopter is a gear manufacturing facility in Pennsylvania. The business has existed for over 100 years and the facility moved to its current location about 40 years ago. The facility had about $70 million in sales in its most recent year, ranking at the lower end of all large gear manufacturers. The facility is a wholly-owned subsidiary of a $200 million corporation, which has various other businesses and facilities. The facility essentially is a large jobbing shop, with customers spread around the country and world. It makes power transmissions and gear boxes for turbines, marine applications, automotive assembly conveyors, air compressors, and spare parts. It manufactures many new, specialized, one of a kind products, where the research and development work and reengineering often is conducted as products are made.

In late 1970's, the facility had about 850 employees and annual sales of around $100 million. Its industry in general experienced difficulties during the 1980's. The facility fared especially badly, losing tens of millions of dollars from the mid-1980's until a few years ago, because it was operated by its owner essentially as a hobby. The facility's owner had somewhat of a sentimental attachment to the business because it had been the origin of the multi-business corporation that it ultimately became. Thus, the owner was unwilling to close the facility, regardless of its losses. The attitude developed among some of the facility's employees that it would continue to operate regardless of its performance. This mindset became one of the most difficult aspects of the facility's operations to change. By the early 1990's, its work force had been cut in half and the corporation moved different processes to other, smaller facilities in right-to-work states.

The third generation owner of the business brought in new management a few years ago to try to make the facility profitable. The new chief executive officer has been there less than three years and the new manager of manufacturing only about one year. Some of the pre-existing managers are reportedly the major obstacles to change, resisting it out of territorialism. A delayering of the facility's management structure has been proceeding in the last few years to achieve a self-directed, empowered workforce. The facility now emphasizes employee involvement, empowerment and ownership, and looks for continuous improvement opportunities.

The facility believes that it used to be the best in the world at gear manufacturing, but that its performance slipped for a time. While the product quality always was good, its record for on-time delivery was a particular problem. The facility's goal is to once again be a world-class company, but it believes that it still has some distance to go. It regards zero defects, an empowered and self-directed workforce, on-time delivery, customer satisfaction, and profitability of at least 35 percent as part of the characteristics of a world class company. The facility has become certified under ISO 9000 and each department must now have goals and a mission statement consistent with the facility's formal manufacturing strategy. It uses trade association benchmark data as guides in establishing its objectives but while there are many metrics in place, there are few real quantitative goals. The facility's recent efforts appear to be helping -- its sales in 1996 were 30 percent higher than expected, and it is projecting another 30 percent increase for

1997. Also, the facility's corporate owner recently purchased one of its major competitors.

The facility previously was unstructured in its management of workers. Now the facility is using process or quality teams to drive its efforts, with a steering committee consisting of managers, union leaders, line workers, and a human resources staffer. These teams or cells are created by product line or manufacturing style. They resulted from 1993 contract renegotiations between management and the union in which the cell concept was established of having workers capable of using more than one machine. The then-vice president of manufacturing initiated the cell concept for organizing manufacturing, but not long thereafter left the corporation, which caused progress to stall for a time.

The objectives of these cells were to increase communication in the facility, educate line workers about the entire production process, and give ownership and accountability to line workers. In addition, concentrating certain machinery in certain areas, and training workers to use more than one machine in their area, minimized the distances between the machines and people needed to work on a part. These distances previously had led to delivery delays due to the time that intermediate work products had spent moving around the facility from one set of machines to another. Celluarization of the machinery was done to reflect an efficient flow of the production process and the facility floor was reconfigured accordingly.

Supervisors (also known as "facilitators") are the cell leaders, and were supervisors prior to the implementation of the cell concept. The facilitators' job is to manage their work areas, obtain the resources that they need, and manage overtime schedules. Line workers' seniority and core competencies enable them to get into a particular cell, and once there they are to cross-train to obtain the skills to work on multiple machines. The cross-training of line workers is primarily left to facilitators, but also some cell workers manage it themselves. There is no switching of line workers between cells, other than temporarily for absent workers, and there is one cell technician classification for all machine operators.

The management views celluarization as very positive because it enabled the facility to increase productivity by moving away from the one-man, one-machine structure. Line workers now are assigned enter and exit dates for machining a part that typically needs five to ten steps, and they have the flexibility to decide how to structure the process. This has created a real sense of worker ownership of the product and increased the facility's throughput. The union leadership has been very cooperative in these efforts, not least of which because it wants to preserve jobs for its membership. Older and long-term line workers have had more difficulty adjusting to the changes, but most line workers are becoming more comfortable with them. About one-fifth of the workers are in cells now, with potentially another three-fifths in the future.

The basic management structure of the facility's manufacturing operations is that it is headed by a president/chief executive officer, who oversees the vice president of manufacturing, who oversees the manager of manufacturing engineering, who oversees the manager of operations logistics, who oversees the operations superintendent, who oversees the supervisors or facilitators, who oversee the line workers. About 80 percent of the supervisors were promoted from line worker positions, as were about 50 percent of managers.

The facility's supplies are mostly forgings, castings, bar stock, steel plates, fabrications, loop systems, and bearings. In the last 12 to 18 months, the perception of the purchasing

function's importance to the facility's profitability has increased, as about 30 to 35 percent of its product cost is in purchased goods and services. The purchasing group now reports directly to the corporation's president, instead of the facility's manufacturing group. The purchasing group does not try to dictate supplier selection, but has roundtable discussions with the manufacturing managers to provide its judgment. The purchasing group works closely with the sales, manufacturing, and engineering staff, including sitting in on negotiations with customers and preparing staff for those negotiations through role-playing exercises.

The purchasing group focuses its efforts on the facility's largest suppliers, using strategic analysis, alliances, partnerships, and leveraging based on the corporation's other divisions. The facility considers it important to develop partnerships with suppliers and customers. It works closely with suppliers, especially on improvements to decrease the amount of processing that it must do, and has visited customers to better understand how its products are used, so as to develop ideas for making more cost-effective products. The facility has a just-in-time inventory program, which has led to special arrangements with some suppliers and substantial monetary savings. One key supplier comes in for three hours daily to maintain inventory at a very low level, while some others come in once or twice a week. The facility has suppliers in for talks and visits them. There is no real checklist when visiting suppliers, but rather the facility observes how busy and clean they are and talks to their line workers. Most of its top suppliers are ISO 9000-certified, but this is not required as some suppliers have better quality control programs. Environmental performance is not generally an important criterion in accepting suppliers and their location is important only for subcontract machining.

The facility has about 400 employees, about 250 of which are unionized, who work day and night shifts. There are many long-tenured workers, due to the facility being part of a very old, privately-owned corporation whose owner was reluctant to lay off workers. The facility considers the labor-management relationship to be very good and the union leaders have worked well with it because they have understood the need for the facility to change.

There are no formal training or apprenticeship programs for line workers. There is, however, a great deal of cross-training and the facility tries to have all line workers able to do more than one job. Line workers receive on-the-job-training on different machines in their respective cells' environment, with older employees training younger ones. They also undergo training in total quality management and quality process techniques. In fact, line workers have taken classes on how to run a factory, and parts of the facility ceased work for an entire week to train line workers on how to improve production.

Though the lines of communication within the facility may be better than ever, the facility is still trying to improve communication with line workers to get their ideas and input. The manufacturing manager strives to be very visible on the facility floor, trying to get workers' ideas. There are periodic meetings, at least monthly, of supervisors with workers to communicate and solicit information (e.g., how the business is going, whether goals are being met, ideas for improvements, etc.). Workers also can submit their suggestions through "Process Change Request Notice" forms, hundreds of which are submitted annually and about 75 percent of which are implemented. In addition, if a problem needs further development, a team of people, including line workers, is identified to consider and make recommendations.

There are three regular meetings with union personnel: a monthly meeting with the union

committee discussing the facility's financial results, a weekly meeting of the union committee and the human resources staff to discuss labor issues, and a biweekly meeting of the "Process Steering Committee," composed of the manufacturing managers and union committee, to discuss employee and team involvement in process improvements, problem solving, and continuous improvement. Information on production performance (e.g., backlogs, on-time deliveries, etc.) of the corporation, department, and cells are posted on bulletin boards within departments. There also are quarterly meetings in which the corporation's chief executive officer gives a presentation on the performance of the business. The facility also uses newsletters to keep employees informed.

Many ideas originate from line workers to improve production processes. There is no formal compensation program for employee suggestions, but a President's Award (given once or twice a year) can involve monetary awards, and small gifts (e.g., dinner certificates) can be awarded to workers for their ideas. Solutions to problems are not recorded for posterity pursuant to a formal program, but about half of the time specific improvements provided by line workers are recorded for future reference.

Proposed projects are evaluated on the basis of their internal rates of return, payback periods, operational performance, and economic value added. A key criterion for capital equipment projects is whether they add process capability, because many of the facility's machines are old and unidimensional. The typical payback period for approved projects is three to four years, but there is no prescribed maximum set and the desired period can vary by the cost of the project.

ENVIRONMENTAL MANAGEMENT

The facility has no specific waste reduction goals, but there is a desire to generally be a good corporate citizen on environmental matters. For purposes of his evaluation review, the environmental manager establishes performance goals, such as reducing the quantity of hazardous wastes and lowering the facility's potential environmental liabilities. These environmental goals are essentially regarded as cost saving objectives. The facility has lowered its hazardous waste generation by about 70 percent in the 12 years of the environmental manager's tenure.

The facility's manufacturing manager is aware of no specific financial benefits from any environmental action undertaken, but he believes that environmental requirements are desirable to avoid cross-contamination on the facility floor. The environmental manager believes that the facility's environmental practices primarily accomplish the basic objectives of avoiding environmental violations and maintaining a good reputation with its customers and the surrounding community. In addition, sometimes environmental regulations force the facility to take a closer look at its processes -- for example, when certain chemicals the facility uses are targeted for more stringent regulation. In such situations, the facility looks for ways to eliminate these targeted chemicals or to use them more sparingly and in only the ways most important for its processes.

The facility's environmental manager divides his time about equally between his environmental and production operations responsibilities. He has served as environmental

manager for 12 years. He believes that others at the facility view him as being cooperative in his role as environmental manager. The primary concern of others at the facility has traditionally been on manufacturing, rather than environmental, issues, and more recently productivity and quality concerns have become especially important. He believes that the line workers understand the importance of complying with environmental requirements, but not their meaning or implications.

There is no publicizing of information to facility workers about the facility's environmental performance, but there is a safety committee in every department, composed of line workers and superintendents. A facility safety committee, composed of the environmental manager, union officials, and maintenance staff, meets at least monthly, depending on the topics to be addressed. Each department also is subjected to monthly safety inspections by other departments' personnel, who particularly check on whether a deficiency that was noted in a prior inspection has been corrected. A third-party conducts a one or two day environmental audit of the facility about every three years. In those years in which no such audit is done, the environmental manager conducts his own audit.

Environmental projects are primarily prompted by pending laws impacting chemicals used by the facility. For major proposed environmentally-related projects, the key criteria are what are the laws and their legal deadlines, and what are the financial and personnel resource requirements. Proposed environmental projects are subject to the same evaluation criteria as other facility projects. The environmental manager stated that all of its environmentally beneficial projects were non-resource intensive common sense solutions, because it had no especially complicated problems demanding complicated and expensive solutions. The environmental budget is only $20,000 a year and the waste disposal costs for this facility and four sibling facilities with related businesses are only $100,000 a year. Environmental costs could be traced back to their respective cells, but they are not, and speculative environmental liabilities are not incorporated into the facility's financial statements, though they are considered in its decision-making processes.

CHEMICAL FACILITY HIGH ADOPTER #1

GENERAL BACKGROUND

The Chemical Facility High Adopter #1 is a large petrochemical manufacturing facility in Louisiana, with annual sales of about $2 billion. The facility is composed of over 20 plants, each of which produces particular chemicals in four distinct lines of business. Almost all of the facility's work involves producing large volume commodity chemicals, along with small amounts of specialty chemicals, for on-site use and bulk shipments elsewhere. About one-third of its production is exported. The product mix has changed little at the facility over time, though there have been process changes. The facility has been located in Louisiana for about forty years, having been attracted to the area due to its abundant natural resources (e.g., brine and salt domes for chlorine production, and oil wells for hydrocarbons), low-cost power (which it generates itself), ample labor supply, excellent transportation (e.g., by rail and a deep water port), and good climate. The facility owner is a Fortune 50 corporation which has been a prominent member of the chemical industry for nearly 100 years.

The corporation recently has substantially reorganized and downsized its operations due to the large increase in foreign competition over the last 10 years. The stability in the commodity chemical markets during the 1960's had led to a certain degree of complacency within the industry. The recent increase in competition is due partly to there now being fewer barriers to transfers of technology. Thus, foreign companies have found it easier to obtain more efficient technologies, and may have a cheaper labor supply. The easier transfer of technologies has especially important implications for the facility's main products, commodity chemicals. Producing these chemicals requires a large initial investment in technology, but the processes used to make them are generally stable. Consequently, it is more burdensome to develop a new technology, but easier to make processes more efficient once that technology has been transferred.

The corporation used to have a 12-layer employee hierarchy, but has now pared it to 8 layers, and is on its way to 4 to 6 layers. The facility is headed by a site manager, who oversees a plant superintendent for each of the facility's plants, who in turn oversee the plant operators. Previously, the plant operators were overseen by operations supervisors, but these positions have been converted to "coaches" while they are being phased out. The corporation is attempting to build in more cross-functional expertise for managers to achieve more flexibility in management.

The corporation also is trying to change its culture to be more risk-ready and entrepreneurial (i.e., proactive vs. reactive) and to motivate all employees to actively try to improve the facility's performance. There has been a strong effort throughout the corporation to change the culture, and site managers at the facilities are tasked with bringing about this attitude change in their employees. The facility's site manager believes that this cultural change has been very important and productive at the facility.

The facility's culture has changed in the last 15 years from a rigid chain of command to much more flexibility and autonomy given to the line workers, with the intent of creating self-managed and self-directed work teams. The emphasis used to only be on results and not on the

process by which someone achieved them. Now the corporation has started a program of setting corporate, plant, and personal goals. Everyone is made aware of the corporate and plant goals and they try to develop their personal goals to reflect those. The corporation wants all workers to think about how to achieve their goals, focusing on the process and not just the end result. Previously, the facility's reaction to about two-thirds of all problems that arose was to spend money correcting them. Now, about the same proportion is resolved through changes in the facility's culture.

Overall worker morale and efficiency has been boosted by the corporation's use of the "R+ program." This program involves providing positive reinforcement to workers for their desirable actions and some negative reinforcement if they cause problems, with a rule of a four to one ratio of positive to negative reinforcement. The R+ program began several years ago because the corporation realized that it needed to focus more on behavior to improve processes and efficiency, rather than just on technical aspects. It realized that more requirements were being placed on workers without offering them proper feedback and encouragement.

The manufacturing strategy for the facility is embodied in a "Site Implementation Plan," which details the facility's production, administrative, human resources, and work process procedures. The facility considers its core mission to be to reliably and predictably produce chemicals in an environmentally sound manner and to be the best globally at what it does. The facility's actions are guided by a corporate strategy document, but individual businesses within each facility have some autonomy on making manufacturing decisions.

The facility's manufacturing strategy reflects a mixture of the corporation's and facility's thinking. Key concepts in the strategy include the global nature of the business, efficient asset utilization, global cost leadership, and reliable product quality. Information used in developing this strategy is gained partly through internal sources, benchmarking, consultants, and industry groups. The facility manager receives internal direction on developing manufacturing strategy from three primary sources: the general manager of manufacturing, the business manufacturing leader, and technology center managers. The technology centers provide direction on new technologies to all of the corporation's facilities.

In 1996, the facility developed "Manufacturing/Service Excellence Teams" ("MSET"). These teams exist in each of the four lines of business at the facility. The teams consist of safety, environmental, maintenance, logistics, and project management people, and plant superintendents. Each team member then reports back to his/her respective functional manager (e.g., the MSET environmental representative reports to the facility environmental manager). This facilitates communication flows between functions and within a function. One plant superintendent from each MSET is on the "Site Leadership Team," which is headed by the site manager and contains representatives from the facility's safety, environmental, maintenance, logistics, engineering, public affairs, legal, human resources, controller, and site services staff.

The facility's major supplies include methane, salt, and petrochemicals. Most of its supplies arrive by pipeline. The facility has a program to encourage its main suppliers to locate in a nearby industrial park, and several suppliers have done so. These suppliers have purchased or leased the land from the facility. These suppliers can also, however, continue to be suppliers for other companies.

