Appendix A

VOLVO CASE STUDY: DRIVING TOWARD GREEN

Interviews with personnel in the Volvo Car Corporation in late 1996 and late 1997 are the primary information source for this case study because written information on its design-for-environment program is scarce. Company brochures were also used when applicable. Please note that case studies are snapshots of an organization. Since these interviews were performed, the details of the program have most certainly evolved. However, subsequent communications with Volvo personnel have indicated that while the details may have changed, the messages are largely the same.

OBSERVATIONS ON VOLVO

There are many interesting and enlightening aspects to environmental management and design-for-environment at AB Volvo and Volvo Car Corporation. Perhaps most important, Volvo is a corporation that recognizes the strategic advantage of incorporating environmental issues into its corporate culture, business processes, and, therefore, business decisions. Volvo believes that consideration of environmental issues can lead to a competitive advantage. Its environmental policy explicitly states that making money is its primary business and only if Volvo remains financially viable can it help the environment; that environmental programs can contribute to long-term profitability and economic growth; and that environmental issues should be treated aggressively within the time and scope constraints of long-term profitability. Volvo sees a dynamic business environment in which competitive advantage is gained through first-mover advantage, process control, and continuous improvement. It evaluates global trends in regulations and incorporates these into the advanced development and product design processes. Within the higher-end automobile market, Volvo anticipates a growing consumer market for "green" products and is setting up organizational processes with its marketing organizations, dealerships, and design groups to collect and manage the information needed to offer such products.

The Volvo environmental policy

- clearly articulates corporate environmental objectives for internal and external communication
- states that proactive management of environmental issues is one factor contributing to strategic advantage
- was developed by senior functional experts, not the environmental managers.

The environmental policy shapes all environmental organizational structures and goals, management processes, and design activities. It is the glue that cements the different parts of the corporation, namely the companies and the units within the companies, together. Because the companies have different resources and face different market pressures, debate is an important factor in the successful implementation of a new policy. Debate builds consensus and commitment to the policy. The companies and units are then free to operationalize the policy in ways consistent with their unique resources, products, and market pressures.

Organizationally, the environmental program is fairly decentralized and relies on communication in all directions. Each level gathers information and solves problems. While consensus building is important for policy development, the corporate management processes of goal-setting and audits illustrate that competition and visibility are used to drive policy implementation. The key elements of Volvo's environmental organizational structure are

- a high degree of senior, line management participation
- environmental policy boards with decisionmaking authority

- parallel organizational structures at corporate and company levels to aid the flow of information.

The corporate Environmental Board and Environmental Council address issues of corporatewide importance to ensure consistency and appropriate action and to drive action. Key processes are

- decentralized goal-setting, with corporate oversight, to reinforce ownership and stimulate action and improvement
- audits to ensure that corporate standards and environmental policy are met by the companies.

Volvo management is pragmatic. The Volvo companies have real constraints and therefore must constantly balance competing interests. They have established a robust process to attain clearly articulated objectives. Volvo searches for "win-win" solutions to environmental problems in a structured way to focus management attention on long-term strategy and ensure that investments made are the most effective means of progress. The process is not rigid, however; it is flexible, strives for success, and learns from failures.

Volvo Car Corporation has approached product design from many dimensions. At VCC, environmental issues are part of strategic planning, but investments are made on competitive grounds within everyday financial constraints. Moreover, environmental criteria compete with many others in new product design and development. Goal-setting is an important part of implementation. Structured goals provide strategic focus. They help to relate specific activities to company goals and facilitate improvement. Clear priorities in this case—business, safety, quality, and environment—make decisions easier. Market interest and company strategy motivate individuals to try to meet and improve goals. The Environmental Competence Center personnel actively inform and remind others of these motivations.[1]

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[1]Since completion of this case study, VCC has decided to reorganize the environmental experts and the Environmental Competence Center. Originally it was felt that the environmental staff should be centralized because they were co-developing new skills and analytic tools with the functional experts. Now that the new skills have been developed and these activities have become operationalized, the Environmental Competence Center staff will be dispersed, in small groups (not singly), to the func-

The Environmental Competence Center personnel interact with design organizations at two levels. At the manager level, the Director of the Environmental Competence Center builds political support and visibility for environmental goals. At the working level, individual relationships increase awareness and support for the goals. They are also instrumental in helping designers develop new competencies. Individual designers are better equipped to think about long-term impacts of their decisions by working through recycling issues and environmental life-cycle assessments. *Individual competence is especially important, because new product design is characterized by decentralized decisionmaking and many design trade-offs.*

Another major aspect of design-for-environment implementation is the development of analytic tools and specialized competencies. Environmental awareness training addresses both individual values and awareness. Analytic tools facilitate environmental analyses and codify values for the analysis process. These are particularly important to design-for-environment implementation because ultimately the environmental profile of a product is determined by many cumulative decisions made by design engineers and others alike, not the environmental experts. Environmental Priorities Strategies (EPS), a life-cycle analysis tool, is used to build new competencies among design engineers. The EPS life-cycle view and the analysis framework also link the various goals and targets that VCC has established. MOTIV, a chemical database, makes information available to the design engineer and not just the EH&S specialists. This has helped reduce the number of chemicals used at AB Volvo. Volvo Dialogue, a general environmental training program, increases the understanding and appreciation of every Volvo employee. It seeks change through education. Finally, education provides a common vocabulary for all employees.

Finally, *implementation of change takes time.* The first AB Volvo environmental policy was issued in 1983. In 1994 the policy was revised for the second time to emphasize the relevance of environmental issues to strategic direction and profitability. In 1997–1998 the policy is being revised again. Expectations are that it will take six

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tional areas, such as production, recycling, and product development. While the Environmental Competence Center will have a smaller staff, the link to strategic planning will become stronger (Fräjdin Hellqvist, 1997).

years, to 2000, to develop a fully operational environmental management system at all AB Volvo companies and units. Another example is the life-cycle model used by Volvo Car Corporation. It has been five years in development, and it is still not considered a mature tool. These time lines highlight the challenge to change and the realistic expectations given business constraints.

ENVIRONMENTAL MANAGEMENT AND INTEGRATION INTO PRODUCT REALIZATION

AB Volvo Overview

AB Volvo was founded in 1927. Six companies, responsible for a series of product lines, make up AB Volvo or the Volvo Group. These companies are Volvo Car Corporation, Volvo Truck Corporation, Volvo Bus Corporation, Volvo Penta Corporation (marine and industrial engines), Volvo Construction Equipment Corporation, and Volvo Aero Corporation (aircraft engines). The entire corporation, AB Volvo, has 38 production facilities in 23 countries that service 100 markets worldwide. The Swedish market accounts for less than 10 percent of Volvo's sales (AB Volvo, 1995).

The Volvo Car Corporation has approximately 30,000 employees worldwide (dealerships add roughly 40,000 personnel, and major suppliers are an additional 2,000, for a total of approximately 70,000 personnel associated with VCC). In 1995, sales reached SKr154,496 million (approximately $20 billion U.S.) for 374,600 cars (for comparison, Volvo Truck Corporation sold 76,500 trucks and Volvo Bus Corporation sold 6,830 buses in 1995) (AB Volvo, 1995). According to our interviewees, Volvo Car Corporation is facing competitive pressure. As a result, they are trying to reorient corporate culture toward cost reduction, innovative design approaches, and problem-solving.

While corporate core values and the environmental policy are common to all the Volvo companies, specific environmental policy implementation does vary. Policy implementation at Volvo Car Corporation, particularly as it relates to design-for-environment, is described in this case study. When information on the diversity of approaches is available, it is presented.

Why Design?

Control of product and process design is one mechanism for seeking cost-effective environmental management. Available estimates range between 70 percent and 80 percent of the product life-cycle costs and are determined during design. So changes in design can cost-effectively leverage effects, both upstream and downstream (Office of Technical Assessment, 1992; Kainz, Moeser, and Simpson, 1995). Volvo personnel also realize that the design phase offers high leverage over the product life-cycle costs and risk reduction and they seek to identify and invest in the most cost-effective technologies to achieve desired environmental performance levels.

Environmental issues are not new to Volvo, and it has taken a life-cycle view of its products for around 10 years. Emission controls have existed since they were first introduced in California in 1965 (AB Volvo, 1989, p. 6). The first serious design issue to arise from environmental concerns was the catalytic converter, which was first introduced by Volvo in 1976. Over the years, catalytic converters have become increasingly capable, reducing an ever broader range of harmful emissions. By aiming beyond compliance and striving for continuous improvement, companies can mitigate the uncertainty associated with regulatory change on the margin and are equipped to negotiate on proposed future regulation. As described later, because of its understanding of automobile life-cycle issues, Volvo was able to successfully suggest changes to the proposed Swedish automobile recycling law to include more credit for energy recovery.[2]

The other dimension to product design at Volvo is driven by market interest as opposed to cost reduction. Volvo detects growing demand in its target market (the higher end) for a “greener” product.[3] One of AB Volvo’s goals established by the AB Volvo Environ-

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[2]The Dutch, considered leaders in sustainability thinking, promote environmentally conscious design as an effective means for chain management. Chain management is the management of the environmental impacts of all players in a product’s value chain as a whole, rather than as individuals. They see chain management, achieved in part through product design, as one way of getting additional environmental improvements and moving toward a sustainable society (Vermeulen, Kok, and Cramer, 1995).

[3]VCC views its product niche as the higher-end automobile emphasizing safety and quality (sometimes referred to as durability).

mental Board in 1993 is: "To ensure that at least one variant per model family in the VCC range meets the requirements of the highest environmental class in the relevant European incentive system."[4] Volvo's CEO, Sören Gyll, has emphasized this in his statements and has called for Volvo officials to build the case for such a profile in its decisions about process and product design and Volvo-demonstrated performance. VCC is beginning to develop an environmental profile for its products, due in part to the desire of dealerships to communicate Volvo's products' environmental attributes to customers.

The remainder of this appendix is organized as follows. Because AB Volvo's corporate environmental policy provides the overall framework for the environmental organization and management processes, the policy is described next. Then the organizational elements that operationalize the policy are explained, emphasizing Volvo Car Corporation's structure. Following this discussion, key management processes and their relevance to design-for-environment activities are described. In the second section, a particularly important design aid, the Environmental Priorities Strategies, is described in greater detail. The third section summarizes the findings of the case study. The fourth section presents Volvo's high-level environmental policy goals.

Volvo Core Values and Environmental Policy Set the Stage for Implementation

AB Volvo aims to elevate environment to the level of its primary core values—safety and quality—and to integrate environmental issues into its way of doing business to the same extent.[5] Yet, managers are fully aware this will take time and persistence. They point to safety, which has been a core value at AB Volvo since the corporation was begun in 1927.

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[4]AB Volvo Goals and Action Programme as reported in *AB Volvo Environmental Report 1995*. Similar goals are stated for Volvo Truck and Volvo Penta (marine) companies.

[5]Numerous studies have shown that it is easier to implement organizational change if the change does not conflict with corporate core values.

Its environmental policy provides the overall framework for Volvo's environmental organization and management processes.[6] The environmental policy is the most significant environmental message from corporate leaders, both CEOs and line managers, and it clearly articulates AB Volvo's views toward environmental issues for both internal and external audiences.[7] The environmental policy is common to the different parts of the corporation, namely the companies and the units within the companies. The companies and units are then free to operationalize the policy in ways consistent with their unique resources, products, and market pressures. Because the policy shapes all environmental organizational structures and goals, management processes, and design activities, understanding the policy and its derivation is critical to gaining insight into design-for-environment implementation.

Because the companies have different resources and face different market pressures, debate is important in the successful implementation of a new policy. From their experience, Volvo personnel have observed that debate builds consensus and commitment to the policy. It also contributes to successful implementation because managers internalize their understanding of the policy's meaning and intent through the debate (Fräjdin Hellqvist, 1996b). The environmental policy is a one-page document originally formulated in 1983, with origins dating to 1972. There was a major revision in 1989, which was debated by top executives from each company in an environmental council meeting (described below). Managers felt this was a very useful process, as the debate built consensus and ensured in-depth understanding by all executives, both environmental and line. In 1994, a minor change was made to the policy to comply with Eco-Management and Auditing Scheme (EMAS) requirements. In

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[6]The commitment to environmental issues is exemplified in the actions of its leaders, who have made statements, spent management time, and approved investments in favor of the environment. Since the company's 1927 inception, Volvo leaders have displayed strong social commitments, and these easily extend to include environmental issues. AB Volvo CEO Pehr Gyllenhammar expanded the corporation's social commitments' scope beyond product safety to include workplace issues (Rothenberg and Maxwell, 1993).

[7]Volvo is one of the first industrial manufacturing corporations in the world to adopt a formal environmental policy (Rothenberg and Maxwell, p. 3). To reach a wider external audience, AB Volvo has been publishing an annual environmental report since 1991.

contrast to the previous revision, this change was not debated. As a result, many feel that these changes were not internalized by managers. The environmental policy was revised in the 1997–1998 time frame. These changes have been discussed and deeply debated by line management from each of the companies. While the new policy has not been officially released, analysts anticipate that the changes will be major without altering objectives. However, its guidance will be sharpened and will more clearly enumerate what needs to be done to implement it (Fräjdin Hellqvist, 1997).

Over time, the content of the environmental policy has changed as well. Initially it was compliance focused; later Volvo management realized there was a stronger connection to business decisions.[8] The current AB Volvo Environmental Policy addresses the broad range of effects that the transportation system has on the environment. This includes land, sea, and air transport's relationship to the environment (e.g., natural resource use, land use, air quality, water quality, all wastes, and noise). The environmental policy explicitly states that:

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[8]This evolution was brought on by a series of events in the mid- to late-1980s. For one, there was a worldwide trend increasing corporate liability for environmental damages. Sweden was also phasing out CFCs on an aggressive schedule. Moreover, environmental groups criticized Volvo CEO Pehr Gyllenhammar's active support of the Scan Link, a road and railroad from Oslo to Denmark. Swedish environmental groups reacted strongly to expansion of the Torslanda paint shop. The Torslanda plant expansion in particular was a turning point in Volvo's view toward compliance. Environmental NGOs thought the company could do better and protested the plant expansion. The Minister of Environment called Volvo the greatest polluter on earth. As a result, Volvo invested in cleaning treatments and rotors to filter the emissions of VOCs. Ironically, because this involved cleaning air through sand at an elevated temperature, Volvo traded a VOC problem for a CO_2 problem. The expenses associated with this change were taken out of profit (SKr1,000 to SKr2,000 per car), although they did contribute to product quality. In the new sport coupe, C-70, Volvo will avoid this problem altogether by using powder-based paints.

This experience drove home to Volvo management the realization that, if environmental issues were treated in a proactive manner, more cost-effective solutions would be found. Volvo also sees the situation as an example of when reactionary actions can lead to detrimental environmental effects. They realized that taking control of environmental issues, establishing goals and responsibilities, and communicating actions to stakeholders could lead to more cost-effective or "win-win" solutions and competitive advantage. The AB Volvo CEO and the board of directors were tired of the criticisms. They invested $50 million of their own stock to become world-class environmental stewards (Fräjdin Hellqvist, 1996b; Rothenberg and Maxwell, 1993).

- Making money is Volvo's primary business and only if it makes money can it use the money to help the environment.
- Environmental programs can contribute to long-term profitability and economic growth of the corporation.
- Environmental issues should be treated aggressively within the time and scope constraints of long-term profitability. (AB Volvo, 1994a.)

The specific environmental policy elements recognize the need for a comprehensive strategy, to include R&D, product development, and manufacturing; the use of sound materials (especially those that are recyclable); a broad focus on transportation systems; the need to comply with comparable laws worldwide; a similar level of care by suppliers; and factual and open information on the impact of company operations (AB Volvo, 1994a).

The environmental policy is implemented within the context of a business perspective. In other words, it is implemented with full recognition that Volvo is and should be principally geared toward making money. Only within this context can Volvo then discuss minimizing environmental impacts. Another important feature of the policy is the explicit recognition that proper treatment of environmental "performance" can lead to competitive advantage. Thus, environmental issues are treated as other strategic business issues are.[9]

Even so, Volvo has found that actually integrating environmental issues with business decisionmaking is difficult because environmental issues touch on individuals' core values and ethics. And these can vary among individual decisionmakers. If environmental effects can be put into monetary terms, it is easier to get personnel to respond. For example, Volvo can easily make the business case for

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[9]Michael Porter suggests that companies can find many "win-win" solutions to both economic and environmental objectives. He presents cases to show that treating environmental issues in corporate strategy to include resource efficiency and green consumerism will benefit the environment and will lead to a competitive advantage for the company. (Porter and van der Linde, 1995, pp. 120–134.) In another *Harvard Business Review* article, Noah Walley and Bradley Whitehead suggest that incorporating environmental issues into business management is not so simple. Their comments will be addressed below.

recycling. If Volvo doesn't meet the requirements of the Swedish recycling law, it must pay a fine, which may mean raising the price of the automobile or earning smaller profits.[10]

The environmental policy statement is the only common environmental policy across the Volvo companies. The specific strategies and goals are left to the companies to develop independently, although there are some worldwide standards and consistent processes. At this point, policy implementation varies across the Volvo companies, in terms of both progress toward a fully established management system and their approaches to implementation. It is expected that generally greater commonality will exist among the production-oriented goals than among the product-oriented ones because products vary.

The following are important implementation lessons regarding the Volvo environmental policy:

- The policy clearly articulates corporate environmental objectives for internal and external communication. It is the common thread linking all Volvo companies.
- The policy objectives are stated in business terms and see the environment as one factor contributing to strategic advantage.
- The policy was developed by senior functional experts, not the environmental managers. Active engagement by managers in policy development was instrumental in ensuring greater awareness and buy-in by line managers.

Volvo companies are actively setting up organizations and processes to operationalize the corporate policy. The next sections discuss the environmental organizational structure at the corporate and company level, focusing on Volvo Car Corporation. Note, the way change is implemented is just as important as the particular changes made. Insights into both sets of issues are provided.

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[10]The Swedish recycling law requires 85 percent of the automobile to be recyclable by 2002.

Environmental Organizations Are the Most Important Element of Policy Implementation

Implementation of the broad environmental policy guidelines is facilitated at the corporate level through the AB Volvo Environmental Board, a decisionmaking body, and the AB Volvo Environmental Council, which supports the board. Overall, environmental organizations at AB Volvo and the constituent companies are a combination of line functions, working groups, project groups, and networks, emphasizing inclusion of activities within the appropriate line functions, especially at the "local" level.

Each company is responsible for developing its own organization to pursue corporate policy. Volvo Car Corporation (VCC) believes that it will be essential to have a clear organizational structure in place before the public, regulators, and environmental NGOs take the company seriously. VCC found that creating the appropriate organizational elements is the most important step in policy implementation—"you must build the bridge before you can cross it." (Fräjdin Hellqvist, 1996a.) VCC aims to create an organization that develops its own goals and strategies by implementing Volvo's environmental management systems (VEMS) throughout VCC.