The corporation, and thus the facility, selects and manages its suppliers through a "Supplier Partnership Process." This process began 10 years ago in North America, along with other quality control initiatives. Suppliers are not required to be ISO-certified, but the process expects most, if not more, of the quality control procedures required in ISO and also includes a requirement for continuous improvement. The process requires that prospective suppliers first be evaluated through a questionnaire which seeks information on their past records for quality, service, and product performance. As part of this evaluation, safety and environmental issues are considered from the perspective of possible insurance liability concerns for the facility. The facility then visits prospective suppliers to determine "Best-In-Class" suppliers and approved suppliers are placed on an "Acceptable Manufacturers List." Beginning several years ago, suppliers began being graded as acceptable, qualified, or preferred. To become preferred, a supplier must pass several types of audits, including environmental audits.

The facility tries to obtain its supplies from suppliers on the preferred list before trying the qualified and then the acceptable lists. About 3,000 suppliers are on these lists, but 95 percent of all supplies are purchased from about 200 of them. As part of its "Qualified Continuance Program" there is an annual audit, for at least a few years, of the suppliers on the lists. The facility also receives quarterly information from suppliers on criteria on which they jointly agree (e.g., quality control procedures, service, on-time deliveries, and number of defects). The facility is now using a statistically-based approach for quality management of supplies, rather than an inspection-based approach. The facility typically checks for quality based on statistical sampling of supplies, rather than complete inspections. It certifies the top one-third of suppliers based on these statistics.

Some suppliers (e.g., gaskets and bearings) come to the facility frequently to manage its inventory, and some suppliers have electronic data interchange with the facility. The facility also works with suppliers to have them produce exactly what it wants, including helping to train suppliers' employees and instructing them on its quality philosophy. In some cases, close working relationships with suppliers have been helpful in jointly trying to develop ways to improve performance. In addition, some corporate staff serve on industry standards committees to encourage standards that would require suppliers to provide higher quality products. Other companies take advantage of the facility's efforts by using the suppliers that it has qualified, knowing that the facility has ensured their quality, and buying the quality products that the facility has worked with the suppliers to produce. Thus, suppliers qualified by the facility benefit from this increased business from other companies.

The facility is especially careful with its supplies that are transported, rather than piped, in. This is because it has a large volume of chemicals being transported to it and, if there is any problem, it assumes that it ultimately will be held responsible. For such suppliers to be certified as approved suppliers, the facility examines their environmental practices and past records, checks their emergency response plans for accidents and spills, and mandates that they meet both legal and corporation transportation rules. If possible, the facility prefers suppliers that are closest to it, for commercial reasons (less miles traveled results in less cost) and for safety and environmental reasons (less miles traveled results in less chance of accidents). Suppliers' overall safety and environmental records, however, are more important than how close they are.

The facility has about 2,000 employees, none of whom are unionized, along with about 1,000 contract employees. Both the managers and line workers stated that the union-

management relationship was good. The facility has both day and night shifts, with typically about six people on a shift in a plant. There is a supervisor usually on the day shift, but on the night shift one of the more senior plant operators generally takes charge.

The plant operators are generally former line workers that have performed the best. Most operators were at the plant about 15 years before becoming an operator. No one becomes an operator until after at least seven years with the plant and they are trained 100 to 200 hours a year to maintain their skills. As operators, they have the responsibility for managing costs, dealing directly with suppliers, detecting errors, and making the product within specifications as inexpensively as possible.

The individuals in each plant work in self-directed work teams that are held accountable for the performance of the plant. Teams are given substantial responsibility to take ownership of issues and solve problems on their own. Of the 168 hours per week that plants operate, upper management is around only 40 hours. Thus, this structure allows matters to be addressed more effectively and promptly than if decisions needed to be made by upper management. A team used to have a lead person designated, but now whomever is most experienced with the particular issue at hand takes the lead and organizes the team to address it. This team system is a relatively new way of operating at the facility. Thus, it currently has a transitional position called "coach" or "process technologist" whose function is to help employees work within, and become familiar with, the new system. Teams are evaluated on safety, environmental compliance, energy usage, quality goals, and pounds of product generated, and individuals are also held accountable to a certain degree.

Using computers to monitor plant operations has tripled the information coming to the operators and made their jobs more manageable and effective. The computer now provides a preliminary indication of a problem and an initial response to it. The operator is then responsible for deciding how to best solve the problem. Many plants have had computer models developed of them, so that operators can use these to try to optimize their plants' processes.

Line workers receive a substantial amount of training upon starting at the facility. The typical training includes in-plant training, an introduction to the facility's basic raw materials and processes, detailed instruction on the raw materials and processes that they work with, environmental training (e.g., industrial hygiene, permits, and pollutant emission levels), the specifics of the equipment relevant to their work, including acceptable emissions levels and what to do if the equipment fails and causes environmental problems. Training is maintained through quarterly safety and environmental training days, which all levels of staff are required to go through, and "booster" training sessions whenever a specific issue arises. The training program has been helpful in encouraging operators and engineers to take ownership of the processes with which they work. They become committed to improving the processes because they are responsible for those processes. Everyone also now knows what the environmental permits require and allow, so they can be certain to be in compliance.

A line worker is given time to become proficient in his/her main job in a plant and then begins the cross-training program to learn the other jobs in the plant. Cross-training has been done for the last 25 years so that workers can do another job if help is needed or if someone is absent. New people are first trained in each area and then everyone rotates jobs to keep their skills fresh in each type of job. The duration between each rotation varies from plant to plant,

from every two to four weeks. It takes one year of training to learn all of the jobs that are done on the outside of the plant, one year to learn those that are done inside the plant, and two years to learn the plant's control systems and computer-related jobs.

The factors that most drive the generation of ideas for capital or other improvement projects are competitiveness concerns, environmental and safety considerations, annual goals, facility plans, and facility objectives that are aligned with business goals. The factors that strongly influence the priorities assigned to projects are return on investment, environmental performance considerations, legal requirements, consistency with corporate goals, and community concerns. When new projects are considered, the economic analysis of them involves assessing the internal rate of return, discounted cash flow, and corporate weighted average cost of capital associated with the project. Sensitivity analyses are done to determine what the economic impact would be if the capital or pricing estimates were off by 10 to 15 percent. Low or negative net present value projects are done only if they are legally required. The facility does not use payback periods much, nor does it have a method to incorporate speculative costs (i.e., avoided health costs). More subjective measures of risk are included in deciding whether to use more or less conservative assumptions in the decision-making process. Approved projects are annually audited to check if they are meeting the original projections.

ENVIRONMENTAL MANAGEMENT

About 10 years ago a culture shift on environmental matters started when the facility created staff positions whose primary responsibility was focusing on environmental and safety considerations, rather than the amount of product generated. At that time, most employees felt that too much effort was being spent on environmental considerations. A few years later, many of them had begun changing their minds. This cultural change, and on-going training, has today made environmental performance a given, in that employees consider it as a factor in their day-to-day decisions.

Each of the corporation's facilities considers the global environmental strategy that the corporation develops, and interprets and further develops it as is most appropriate for them and their particular state regulations and community needs. The facility's two overarching goals are to maintain its competitiveness and to comply with environmental rules. The individual plants within the facility take direction from the facility's environmental strategy, including contributing some reductions in emissions to meet their shares of the corporation's overall reduction goal. Each plant also is responsible for managing its own wastes. Individual employees then develop environmental goals consistent with the goals of the plants in which they work.

The facility has developed a "Strategic Plan for Compliance and Emissions Reductions." Its general environmental strategy is mostly compliance based, and the main concern is to keep chemicals within the facility and to avoid any serious releases of them to the environment. The facility is striving for zero compliance problems. In a typical year the facility confronts about 50,000 compliance requirements, and there were only 7 times in 1995 that it was not completely satisfied. This performance has led compliance auditors to inspect the facility less intensely over the years because they doubt that problems exist. The facility also is trying to have all employees thinking about the environment on a daily basis so that it becomes a routine consideration and

part of the culture. Part of this involves persuading more employees that environmental projects will provide long-run competitive advantages.

Even though environmental spending has decreased over time, environmental performance keeps improving, largely due to the cultural change as employees actively seek ways to make the facility more environmentally reliable. For example, plant operators will now challenge a change in a process if they believe that it is not meeting safety or environmental concerns. Line workers believe there is too much paperwork and extra procedures that are linked to environmental requirements. The environmental staff tries to explain to workers the procedures that must be followed and their rationale, but workers' motto for environmental requirements has become that "environmental does not have to make sense, we just have to do it." The employees are often able to improve performance by non-resource intensive common sense solutions which they can implement on their own. The facility's business manager believes that two-thirds of the credit for improving the facility's environmental performance is attributable to its cultural change.

The environmental staff is now examining ways to make the facility more competitive, as well as to lower pollutant emissions. They believe that substantial emissions reductions (e.g., over 50 percent) are needed to satisfy public expectations. The environmental staff now looks more at the bigger picture and tries to initiate projects that will have an impact on the entire facility and have a large financial benefit. They also are trying to be more proactive, rather than reactive, and to reap avoided costs resulting from environmental improvements.

According to the production operations managers, the facility's environmental efforts can lower costs and increase productivity. For example, the facility has instituted an early-warning system that catches leaks in pipes and other production inefficiencies. This also benefits the facility, because previously if the leak went unnoticed for a while, the whole production process might have to be stopped, thereby causing large economic impacts, when it became so large as to be a serious problem. Also, during a restoration project on one plant, the facility is using a new tracking technology to detect pin-hole size leaks, and upgrading any areas as needed. The project has produced very favorable economic results.

The facility's environmental management consists of an environmental manager who oversees 5 environmental superintendents, who in turn oversee over 20 environmental coordinators (one for each plant). The environmental manager has been in the environmental department for nearly 10 years and with the facility for over 15 years. The facility was the first in the corporation to adopt the concept of environmental superintendents for the plants. The facility also had been, several years previously, the first to create safety superintendents for the plants.

About 10 years ago, the facility realized that it needed staff in functional leadership positions to resolve environmental issues. This decision was driven by the facility's increased focus on accident and spill prevention, environmental reporting burdens (particularly reporting under the federal Toxics Release Inventory program), foresight by corporate managers on what their future needs would be, concerns about a new governor who was apparently hostile towards chemical companies, the implementation of new federal environmental programs, and good insight by the facility on how to best implement the program. The environmental superintendents are the link that passes initiatives that occur in a particular plant to other plants,

as well as to the facility-wide environmental organization. Though the environmental superintendent program is being diffused throughout the corporation, other of its facilities are having more difficulty implementing it. This is partially because they are unionized facilities and unions tend to consider environmental tasks as operational work, and thus should be their functions.

The environmental staff receives regular training on a quarterly basis. There are also specific training modules depending on the plant with which an environmental staffer is working. The environmental coordinators learn about the production and operations of their plants by attending some of the line workers' training modules. The environmental staff also sometimes receives training from outside environmental consultants.

The facility belongs to an organization of a number of local chemical facilities. It was created in the late 1980's as an outgrowth of the "Responsible Care" initiative of the Chemical Manufacturers Association. The organization's goal is to create a consistent community outreach program among all the local chemical facilities. The facility also belongs to the Louisiana Chemical Association, which helps with legislative issues, environmental issues, and educational programs on the chemical industry. The facility also has helped to fund a "Community Advisory Panel," which meets once a month with the facility manager to make suggestions and express their concerns. This panel is run by the community and its members rotate over time. The facility also has a quarterly television program where the community can call in questions.

The facility conducts its own regularly scheduled audits. The operators of each plant conduct inspections of their waste management areas during their daily rounds. Every month, every plant does a basic audit of itself to track its emissions. Every three years, environmental superintendents conduct an audit of each plant. Every five years, and every three years for plants that are considered to be high risk, a week-long audit is conducted of each plant by staff from other of the corporation's divisions. The corporation's technology centers also conduct their own audits on technology maintenance issues and evaluate a facility's technology needs. In addition, every year environmental agencies subject the facility to an air inspection, water inspection, and several hazardous waste inspections.

Every environmental incident at the facility is tracked and recorded, and a root cause analysis of it is done. The facility considers any release of chemicals or wastes of over 10 pounds from any primary containment as an event which requires internal reporting, even if it is not legally required to report it to any government agency. Any such releases are managed by the work team that is responsible for the process where the release occurred. Releases of greater amounts are evaluated by additional personnel. The facility uses a voice-mail system as its initial release reporting mechanism. This was developed to enable employees to report and record an incident and state why it happened as soon after the incident as possible so that no details are omitted. The employees on the shift at the time of the incident are responsible for collecting the appropriate information and reporting it, and trying to resolve the problem. This is preferred over the prior procedure where they first tried to gather all of the managers, who usually were not at the location of the incident, and wait to have them address the problem.

There is a monetary incentive for managers and workers to avoid creating an environmental or safety incident. If they, or the workers that they manage, create such an incident during a year, they lose a 10 percent salary bonus at the end of the year. Also, at an

annual ceremony, awards are given to employees that suggested projects that were particularly successful, including environmental projects. Environmental projects have been suggested and initiated by all different groups at the facility, including from production workers.

Employees used to think of the environmental staff as "compliance police" or "one of them" until several years ago. Now they are viewed as people who are trying to make workers' jobs easier. This perception has changed for several reasons. First, employees now realize that environmental regulations and procedures are here to stay and thus they need to learn how to work effectively within the rules. Second, the environmental staff began using a more cooperative, rather than conflict-oriented, approach to addressing issues. Third, environmental staff were brought in who had already worked in production and manufacturing, thus providing them with an understanding of that aspect of the business. Now only people who have already worked for some years in production and manufacturing are taken onto the environmental staff. The current environmental staff has worked an average of 10 years for the corporation. Fourth, more training and explanation is offered to workers as to why certain environmental tasks must be done. If workers understand the reason for doing something, they are far more motivated to do it, their morale is higher, and they usually determine the most efficient way of accomplishing the goal. Finally, the environmental staff's name was changed from "Environmental Control" to "Environmental Services."

The environmental staff uses e-mail within the facility to communicate, distribute ideas, and make employees aware of particular issues. The environmental staff is supposed to be the clearinghouse for obtaining information from outside of the organization (e.g., trade associations) and disseminating it within the organization. The facility is not especially motivated to disseminate to outside parties its experiences with pollution prevention technologies, as that may dissipate its competitive advantage. It also believes that sometimes it has definitely been disadvantageous to be first in implementing a new idea or technology as it has borne more of the initial costs, and other companies have been able to take advantage of its efforts.

Most of the facility's wastes today are dealt with on-site. The only materials that it currently disposes of off-site are PCB, mercury, and radioactive wastes. The facility performs an exhaustive evaluation of off-site disposal facilities, checking all of their permits and compliance histories prior to using them. The facility is committed to incineration of wastes, rather than landfilling or deep-well injection. It has a biological wastewater treatment plant which is currently at capacity, ample landfill capacity, and excess incineration capacity, due to its waste reduction practices.

About $20 million annually is spent on compliance issues at the facility: one-third each on waste incineration, on fugitive emissions and regulatory affairs, and on compliance personnel, respectively. Historically, about one-third of the capital cost of the facility is due to waste treatment equipment and environmental technologies for emissions reductions. Waste cleanup and disposal costs are included in overhead accounts, while environmental compliance and treatment costs are included within each plant's manufacturing costs. The facility is trying to create a system by which downstream environmental costs (e.g., cost of landfilling, cost of wastewater treatment, etc.) are charged back to the business that created the cost. It still is far, however, from fully instituting this system. The facility also wants to move towards life-cycle analyses of its products and the corporation recently acquired a small company to help in this.

Most suggested environmental projects are for pollution control, but a significant number are for source reduction. For projects that are not legally required, the facility is trying to focus on what economic gains can be generated from them over a 10 year time horizon. The environmental staff has an idea of the processes that generate the most emissions, so projects directed at these processes are preferred. Some processes are difficult to evaluate because more data are needed and they are not being collected. When prioritizing environmental projects, the metric of pounds of emissions reduced per dollar is often used. Generally, environmental projects are evaluated on the same bases as other projects. If a project is legally required, the facility attempts to find ways to obtain other advantages during its implementation (e.g., upgrading technology or increasing efficiency). If such a project unavoidably has a negative return, the facility searches for ways to lower the costs.

Some internal and external factors complicate the facility's project prioritization. These include the fact that stockholders do not like payback periods of 10 years. In addition, regulations that mandate specific pollution control technologies may not be the most efficient, or otherwise make the most sense, for the facility. Also, an inflated importance is attributed to certain of the facility's wastes and thus more attention is devoted to them than is justifiable. For example, certain wastes are used as inputs in different facility processes to ultimately create a saleable product, but these wastes also have to be counted in the facility's waste volumes. Consequently, the importance of such wastes are exaggerated and they are then targeted for action, even though other wastes may actually be more important to address.