AB Volvo Environmental Organization

The overall governing body for environmental issues at AB Volvo is the AB Volvo Environmental Board. Members of the AB Volvo Environmental Board are the top vice presidents for each company. The specific vice president represented on the corporate board varies from company to company. However, generally the line functions represented are related to the corporation's core values of safety and quality. For example, the VCC representatives to the AB Volvo Environmental Board are the car company's senior vice president and the marketing director. Some of the line-oriented members on the AB Volvo Environmental Board also sit on the Corporate Executive Committee, which is the highest corporate committee of line vice presidents at AB Volvo. The corporate Environmental Board makes decisions on environmental issues of major strategic importance to the entire corporation. This includes policy decisions, common guidelines and coordination, other corporatewide matters, and audits. This is a decisionmaking board that receives input from the corporate Environmental Council. There also are working groups on specific corporatewide issues that report to the corporate Environmental Board.

Environmental managers of the various companies serve on the corporate Environmental Council, which proposes policy and advises the decisionmaking Environmental Board. The seven environmental managers on the council come from corporate AB Volvo and the six companies: Volvo Car Corporation, Volvo Truck Corporation, Volvo Bus Corporation, Volvo Penta Corporation, Volvo Construction Equipment Corporation, and Volvo Aero Corporation. This structure is shown in Figure A.1.

The organizational elements common to all Volvo companies are environmental boards and coordinators. The environmental boards (at all other levels the environmental boards are equivalent to the council at the corporate level) are established for the overall corporation, for each company in the Volvo Group, and for each "main

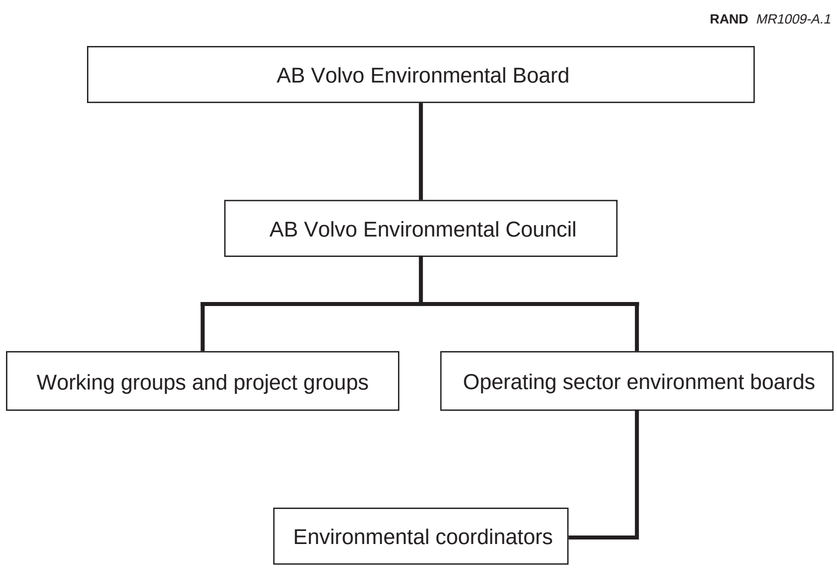

Figure A.1—Volvo Environmental Organizational Structure

unit" within a company (which may be a facility).[11] An environmental coordinator for each company and for each "main unit" directs and evaluates environmental programs at the local level. These coordinators are selected by the company or unit managers. This parallel organizational structure facilitates information flow both up and down the links as well as across them and aids decision-making at the local level.

The corporate Environmental Board uses a number of key mechanisms to drive action. They address issues of mutual concern, challenge the companies with goals, and monitor progress and create visibility with audits. Some of these mechanisms are part of the specific processes that make up the Volvo Environmental Management System, and these are described in greater detail below. However, to show how the corporate board and council work with the companies, we present an example of developing an overall corporate policy on a specific environmental issue.

If the corporate Environmental Board seeks to develop a corporate policy, it works through the Environmental Council. As mentioned, the AB Volvo Environmental Council handles special corporatewide issues, such as global change, particulate matter, or recycling and plastics. An individual council member is responsible for collecting information on a specific topic and for developing a draft policy. For example, on the global change issue, an Environmental Council member gathers information from both internal and external experts and shares this with the Environmental Council and others, as appropriate.[12] Scientists' and experts' views are sought on the specific issue, while the Agenda 21 process[13] provides benchmarking information on other companies' activities.[14] (On the global change

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[11]It is confusing, but councils are called boards at the company level, and the corporate level is the only one that has two groups. For all other levels, company and unit, the "board" and "council" are the same organization. The corporate board coordinates policy and programs with the various companies through the company environmental boards.

[12]External experts also can be another "messenger" to the corporate line management, which at times can add credibility to the point being made.

[13]Agenda 21 originated at the 1992 Earth Summit at Rio de Janeiro to help communities work locally to preserve future environmental quality of life.

[14]In contrast, the Dow environmental advisory board includes environmental experts from environmental NGOs and elsewhere. It is a forum that meets regularly to provide

issue, renowned scientists on both sides of the issue have been to Volvo.)[15] Internally, the council member discusses the issue with the various company vice presidents. Their responses are tallied on a scorecard and reported to the board. Sharing these responses with the board creates a little competition between companies and encourages thoughtful responses on the part of the company vice presidents. For example, coordinating a response with the companies and the AB Volvo Board on the global change issue has been ongoing for approximately one year. The Environmental Council then presents a proposed policy and an implementation plan to the corporate Environmental Board for a decision. These decisions are then implemented through the environmental boards and coordinators at each of the companies and their business units.

Generally speaking, Volvo recognizes that associating power with an issue is a way of getting people's attention and ensuring that they take the issue seriously.[16] For example, the AB Volvo's environmental vice president is one of the 60 top line managers corporatewide.

So, organizationally, the environmental program is fairly decentralized and relies on communication in all directions. Each level gathers information and solves problem. The corporate Environmental Board and Council address issues of corporatewide importance to ensure consistency and appropriate action. We will see later that management processes are in place to eliminate discrepancies

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external review of Dow environmental policies. Volvo feels that this approach is too formal and restrictive for its purposes. It wanted a more flexible, adaptive structure, capable of achieving wider outreach.

[15]The specific audience-speaker combination varies depending on the topic and the objective. Sometimes the audience is top management; sometimes it is general staff.

[16]Leonard-Barton (1996) discusses the issue of corporate values and their operationalization. Corporate values define how employees are expected to act and are operationalized through a myriad of ways. One way in which corporate values are signaled to employees is by the amount of status attributed to, say, a particular technical capability. For example, the elevation of environmental specialists could indicate a high level of importance to company core values. This in turn could serve to attract higher-quality personnel, reinforce their credibility, and promulgate environment as a corporate value. This may be how Volvo management is attempting to elevate environmental concern as a core corporate value. Often, employees confuse a change in operationalization of a value with a change in the core value itself. This is why even small change is often difficult to implement.

across companies if they develop and to verify that corporate environmental policy is followed. The following are the key elements of Volvo's environmental organizational structure:

- A high degree of senior, line management participation.
- Environmental policy boards with decisionmaking authority.
- Parallel organizational structures at corporate, company, and unit levels to aid the flow of information.
- Use of consistent corporate policies and management processes (goal-setting and audits, described later) to drive action. These processes involve some standard-setting and competition between companies and units.

Volvo Car Corporation Environmental Organizations

VCC has a company environmental board to mirror the AB Volvo corporate structure. This board includes nearly a dozen VCC executives from the following line functions: purchasing/production, design, development and engineering, marketing, after-sales, information systems, and the core business areas (models S/V 40, S/V 80, S/V 90, and 940 product series), business strategy, and mobility. This board establishes environmental policies and procedures for VCC and its units. The decisionmaking authority of this board is critical to its effectiveness. Eventually, Volvo will have 18 subordinate boards at the "main units" within the Volvo Car Corporation. Currently, it has boards at six of these units.[17]

VCC has decided to place all the environmental experts, 30 to 35 of them, into a centrally managed environmental group called the Environmental Competence Center. The director of the Environmental Competence Center acts as secretary to the VCC environmental board.

[17]These groups include the five market areas (VCC-USA, VCC-Europe, VCC-Japan, VCC-Asia Pacific, VCC-International); the three business areas (400 series, 800 series, 900 series); transmission; engine; process and product engineering; purchasing and strategic sourcing; body production/stamping plant; marketing support; quality; strategy and business development; and after-sales.

VCC has about 18 main units. The top manager at each unit is responsible for environmental issues; and these managers are typically not environmental experts. After about six months with the new organization, none of these managers fully understood environmental issues, and only one was problematic. After about 18 months, all the unit managers were aware of and understood the environmental issues. Each main unit was asked by the Director of the Environmental Competence Center to designate an environmental coordinator—someone they could trust. The coordinators are responsible for seeing that audits, plans, and goals are performed and established. This includes developing the units' environmental policy and statement, performing an environmental analysis for the unit, developing the unit environmental program, and establishing an environmental management manual and procedures.[18]

It is very important to get someone who is committed and takes the initiative in these roles. Motivation must come from the "heart and the brain" and requires a deep understanding of all the issue elements in the political, economic, and ecological realms. Management should be prepared to modify personnel choices as the system progresses. The environmental coordinators and unit managers from all the units (marketing, plant managers, etc.) meet once a year to discuss issues. Coordinators meet an additional two times per year to share information.