Most environmental projects at the facility are driven by regulatory requirements. Consequently, the facility looks for other benefits that could be gained while doing the project, especially when the technology is not mandated. Regulations have driven some of their innovations, but a short compliance schedule sometimes does not allow for a full consideration of the alternatives and the best environmental alternative may not be selected because the facility is rushed to make a decision. Newer regulations are allowing somewhat more compliance-schedule flexibility. In a typical year four to eight years ago, the total of all environmental projects had a negative net present value. More recently, the total of all environmental projects usually has a break-even or slightly positive net present value. Most projects are negative net present value, but there are a few that are highly positive.

The biggest barrier to accomplishing environmental improvements is the inability to quantify the costs and benefits of environmental projects. For example, it is difficult to predict the future costs of energy or of regulations, and often the necessary data are not tracked back to certain processes. The facility's least successful environmental projects have occurred when there was poor predictions of energy costs and/or poor economic forecasting. Another significant barrier is the size of the environmental staff. In the last few years there has been a greater realization that there is a need for more environmental staff as regulations have become more complex. It currently has enough people to accomplish all of the compliance activities, but it is very difficult for them to manage more, such as pollution prevention issues.

CHEMICAL FACILITY HIGH ADOPTER #2

GENERAL BACKGROUND

The Chemical Facility High Adopter #2 is a large chemical manufacturing facility in Louisiana. The facility has been located in Louisiana for over 25 years. The facility has four manufacturing units making agricultural chemicals and its customers are distributors and large farm co-ops. The facility owner is a large foreign corporation with a long history of involvement in the chemical industry.

When the facility was constructed, it was with the intent of creating a workplace which would not result in the same labor troubles as at a corporate sibling facility in another state whose operations it was supplementing. Also, the difficulties of using unions to construct the facility encouraged the management to consider alternative worker management procedures. Thus, there was a conscious decision to treat salaried and hourly workers well and equally (e.g., same vacations, sick days, insurance, etc.). This approach has made a substantial difference in what is accomplished and with encouraging communication with and ideas from workers.

In the facility's early years, the management encouraged friendly competition between workers (e.g., shifts) to increase productivity. Around 1990, the management began working to eliminate this competition and had largely succeeded by 1993. The facility now emphasizes educating workers on all aspects of the business, on the concept of teamwork -- rather than competition, and on the broader implications of what they do. As a result, this facility is more team-oriented than its sibling facilities and is the corporation's only non-union U.S. production facility. While the "teams without leaders" concept has not been adopted throughout the facility, the team concept has. The continuity and agreement among the 8 to 10 management directors of the facility since it was built was a large factor in inculcating this team philosophy.

Cross-functional committees have been used at the facility for over 10 years. Such committees are composed of employees representing the various departments of the organization that would be relevant to the issue that is being addressed. They are viewed as producing better decisions than just having a few corporate directors make decisions, and they inherently achieve the parties' commitment to the final decisions. Cross-functional committees are sometimes selected by the facility's directors. The facility has tried self-directed work teams with "coaches" in some departments, because the prior facility manager had heard of the concept and tried to encourage it, but mostly it uses cross-functional committees.

Most of the facility's raw materials come by pipeline from two adjacent facilities, which located there specifically to service the facility and with whom it has a very good working relationship. The facility has at least 100 major suppliers and about 2,000 suppliers overall, few of which are located nearby. A material resource planning system is used to try to achieve just-in-time inventory. Suppliers regularly suggest new ideas and the facility considers itself to be an industry leader in developing partnerships with suppliers.

The facility's divisional headquarters has a "Chemical and Packaging Council," composed of employees specially trained to do audits of prospective and current suppliers. This council

meets quarterly to determine which suppliers to audit. Suppliers complete questionnaires even before they are audited, which sometimes indicate that a supplier is not even ready for an audit. These audits are based on ISO 9000 criteria and the facility encourages significant suppliers to seek ISO 9000 certification. These audits examine suppliers' production processes, but not too deeply. The questionnaire responses and audits enable the facility to grade suppliers and to determine its preferences. After a few years, each supplier is audited again. All major raw material suppliers have been audited by now, except intermediates suppliers that are sibling facilities.

Part of these audits is environmental concerns (e.g., how wastes are handled), as the facility prefers not to deal with suppliers that are not environmentally conscious. Environmental subjects have, since at least the early 1980's, been part of the audit process, though they have increased in prominence since then. After they are approved, suppliers' environmental practices are not thereafter examined.

Job applicants must complete a "Chemical Operator Training" program, which includes over 100 hours of unpaid night school instruction in what such operators must know (e.g., chemistry, mathematics, environmental and safety issues, engineering, etc.), taught by facility workers. Line workers also review job applications and do interviews of job applicants to assess their initiative, teamwork, can-do attitude, and leadership. Line worker involvement in selecting and training applicants began in the early 1970's to counteract the "old boy network" way of getting jobs. The facility has made a conscious decision to avoid the cycles of hiring and firing employees during business fluctuations and thus there have been no layoffs in many years.

The basic management structure of the facility's production operations is that the facility's manager oversees the director of production, who oversees the unit superintendents (typically college graduates in chemistry or engineering) in charge of certain processes (e.g., herbicide production, packaging, etc.), who oversee the production engineers (college graduates in chemistry or engineering) and day maintenance supervisors. The production engineers and unit superintendents oversee the shift supervisors and foremen, who oversee the technicians (typically 6 to 13 per shift). The technicians are required to undergo nearly 300 hours of training, including a computer-aided training system on the details and procedures of the facility's production systems.

The facility has a formal suggestion system, including suggestion boxes, for employees, and about $115 million in cost savings have resulted from employee suggestions over the facility's history. Suggestions also can be offered at periodic safety and environmental meetings, and at "D-shift" meetings every two months, which are composed of one technician from each unit who meets with the facility's manager and directors. In addition, employees can submit forms to make suggestions. The facility also has a program which allows employees to offer suggestions to or raise concerns with the facility's nurse, who then provides the information to the facility's management for its response, though she is the only one who knows the identity of the employees who contact her. Finally, the facility has a cost improvement program in which each employee has to suggest cost improvement ideas as objectives, which are tracked monthly. These ideas are submitted to the facility's management, who, if it approves, send the ideas to the divisional management.

To inform managers and line workers of relevant developments, the facility uses a weekly

newsletter, a monthly newsletter from the division, a monthly publication from the facility, e-mail messages, daily conference calls with the facility's directors, weekly lunches of selected employees with the facility manager to share information on business developments and suggestions, a weekly voicemail message from the corporation's president, walks around the facility by managers, biweekly staff meetings, and weekly department informational meetings. In 1995, networks (e.g., on process safety, environment and energy, and product distribution issues) were established between the corporation's sibling facilities to exchange information and to meet every two months. There is a monthly report of key performance indicators (e.g., environmental objectives, safety objectives, etc.) and everyone's compensation is affected by the facility's performance versus those objectives. Also, each employee has individual objectives -- financial, safety, and environmental -- which affect their year-end bonuses.

ENVIRONMENTAL MANAGEMENT

The stated commitment of the corporation, and thus the facility, to environmental protection is memorialized in a formal policy, entitled "Vision 2000," that was issued by its board in 1990. The policy's intent is that the corporation should strive to balance social, environmental, and economic concerns. The corporation's worldwide management attended seminars to be instructed in this philosophy. This necessary top management support and vision helps everyone focus on always considering environmental factors in decision-making and has made environmental consciousness part of the corporation's culture. For example, the corporation was one of the first to produce an annual corporate environmental report which publicizes information about its manufacturing operations.

The corporation's greater concern about environmental matters was partially prompted by an accident that occurred at one of its European facilities in the mid-1980's that led to chemicals flowing into a river. The ensuing negative publicity triggered a greater environmental consciousness on the part of the corporation. The corporation realized that it was better to prevent pollution than to clean it up afterwards, leading to its increased waste reduction efforts and a move to incineration from landfilling, and also better to set the standard than to have to follow someone else. This environmental consciousness has been reinforced by the substantial amounts that the corporation had to pay to clean up pre-existing contamination at facilities in the U.S. that it had purchased many years ago.

The facility has an "Environmental Committee," which is "coached" by the production director, and a long-range (15 years) environmental plan produced by a multi-disciplinary committee. The long-range environmental plan was issued in 1993 after obtaining input from around the facility, division, and corporation, and listed dozens of environmental projects to be done. The facility also has environmental and "Responsible Care" committees, with representatives from every unit in the facility. In addition, each shift has a safety committee.

This special concern about environmental issues motivated the facility to, among other actions, spend millions of dollars installing extra scrubbers and gas combustors to remove certain chemicals from its air emissions and to close settling ponds, even though these actions were neither legally required nor economically beneficial. The facility also installed on-site incinerators because of its philosophy that it is responsible for its own waste and because,

compared to landfilling, the associated potential liabilities are lower.

The environmental staff is viewed as partly "cops on the beat" and partly helpers to the production people. Much of the facility's environmental efforts are implemented through cross-functional committees of workers from many departments. Thus, efforts by such groups are not seen so much as done by "cops." The facility relies upon the environmental staff to help the facility keep up with changing environmental laws and to explain to workers the rationales for environmental objectives and procedures. Line workers appreciate the facility's environmental accomplishments, particularly the fact that many of the pollution prevention efforts reduce their personal exposure to chemicals.

To provide employees with updates on safety and environmental issues, the facility issues "Safetygrams" when relevant. Detailed environmental data (e.g., spill and waste management information) are available to everyone at the facility through its computer network. There also are environmental information bulletin boards around facility. Also, the facility has an "Instant Accident Tracking System." Anytime anyone has an accident, no matter how minor, the affected employee and his/her supervisor must, by the end of the day, complete a computer form describing the accident (what happened and how to prevent it in the future), which goes to management for approval and then automatically is distributed to everyone in facility. A similar system exists for spills, to facilitate achieving the goal of a 20 percent annual reduction in spills. These spills are analyzed to determine the appropriate corrective and preventative actions. The overriding purpose of these systems is to share information and facilitate everyone's learning from it.

The facility's "Safety, Health, and Environmental Department" is comprised of the following groups of employees: the department director, a loss prevention superintendent, who interacts with insurance providers and government emergency planning committees; a safety superintendent; an industrial hygienist; a senior environmental counselor, who attends trade association meetings and interacts with environmental agencies; three quality assurance staff; a 24-person "Environmental Analytical Section," who engage in laboratory and sampling work; and an eight-person "Environmental Regulatory Affairs Group," who monitor regulations in their areas of specialization. There is a corporate environmental group that also monitors environmental regulations, but none at the divisional level. The head of the environmental staff has been at the facility for nearly 10 years, the first several of which were on the production staff. Many of the other environmental staff also previously worked in production.

The facility knows for each manufacturing unit how much is spent for waste disposal. Environmental and safety costs comprise about 30 percent of the facility's budget, even though the facility estimated that about 90 percent of its environmentally beneficial projects were non-resource intensive common sense solutions. Much of the facility's capital spending is on environmental projects and they are generally evaluated on the same basis as other projects. The capital return guidelines for environmental projects, however, are five percentage points less than for other projects. Projects can be proposed by completing a one-page form explaining the proposed idea and the range of its cost, which the divisional management will then review. There is no required payback period for environmental projects, but a two to three year period is necessary for other projects.

CHEMICAL FACILITY LOW ADOPTER

GENERAL BACKGROUND

The Chemical Facility Low Adopter is a chemical manufacturing facility in Texas. It is owned by a corporation which has four other chemical manufacturing facilities in the U.S. and England. The corporate specialty is nitrogen chemistry, using formaldehyde and hydrogen cyanide to make amino acids. About half of the facility's business is in amino acids and it also manufactures dispersing agents. The facility makes about 50 to 60 variations of its basic products. In terms of its sales, the facility would be considered a large chemical manufacturing facility, but the corporation would be considered a small to medium size chemical manufacturer on the basis of its total sales.

The facility opened in the early 1980's, owned by a Fortune 100 corporation. At end of 1992, the division of that corporation that included the facility was acquired by some of its managers in a leveraged buyout which was completed in 1995. The division was then purchased by its current owner, a foreign corporation. Despite the shifting ownership over the last few years, the transition was described as seamless.

The facility has had no formal, written manufacturing strategy, but one is now being developed at the corporate level. The facility and corporate marketing managers are developing a formal strategy describing where they want the business to be in three to five years. The desire for a formal strategy is being driven by the three new managers of the U.S. facilities, all of whom worked together at one of these facilities in the early 1980's. They were concerned that, absent more coordination between their facilities, they were duplicating efforts, missing opportunities, and not exporting expertise enough between the facilities. They also believed that, absent any scorecard or roadmap, they would be less likely to meet their goals. They were especially interested in doing benchmarking studies and in instilling a philosophy of predictive maintenance (i.e., measuring various processes to determine when maintenance will be needed, thereby enabling it to be done in a planned manner, rather than waiting for a problem to develop). The corporate management has been supportive of their efforts, but typically has not originated any initiatives nor interfered in the facility's operations.

The facility is certified under ISO 9000. A corporate sibling facility in England also is ISO 9000 certified, and other U.S. sibling facilities are planning to pursue this. According to the facility, ISO 9000 certification has reduced the number of audits that it has to undergo from prospective customers, assisted in its export business, helped to make management procedures consistent within the facility, ensured that problems are followed-up on and resolved, and focused its efforts on continuous improvement. The facility perceived no disadvantages from ISO 9000 certification. It always is looking for ways to improve, and is particularly interested in trying to upgrade its collection and processing of data about its performance.

The facility has about 50 suppliers of raw materials and 40 suppliers of equipment, about 75 percent of whom are nearby. The facility works closely with the corporate purchasing office in selecting suppliers, and some intermediate products are obtained from its sibling facilities. In particular, much of the purchasing for supplies needed by more than one of the corporation's

facilities is handled by the corporate staff. Thus, the facility is not responsible for much high volume, expensive purchases.

When there is a small number of potential suppliers for a product, the facility negotiates with all of them to ensure that a backup supplier exists for the one that it ultimately chooses. If, after the initial negotiation, obtaining a competitive price appears possible with a particular supplier, the facility proceeds with the supplier approval process described in ISO 9000 (e.g., product sampling, obtaining historical data, possibly audits, etc.). The facility does not audit large, well-known suppliers, because most are ISO 9000-certified, but each year it selects a few others to audit. The facility's audit team usually includes someone from its purchasing, quality control, and environmental staffs, using a questionnaire that includes some environmental items. Generally, the facility does not, other than during audits, examine the processes of its suppliers, but it does require them to give notice of any major changes in their processes.

The primary criteria used in its selection of suppliers are the quality of the product or service, suppliers' location, the extent of technical assistance available, and the certainty that the product or service will be available in the necessary quantities in the long run. Suppliers are not required to be ISO 9000-certified, but it is taken into consideration and makes it easier to certify them as acceptable. About half of its suppliers are ISO 9000-certified. After their selection, there is some information exchange with suppliers (e.g., discussions among their process engineers to ensure that the facility is using the right storage methods and piping) and larger suppliers typically provide product-related information. The facility has very close relationships with some major raw material suppliers, with suggestions offered and roundtable discussions held among them. Rarely, if ever, has the facility obtained environmental improvement ideas from suppliers.

There is a daily checking of the facility's supply inventories and needs, and it tries to maintain a minimum inventory by tying its production rate to its sales rate, but it does not try for a just-in-time inventory system. Rather, the facility often maintains substantial inventories, especially of chemicals, because railcars of supplies can take a few weeks to reach it from some locations. The corporation is considering getting a new system based on material resource planning principles because desired information from all of the corporation's facilities presently is unavailable on a corporate basis (different facilities have different systems) to make decisions.

The facility has about 100 employees and 50 to 60 contract employees (primarily maintenance), none of whom are unionized, and there has been little turnover in the past. The facility's basic management structure is headed by the facility manager, who oversees an operations manager, who oversees two general supervisors, who oversee the shift and area supervisors, who oversee the line workers. The employees work in four shifts (the facility runs 24 hours a day, 7 days a week), with a shift supervisor overseeing groups of six or seven line workers. All of these supervisors formerly were line workers.

All of the facility's operators are trained to operate all of its processes. There are seven distinct operator positions and workers must demonstrate competency in each of them to achieve the full rate of pay and must annually thereafter recertify their competency. Rotations of jobs occur, depending upon the desires of the workers in the shifts. Most workers appear to like this structure because it allows them more variety in their work. It also appears to lead to their identifying more with their work and to their integration with other workers because they see

how each part of the production process impacts others.