VCC Environmental Competence Center

VCC has a central environmental department, called the Environmental Competence Center, which is responsible for monitoring the political, economic, and environmental aspects of issues.[19] It also

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[18] There are 40 to 50 people companywide responsible for environmental issues—including the competence center staff and the unit coordinators.

[19] In 1997 VCC decided to reorganize the environmental experts and the Environmental Competence Center. Originally it was felt that the environmental staff should be centralized because they were co-developing new skills and analytic tools with the functional experts. Now that the new skills have been developed and these activities have become operationalized, the Environmental Competence Center staff will be dispersed, in small groups (not singly), to such functional areas as production, recycling, and product development. While the Environmental Competence Center will have a smaller staff, the link to strategic planning will become stronger. Finally,

focuses on technical capabilities.[20] Environmental experts from the competence center work with the environmental coordinators to develop goals and strategies for the company and the units. The staff of approximately 35 people in the Environmental Competence Center includes experts in all phases of the automobile life cycle: development, production, use, and recycling. The center director believes that having a central "home," with critical mass for mutual support and information sharing among environmental personnel, is essential. Other Volvo companies have decentralized environmental organizations, where managers and specialists are integrated into line organizations with a small central coordination staff led by an environmental manager.

The Environmental Competence Center is in VCC's Strategy and Business Development organization. Strategy and Business Development is broadly responsible for property development, product planning, customer software and hardware development, marketing, and target market decisions. Previously, the Environmental Competence Center was part of VCC's design department and was generally consulted for information on an "as needed" basis. The shift to strategic planning gives the environmental group a broader mandate and an improved ability to address environmental issues proactively. This includes a better ability to think strategically about creating and exploiting an environmental profile for VCC, as well as integrating environmental attributes into facility expansion, supplier relationships, and product support over its lifetime. Volvo personnel feel that product planning, and design in particular, can be a more cost-effective means of managing life-cycle environmental issues. After the product design is determined, it can cost a lot of money to go upstream and downstream for improvements. Linking environmental issues to strategy and business planning brings them closer to the company's overall strategy, which, in turn, influences the products and their attributes before, rather than after, key decisions are made.

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the VCC Environmental Board is now the same entity as the Executive Management (Fräjdin Hellqvist, 1997).

[20]Its external sources of information include universities, technical journals, and research organizations.

The director of Strategic Planning and Business Development is the line manager for the Environmental Competence Center's administration, personnel, training, and budgeting. Substantive decisions on strategic direction, on the other hand, are made at the top, by the vice president of VCC. For example, if the director of the Environmental Competence Center thinks that VCC's policy should be to eliminate mercury, then this policy will be discussed with the environmental coordinators at their environmental board meeting (or not, depending on the particular issue and timing) and reviewed by the vice president of VCC.[21] Placing environment in strategic planning is very unusual among corporations, and other Volvo companies have either not organized in this way or have not developed new organizational plans as yet. VCC is a model for others, since by linking environmental to business strategy, the environmental personnel have enough power to accomplish things. In what seems a slight contradiction at first, the Environmental Competence Center does not have a budget to make investments completely on their own (note: they have a budget for training and other staff-related expenses). This way, environment is not seen as an additional cost or a completely separate management process. The competence center is forced to become a part of all business practices and decisions and justify these investments on general strategic and financial grounds.

After approximately one year with the new organization, no one could point to any concrete results of the change, because it was too early.[22] The consensus was that the change was good from the point of view of integrating environmental thinking into VCC's broader decisionmaking. Environmental issues were on the agenda "everywhere," and they were getting greater attention in core business decisions within VCC. Importantly, VCC had a process in place to insert environmental considerations proactively and strategically into new products, as well as the clout to do it.[23]

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[21]Again, according to Leonard-Barton (1996), giving an issue status signals the importance of the issue to the rest of the company.

[22]The new organization was established in 1995, one year prior to the time the interviews were performed.

[23]This is in contrast to previously, where the environmental staff was not part of the decisionmaking process. They were strictly an information source.

Volvo's general philosophy about organizational structure is to be flexible, ensure that organizations are aligned with the right structure, and employ leaders. If the organization or people are not working out, be open to change. VCC has found that it is more important to have someone with good leadership skills than with substantive knowledge of the environmental area, at least at the manager and coordinator level.[24] The director of the Environmental Competence Center emphasized that organizational issues are the most critical aspect of the implementation process and must be addressed early if the process is to succeed.[25]

To summarize, VCC has an environmental organization that parallels corporate organizations. AB Volvo has environmental boards; one for the entire corporation, one at each company and each main unit within the company to implement the corporate environmental policy. This parallel structure facilitates information flow. Environmental boards and designated coordinators extend responsibility and knowledge beyond the boundaries of environmental expertise. VCC's method of organizing its environmental experts was not imposed on it by corporate management. Indeed, the companies vary in the amount of centralization and decentralization they employ. At first VCC found centralization useful because it provided important cross-fertilization and a sense of purpose to the environmental staff. Environmental Competence Center personnel work with other experts to integrate environmental issues into all other decisions and processes. Moreover, VCC placed the central environmental organization in strategy and business development. This is quite consistent with the corporate environmental policy, which seeks to use environmental issues for strategic advantage. Requiring environmental investments to be made by the other functional units, and not by the Environmental Competence

[24]Effective managers must have in-depth enough substantive skills to get the job done and a broad enough view to understand the relationship between their actions and the rest of the organization. This orientation is referred to as "T" skills (Leonard-Barton, 1996).

[25]This echoes Allenby (1994), a pioneer in design-for-environment at what is now Lucent Technologies, who said, "No firm has yet implemented a comprehensive DFE system" and "fully implementing DFE practices will require that most firms develop new competencies, organizations, and information systems as well as changes in organizational cultures."

Center, is also consistent with corporate policy. If environmental investments are to lead to long-run profitability, they must be made on financial and strategic grounds and must not require a separate budget. Moreover, other functional units must embrace these issues for true proactive treatment to be ensured.

THE VOLVO ENVIRONMENTAL MANAGEMENT SYSTEM: CORPORATE KEYS TO PROGRESS

AB Volvo is building an environmental management system to implement the environmental policy. The environmental management system is comprehensive and includes all the management elements outlined in ISO 14000—policy, planning, implementation and operation, checking and corrective action, and management review.[26] From our observation, while all these elements are necessary to have a complete environmental management system, at the corporate level two processes—goal-setting and audits—are especially important to drive action at each of the companies.[27] Goal-setting generates activities and investments within each of the companies. Audits are important to ensure that companies actually implement corporate environmental policy in a consistent way. They are also an important mechanism for disseminating lessons learned across companies. Although consensus building is important to policy

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[26]In Volvo's view, no one national or international standard offers all that is needed to become world-class. So the Volvo environmental management system (VEMS) is structured to encompass all national and international standards, including ISO 14000, EMAS, BS 7750, and the International Chamber of Commerce's Business Charter for Sustainable Development. Volvo companies and their individual units are free to certify to the most applicable standards. Volvo feels that ISO 14000 is not robust enough because it does not include services (products and processes focus) and is internally focused (no need for third-party audit or public disclosure, such as in EMAS). Volvo wants to do more. EMAS is better on external focus but only applies to production. BS 7750 is somewhere in between. All the standards—ISO 9000, ISO 14001, BS 7750, EMAS—are linked to quality. Volvo will comply with ISO 14020, eco-labeling guidelines, when they are released. Our interpretation of Volvo's position on international environmental management standards is that it employs total quality thinking, where compliance with standards is *not* the ultimate objective. The real objective is self-determination of environmental objectives and investments.

[27]Remember, AB Volvo is the overall corporate entity or group and the individual companies are Volvo Car Corp., Volvo Truck Corp., Volvo Bus Corp., Volvo Penta Corp., Volvo Construction Equipment Corp., and Volvo Aero Corp—which are referred to as the companies.

development, competition and visibility (through audits and the environmental board meetings) are used to drive implementation.

Corporate Goal-Setting

The AB Volvo Environmental Board challenges the companies every year to set goals. It is up to the companies to set their specific goals, but the corporate Environmental Board reviews them. Individual company's goals are compared to provide cross-fertilization. Comparison and discussion also help bring up issues that might not have been considered previously by the companies when they set their goals. The Environmental Board will revise the goals if they are either too challenging or not challenging enough. There is spirited competition between the companies (VCC and Volvo Truck are particularly competitive), but this is not driven by expectations of financial rewards. While consensus building is important for policy development, decentralized goal-setting, with corporate oversight, reinforces ownership and stimulates improvement. Decentralized authority is consistent with Volvo's corporate culture. Both Volvo's and the Swedish culture emphasize concern for societal interests. Where corporate culture may not be as strong, such as in the United States, it is unclear whether this approach will be as effective.

In 1993, the AB Volvo Executive Committee implemented the "Environment 95" action program to run to the end of 1995. Twenty goals, ranging from plant emissions to organizational change to specific product environmental performance, were established for the corporation. Each year, progress toward these goals is evaluated and summarized in the environmental report. The specific goals established in 1993, with progress evaluations, are presented at the end of this appendix. In 1996, a new program of objectives, emphasizing the environmental impacts of products, EMS, production processes, and communications, was implemented. This program covers such areas as the VEMS, education, energy use, and water waste.