While there are no formal work teams, the batch process nature of the facility's operations leads to integration among the line workers. A sibling facility, in contrast, is structured into work teams, with operators taking on additional responsibilities which are integrated into daily functions (essentially, compared with this facility, there are no production supervisors). At this facility, some feel that there is too much inertia in some situations because line workers are not allowed to make decisions themselves.

There is a daily meeting of the management staff to oversee the facility's production and scheduling, and a monthly reporting system for the staff. To keep the employees informed, there is a monthly company newsletter and meetings every several months of all employees in which business conditions are discussed. To ensure the preservation and dissemination of solutions to problems that it encounters, the corporation's chemical and engineering professionals write research reports after they have resolved problems in their processes. These reports are then provided to corporate management, which retains them in an indexed computer system for easy retrieval by others in the corporation. There is no formal process, however, for employees to make suggestions for improvements in the facility's operations and no financial incentives for any such ideas.

ENVIRONMENTAL MANAGEMENT

The corporation has a formal environmental strategy, but no formal environmental strategy has been prepared for the facility. In general, the corporate staff provides the facility with little environmental management input, and instead just assumes that everything is operating smoothly. The facility's philosophy is that safety and environmental considerations are its top priorities. When the new corporate owner took control, it retained a consulting firm to do environmental audits of all of its facilities, and the results of these audits are guiding the environmental issues to be addressed. Thus, there is no standard environmental audit at the facility, but it is addressing the findings of the corporate-sponsored audit. When the new manager took over at this facility, he decided to elevate the stature of the environmental department by having it report directly to him, rather than continuing as a sub-department of the facility's technical department. The new facility manager had previously been the environmental manager at a sibling facility for a time.

The facility is planning to prepare an ISO 14000-like plan within the next year, so that its environmental management would be similar to its ISO 9000 procedures for production operations. For example, currently the facility records environmental incidents (e.g., spills) that occur, but it does not manage the information or necessarily follow up on it as would otherwise be required under ISO 9000. Also, the facility tracks its waste minimization performance only annually, not monthly, because there is no management system in the group.

Some of the facility's prior environmental managers acted somewhat like "cops on the beat," and created an adversarial relationship with the production staff. The current environmental manager, who formerly led a process management group at the facility, has been in his position for eight months and with the facility for six years. He is working more like a

partner with the production staff to help in resolving concerns. According to the environmental manager, to get general acceptance of his role by the workforce, he strives to be proactive, rather than acting as the cop on the beat. Based upon his experiences on the production side, he realized that environmental aspects needed to be attended to more.

For example, he provides input to a safety committee composed of line workers, but he does not try to run it. He tries to provide user-friendly information to other employees, particularly on the rationale behind various environmental requirements. Workers are starting to understand that some environmental requirements may not make sense, but they still must be complied with. As a result, workers are coming to him for guidance more than ever and the facility's management always has supported him when he weighted environmental concerns more than production concerns.

In the past, the environmental staff was never in the main flow of decisions at the facility, even in project development, and there were no formal corporate-wide documents on integrating environmental considerations into planning. Now the environmental staff consults with the project managers, is being included in project meetings, and is updating project management manuals to include environmental considerations. In general, the environmental manager is seeking a more formalized way of incorporating environmental concerns in decisions.

According to the facility manager, many actions done primarily for environmental reasons have saved the facility substantial amounts of money, and the facility at which he was formerly the environmental manager saved millions of dollars from such projects. Without focusing on waste streams, he believes that people sometimes do not think about the potential savings of reducing wastes. Thus, the philosophy should be that all employees should be thinking about reducing wastes, and this will produce many ideas that are environmentally and economically beneficial.

For example, the facility recycles certain of its non-hazardous waste streams and designed one process to produce no liquid waste. These efforts have reduced its wastes, conserved its water, and improved its industrial hygiene. The facility has engaged in some recycling since 1986 and more recently committed itself, in a state-required waste minimization plan, to a 15 percent reduction in waste over 5 years, which it already has far exceeded. The facility always is trying to minimize its waste streams, but it is difficult, at best, to eliminate them.

According to the environmental manager, in the past all environmental ideas originated from the production staff. There is, for example, a waste minimization team, consisting mostly of operations people, which meets at least monthly to generate recommendations. The environmental manager also does a substantial amount of networking with environmental managers of other local businesses and attends local, regional, and trade association seminars on environmental topics. The facility indicated that its environmentally beneficial projects were a mix of non-resource intensive common sense solutions and capital-expensive solutions that had complicated implications.

Proposed projects, including those that are environmental in nature (other than those that are legally required), exceeding $100,000 in estimated costs must have no more than a three year payback period, with the possible exception of those that increase production capacity. Less expensive projects do not need a specified payback period, though three to five years is the

typical period. Each project that is proposed at the facility has environmental costs estimated for it and sometimes environmental costs are attributed to particular products.

When asked to calculate the possible costs for new products, the financial staff consults with the environmental staff to determine the potential sources of environmental costs. They are trying to better incorporate the capital costs of meeting environmental regulations into calculations of their costs. Worst-case scenarios are developed, including speculative environmental liabilities, in considering costs for proposed projects and products. The facility's environmental and waste disposal costs have become a bigger issue in recent years because it no longer can use its on-site deep injection wells for as much of its waste disposal as in the past. In addition, it has had to implement several expensive legally required environmental projects in the last few years and more are upcoming.

AUTO PARTS FACILITY HIGH ADOPTER

GENERAL BACKGROUND

The Auto Parts Facility High Adopter is a large auto parts manufacturing facility in Michigan. The facility, owned by one of the "Big Three" auto companies, has been located in Michigan for over 30 years, having expanded to comprise about two million square feet. The facility is a major, state-of-the-art producer of over 2,600 different parts, including interior soft trim for automobiles, such as door trim panels, headlinings, bolster pads, and small parts, and exterior plastic components, such as thermal plastic olefin ("TPO") and reaction injection molding ("RIM") fascias, bumper covers, taillights, and exterior moldings. On a daily basis, the facility ships nearly 200,000 parts to numerous North American and foreign assembly plants.

Because of its size and complexity, the facility has divided its production into four areas of operation to efficiently manage its resources. The first and largest area manufactures interior door trim panels, the second area paints and assembles RIM and TPO fascias, the third area molds the fascias for the second area and manufactures energy-absorbing foam, and the fourth area manufactures car and truck headliners, dials, and miscellaneous small parts. The facility uses a variety of processes in its manufacturing, including dielectric and pressure bonding, low-pressure and injection molding, vibration and sonic welding, heat and sonic staking, robotic painting and material adhesive application systems, and waterjet cutting systems. According to the company that handles some of the facility's recycling, the facility is the corporation's non-assembly facility that is viewed as the most innovative and that is used as the test-case for its other facilities.

The business plan for the facility is ultimately based upon a set of seven strategies established by the corporation, one of which involves corporate citizenship, which includes environmental concerns. These strategies reflect a mission statement and set of written values issued by the corporation in the last few years. A business plan is written for each division and then for each facility. The business plan explains the principles, personnel roles and responsibilities, and deliverables necessary to pursue each of the corporation's basic strategies. The environmental staff is not part of the development of the facility's business goals.

The facility's progress towards meeting its goals is measured, among other ways, by a detailed monthly "Manufacturing Datacard" report prepared for the facility. This report lists the facility's performance over the preceding 12 months and over the year-to-date in meeting six basic goals: leadership in customer satisfaction, empowered people, nimble through process leadership, worldwide product excellence, low cost producer, and leadership in corporate citizenship. These six basic goals are divided into 24 areas, which are further separated into dozens of specific, measurable objectives and "stretch" objectives (i.e., 25 percent better than the objective). The facility's performance in meeting each of these objectives is then graded as meeting or exceeding the stretch objective, meeting the objective without any issues or concerns, not meeting the objective but having a documented action plan to do so, or seriously missing the objective with no defined resolution or one which requires management attention.

The facility is served by about 250 suppliers. All suppliers must be certified as satisfying a

certain set of quality standards developed by the corporation, similar to those embodied in ISO 9000. Ultimately, however, all suppliers will have to be ISO 9000-certified. As part of this certification process, a review team from the corporation, including process engineers, audits prospective suppliers. No professional environmental review is automatically included in these audits, but if any environmental concerns are raised, further investigation is done. Only a small percentage of its suppliers are located nearby, but this is important only for tooling.

The facility has about 3,000 employees, about 2,500 of which are line workers who are unionized. There is a lukewarm relationship between management and the hourly workers. The basic production management structure is that there is a unit supervisor who oversees technical engineers, who in turn oversee area coordinators and technicians. About half of the supervisors previously were line workers, but the facility now is seeking to hire first-line supervisors with technical degrees. There are no formal, but some informal, work team approach mechanisms. Some line workers are selected by their supervisors to assume more responsibility for managing their work, and these workers sometimes coordinate their activities with other workers. These informal teams are unlikely, however, to rotate their functions. In addition, groups of line and management workers are sometimes formed to jointly troubleshoot problems. Furthermore, in an attempt to get more involvement and feelings of ownership by line workers, the facility has established groups of employees who meet voluntarily to solve problems.

ENVIRONMENTAL MANAGEMENT

According to the company that handles some of the facility's recycling, the facility was more proactive environmentally in the early 1980's than most of its corporate sibling facilities are now. This facility's advantage, according to that company, is the long tenure of the head of the environmental staff, because high turnover disrupts the daily attention needed to maintain pollution prevention efforts. The facility believes that the community around it can have a significant impact upon its long-term viability (e.g., expansions of and permits for the facility), so it strives to do more than just what is legally required environmentally. Among the environmentally beneficial acts engaged in by the facility is its agreement not to develop 10 acres of its property. It also has reduced its emissions of volatile organic compounds by over 90 percent over the last ten years, partly by moving from solvent-based to water-based adhesives. This action was primarily motivated by pressure from the state environmental agency to reduce odors emanating from the facility that had irritated some nearby residents.

The facility's management, which had been investigating recycling and waste minimization opportunities as early as 1983, is starting to view possible monetary benefits from recycling as secondary to meeting the recycling goals set by the facility and the corporation. Environmental success stories, rather than just cost savings, are important in the corporation's evaluation of the facility, as the amount of waste recycled is the main metric used in satisfying the corporate citizenship objective in the facility's "Manufacturing Datacard" report. Thus, the facility is recycling plastics from its cafeteria and office paper because it increases awareness of its recycling efforts, even though this may not be economical. It is sometimes difficult to find markets for the facility's recyclable materials, because the facility will not pay more than the otherwise applicable disposal costs for these materials and the facility insists on knowing where the materials are ultimately destined after being recycled. The facility also has a wastewater recycling system,

closed-loop cooling towers, cardboard recycling, and an arrangement where it returns, rather than discards, packaging from some supplies to their supplier, earning it rebates.

The corporation has a corporate environmental office. The facility environmental staff understood that that office was only a satellite of the corporation, unconnected in a corporate sense except for the office's vice-president, to avoid undue influence by the corporation on environmental decisions. Subsequent contacts with that office, however, indicated that there was a formal organizational connection between it and the corporation. According to the facility environmental staff, the corporate environmental office formerly was divided into substantive specialties, but reorganized recently so that each staffer now is responsible for all environmental subjects. Subsequent contacts with that office, however, indicated that their breadth of responsibility was more limited. Each division of the corporation has its own environmental staff, which has no environmental specialists. The division staff collects environmental information from its facilities and provides it to the corporate environmental office and that office also seeks information directly from the facilities. There is a constant turmoil between the divisions' and the corporate environmental staffs, with the former trying to make the latter aware of the practical difficulties of implementing environmental programs at the facility level.

Environmental goals often trickle down from the corporate level to the divisional level to the facility's manager to the facility. Goals are sometimes initially set unrealistically high, and then revised as more knowledgeable people review it. Several years ago, the corporation began placing more emphasis on waste minimization and recycling. It formed several recycling efforts at the corporate level, which eventually trickled down to the facility.

The corporation has issued policy letters on waste minimization, recycling, environmental project funding, and pollution prevention. There is no environmental strategy written specifically for the facility, because everything is based upon corporate directives, bulletins, and policy letters. It is striving to be a "green" corporation, but the exact details of what this goal entails are not finalized because it has been awaiting guidance from the issuance of the ISO 14000 standards for environmental management.

According to the facility environmental staff, the corporate staff does not solicit much input from facilities in the development of its environmental policies. The corporate and division staff do not come from or know much about the facilities, because they typically come directly from college or consulting firms. (Subsequent contacts with the corporate environmental office, however, indicated that most of its staff do come from the facilities.) Thus, there is a constant battle with them about the practical aspects of implementing the programs that they design. The division staff who originally worked in facilities are helpful, but others without that experience are unhelpful and more of a hindrance. Recently, the corporate staff has broached with the facility staff the idea of the former visiting the facility for a couple of weeks to better understand how facilities work and how corporate policies affect them. The facility also complains that sometimes it does not receive information about legal requirements applicable to it until very late or after a law is in effect. The environmental manager generally believes that using his own initiative is better.

The environmental staff is part of the facility's Plant Engineering Department. According to the environmental manager, his staff is largely viewed by others in the facility as performing a regulatory type function focused on ensuring compliance. The environmental staff is a financial

drain on, rather than economically beneficial to, the facility. People come to them with many questions and they have to sign off on every proposed engineering project, which number about 200 annually, after reviewing their environmental implications. The environmental staff is involved in production decisions largely only when a proposed change would increase emissions beyond the facility's permitted level. In such situations, such emissions would have to be offset or other emissions reduced to enable the change, which might involve costs that would make the change uneconomical.

The hourly workers are perceived to be pro-environmental. They are not, however, especially involved in environmental decision-making, as they do not have the necessary information. For example, a suggestion box that at one time was posted for recycling ideas was unproductive. At least some middle managers and lower-level salaried workers, though, view environmental requirements as obstructions, partly because of traditional habits among workers, and thus their cooperation with environmental efforts is problematical. There has been no significant change in this situation over the years. Upper-level management is supportive of those efforts, however, at least partially because it is they who would be held responsible for any legal violations. It is hoped that new procedures motivated by ISO 14000 will help in achieving more support for environmental efforts.

On a monthly basis, the environmental staff reports to management on the facility's air emissions and waste disposal costs. In particular, they provide information to management on environmental performance that could potentially affect production, such as whether the amount of the facility's air emissions would prevent it from increasing its production. There also are occasional articles in company publications about the facility's environmental performance, but no presentations on environmental topics are made to hourly workers.

As early as 15 years ago, the budget of each area manager in the facility began being charged for that area's wastes, thereby sensitizing them to these costs and encouraging them to practice source reduction. A few years ago, each area's budget began being charged its pro rata share of the costs of transporting shipments of its wastes that were combined with wastes from multiple areas. Previously, the area initially requesting the transportation would have been the only one charged for the combined shipment. Again, this change was intended to more fairly apportion these environmental costs, thereby encouraging source reduction. Any hourly charges for personnel used for some environmental task also are assigned to the responsible area. Because of the enormous number and variety of different products made by the facility, it is not feasible to apportion costs to individual product lines.

The head of the environmental staff has been with the facility over 15 years and originally worked in its quality control group. Another recently-hired salaried staff member came from an environmental consulting firm, while the five others are hourly employees who formerly worked in production. An advantage of having an hourly employee on the staff is that sometimes other hourly workers give them information that they are unlikely to tell managers.

The environmental staff meets weekly to coordinate their work. They undergo periodic legally-required environmentally-related training and also attend seminars and division and corporate conferences on environmental subjects. There also are quarterly meetings at corporate headquarters for recycling teams from the facilities and a corporate computer bulletin board system for recycling information. Also, several years ago the facility created a "Recycling

Committee," presently composed of a few hourly workers and a few salaried workers, to encourage various recycling efforts. Previously, only one person handled recycling, without much involvement from others.

The facility estimated that about half of its environmentally beneficial projects were non-resource intensive common sense solutions. Almost all of the projects cited as implemented in the last 10 years, however, involved resource-intensive and fairly complicated changes in production equipment. For example, changing from solvent-based to water-based adhesives and using sonic welding and low-pressure molding.

All funds allocated for environmental projects are held at the division level to ensure that they not diverted to other facility projects, as happened in the past. The major criteria for evaluating projects in general are their profitability and their contribution to the facility's long-term strategy. With respect to environmental projects, the key criteria are whether the projects are feasible, inexpensive, not too disruptive, and substantial steps forward in meeting established goals. There is a 20 percent minimum required return on investment for any proposed cost-saving project, including environmental projects, and the typical payback period for approved projects is two to three years. A project can be submitted for funding without the necessary rate of return, however, if it is consistent with the corporate objective of increasing recycling. When uncertainties are involved in proposed environmental projects, sensitivity analyses are conducted to determine the likely bounds of any financial results.