Corporate Environmental Audits

Environmental audits are performed by the AB Volvo environmental auditor with staff from the various companies. Audits are comprehensive. In addition to organizations within AB Volvo, they review the systems of major suppliers, waste processing firms, and companies in the process of being acquired. These audits have three purposes:

- Evaluate compliance with existing legislation.
- Assess compliance with likely future legislation.
- Assess implementation of corporate environmental policy. (AB Volvo, 1995.)

Internal audits cover all aspects of the environmental policy and management systems and are crucial facilitators of environmental management. Volvo personnel view them as a mechanism to evaluate progress in a rigorous and consistent way and transfer lessons learned across companies and units. They ensure that corporate standards and environmental policy are met by the companies and force managers to take a hard look in a structured way at what they are doing. Because each company of the Volvo Group can design its own organization to meet corporate standards and policy, in effect each company represents an experiment in environmental management. Audits are used to learn from this series of experiments and to ensure that corporate environmental policy is consistently applied.[28] Performance on audits can also be used to generate a healthy competition between business units (Fräjdin Hellqvist, 1996b). VCC has seen that people benefit from the audit experience. Because of its ISO 9000 experience, it is quite comfortable with audits. Although ISO 14000 is different from ISO 9000, the processes are similar. Corporate audits are performed every two to three years. Internal company audits are performed once per year in between. All AB Volvo facilities have been internally audited.[29]

VEMS at the Company Level

At Volvo Car Corporation (the company level) two processes—goal-setting and tool building and training—are especially relevant to

[28]Firms that are successful at innovation—both organizational and product—promote experimentation. Most important, they systematically evaluate the experiments, both formally and informally, to share lessons learned (Leonard-Barton, 1996).

[29]With the exception of recently acquired properties.

incorporating environmental concerns into new product design. Each of these processes and their relationship to environmentally conscious design will be discussed in the next subsections.

VCC sees a synergy between bottom-up oriented and top-down oriented activities required to implement environmental management. Bottom-up activities, such as training, competence development, and communication, improve the understanding of the individual employee. This facilitates a dialogue between all levels of management and expertise. Furthermore, it begins to allow individuals to internalize environmental issues so that their decisions will consider these impacts. The Volvo Dialogue program is its environmental awareness training program, which addresses employee facts and insights. The top-down activities associated with VEMS, such as policy development, goal-setting, integration with business processes, and auditing, generate action. The Volvo environmental management systems (VEMS) is currently under development at one-third of the 18 VCC units.[30] New products and process development address improvement. All of these activities will be performed worldwide by VCC. VCC views them as basic elements of implementation, which build on each other. Figure A.2 illustrates the building blocks of Volvo's environmental activities.

How Goal-Setting Is Done at the Company Level

As mentioned earlier, AB Volvo challenges each company annually to set goals for its environmental management system. VCC sets both production and product goals for the following four categories:

- energy (energy efficiency and fuel consumption)
- emissions (manufacturing process and product use)

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[30]These six are the transmission, engine, strategic sourcing/purchasing, stamping production, VCC-UK sales unit, and the Ghent assembly plant; a dealer (not owned by Volvo) is also involved. VCC's aim, which is the objective of the entire AB Volvo Group, is to have a system completely in place by 2000.

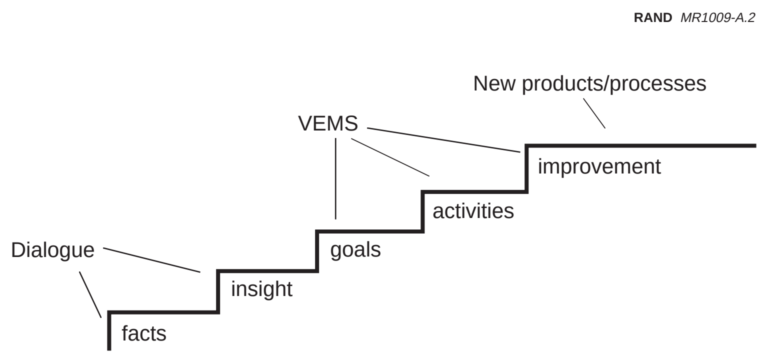

Figure A.2—Building Blocks of an Environmental Program

- recycling and waste management
- sustainability.

All of the goals are reviewed and approved by the VCC Environmental Board, about half of whom also sit on the VCC Executive Board, which is the senior management decisionmaking group for the company generally.[31] Two features of the goal-setting process appear to be the most critical. First, there must be a framework to guide goal-setting and decisionmaking. Once a goal is selected, it is transformed into a clear target and progress is tracked against that target until it is achieved. Second, the goals are built through intensive networking between the environmental group experts and the other functional units.

VCC's framework for goal-setting uses life-cycle thinking to integrate the set of measures and goals. VCC then focuses on places with the greatest leverage. The environmental goals are a subset of all the general VCC goals, and even the environmental goals are not mutually independent. Because many trade-offs are performed in any decisionmaking process, a structure or framework helps make these

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[31]Since the interviews were performed, VCC has reorganized its environmental management organization—now all members of the VCC Executive Board are on the Environmental Board (Fräjdin Hellqvist, 1997).

trade-offs easier to assess.[32] The Director of the Environmental Competence Center stressed the importance of having a framework to integrate the goals. In the past, VCC did not have a framework, so regulations drove structure. Having a framework aligns investments with company strategy and provides a means to prioritize those contributing the most to strategically desired environmental improvements. Moreover, it focuses management attention on the important issues and facilitates action in a technical environment, which is highly quantitative. Finally, the structured goals and targets help to relate specific activities to company goals.[33] Clear priorities are used for decisionmaking and investments.

VCC's priority for investments is clear: first business, then safety, and then environment. Specific investments are always chosen by senior management, so environmental issues are not treated differently. VCC invests in the economically feasible technology with the best environmental performance attributes. This may mean that VCC invests in the "80 percent solution" until it becomes clear that the "100 percent solution" is the effective way to go. However, there is a minimum acceptable environmental performance—no new investment can degrade existing environmental performance. Corporate guidelines for investments include a "checklist" that ensures that each department, including the environmental department, is involved in the decisionmaking process for each investment. Incremental environmental improvement is VCC's general strategy. Where warranted, significant investments will be made to improve

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[32]Walley and Whitehead (1994) point out that one of the real problems with Porter's win-win paradigm is that searching for these opportunities can divert too much management attention from other core business processes. An example of a win-win situation found in a structured way was at the Torslanda plant. The plant performed a waste management study over a two-week period and found a way to save $3 to $4 per part through packaging reduction without any investment. This structure is provided by the combination of organizational entities, the life-cycle framework, goals, and priorities.

[33]The use of long-term strategic planning to guide investments, which meet financial criteria, is recommended by Claude Fussler, Environmental Health and Safety, New Businesses, and Public Affairs, Dow Europe. It is the long-term view that allows innovative companies to persist, to better anticipate major technological changes, and to exploit this change for their competitive advantage. Given the three drivers of environmental issues—population and demographics, environmental stress, and value creation—he anticipates significant innovations in the future (Fussler with James, 1996, pp. 20–21).

environmental performance. Like any other strategic investment, environmental investments are justified in terms of competitive advantage.

Second, the goals are built through intensive networking between the environmental group experts and the other functional units. Goals tend to be driven top-down within VCC, with a heavy reliance on information collected through the networks of environmental coordinators from the business units and environmental experts from the Environmental Competence Center. That is, VCC tests goals through the network, but will announce them before clear implementation plans are in hand. VCC then develops an implementation plan using the expertise from the units.[34] Especially critical are the ways in which others are enabled to make informed decisions regarding environmental issues, because many individual decisions will determine the ultimate environmental profile of a product. Whichever environmental actions are undertaken, however, the investments must compete on an equal basis with any other investment.[35]

The environmental experts motivate line organizations to consider environmental effects and provide expertise on environmental issues. The line experts are responsible for actually incorporating environmental concerns into their analyses and decisions. The networking is performed in all settings—design, advanced engineering, production, etc.—and is reinforced with the environmental boards and working group organizations.

The business units have the required expertise to provide feedback on the feasibility of the goals and to offer suggestions for ways to meet the goals. So the environmental experts work with the line or other functional experts to develop feasible targets, given environmental as well as business development objectives, and to overcome

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[34]This sounds like the Toyota concept of target pricing—set an acceptable price and then work backward to get cost down enough so that you can charge that price.

[35]Texas Instruments has a similar sounding process that it calls “catchball.” In this process, the business units identify goals and share them with other units, as well as with upper unit management. This helps build consensus around a goal and creates buy-in to eliminate the barriers that may hinder achievement of the goal (Ufford, 1996).

barriers to these objectives.[36] By working with relevant functional experts, Environmental Competence Center personnel create buy-in and generate more creativity than if they worked in isolation. For example, a design engineer, not an environmental expert, suggested extending the tailpipe life to meet an environmental goal. However, because this idea did not pass muster with the business side of the house, it was eliminated as an option.

Competence center personnel may also help the other functional experts relate their actions to specific measures and goals. The company's environmental training provides a common basis of understanding for dialogue within and between all levels. The Environmental Competence Center measures success by the number of debates and dialogues on environmental issues that arise. When the VEMS is mature, environmental improvements will be completely integrated with line management.

The Environmental Competence Center creates visibility for these goals and builds political support for their realization throughout the company. The center works to build an organizational process and the required competencies to implement and internalize these goals.

How Goal-Setting Relates to Product Design and Advanced Research

As mentioned earlier, VCC focuses on four basic sets of environmental goals, and it either has, or will have, explicit targets to move toward. The goal set is presented in Table A.1. The development of these goals requires coordination between the Environmental Competence Center and the units that will have to implement them—in this case product design and advanced research.

VCC has clearly prioritized its product-oriented issues in this order: energy, emissions, and recycling. These priorities have evolved over 24 years and are not mutually exclusive. Progress toward these goals can be difficult, requiring lots of analysis and judgment. Or progress

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[36]This is feasible in part because there is greater knowledge of business issues at the lower levels of the corporation than even five years ago. Then, the bigger picture was only in the heads of top management.

Table A.1

Volvo Car Corporation Goal Set

Goal	Production, Services	Products
Energy use/fuel consumption (CO_2)	Specific numerical targets pending	Cut 25% by 2005 (1990 baseline)
Emissions (VOCs, etc.)	Explicit time schedules by chemical (including CO, HC, NO_x, PM, ...)	Explicit time schedules by chemical (including CO, HC, NO_x, PM, ...)
Recycling/waste management	Still pending announcement	85% recycle by 2002 95% recycle by 2015[a]
Sustainability	"Use life-cycle assessment"[b]	"Use life-cycle assessment"

[a]Actually, Swedish law requires the more stringent of the total disposed weight requirements and the recycling percentage to apply. Specifically, by 2002 either 85 percent of the car by weight has to be recyclable or not more than 152 kilograms can be sent to disposal, whichever is more stringent. By 2015 either 95 percent by weight must be recyclable or no more than 50 kilograms can be sent to disposal.

[b]While, life-cycle thinking is not new to Volvo, the broad discussion suggests that it can be conducted much more thoroughly to understand more long-term implications of decisions made today. Thinking in terms of sustainability is quite different from thinking in terms of LCA analysis to support traditional financial decisions.

can be straightforward and simply a matter of awareness and concern. For example, energy issues are tricky because improved fuel consumption requires new technologies and is a systemic issue touching on many elements of automobile design from weight to shape to engine design to use to the fuel itself. Therefore, designers look for leverage points. Global warming is driving this interest. Emissions issues are more straightforward. Process designers know what needs to be done and employ everything from improved housekeeping to process change. Some multimedia issues arise as well. Emissions during manufacture and during vehicle use present challenges, but it is relatively easy to relate design changes directly to the particular emissions to reduce. Recycling is fairly straightforward and is in the company's self-interest because of the regulatory fines. Material used in manufacturing a car is either captured and reused or burned to recover some energy value. So recycling is just a matter of doing it.

Goal-Setting in Advanced Engineering

The integration of environmental issues into business processes is manifested in R&D planning through advanced engineering. Advanced engineering activities are performed before product design, that is, before there is a letter of intent. Advanced engineering is seen as a low-risk mechanism, relative to platform-related investments, to test solutions to technical problems. The technical gaps on the business development side can be addressed in the advanced engineering context at minimal cost relative to platform development.[37]

The Environmental Competence Center works with each department—exterior, body, chassis, engine, transmission, styling, interior, etc.—to develop an environmental investment strategy for its research investments. The Environmental Competence Center is responsible for monitoring the political, economic, and environmental aspects of issues as well as technical capabilities. Its external sources include universities, technical journals, and research organizations. These trends are then combined with business development needs to contribute to the R&D agenda so that technical capability is ready for product lines as needed. The center's information gathering and internally oriented outreach activities also help train functional line managers or make them aware of new technological solutions.

Working-level personnel have developed a structured process to discuss environmental issues using the template shown in Figure A.3. First, they walk through the aspects relevant to the product—resource use, clean production, emissions during use, materials use, noise, recyclability—and determine what a "green" system might look like. They determine the relationships between system characteristics and these environmental characteristics. Once the baseline characteristics are established, they identify the technological barriers to improvement. Technology investments to

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[37]Experimentation and prototyping are low-cost ways of testing new ideas and hedging against catastrophic failure. To experiment successfully, a company must recognize that failure is part of the learning process. These activities are generally performed well by knowledge-building companies (Leonard-Barton, 1996).

RAND *MR1009-A.3*

DEPARTMENT XX				
Aspects	Green characteristics	Areas for improvement	Activities	Time frame for introduction 96, 97, … 2006
Efficient use of resources				
Clean production				
Emissions during use (CO_2, fuel consumption, NO_x, VOC, electrical)				
Clean materials use				
Allergic/toxic reactions				
External noise				
Recycled vehicle				

Figure A.3—Template for Advanced Engineering Planning

eliminate these barriers are planned over a 10-year horizon. The actual investments are made based on market demands and anticipated market introduction by competitors. So the matrix presented in Figure A.3 is fleshed out for each department—exterior, body, chassis, engine, transmission, styling, interior, etc.

Finally, a life-cycle assessment using EPS is performed to determine high-leverage areas and prioritize investments. Thus, investments are ultimately prioritized according to market interest (willingness to pay), competitor actions, and leverage over environmental performance.

To summarize, the line organization—advanced engineering in this case—is ultimately responsible for making the investment decisions. The environmental group provides recommendations, and the project personnel and advanced engineering personnel work back and forth on what is required and available. To back up the working-level personnel, the director of the Environmental Competence Center discusses the plans and progress with the top manager of each department twice per year. VCC has completed this analysis for 10 departments and the complete vehicle over an 18-month period. The director of the Environmental Competence Center has met with each department manager twice.

This structured approach with the template and investment strategies helps departments combine strategies for all performance attributes and facilitates more cost-effective decisions. Some departments have been more open to this approach than others. In general, the departments tightly coupled with customer demands, such as transmissions, engines, and interior, are more responsive to this process than other departments have been so far.

Environmental Management in Product Development

Volvo design processes. Volvo design teams are cross-functional teams that stay in place for the duration of a project, defined as ending three months after product launch/production start.[38] At peak, a project will have 100 engineers working on the design team. Design teams have been restructured so the manager has more incentives to build staff skills, while the product is the responsibility of the entire team. This is somewhat new at Volvo, and Volvo feels that it allows for a greater degree of creative input to design because the whole team gets recognition. This approach also gives more decision-making authority to the individual team member. User or customer preferences are fed through both the dealerships and marketing organization. The dealerships send information on repair records, warranties, servicing, etc., to designers through the quality system. Marketing seeks input through focus groups, research studies, and surveys. Common environmental awareness training, the Volvo Dialogue, facilitates the incorporation of user or customer input.

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[38]Design time periods are two to three years if working from an existing platform and engine, six to eight years if a new platform is being developed, and five to ten years if a new engine is being developed.

In the first phase of design, the new property requirements are established and documented in a “letter of intent” for a new automobile. These simply include a basic description of the target market and price goal for the automobile. Property requirements are then described in general terms in the areas of performance, safety, and environment, and additional analysis is performed on the target market and willingness to pay. The third phase of design, the property analysis phase, is iterative. Initially the property description is developed in nonquantitative terms. A functional analysis is performed from the complete automobile to lower and lower systems, components, and finally parts, to determine overall characteristics. The functional analyses are iterated at all levels to refine the technical and functional requirements of the automobile and its systems. The result is a complete quantitative description of the automobile as well as its detailed components and parts.

The environmental issues are part of roughly 35 overall attributes of concern for an automobile.[39] For example, attributes include automobile weight, air resistance, and rolling resistance. The only attributes exclusively driven by environmental requirements are emissions and recycling rates, followed closely by materials and fuel consumption. But environmental requirements affect virtually all 35 attributes in some fashion. Ultimately the project manager must decide whether or not to meet the environmental goals. If they are not going to be met, marketing might be consulted. Many attribute trade-offs are made, and on occasion, if the goals cannot be met, the project review board can cancel the project. Cancellation has occurred, but it is a big deal. In the past, environmental issues have not been weighted as heavily as they are now. Environmental attributes are justified on the grounds of market demands today and those expected in the future.

Incorporating environmental concerns. The Environmental Competence Center facilitates design-for-environment in a number of ways. At the management level, it reviews strategic issues with each of the design departments for a particular product. At the working level, the competence center staff engage design teams directly to

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[39]Design is a high-leverage phase and is cost-effective because there is considerable freedom during this phase. However, the problem becomes one of establishing priorities and decision criteria for making the associated performance trade-offs.

develop and monitor environmental performance attributes. At the skill level, the center co-develops tools and educates engineers on the environmental effects of their designs.

At the management level, the director of the Environmental Competence Center has had a series of discussions with the managers of each of the design organizations, such as design and styling, to cover the environmental issues in their area. She has done this with all groups, about 20 in total, over the last year and a half and is ready for the second round. Through these conversations, the director of the Environmental Competence Center has increased the awareness and demonstrated the importance of these issues. After these sessions, some groups have returned with interesting ideas on how to approach the environmental issues. This is taken as a sign of progress.

At the working level, each system (e.g., transmission, gears, door panel, instrument panel) has four or five engineers working on the design. The Environmental Competence Center contributes one individual to each cross-functional team. The center personnel work with the system engineers to establish targets for environmental attributes and develop awareness. The center also monitors and tracks the environmental attributes of concern (e.g., recycling rate, fuel economy, emissions, materials, weight, noise) to ensure that they meet the targets established. Center personnel also suggest improvements and check for internal consistency. They plot actual performance against each goal for the environmental attributes of concern. If an issue or trade-off cannot be resolved at the team level, it is elevated through line management and may involve other line functions, such as marketing. This option is not exercised often. Ultimately, design projects are monitored by a project review board, which has final say in the outcome of the series of design trade-offs.