OVERALL FINDINGS

As will be described in more detail in this and later sections, there was substantial adoption of both innovative workplace practices and ECM techniques by the 11 facilities that were visited. Naturally, it was assumed that the seven facilities that were selected because they were identified as high adopters of ECM would confirm their statuses, as six of them did. The fact that two of the four facilities selected, based upon past information, as low adopters of ECM would have evolved in just a few years into arguably high adopters was at least an indication of how quickly such statuses can change, and perhaps of the extent of the diffusion of these practices throughout industry.

What was obviously unknown prior to visiting the facilities, and was a primary purpose of visiting them, was the extent to which they had adopted innovative workplace practices. What was found was a high degree of use of such practices. Naturally, it cannot be assumed that these facilities are representative. Because, after our initial identification of them, these facilities effectively self-selected themselves to participate in the research, it is likely that most did so because they regarded their workplace practices to be superior. Those less willing to subject their management processes to scrutiny were likely to be among the few facilities that declined to participate in the research. A similar situation likely arose with respect to environmental practices – facilities that truly deserved low adopter status, or whose prior high adopter status was no longer applicable, may have avoided participating. Consequently, it would be inappropriate to try to extrapolate these findings to all facilities, or to read too much meaning into the apparent relationships between innovative workplace practices and ECM.

WORKPLACE MANAGEMENT PRACTICES

That caveat aside, however, it is clear that innovative workplace management practices were in use to at least some extent at almost all of the facilities. Figure 1 provides a graphic display of the extent to which various of these practices appeared to be present at each facility, as well as other descriptive information about each facility. The more of a pie chart that is filled in, the more that the practice or characteristic is associated with the facility in question.

"Mission Statements" indicates whether the facility possessed and disseminated a formally-adopted, written, facility- or corporate-level overall policy expressing the organization's basic principles, objectives, and operating style. "Explicit Quality Management Systems" reflects the extent to which the facility has a formal and reasonably comprehensive management system designed to monitor and ensure the quality of its production operations. "ISO-Certified" refers to whether the facility's management systems have been officially certified as satisfying the quality control requirements of International Organization of Standardization ("ISO") 9000. "Supplier Quality Assurance" measures the degree to which the facility has a formal and consistent procedure for evaluating the quality of its suppliers, both before and after they become suppliers of the facility. "Supplier Partnerships" denotes whether the facility has an explicit program to encourage cooperative agreements with some of its suppliers to act as partners in the development and production of the facility's products, rather than simply functioning as suppliers and customers. "Just-in-Time Inventory" means whether the facility has formal procedures to

FIGURE 1

WORKPLACE MANAGEMENT PRACTICES

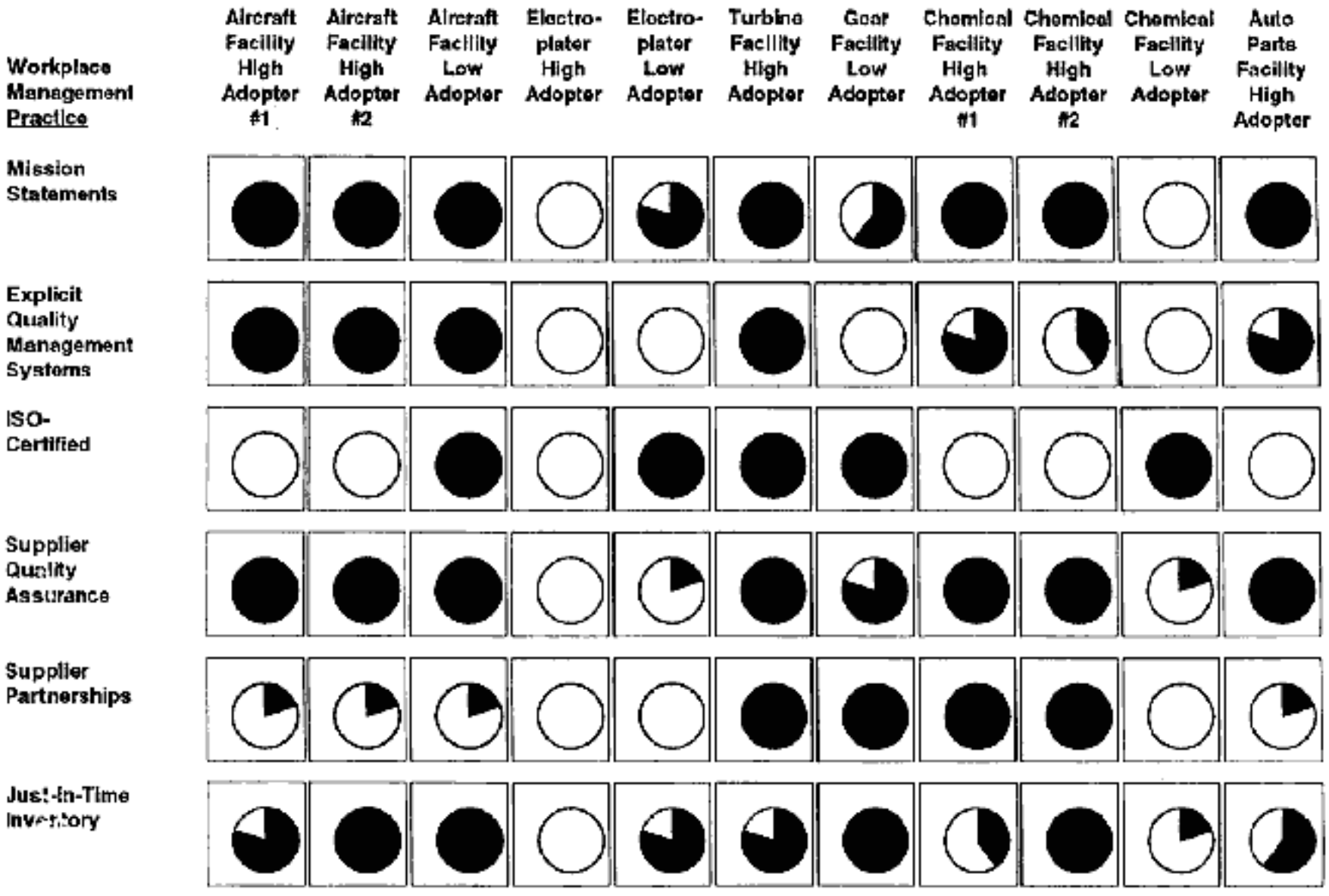
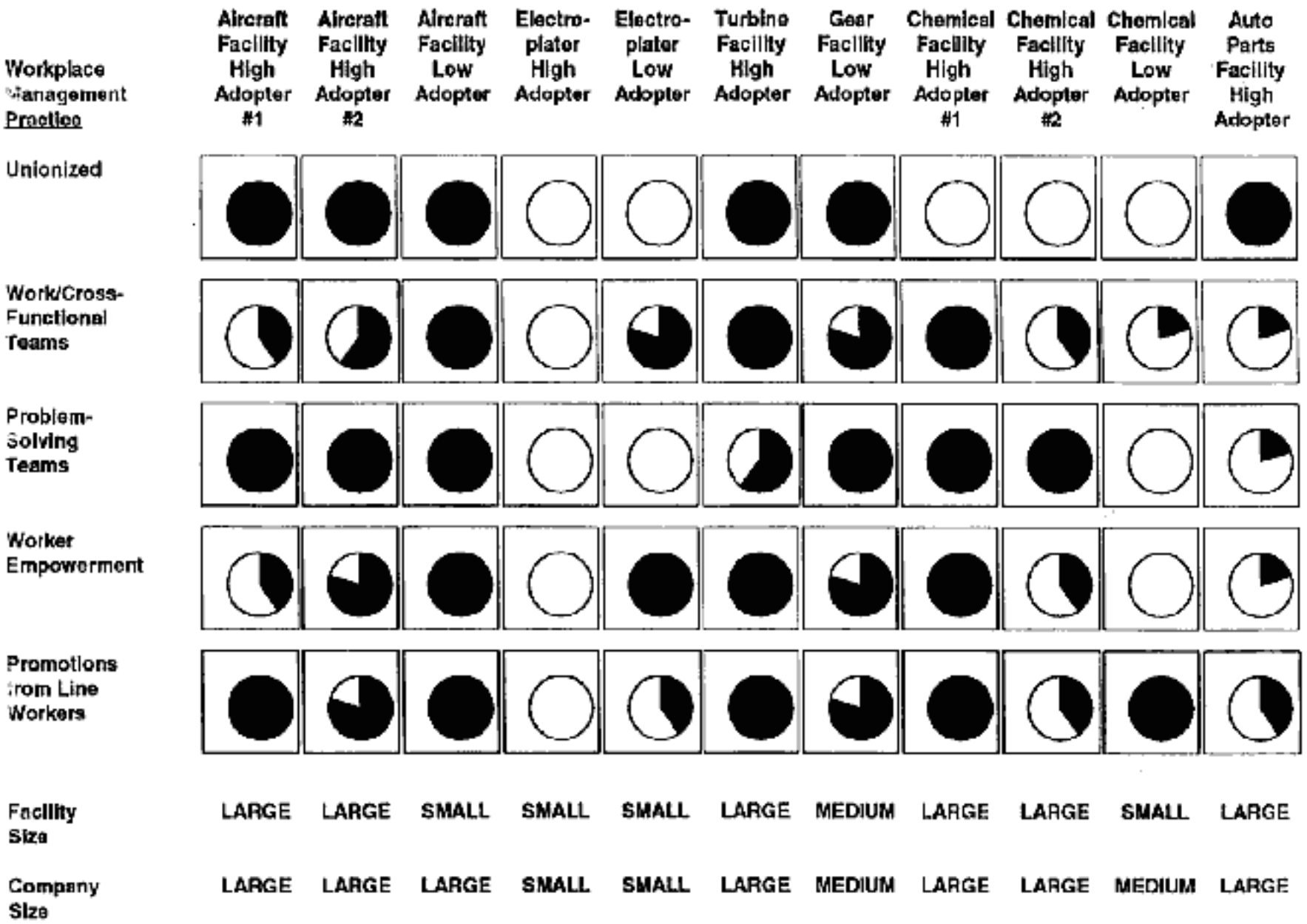


FIGURE 1 (cont.)

WORKPLACE MANAGEMENT PRACTICES



minimize its inventory by only ordering supplies when they will be needed imminently.

"Unionized" simply indicates whether the facility's line workers are unionized. "Work/Cross-Functional Teams" reflects the extent to which the facility has structured its workforce into team-like units, centered around certain products or production operations, or has created various cross-functional teams bringing together workers from different departments within the facility to address continuing operational issues. "Problem-Solving Teams" refers to whether the facility creates special teams of workers to address particular operational issues that sporadically arise requiring attention. "Worker Empowerment" measures the extent to which line workers have been given the authority to control the work practices and production processes within their assigned areas of responsibility. Finally, "Promotions from Line Workers" denotes how likely it is that production operations supervisors were promoted to their positions after first having been line workers.

Thus, as Figure 1 indicates, almost of the facilities had organized their production workers into explicit work teams, or had institutionalized the creation of teams to address specific production operations when they arose. Most of the facilities had, in one way or another, explicitly attempted to empower their production workers by providing them with decision-making responsibility. Most of the facilities, with the major exceptions of the smaller ones, had a practice of selecting almost all of their supervisors by promoting their production workers.

Only half of the facilities were ISO 9000 certified, though others adhered to corporate quality standards that were intended to be comparable to or more ambitious than ISO 9000. Most of the facilities had overarching corporate mission statements to guide their operations and objectives, though only about half had implemented a specific and pervasive quality management system. Almost all of the facilities had some type of procedures to assure and monitor the quality of their suppliers, though only a few had explicit supplier partnership programs. Most had an explicit goal of achieving just-in-time inventory.

Thus, overall, these facilities reflected the adoption of many innovative workplace management practices. Furthermore, the failure on the part of some facilities to adopt some such practices was often due to the small and/or relatively uncomplicated nature of their operations. For example, the electroplating facilities, with only a few managers and a few dozen workers, would not necessarily significantly benefit from some of the more elaborate and resource-intensive management practices that larger and more complex facilities would find desirable.

RELATIONSHIP OF INNOVATIVE WORKPLACE MANAGEMENT PRACTICES TO ECM

While the next section of this report describes in detail the findings with respect to ECM practices, Figure 2 provides a graphic display, similar to Figure 1, of the extent to which various of these practices appeared to be present at each facility, as well as other descriptive information about each facility. "Catalyzing Incident" indicates whether the facility or parent company was subjected to some extreme incident or set of occurrences that largely prompted it to reevaluate its environmental practices. "Management Commitment" reflects the extent to which the senior

FIGURE 2
ENVIRONMENTAL MANAGEMENT PRACTICES

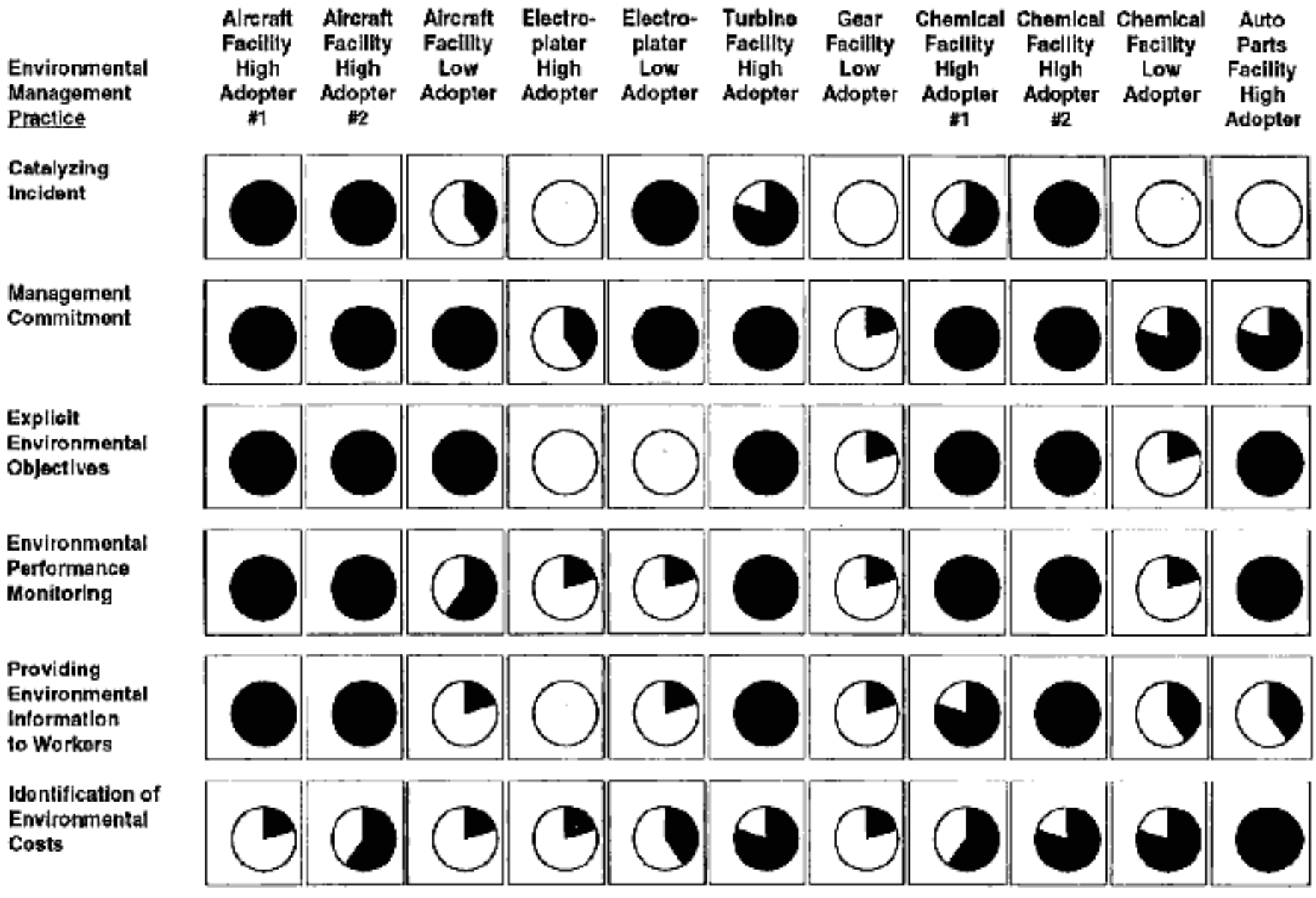
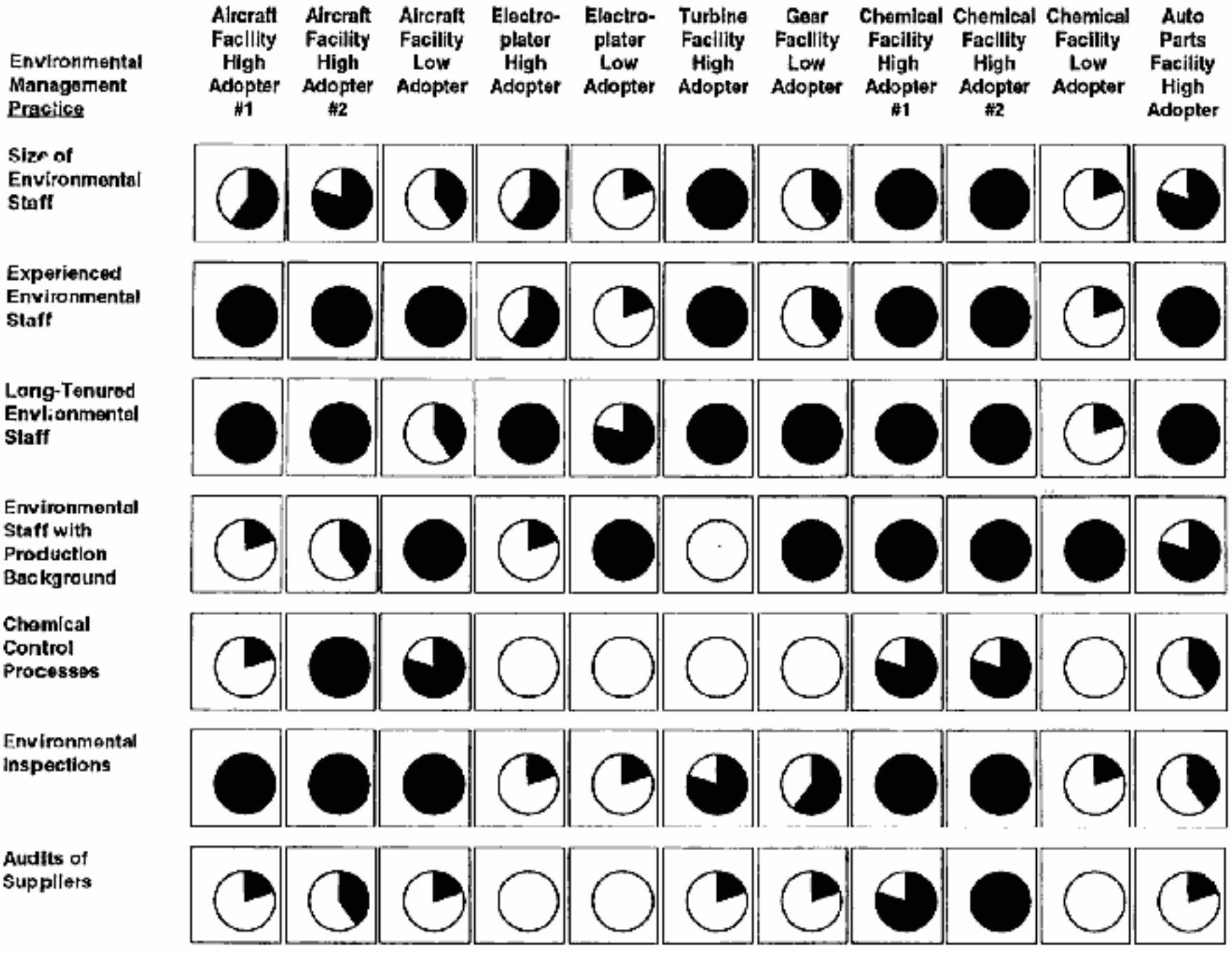


FIGURE 2 (cont.)
ENVIRONMENTAL MANAGEMENT PRACTICES



management of the facility and parent company are overtly supportive of efforts to adopt ECM. "Explicit Environmental Objectives" refers to whether the facility has set specific and quantifiable objectives to be attained through its environmental practices and publicized these to its workers. "Environmental Performance Monitoring" measures the degree to which the facility has established formal, structured procedures through which its environmental activities are monitored and assessed. "Providing Environmental Information to Workers" denotes the effort the facility expends in consistently disseminating information about its environmental practices and performance to its workers. "Identification of Environmental Costs" means the ability that the facility has to track its environmental costs back to specific products or production processes.

"Size of Environmental Staff" indicates the adequacy of the number of environmental personnel at the facility, given the variety and nature of the environmental issues that it faces. "Experienced Environmental Staff" reflects the amount of experience solely in environmental matters possessed by the facility's environmental staff. "Long-Tenured Environmental Staff" refers to the typical length of time that the key environmental personnel have been at the facility, regardless of the specific positions that they may have previously worked at there. "Environmental Staff with Production Background" measures the frequency with which the primary environmental staff have some prior training or employment in the production operations relevant to their facility. "Chemical Control Processes" denotes the degree to which the facility has formal management and recordkeeping procedures in place to safeguard, monitor, and track the usage of its chemicals by workers. "Environmental Inspections" means the frequency with which the facility is audited for environmental purposes by its own staff, by corporate staff, by retained consultants, or by government agencies. Finally, "Audits of Suppliers" indicates the frequency with which the facility's suppliers are audited for environmental purposes by facility or corporate personnel.

By comparing the ratings of each facility on the two figures, there does appear to be a positive relationship between facilities that have implemented innovative workplace practices and those that have adopted ECM. The correlation is imperfect, partly because, due to their size and/or environmental characteristics, some workplace and/or environmental practices are not particularly applicable to some facilities. Thus, confined only to those practices that are truly relevant to a particular facility, the comparison would show an even stronger relationship.

The fact that such a relationship exists should not be surprising given the many common elements and objectives that drive the implementation of innovative workplace practices and ECM. Both sets of practices typically are driven by explicit and forceful expressions of commitment and support by upper management levels. Progress in achieving both sets of practices is ordinarily pervasively and frequently monitored and compared against specific management objectives. Continuous improvement in production processes and efficiency, with a particular emphasis on reducing waste, either in the form of costs or substances, underlies both types of practices. In both situations, workers are encouraged and empowered to identify opportunities for operational improvements and to offer solutions to problems. Finally, success in both sets of practices is enhanced by close examination of the specific costs and processing steps of production operations. Thus, given these similarities in some of the main underpinnings of these sets of practices, it should not be unexpected that facilities that adopt one of them tends to implement the other set of practices as well.

Naturally, however, the adoption of either set of practices could be impeded by the

specific environmental or workplace characteristics of a facility, regardless of how inclined a facility might otherwise be to adopt them. As mentioned earlier, the size of a facility and the volume and nature of the chemicals and wastes which it handles can affect how worthwhile it would be for it to adopt ECM or innovative workplace practices. Thus, these structural characteristics of facilities must also be kept in mind when evaluating the extent to which adoption of both sets of these practices occurs at facilities.

DETAILED FINDINGS: ENVIRONMENTAL MANAGEMENT

The following are the major findings from the field research with respect to environmental management practices, along with specific examples of them from the facilities. These findings are grouped into four basic areas: outside influences on ECM adoption and implementation, organizational influences on ECM adoption and implementation, individual influences on ECM adoption and implementation, and the mechanics of ECM adoption and implementation.

OUTSIDE INFLUENCES ON ECM ADOPTION AND IMPLEMENTATION

- **Single incidents (e.g., chemical spills, government enforcement actions, new environmental reporting requirements, etc.) can lead to such substantial adverse consequences (e.g., widespread negative publicity, large penalties, community hostility, etc.) that the company and/or facility reevaluates and improves its entire approach to environmental concerns. Sometimes less serious incidents can still motivate change when they occur while the facility is in the throes of reevaluating all of its operations due to difficult business conditions.**

For example, the corporate-level management of Aircraft Facility Low Adopter became more proactive about environmental concerns after some of its facilities were fined millions of dollars for environmental violations. The corporate-level management of Chemical Facility High Adopter #2 became more proactive after a large chemical spill from one of its facilities in Europe contaminated a river, causing a large fish kill and much adverse publicity. The management of Turbine Facility High Adopter became more environmentally conscious after being fined substantial amounts for environmental noncompliance and after having to publish in newspapers warnings required by state law about potential cancer risks at the facility, which occurred at the same time that it was otherwise overhauling its operations for business reasons. The corporate-level management of Aircraft Facility High Adopter #1 and Aircraft Facility High Adopter #2 increased its attention to environmental issues after one of its formerly operating facilities produced hundreds of millions of dollars in lawsuits, fines, and contamination cleanup costs. Chemical Facility High Adopter #1 created a new layer of environmental management for its facility primarily after feeling pressured by new environmental reporting burdens, concerns about a new governor who was apparently hostile towards chemical companies, and the implementation of new federal environmental programs. Thus, large shocks such as these can trigger dramatic improvements in the ways facilities approach environmental considerations.

- **Some diffusion of ECM practices occurs through supplier chains (both up and down such chains), but it does not appear to be substantial. The opportunity appears to exist, however, for more such diffusion. This diffusion process is likely inhibited by the geographical distance between many suppliers and their customers.**

All of the facilities' relationships with their customers and/or suppliers included processes by which information about ECM practices were exchanged or adherence to such practices was evaluated. This included facilities being the subjects of environmental evaluations by current and prospective customers, being the initiators of environmental evaluations of, or of ECM ideas to, current and prospective suppliers, and being the recipients of ECM ideas from suppliers. The extent to which suggested ECM practices flowed through these links, however, appeared to be fairly modest.

This appeared to be partly due to the geographical distance between the facilities and most of their suppliers and customers. Most of the facilities used suppliers and had customers from all over the country and even the world. Thus, it would have been difficult for the frequent on-site presence to develop between these business entities that likely would be needed to encourage the sharing of ECM practice ideas. Also, much of these facilities' supplies were bulk raw materials, which would not necessarily lead to an extensive amount of interaction with their suppliers.

Furthermore, it is unclear whether there is much appetite among all parties to the customer-supplier relationship to engage in extensive, time-consuming, and intrusive examinations of their suppliers and customers. For example, environmental and safety records are not part of the supplier questionnaires or audits used by Aircraft Facility Low Adopter, Aircraft Facility High Adopter #1, or Electroplater Low Adopter. The latter facility, however, was itself subjected to an intensive environmental audit by a large customer before the customer agreed to use the facility extensively, due to a past problem the customer had with another electroplater in which the customer was held liable for that electroplater's contamination. While environmental and safety records were part of the questionnaires or audits required of the Electroplater High Adopter by prospective customers, audits were rare and the questionnaires mostly concerned with whether the facility had any chlorofluorocarbon-related emissions or problems.

- **At least some facilities perceive that at least some environmental agency personnel are more motivated by a desire to find and fine violations, even if they are unintentional and inconsequential, rather than to predict and prevent potential problems and propose pollution prevention solutions.**

For example, Electroplater Low Adopter and Electroplater High Adopter both stated that regardless of their past displays of compliance and commitment to environmental protection, state environmental agency personnel routinely inspected them with the objective of finding and fining violations. On at least some occasions, the violations alleged were arguable or inconsequential. Both facilities perceived that they were being harassed for no justifiable reason, and that both their resources and those of the state could be better spent on pollution prevention efforts. Auto Parts Facility High Adopter also believed that environmental agency personnel were primarily interested in identifying violations. These facilities believed also that many environmental agency personnel were inadequately trained to assess possible violations or to offer much advice.

- **Pressures created by environmental laws can motivate facilities to adopt ECM practices**

that exceed the laws' requirements. This may be due to a desire to reduce materials use and/or waste generation to levels that exempt a facility from those laws, to pollution prevention opportunities identified as a result of considering process changes necessary to comply with laws, to public concerns over perceived environmental dangers from the facility, or to facilities' better understanding of their processes' inputs and outputs due to increased monitoring and record-keeping requirements.

For example, Gear Facility Low Adopter stated explicitly that more stringent environmental laws forced it to reanalyze its processes to identify opportunities to reduce certain chemicals or emissions targeted by the laws. Aware that their allowable air emissions were likely to be reduced in the future, the facility was seeking ways to preemptively substitute certain chemicals to avoid the interruptions in operations that might otherwise result. Auto Parts Facility High Adopter was required by its state environmental agency to reduce its odors, which ultimately led it to enormously reducing its emissions of a certain solvent. Thus, this not only addressed the odor problem, but also the more serious problem of the chemical emissions. Aircraft Facility High Adopter #1 successfully reduced its use of certain chemicals to enable it to be exempted from certain federal chemical release reporting requirements. Aircraft Facility High Adopter #2 was required by its local environmental agency to measure its daily use of certain chemicals. The facility not only created a control system for those chemicals, but extended it to cover all of its chemicals, enabling it to closely monitor chemical use. Chemical Facility Low Adopter searched for and found a way to recycle certain wastes whose concentrations of chemicals it had decreased but whose volume had increased. It did so because it was required by its state to submit a waste minimization plan and it did not want to be perceived as increasing its waste stream, even though its hazardous characteristics had been substantially lessened. Thus, regulatory pressure appears to not only accomplish the laws' immediate objectives, but also to stimulate facilities' efforts at ECM practices.

- Some facilities expressed dissatisfaction with the apparent irrationality or irrelevance of some environmental requirements (e.g., requiring reporting of spills for some quantities of chemicals that were too low to pose any meaningful risk or managing some common household materials as hazardous wastes). Such requirements imposed costs upon them, without any, or any comparable, environmental benefit.

For example, Chemical Facility High Adopter #1 noted that the thresholds for requiring reports of spills for some chemicals at its facility was lower than what ordinary people often spill in the exposed environment. Similarly, Aircraft Facility Low Adopter noted that employees have more problems complying with or remembering environmental regulations whose rationales they do not understand or believe, for example having to dispose of insect spray cans as hazardous wastes, contrary to what they do at home. This facility's environmental manager recommended writing laws with common sense explanations attached, so that lay people could understand the real reason for the law.

- Obtaining accurate, timely, and understandable information on environmental requirements is a barrier to ECM practices. Some facilities reported difficulty in obtaining such information from either their higher corporate level environmental groups

or from government entities.

For example, Auto Parts Facility High Adopter complained that it sometimes was not informed in a timely manner by its corporate environmental group of legal requirements that were imminently becoming effective. Electroplater High Adopter found it difficult to keep up with changing environmental requirements and did not believe that it could depend upon the state environmental agency to provide that information. Electroplater High Adopter also stated that it is afraid to use government technical assistance programs too much due to concerns that the program might report this to the state environmental agency, which will then scrutinize the facility further.

- **The fear of potential liabilities from sending wastes off-site for disposal has motivated facilities to engage in pollution prevention, on-site waste treatment or disposal, or off-site recycling.**

For example, Electroplater Low Adopter now sends its sludge waste to an off-site recycling facility, rather than a hazardous waste landfill. Although there are no immediate cost savings, it believes that it eliminates any future liability concerns by sending the waste to a recycler, rather than to a landfill that could conceivably become a contaminated waste site. Most of Chemical Facility High Adopter #1's wastes today are dealt with on-site, through incineration, landfilling, or treatment. The only materials that it currently dumps off-site are PCB, mercury, and radioactive wastes. Chemical Facility High Adopter #2 also installed incinerators because of the philosophy that it is responsible for its own waste and because, compared to landfilling, the associated potential liabilities are lower.

ORGANIZATIONAL INFLUENCES ON ECM ADOPTION AND IMPLEMENTATION

- **The explicit commitment of top corporate and facility management to ECM practices provides leverage and support to lower-level managers to promote such practices at the facility level.**

For example, several of the facilities stated that it was their absolute corporate and/or facility policy that environmental and safety considerations took precedence over everything else. These commitments were explicitly expressed in corporate and/or facility environmental rules and plans. Chemical Facility High Adopter #1, Aircraft Facility Low Adopter, Auto Parts Facility High Adopter, Chemical Facility High Adopter #2, Turbine Facility High Adopter, Aircraft Facility High Adopter #1, and Aircraft Facility High Adopter #2 all had written environmental goals and statements that were adopted by the facility and/or corporation as a whole. Aircraft Facility Low Adopter had its written environmental policy statement, signed by the plant manager, posted pervasively throughout the facility. In addition, any employee at that facility has the authority to stop a process if s/he believes that it poses safety or environmental problems.

In contrast, all of the other low adopters had no explicit environmental policy. For example, Chemical Facility Low Adopter has no formal environmental strategy and its corporate staff provides it with little environmental management input, instead just assuming that everything is operating smoothly. Thus, such policies may provide evidence of upper management's commitment to ECM practices and direction for those efforts, thus motivating other managers to aggressively address those objectives.