Individual design engineers are introduced to environmental thinking in two ways: through recycling analyses and life-cycle environmental assessment analyses. Both approaches seek to improve thought processes used by designers to consider the long-term impacts of design decisions. Volvo personnel believe that thinking recycling all the way through requires design engineers to consider long-term impacts of material selection. How will material choice affect the ability to reuse or recycle the component or part? How will material characteristics hold up after recycling? How many cycles can the material withstand? Recycling is also fairly straightforward to motivate because of the Swedish law requiring recycling rates of 85 percent by 2002 and 95 percent by 2015. If Volvo does not meet the provisions of the law, it either must raise car prices or earn lower profits. The Volvo joint venture dismantling facility also provides practical experience with dismantling and recycling so designers can view practices and results first-hand.[40] Recycling issues are more straightforward and somewhat easier to understand than all of the environmental life-cycle effects.

Life-cycle assessment issues are broader and longer-term than recycling. The life-cycle assessment model and database used by Volvo is called the Environmental Priorities Strategies (EPS), described in greater detail below. It calculates all environmental effects from biodiversity loss to human mortality for material and process choices. The time horizons are long-term. By using the EPS system, designers improve their understanding of the relationships between design features and material choices and the environmental impacts. This increases their appreciation of the environmental ramifications of numerous design trade-offs. Today, not every design engineer is trained to use EPS. Nor has it been used on an entire car design. While EPS analyses are comprehensive, short-term profitability ultimately limits the number and type of issues that can be addressed by Volvo, so it is necessary to have a framework of metrics and goals to target and prioritize analyses.

We did not discuss how much attention the project review board gives to environmental issues. Generally it appears that decisions on environmental issues employ a bottom-up process, where working-level environmental personnel build awareness and work with designers to establish priorities. Design decisions are made at the lowest appropriate level by the functional experts. The awareness of

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[40]The joint venture among VCC, Stena Bilfragmentering AB, AB Gotthard Nilsson, and Jönköpings Bildemontering AB is called Environmental Car Recycling in Scandanavia (ECRIS). It was established in 1994 to scrap vehicles and process waste materials from suppliers, dealers, and production operations. The test facility is also used to generate parameters for the life-cycle model EPS (specifically the trade-offs between initial raw material use and energy consumption of recycled materials) and, as mentioned, to train design engineers. Material recycling and energy recovery techniques and recycled materials markets are evaluated for profitable dismantling.

environmental issues generated at the management level reinforces this bottom-up approach during project review. Corporation goals and market analyses are the only real “forcing functions” from above.[41] Design processes and environmental attributes are linked to financial systems. These financial systems approach activity-based structures but are not identical with them. Activity-oriented analyses are performed frequently on a project basis and have led to unanticipated results.

To summarize, VCC has approached product design from many dimensions. Goal-setting is an important part of implementation. Structured goals provide strategic focus. They help to relate specific activities to company goals and facilitate improvement. Clear priorities in this case—business, quality, safety, and environment—make decisions easier. Market interest and company strategy motivate individuals to try to meet and improve goals. The Environmental Competence Center personnel actively inform and remind others of these motivations. Because of this, and the general Volvo corporate culture, most management processes rely on co-operation and competence development. Environmental Competence Center personnel interact with design organizations at two levels. At the manager level, the director of the Environmental Competence Center builds political support and visibility for environmental goals. At the working level, individual relationships increase awareness and support for the goals. These relationships between Environmental Competence Center personnel and design personnel are also instrumental in helping designers develop new competencies. Individual designers are better equipped to think about long-term effects of their decisions by working through recycling issues and environmental life-cycle assessments. Individual competence is especially important because new product design is characterized by decentralized decisionmaking and many design trade-offs.

[41]Xerox has a different corporate culture and procedures. Xerox managers feel that its specific environmental design exit criteria are key contributors to its design-for-environment program. These criteria make design engineers pay close attention to environmental attributes. Note, other key elements of the Xerox program include training and use of a blended unit cost, which includes production and disposal expenses to encourage ownership (Azar, 1996).

Environmental Management Tools and Training Programs

The second major aspect of environmental management implementation that is especially important to implementing design-for-environment is the development of analytic tools and specialized competencies. Training addresses both individual values and awareness, while analytic tools facilitate environmental analyses and codify values for the analysis process. Three of the major tools and training programs are described in this section. These are EPS, a life-cycle analysis tool; MOTIV, a chemical database; and Volvo Dialogue, a general environmental training program.

Life-cycle assessment: Environmental Priorities Strategies (EPS). EPS is a life-cycle assessment tool used by design engineers at VCC. EPS has two elements, a database and a methodology, that employ sustainability principles to calculate the environmental effects of products.[42] Volvo is one of about a dozen industrial firms in Sweden that have collaborated with research organizations to develop EPS. This subsection will briefly review the guiding principles used to develop EPS to provide a foundation for understanding how it has actually been used by designers at Volvo. Volvo finds the structure of the system useful for thinking through all the environmental issues associated with product design—for educating product designers as well as for determining high-leverage areas for investment and additional study. As discussed in this subsection, it does not however,

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[42]The most important aspect to implementing new technical processes and tools is to treat and manage the implementation process as a innovation itself, rather than as "the mere execution of a plan." Using the analogy of new product development for the implementation of new processes and tools means that the customers are the internal organizations that will employ the new practices. It follows that successful implementation will involve users to develop the new process or tool design and create buy-in. As much attention should be given to selecting experimental users as is given to the specific tool or process design. In particular, experimental users should be interested and willing. They should also possess a knowledge base representative of the user group. Co-development is a very useful way of incorporating user input because both users and developers are forced to share problem-solving and hence responsibility for the success of implementation. Furthermore, mutual understanding is garnered at the group level rather than the individual level. Moreover, mutual adaptation, where the new tool is influenced by the users at the same time that user processes are affected by the tool, is more often associated with co-development. This iterative process of introducing new concepts with the requisite organizational change is more easily addressed with co-development. This can also help mitigate the negative affects from uncontrolled change. (Leonard-Barton, 1996.)

use the system in a fashion completely consistent with the objectives of the developers. For a more detailed history and description of EPS, see Chapter Two.

What is EPS? EPS is an analytic tool that performs the four major steps in a full life-cycle analysis. These steps are:

- Establish goals and *scoping* components that explicitly identify the reasons for performing the LCA.
- *Inventory*, or characterize, the life-cycle environmental impacts of a given product to include natural resource use; energy use; and air, water, and soil emissions during manufacture and use.
- Assess the *impact* of the products' emissions and resource use on human health and the environment, such as biodiversity loss and air quality.
- Evaluate *improvement* opportunities and options through alternative product designs.[43]

Industry participants and research scientists agreed on several ground rules or guiding principles for EPS. These guiding principles were established to ensure that EPS would be useful to and employable by design engineers while meeting the tenets of sustainability and considering all environmental effects appropriately.[44] The following are the agreed-on principles:

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[43]Life-cycle assessments are separated into component parts by ISO, SETAC, and others involved in guideline and methodology development. These components are called inventory assessments, impact assessments, and improvement assessments. ISO is developing guidelines, with mixed degrees of success, for each of these components (proposed standards in the 14040 series) (SETAC, 1990, p. xviii; Ryding et al., pp. 3–4).

[44]Allenby (1996) placed the three extant life-cycle assessment methods into the following categories: high-level qualitative matrixes (AT&T/Lucent Technologies' approach), which are primarily good for internal use, involve lots of judgment, and are not good to communicate to external audiences; quantitative methods with detail on values (EPS), which cause problems when costs or values are unknown; and the thorough and detailed approach (SETAC), which can get overly complex and detailed given data availability and large uncertainties.

- Create a tool that is quick to use and can be incorporated into multidimensional product design analyses. Generate one quantitative measure for all environmental impacts.
- Use a comprehensive perspective; that is, include all environmental effects.
- Treat all generations and geographic areas of the world equally.
- Employ the precautionary principle to environmental threats.
- Provide a uniform baseline as a default scenario.
- Maintain transparency and expose all assumptions clearly.
- Include uncertainty explicitly.
- Weight safeguard subjects with willingness-to-pay information to get one numerical result.

The EPS uses average-risk-assessment methodologies to relate risk to results, such as human mortality or loss of biodiversity, in five safeguard subjects: biodiversity, human health, production, resources, and aesthetic values. Because EPS employs sustainability principles, results are based on assumptions with very long time horizons (hundreds of years in some cases) and broad societal values.[45] Volvo finds EPS useful to design-for-environment implementation in several ways. And while the principles listed above are important to the EPS rationale, in a practical sense, Volvo views the outputs in numerous ways.

EPS helps with environmental strategy formulation and designer awareness. One of the ways in which Volvo finds EPS useful is for developing an overall environmental strategy. Since the environmental issues associated with the automobile life cycle are complex and wide-reaching, it is very useful to have a method for structuring and assessing the myriad sets of issues. The structure of the EPS system and the framework of the resulting analyses help the company organize environmental goals, look for high-leverage areas, and

[45]One ground rule established between industry and scientists was that EPS be comprehensive, because in early stages of design there is considerable freedom, and the opportunity to affect environmental performance is great. This leads to assumptions about sustainability. See Chapter Two for a longer discussion of this rationale.

communicate information to managers, designers, and customers alike. The managers and designers can then focus their analyses and investments on those areas that provide the greatest leverage to environmental issues and may constrain automobile design in the future. An example of how EPS helped Volvo focus on an issue previously given limited attention concerns radium, a rare-earth metal used in electric car batteries. The natural resource calculations in EPS indicated depletion of this resource. With this focus in mind, designers and environmental experts reviewed discussions in the scientific community about this issue, which they might not have noticed otherwise. Also, EPS analyses provide a foundation and rationale for communicating environmental impacts of automobile design both within the corporation (to business managers and decisionmakers) and outside (to policymakers, customers, and the public).