- **Barriers to the diffusion of environmentally conscious practices exist between corporate sibling facilities, even despite the expressed commitment of overall corporate management to such practices. Thus, corporate-level analyses may not indicate the true extent of ECM practices, nor would corporate-level policies necessarily ensure the adoption of such practices throughout all facilities.**

For example, Auto Parts Facility High Adopter, which has been especially aggressive in pursuing ECM practices, noted that its suggestions to its sibling facilities on adopting such practices had largely been ignored. Also, Chemical Facility Low Adopter indicated that the extent to which ECM activities had been implemented at its sibling facilities varied considerably. Chemical Facility High Adopter #1 noted that its creation of the environmental superintendent position had not spread throughout all of its sibling facilities. Aircraft Facility Low Adopter stated that its environmental practices were considered to be more advanced than those of the corporation in general. Thus, facility-specific barriers to diffusion of ECM practices appear to exist, and evaluating the corporate-level commitment to such practices may be misleading as to their actual implementation throughout the corporation.

- **Some facilities did not obtain the assistance that they desired in developing ECM practices from intermediate corporate levels (e.g., divisional headquarters staff). Thus, the overall corporate and individual facility environmental goals were not always being facilitated by all levels of the organization.**

For example, Auto Parts Facility High Adopter complained that it sometimes was not informed in a timely manner by its corporate environmental group of legal requirements that were imminently becoming effective. Furthermore, sometimes organizational changes in that group made it difficult to coordinate efforts with facility staff. Chemical Facility High Adopter #2 indicated that it largely depended on its facility's environmental staff, rather than those at the divisional level. Also, Aircraft Facility Low Adopter expressed the opinion that its environmental staff were more advanced than those at the corporate level. Thus, there may be opportunities for greater adoption of ECM practices if these organizational inefficiencies are resolved.

- **Setting lower financial return thresholds for approving environmentally-beneficial projects can encourage their adoption.**

For example, in Auto Parts Facility High Adopter, a project can be submitted for funding without the rate of return ordinarily necessary if the project is consistent with the corporate objective of increasing recycling. Also, Chemical Facility High Adopter #2 has a return on

investment threshold for approving environmental projects that is significantly lower than for other types of projects.

INDIVIDUAL INFLUENCES ON ECM ADOPTION AND IMPLEMENTATION

- **Individual environmental managers behaving proactively and innovatively can push a facility into more ECM practices, even in the initial or continued absence of a noteworthy overall facility or corporate support of such practices.**

For example, acting alone and without any prompting from his management, the environmental manager of Electroplater Low Adopter -- who only recently had assumed those responsibilities and had relatively little environmental background -- sought out ways to recycle, rather than dispose of, some of the facility's wastes off-site. This change involved the environmental manager researching 25 different options for the sludge and determining that recycling technology had become sufficiently reliable for its type of material. Also, the new environmental manager of Aircraft Facility Low Adopter dramatically and quickly improved upon the desultory efforts of his predecessor by continually searching for ways to achieve source reduction and constantly seeking input from the production workers. He now is viewed by corporate-level management as being ahead of its corporate efforts. In addition, the environmental manager of Auto Parts Facility High Adopter has over the years spearheaded a number of ECM practices in source reduction, recycling, pollution control, and environmental cost accounting, with sibling facilities lagging behind. Thus, motivated and competent environmental managers can greatly determine the extent to which ECM practices are adopted by facilities, regardless of the involvement by upper management.

- **The involvement of line workers can be very beneficial in developing ECM practices, because most pollution prevention improvements require relatively simple and inexpensive changes that may be most obvious to the line workers directly involved with the process in question.**

For example, line workers in Chemical Facility High Adopter #1 are motivated to adopt ECM practices because their team-like structure makes them responsible for environmental concerns in their areas, such as noticing and reporting actual or potential chemical releases. Even though environmental spending has decreased over time, environmental performance at the facility keeps improving, largely due to the cultural change as employees actively seek out ways to make the facility more environmentally reliable. The employees are often able to improve performance by non-resource intensive common sense solutions which they can implement on their own. The facility's business manager believes that two-thirds of the credit for improving environmental performance is attributable to this cultural change.

In Aircraft Facility Low Adopter, line workers originated simple ideas for using smaller rags with which to clean parts, which substantially reduced waste generation, and for compacting wastes, which greatly increased the amount fitting in each waste container, thereby dramatically

cutting waste disposal costs that were based on each container. In addition, at this same facility, a line worker originated the idea of providing small cups, rather than buckets, of paint to workers doing small paint jobs, thereby reducing the leftover paint and thus wastes. On a daily basis, the facility's environmental manager emphasizes to employees the need for waste minimization, thus encouraging such ideas.

Line workers at Turbine Facility High Adopter produced a simple idea to segregate waste shavings from different metals, thereby enabling the facility to sell these wastes for the greater return associated with pure, rather than mixed, metals. In the past at Chemical Facility Low Adopter, all environmental ideas originated from the production staff and there currently is a waste minimization team, consisting mostly of operations people, which meets at least monthly to generate recommendations. Thus, facilities with programs to involve and empower line workers may be better able to elicit more ideas for ECM practices.

In contrast, Electroplater High Adopter claimed that most of its line workers did not know or care about environmental issues. Even in terms of worker safety, the workers often did not make an effort to follow the rules.

- **Possessing personnel in-house with environmental expertise is important in identifying, implementing, and monitoring ECM practices. Due to the complexity of environmental law, such expertise is important in understanding the legal implications of possible changes in production process inputs and outputs. Larger facilities, or facilities that are part of larger companies, are more likely to have that expertise immediately and relatively inexpensively available.**

For example, Chemical Facility High Adopter #1 had a staff of over 30 environmental professionals with extensive experience at the facility, and could draw upon the expertise of other staff in the corporation, which is one of the world's largest chemical manufacturers. Similarly, Chemical Facility High Adopter #2 had nearly 50 environmental personnel at its facility alone and could get assistance from other staff in the corporation, which also is one of the world's largest chemical manufacturers. Turbine Facility High Adopter has about 10 people on its environmental staff. Auto Parts Facility High Adopter had seven environmental staffers, and could get assistance from other staff in the corporation, which is one of the world's largest motor vehicle manufacturers. Both Aircraft Facility High Adopter #1 and Aircraft Facility High Adopter #2 had at least a few environmental staffers apiece, but both could get assistance from other staff in the corporation, which is one of the world's largest aircraft manufacturers.

In contrast, both Electroplater Low Adopter and Gear Facility Low Adopter had only one person responsible for environmental matters, and that person spent about half of his time as a production operations manager. In both cases, this environmental manager came from a production, rather than environmental, background and both spent only part-time on environmental matters. Aircraft Facility Low Adopter and Chemical Facility Low Adopter had only one person performing environmental functions, with the Chemical Facility Low Adopter environmental manager coming from a production background. Electroplater High Adopter had the equivalent of about 1.5 persons engaged in environmental work, only one of whom was a trained environmental professional. Thus, the high adopter facilities had far greater breadth and

depth in environmental personnel resources than did the low adopter facilities.

- **Most facilities indicated that unionized workers would be less receptive than other workers to efforts by management to seek their ideas in developing and implementing ECM practices.**

Most of the facilities, especially those without unionized workers, indicated that they believed that they would be less likely to develop relationships with such workers that would encourage those workers to offer ideas for ECM practices. The apparent rationale for this belief is not that unionized workers would have fewer ideas, but rather that they would not perceive it to be their function in general to provide management with such ideas. For example, Chemical Facility High Adopter #1 stated that its sibling facilities are having more trouble implementing the environmental superintendent program because they are unionized facilities. Unions tend to consider environmental tasks as operational work, and thus that they should do those functions.

- **The continuity of environmental managers in their positions appears to be important in facilitating adoption of ECM practices. This could be explained by the fact that some ECM practices require relatively long lead times to implement, that line workers may be more likely to offer ideas to managers whom they have known for some time, that some ECM practices require a detailed understanding of the facility's production and labor practices that only develops with tenure, and that more senior managers may have more influence on upper management's decisions.**

For example, the environmental managers in Chemical Facility High Adopter #1 and Auto Parts Facility High Adopter had been with their facilities for nearly 20 years. The environmental managers for Turbine Facility High Adopter, Aircraft Facility High Adopter #1, and Chemical Facility High Adopter #2 had been with their facilities for about 10 years exclusively working on environmental matters, with the exception of the latter, who had been in production operations until about a year before. The environmental managers in both Electroplater High Adopter and Gear Facility Low Adopter had been with their facilities for over 10 years each, though only working part-time on environmental issues. The Aircraft Facility High Adopter #2 environmental manager has been in his position only a few years, coming from years in production operations, but he is supported by a number of people with specific environmental backgrounds who have been with the facility for many years.

In contrast, while the environmental manager for Electroplater Low Adopter had been with the facility about seven years, only in the last few years has he had specific responsibility for environmental matters, and then only on a part-time basis. The environmental manager for Aircraft Facility Low Adopter had been with the facility only three years. The environmental manager for Chemical Facility Low Adopter had been with the facility for several years in production operations, but had only begun overseeing environmental matters several months earlier. Thus, tenure with the facility and in working on environmental issues appears to be indicative of environmental managers that adopt ECM practices.

- **The geographical proximity of suppliers and customers to facilities appears to have no substantial impact upon the diffusion of ECM practices among these entities.**

Because none of the facilities indicated that they exchanged a substantial amount of advice on ECM practices with their suppliers and customers, the geographical proximity of the supply chain in spreading such practices was inherently unimportant. All of the facilities stated that having suppliers close by was advantageous for developing relationships and exchanging information. The availability, however, of various modes of communication and the infrequency of anything critical needing to be communicated made geography less relevant.

MECHANICS OF ECM ADOPTION AND IMPLEMENTATION

- **Using measurements of environmentally-related activities and outcomes (e.g., materials use, environmental costs, wastes generated, spills, etc.) is an important tool for determining progress, evaluating efforts' effectiveness, motivating further initiatives, and identifying opportunities for new ECM practices. Most facilities, however, have not attempted or succeeded in assigning environmental costs to specific products or operations, thereby undermining efforts to identify and justify possibilities for environmental and efficiency improvements.**

For example, Chemical Facility High Adopter #2 developed systems to track any spills or accidents at the facility and to disseminate reports on them around the facility. While most such spills and accidents did not legally have to be reported, and some were trivial, the facility stressed the importance of learning preventative measures from even minor events so that more serious occurrences could be avoided. Similarly, every environmental incident at Chemical Facility High Adopter #1 is tracked and recorded, and a root cause analysis of it is done. The facility considers any release of chemicals or wastes of over 10 pounds from any primary containment as an event which requires internal reporting, even if it is not legally required to report it to any government agency.

Aircraft Facility High Adopter #2 has a control system over all of its chemicals that requires containers of them to be checked out by workers from centralized locations around the facility, with the weight of each container measured before workers take it and after they return it. This enables the facility to closely monitor chemical use and to be aware if any significant amounts are spilled. Similarly, as part of its overall materials control procedures, the Aircraft Facility Low Adopter has what it calls "Materials Pharmacies." These are restricted areas where most materials in the facility are logged in when they arrive, are stored, and are logged out when they are dispensed to employees in the necessary amounts. This enables the facility to manage and monitor the usage of materials, thereby enhancing their inventory control and, when chemicals are involved, their environmental and safety performance.

In contrast, Chemical Facility Low Adopter currently records environmental incidents (e.g., spills) that occur, but it does not manage the information or necessarily follow up on it. Also, the facility tracks its waste minimization performance only annually, not monthly, because

there is no management system in the group. Thus, the more information available within facilities about their environmental costs and benefits, the better able they are to identify opportunities for improvement.

Alone among all of the facilities, Auto Parts Facility High Adopter had devised systems to track environmental costs back to the specific operations that produced them, motivating those operations to be sensitive to pollution prevention opportunities. Other facilities had not tried or had not fully succeeded in accounting for costs with that degree of specificity. Aircraft Facility Low Adopter, Aircraft Facility High Adopter #1, and Aircraft Facility High Adopter #2 simply include all of their environmental costs in a general overhead category, which may largely be an artifact of their government contractor status. Therefore, such costs are allocated over all work through the common overhead rate, rather than being charged to the particular work that generated the costs. Electroplater Low Adopter and Electroplater High Adopter also include all of their environmental costs in its general overhead. Thus, implementing detailed environmental cost accounting appears to be challenging, and thus a barrier to fully integrating such costs in decision-making.

- **Most pollution prevention improvements involve relatively simple and inexpensive source reduction efforts, such as materials substitution, waste segregation, equipment monitoring, and minimization of materials inputs.**

All of the facilities noted that at least half, and typically an overwhelming majority, of the pollution prevention projects they had implemented were relatively technically simple and inexpensive, as opposed to ones requiring substantial planning and capital investment. For example, Aircraft Facility Low Adopter began using smaller rags to clean parts, substantially reducing waste generation. Also, this facility began compacting its wastes, greatly reducing the number of barrels of wastes that it disposed of. In addition, rather than mixing large batches of paint primer, some of which inevitably had to be disposed of as wastes, this facility now buys pre-mixed primer and allows employees to take small cups of it adequate for their needs. Furthermore, small cups, rather than buckets, of paint are provided to workers doing small paint jobs, thereby reducing the leftover paint and thus wastes. Finally, the facility replaced much of its solvent used for cleaning purposes with a non-toxic household cleaner.

Turbine Facility High Adopter began segregating waste shavings from different metals, thereby enabling the facility to recycle these wastes more profitably. It also began sifting out grinding grit for recycling, combined sewers and water collection points to reduce the cost of sampling and analyzing water, reduced a three-step paint process to two steps, and began refining oil on site for reuse. After hiring a company to analyze the composition of its trash, it also started separating out certain wastes to reduce its disposal costs. Thus, it appears that substantial opportunities exist to adopt relatively low-cost ECM practices.

In contrast, Electroplater Low Adopter stated that the main barrier to improving environmental quality at the facility is the equipment that it uses, with newer, better, and far more expensive technology needed.

- **In many situations, facilities adopted practices that ultimately were environmentally conscious, but did so primarily to reduce costs or improve their production processes. Thus, environmental benefits often were fortuitous byproducts of changes motivated by other reasons.**

For example, to meet production needs, Aircraft Facility High Adopter #1 used a new procedure that removed paint from airplanes without using chemicals. While this was done expressly to shorten the time needed for this activity, it also substantially lowered the facility's chemical use and emissions. Also at this facility, at one time military specifications required five separate paintings of certain electrical parts, which led to difficulty in their performance. The facility developed a new process that required only one application of paint. This process not only improved product quality and cut costs (by eliminating the need for one painter), it reduced the paint used and thus any emissions and waste.

To reduce costs, Aircraft Facility Low Adopter used smaller rags to clean parts and compacted wastes to enable more to fit within waste containers. Naturally, however, these actions also reduced its waste volumes. Aircraft Facility Low Adopter also made a concerted effort to maintain a very clean working environment. Though there are undoubted potential environmental benefits from doing so (e.g., reduced chances of chemical spills), the facility's primary motivation is to prevent damage to aircraft from foreign objects that undermine its quality control requirements. In addition, the facility believes that its overall cleanliness impresses its customers. Also, rather than mixing large batches of paint primer, some of which had to be disposed of as wastes, the facility now buys pre-mixed primer and allows employees to take small cups of it adequate for their needs. This saves the time of mixing, thus enhancing productivity, and reduces the waste primer, decreasing waste generation and costs.

Auto Parts Facility High Adopter has sought to generate revenues and reduce waste by finding a variety of ways in which to recycle its scrap materials. Furthermore, in the last several years, Electroplater Low Adopter has cut its chemical use in half by tightening its control processes. The motivation for this initiative was to improve production efficiency, but it generated environmental benefits as well by reducing input materials. In general, when asked whether certain actions with beneficial environmental outcomes were motivated by the desire to save money or to prevent pollution, facilities almost always selected either the former objective solely or a combination of the two.

- **The setting of explicit, ambitious, and quantitative environmental improvement goals at the corporate and facility levels helps to motivate and direct facilities to meet and exceed those goals.**

For example, Auto Parts Facility High Adopter, Chemical Facility High Adopter #2, Turbine Facility High Adopter, Aircraft Facility High Adopter #1, and Aircraft Facility High Adopter #2 all set explicit quantitative goals for reductions in waste generation and/or emissions. In the cases of Auto Parts Facility High Adopter and Chemical Facility High Adopter #2, goals were established at the corporate level, which then were translated into goals by facilities. In the case of Gear Facility Low Adopter, specific environmental objectives for the facility were included by the environmental manager in his annual job self-appraisal and plan for the

forthcoming year. The Aircraft Facility Low Adopter sets goals for waste minimization, accident prevention, and recycling opportunities. Included are numerical goals for the number and weight of barrels of hazardous waste generated. Thus, there was a conscious effort by high adopter facilities to set ambitious goals. In contrast, specific goals were typically not set by the low adopter facilities. Thus, having express goals to achieve provided facilities with a known quantity against which to measure and motivate its performance.

- **Frequent inspections of facilities can provide the continual pressure to be attentive to environmental concerns. Such inspections can be by internal facility staff, corporate level staff, outside consultants, customers, environmental agency personnel, or other government inspectors (i.e., when the facility is working on government contracts).**

For example, Aircraft Facility Low Adopter, Aircraft Facility High Adopter #1, and Aircraft Facility High Adopter #2 -- all of whom are defense contractors -- were subject to government inspections on average every few weeks. While most of these were not by environmental agencies, the continual monitoring of their performance by outsiders motivated them to maintain high standards in all areas, including environmental matters. In addition, the high adopter facilities conducted frequent environmental inspections on their own and were inspected by corporate teams on a regular basis. In contrast, the low adopter facilities -- with the exception of Aircraft Facility Low Adopter -- were not frequently inspected by outside or corporate parties. For the Electroplater Low and High Adopters, the environmental manager only does a quarterly audit of the facility's environmental and safety conditions. In the Chemical Facility Low Adopter, there is no standard environmental audit.

- **Including environmental performance as part of workers' and facilities' overall performance evaluations can help to sensitize everyone to the importance and benefits of taking environmental considerations into account. In addition, providing financial incentives for waste reduction or other environmental ideas can be desirable.**

For example, in reward for its environmental manager's performance, Electroplater Low Adopter established a scholarship fund at a local educational institution, thereby assisting him in adding to his environmental skills. Aircraft Facility Low Adopter and Auto Parts Facility High Adopter gave cash awards of hundreds or thousands of dollars to employees who contributed ideas for reducing wastes and waste disposal costs. Aircraft Facility High Adopter #2 provides monetary awards to employees suggesting environmental projects. In Chemical Facility High Adopter #1 there is a monetary incentive for managers and workers to avoid creating an environmental or safety incident. If they, or the workers they manage, do create such an incident during a year, they do not get a 10 percent bonus to their salaries at the end of the year. In addition, for purposes of his evaluation review, the environmental manager of Gear Facility Low Adopter establishes performance goals, such as reducing the quantity of hazardous wastes and lowering the facility's potential environmental liabilities. Environmental and safety performance also was an explicit part of the overall job evaluations of employees in Chemical Facility High Adopter #1, Chemical Facility High Adopter #2, Turbine Facility High Adopter, Aircraft Facility High Adopter #1, and Aircraft Facility High Adopter #2. The latter facility, however, has no formal employee suggestion process.

- **Most facilities' environmental managers had a background in the production aspects of their facilities, typically by having come into their environmental positions directly from a production-related function.**

For example, the environmental managers in Electroplater Low Adopter and Gear Facility Low Adopter had previously worked in production for the facility and still spend part of their time as production supervisors. The Aircraft Facility High Adopter #2, Chemical Facility High Adopter #1, Chemical Facility High Adopter #2, and Chemical Facility Low Adopter environmental managers also come from a production operations background. In fact, only people who have already worked for some years in production and manufacturing are taken onto the environmental staff in Chemical Facility High Adopter #1. In addition, the Auto Parts Facility High Adopter environmental manager previously worked in the facility's quality assurance department. In contrast, the Electroplater High Adopter's environmental manager had no formal background in production operations, though she had been associated with facility in different capacities for about 30 years. The Aircraft Facility High Adopter #1 environmental staff are not formally trained in production operations, but rather have learned what they need on their own.

- **Line workers are more receptive to environmental requirements when the purposes behind them are made clear.**

Most of the facilities expressly mentioned how important and helpful that it was to explain to line workers the rationale for environmental requirements. For example, Chemical Facility High Adopter #1 explains to workers why certain environmental tasks must be done. It believes that if workers understand the reason for doing something, they are far more motivated to do it, their morale is higher, and they usually determine the most efficient way of accomplishing the goal. Chemical Facility High Adopter #2 also explains to workers the rationales for environmental objectives and procedures. Similarly, Chemical Facility Low Adopter tries to provide user-friendly information to other employees, particularly on the rationale behind various environmental requirements.

- **Facilities that had adopted ECM practices were more likely to communicate their environmental objectives and progress to their workers.**

For example, the Aircraft Facility Low Adopter's stated commitment to environmental protection was memorialized in a formal "Environmental, Safety, and Health Policy," which was signed by the facility manager and posted on numerous walls around the facility. In addition, the slogan, "Responsible Manufacturing Saves Our Environment," is prominently displayed on a board at the facility. Twice annually the facility's EH&S manager provides employees with a status report of how much waste was generated in the past and what were its disposal costs.

The Aircraft Facility High Adopter #1 environmental staff uses a variety of means with which to communicate the facility's environmental performance, including bulletin boards, monthly presentations, bulletins, and newsletters. The workers are kept informed of various

performance measures, including the amounts of waste disposed, recycled, and landfilled. Information on Aircraft Facility High Adopter #2's environmental performance is provided in a monthly meeting with building managers, who then disseminate it to workers. Quarterly meetings also are held to disseminate information on all of the areas of the facility. In addition, there are company newspaper articles and brochures for sharing environmental information.

The Turbine Facility High Adopter's environmental goals are articulated in its formal mission and business statements and in its core business principles and environmental issues have been added to the facility's monthly safety meetings. The environmental staff uses newsletters, brochures, and videos to communicate further environmental information to workers.

At Chemical Facility High Adopter #1, individual employees develop environmental goals consistent with the goals of the plants in which they work, whose goals reflect the facility's environmental strategy. At Chemical Facility High Adopter #2, the stated commitment of the corporation, and thus the facility, to environmental protection is memorialized in a formal policy, that was issued by its board in 1990. To provide employees with updates on safety and environmental issues, the facility issues "Safetygrams" when relevant. Detailed environmental data (e.g., spill and waste management information) also are available to everyone at the facility through its computer network. There also are environmental information bulletin boards around facility.

In contrast, none of the low adopter facilities, other than the Aircraft Parts Low Adopter, made any particular efforts to communicate their environmental goals and progress to their workers.

APPENDIX A

OVERALL PLANT MANAGEMENT

1. Does the plant have a formal manufacturing strategy?

2. Is this primarily a corporate- or plant-driven strategy?

3. What sources of information or advice are important in developing that strategy?

4. Does the plant have a formal environmental strategy?

5. Is this primarily a corporate- or plant-driven strategy?

6. What sources of information or advice are important in developing that strategy?

7. What is the relationship between the plant's manufacturing and environmental strategies (e.g., are pollution prevention and quality control separate turfs)?

8. How did these relationships evolve?

9. Which people or groups helped develop them?

10. In what ways do environmental practices or requirements affect the plant's competitiveness?

11. How do different groups in the plant perceive the role of environmental managers (e.g., compliance police or aiding competitiveness)?

12. About how many key suppliers of raw materials and equipment are there?

13. What are the plant's relations with these suppliers (e.g., are they local, friendly or antagonistic, interactive -- personnel exchange or electronic data interchange, joint design of materials)?

14. Are there occasions on which suppliers, either on their own initiative or in response to your requests, suggest innovations (e.g., choice of technology, materials, recycling, cost and waste reductions)?

15. Have there been occasions on which the plant has accomplished some production or environmental innovation?

16. Were there any advantages or disadvantages due to being first?

OVERALL PLANT MANAGEMENT (cont.)

17. How does information flow to and within the plant (e.g., between management and workers, corporate and plant staff, outside parties and plant staff, environmental and manufacturing staff, etc.)?

18. Is there a formal system by which "lessons learned" at the plant get passed on to future plant workers?

19. How do you analyze and prioritize proposed projects?

20. What criteria are used to determine which projects get done (e.g., environmental metrics)?

21. Are production teams involved in environmental decision-making and vice versa?

22. How many levels of management are there at the plant?

23. How many formal job titles are there for the plant's production workers?

24. What percent of the plant's supervisors or managers were promoted from a production worker position?

25. Are the plant's production workers represented by a labor union in contract negotiations?

26. What is the plant-union relationship like?

27. What strategies has the plant used to avoid layoffs (e.g., reduced overtime or regular working hours, buffered with temporary workers, limited subcontracting, smoothed production demand, multi-skilled workers, trained under-utilized workers, offered early retirement, etc.)?

28. What kind of training do production workers receive (e.g., improving product quality, environmental issues, worker safety, etc.)?

29. Is this training on- and/or off-the-job?

30. Is there a formal process for employees to make suggestions?

31. How many suggestions are made in a typical year?

32. What percent of these suggestions are ultimately implemented?

33. What percent of these suggestions are directly concerned with environmental practices?

OVERALL PLANT MANAGEMENT (cont.)

34. What methods or practices are used for organizing and managing your plant's work force?

35. What methods or practices are used for organizing and managing your plant's production processes?

PRODUCTION OPERATIONS MANAGER

101. What methods or practices are used for organizing and managing your production processes?

102. When did you begin using these practices?

103. How did these practices evolve to become the standards (e.g., upper management or shop-floor worker involvement or support)?

104. What are the goals driving each of these practices (e.g., zero defects, zero inventory, zero emissions)?

105. What are the barriers in attempting to implement these practices (e.g., information flow, culture or consciousness barriers, or human, financial, or technological resources)?

106. What methods or practices are used for organizing and managing your work force?

107. When did you begin using these practices?

108. How did these practices evolve to become the standards (e.g., upper management or shop-floor worker involvement or support)?

109. What are the goals driving each of these practices (e.g., zero defects, zero inventory, zero emissions)?

110. What are the barriers in attempting to implement these practices (e.g., information flow, culture or consciousness barriers, or human, financial, or technological resources)?

111. How do you perceive the role of environmental managers (e.g., compliance police or aiding competitiveness)?

112. Are production personnel involved in environmental decision making?

113. About how many key suppliers of raw materials and equipment are there?

114. What are your relations with these suppliers (e.g., are they local, friendly or antagonistic, interactive -- personnel exchange or electronic data interchange, joint design of materials)?

115. Are there occasions on which suppliers, either on their own initiative or in response to your requests, suggest innovations (e.g., choice of technology, materials, recycling, cost and waste reductions)?

116. Have there been occasions on which your area has accomplished some production or environmental innovation?

117. Were there any advantages or disadvantages due to being first?

118. How does information flow to and within the plant (e.g., between management and workers, corporate and plant staff, outside parties and plant staff, environmental and manufacturing staff, etc.)?

119. Is there a formal system by which "lessons learned" at the plant get passed on to future plant workers?

120. How do you analyze and prioritize proposed projects?

121. What criteria are used to determine which projects get done (e.g., environmental metrics)?

122. Are production teams involved in environmental decision-making and vice versa?

123. In the last 12 months, how many times has your area changed its production processes?

124. What prompted these changes?

125. In the last 12 months, how many times has your area changed its product design?

126. What prompted these changes?

127. In the last 12 months, how many new products or new product generations has your area begun production of?

128. How old is the main production technology used in your area?

129. To what extent are your area's production processes automated?

130. What kind of training do production workers receive (e.g., improving product quality, environmental issues, worker safety, etc.)?

131. Is this training on- and/or off-the-job?

PROCUREMENT OFFICER

201. What is the process used for selecting equipment and raw materials?

202. What criteria are used to select suppliers?

203. What are the most important of these criteria?

204. How important is location?

205. How important is quality and how is it measured?

206. How important are environmental considerations and how are they measured?

207. Do you require suppliers to be certified under ISO 9000, ISO 14000, or some other standards for quality or environmental management?

208. How has this affected their operations or ability to meet your needs?

209. About how many key suppliers of raw materials and equipment are there?

210. What are the plant's relations with these suppliers (e.g., are they local, friendly or antagonistic, interactive -- personnel exchange or electronic data interchange, joint design of materials)?

211. What types of information are requested from suppliers (e.g., costs, breakdown of production process steps, product quality data, production scheduling information, capital investment plans, etc.)?

212. What kinds of technical assistance or training has the plant provided to suppliers (e.g., cost reduction, quality control, product delivery scheduling, product design and development, environmental technology, environmental management systems, etc.)?

213. Do you have a formal inventory planning and management system (e.g., a JIT schedule synchronized with production)?

214. Do you perform quality control checks on delivered goods?

FINANCIAL OFFICER

301. How do you analyze and evaluate the financial performance of the plant?

302. Are environmental costs relevant in the analysis?

303. How is financial risk and liability incorporated in the analysis?

304. Is environmental risk evaluated and incorporated as well?

305. What cost accounting system is used in the plant?

306. Does this system fully incorporate environmental costs?

307. Does this system track environmental costs back to the products and/or processes responsible?

308. What systems and tools are being developed to make this a reality (i.e. life-cycle cost estimating tool, standardized reports to collect environmental cost data, etc.)?

309. Who is involved in collecting and recording the environmental cost data (i.e. financial staff, accounting staff, environmental health and safety staff, business operations staff, etc.)?

310. What is your process for evaluating proposed projects?

311. Is this process different for environmental projects?

312. Do you obtain adequate cost-benefit data to evaluate environmental projects?

313. What are the barriers to collecting this data?

314. What is being done to overcome these barriers?

315. What is the maximum accepted time horizon for payback?

316. What is the typical accepted time horizon for payback?

317. Are there any financial incentives given to the plant from the government to do environmental projects (i.e., investment tax credits)?

318. Are there any financial incentives given to managers to do environmental projects (i.e., depreciation policies that could enhance the returns from environmental projects)?

319. Are there any financial incentives given to workers to make or suggest environmentally beneficial improvements in products, processes, or technologies?

PRODUCTION LINE WORKERS

401. How are you organized to produce a product?

402. Do you work in teams?

403. How do these teams operate?

404. Who selects the team leaders?

405. Who selects the team members?

406. Who makes the job assignments within teams?

407. Do team members regularly switch jobs within teams?

408. Do you rotate jobs amongst yourselves?

409. What is the official job rotation policy?

410. Are there problem-solving groups (e.g., quality circles)?

411. How do these groups operate?

412. Do these groups meet on your time or on company time?

413. What kinds of training are available to you?

414. Any formal training in improving product quality?

415. Any formal training in environmental issues?

416. Any formal training in worker safety issues?

417. Does this training occur on your time or on company time?

418. What information do the plant mangers share with you (e.g., plant or corporate financial performance, performance of plant's or competitors' products, plans for new products, environmental performance, etc.)?

ENVIRONMENTAL MANAGER

501. How do you believe others in the plant perceive the role of environmental managers (e.g., compliance police or aiding competitiveness)?

502. How does participation in environmental strategies affect worker morale?

503. Do you record and publicize information on the plant's environmental performance?

504. What information do you use?

505. What kinds of training are available to you?

506. Are you fully-trained in production areas?

507. Does this training occur on your time or on company time?

508. Does the plant have a formal environmental strategy?

509. Is this primarily a corporate- or plant-driven strategy?

510. What sources of information or advice are important in developing that strategy?

511. What is the relationship between the plant's manufacturing and environmental strategies (e.g., are pollution prevention and quality control separate turfs)?

512. How did these relationships evolve?

513. Which people or groups helped develop them?

514. In what ways do environmental practices or requirements undermine or enhance the plant's competitiveness?

515. What methods or practices are used for organizing and managing your environmental procedures?

516. When did you begin using these practices?

517. How did these practices evolve to become the standards (e.g., upper management or shop-floor worker involvement or support)?

518. What are the goals driving each of these practices (e.g., zero defects, zero inventory, zero emissions)?

519. What are the barriers in attempting to implement these practices (e.g., information flow, culture or consciousness barriers, or human, financial, or technological resources)?

520. What factors are important in prompting consideration of environmental projects?

521. How do you analyze and prioritize proposed projects?

522. What criteria are used to determine which projects get done (e.g., environmental metrics)?

523. Are production teams involved in environmental decision-making and vice versa?

524. What percentage of your environmental solutions are low-tech versus high-tech?

525. Have there been occasions on which your area has accomplished some production or environmental innovation?

526. Were there any advantages or disadvantages due to being first?

527. What cost accounting system is used in the plant?

528. Does this system fully incorporate environmental costs?

529. Does this system track environmental costs back to the products and/or processes responsible?

530. What pollution prevention measures have been most successful and why?

531. What pollution prevention measures have been least successful and why?

532. Does the plant conduct environmental audits?

533. Are they internal or external audits?

534. What purpose do these audits serve for the plant (i.e., giving guidance on business acquisitions and divestitures based on environmental risk)?

535. Is the plant involved in any of EPA's voluntary environmental programs (e.g., Green Lights, 33/50, WasteWi$e, Design for the Environment)?