The other primary way in which EPS is used by Volvo to implement design-for-environment is to educate designers about environmental issues. The entire set of environmental issues and the relationship of design to environmental impact in EPS are used to train designers to think about the long-term and the life-cycle environmental effects of their design, material, and process choices. For example, EPS helps designers walk through the material selection process to understand the effects of their choices on recycling potential and multi-life products. Currently 20 to 30 design specialists at Volvo are being trained on EPS. They are learning the tool and the thought processes. Environmental experts see that this additional understanding motivates designers to consider and take environmental issues seriously. It also provides them with the capability to do so.

The application of EPS is limited. The EPS model and database are still under development. Even so, Volvo analysts are comfortable that results are now accurate enough for decisionmaking, if a specialist operates the model and interprets the results in the context of business decisions.

Generally EPS is applied strategically, that is, on those systems where processes or materials can be changed or where there is potential for significant environmental improvement or when analysts want to compare two or more concepts in the early design phases. Right now, the decisions on where and how to apply EPS are made with the help of the environmental experts. Only on a limited basis has EPS been used for entire systems: Volvo's environmental concept truck, environmental concept car, and environmental concept bus. For example, EPS has been used on design of a bumper because the results are easier to comprehend and apply, making it a good application for educating designers on environmental issues. They can use the model and its structure to generate the right questions about design choices and environmental impacts, such as material use and recyclability, and thus to build design competencies on environmental effects.

Volvo also breaks down the results of EPS into their constituent parts for product design analysis, instead of always using only the aggregated numerical output. The ability of the company to develop sustainable products in the EPS sense is limited by its planning horizons and financial constraints. Therefore, Volvo will substitute five- to ten-year projections for resource prices (versus recovery costs as provided in EPS) and will focus on the emissions piece. For the automobile, such emissions as CO_2, CO, and NO_x as well as prices of the rare-earth metals dominate Volvo's concerns. Not surprisingly, these modifications are not recommended by the EPS developers because they violate the established principles.

Finally, because of the way EPS was developed, there are many potential benefits beyond product development. First, EPS is really a database and a model. The database especially requires constant updates and refinements. Because EPS is a collaborative effort, these expenditures can be shared with other industrial companies. In addition, because EPS was developed by major companies in Sweden, in collaboration with a research institute and the government, the baseline data and scenarios can easily be used for discussions on specific environmental issues among all stakeholder groups. In fact, model results have been used successfully to recommend changes to specific elements of the Swedish recycling law to increase allowances for energy recovery.

To summarize, the comprehensive treatment of environmental issues and the structure and framework developed for the system help Volvo link the various environmental goals and targets that it has established and to communicate priorities and decisions to others both internally and externally. In addition, EPS is a design aid that walks designers through the environmental effects of their decisions and, because of this, builds new competencies to handle environmental issues. In addition to EPS, Volvo also has design checklists and guidelines, training, and manuals to aid design decisions.

The Volvo chemical blacklist. The blacklist is a group of chemicals prohibited by Volvo for its own operations as well as for those of its suppliers. The list is a compilation of substances banned in countries around the world, as well as those that Volvo has deemed too risky to use. The associated "gray list" includes those chemicals that Volvo is phasing out. These lists are updated approximately once per year. They are fairly new (about one year old) and change often, so they have not been electronically linked to the corporate chemical database, MOTIV, as yet. This list is available to all Volvo employees, including design engineers—not only EH&S specialists—so all employees can easily avoid using these chemicals in the first place.

Chemical database: MOTIV. MOTIV is a corporate database of 4,000 chemical products used by AB Volvo (10,000 different chemicals are in use worldwide). It was established in 1991 and includes information on chemicals used in all products and processes in all Volvo companies. It was developed to help minimize the use of environmentally hazardous substances and to simplify the specification of various chemicals. As a result of having this information generally available, the number of chemical products purchased by Volvo per year was halved from 800 to 400 (AB Volvo, 1994b) and the use of several substances was discontinued (AB Volvo, 1995). MOTIV cost approximately $380,000 to develop and costs $170,000 per year to maintain. As of spring 1992, Volvo had already saved $170,000 in one year, after expenses (Rothenberg and Maxwell, 1993).

The database is managed by the safety engineers and includes information on environmental effects, health, fire, transport, place of use, and chemical composition. Chemical products are submitted by the users and reviewed by Volvo's occupational health and safety organization with input from the environmental organization. The chemical recipe for each chemical must be submitted by its supplier to Volvo or the product is not purchased. This sensitive information is accessible only to a handful of users at each company.

This database can easily be consulted to ensure that chemicals on the blacklist are not being used or to determine the locations of particular chemicals in use. Designers can use it to focus on those already in use and to see which chemicals are being phased out by the corporation. Because this information is readily accessible, it can be used both to resolve short-term emergencies and to assist in product and process chemical choices. "Environmental questions have to be answered directly in product development. These are the best people to make the decisions." (Rothenberg and Maxwell, 1993.)

Environmental awareness training: Volvo Dialogue. The Volvo Dialogue program is an environmental awareness program that is provided to all VCC employees worldwide, dealers (both sales and service personnel), and suppliers. The program has been modified slightly for U.S. personnel. The Dialogue program is geared toward changing employee attitudes and values regarding the environment by giving employees information to do so.[46] Volvo has never had a training program so large. When the program is complete, after three years, more than 70,000 personnel involved in every product stage, including all Volvo employees, as well as dealers, sales and service personnel, and suppliers, will have been trained. Attendance has not been a big problem, although there has been some slippage in scheduling the latter sessions.[47]

In order to change behavior, VCC's environmental experts believe that they must modify the attitudes and values of employees who are either open to change or recognize that there is a problem.[48]

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[46]Safety is the highest corporate core value and has been part of training since the company's inception in 1927. To get awareness of the environment to the same level will be more of a challenge. Because safety is a more immediate life-and-death issue, its importance is easier to explain than that of the environment, where the issues can be longer-term and indirect.

[47]Only one other company that the authors are aware of has undertaken such a large training program—Motorola. Motorola planned to train more than 100,000 employees in one eight-hour environmental awareness session from 1993 to 1996 (Eagan, Koning, and Hoffman, 1994).

[48]This approach contrasts with the approach taken by the Department of Defense on racial integration in the late 1940s and early 1950s. Largely considered a success relative to private attempts at integration, DoD implemented racial integration by espousing a clear policy with swift enforcement. The key element of this program was that it sought behavioral, not attitudinal change. Shared work-tasks facilitated this change. Note, at the time this policy was being implemented, there was strong public opinion against racial integration (Rostker et al., 1993, pp. 183–190). It is not clear how analogous this situation is to environmental issues. In contrast to general attitudes on integration in the 1940s and 1950s, public opinion is generally supportive of envi-

According to many, "Education can be a powerful potential change agent for companies," and can provide a common vocabulary for all participants (Eagan, Koning, and Hoffman, 1994).

The Dialogue program's three sessions address the "facts" and "insights" steps in the staircase presented in Figure A.2. The first session is meant to scare and shock or get attendees' attention. This is presented by a professional trainer in a venue for about 250 people. The second session is a dialogue between a Volvo employee and other staff to relate transportation issues to environmental issues. The third session addresses Volvo and the environment. It considers historical aspects but concentrates on relating individual contributions to corporate goals. The second and third sessions are in smaller groups of 15 in interactive sessions, or "dialogues." A colorful three-ring binder of materials is provided to personnel.[49] Time between phases is considered a key aspect of the program. This time allows employees to digest messages and provides for more interactive sessions in the latter phases.

Employees' attitudes are surveyed to determine the effect of training and awareness programs. In 1994, Volvo surveyed employees to assess their attitude toward environmental issues. In that survey, on a scale from one to five in terms of awareness and willingness to change behavior (1 = Unaware, 2 = Questions the problem, 3 = Realizes there is a problem, 4 = Willingness to change, 5 = Actively changing), Volvo employees were between 2 and 3. In a 1996 survey, employees were between 3 and 4. These results, along with the increase in the number of environmental questions coming from employees to the environmental staff, is interpreted as progress.

Design engineers question the utility of this training program for their purposes because they feel they already know the material. However, the common training allows the engineers, and anyone for that matter, to have a level of understanding common to personnel

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ronmental causes. Moreover, behavioral change is difficult to prescribe or enforce. This is particularly true in the case of pollution prevention, where success depends on the creativity of individual employee ideas and actions.

[49]For comparison, the Motorola awareness program is presented in one eight-hour session, which covers environmental problems and problem-solving ideas, global environmental issues and their relationship to the individual, environmental regulations, and the value in going beyond compliance.

corporatewide. Therefore, engineers can more effectively respond to input and questions by others.

The other Volvo companies—bus, truck, aero, and construction—are beginning the Dialogue program developed by VCC. Over the years, other training courses for specialized issues and audiences have been offered within various companies in AB Volvo.[50]

To summarize, the second major aspect of environmental management implementation is the development of analytic tools and specialized competencies. Environmental awareness training addresses both individual values and awareness. Analytic tools facilitate environmental analyses and codify values for the analysis process. These are particularly important to design-for-environment implementation because ultimately the environmental profile of a product is determined by many cumulative decisions made by design engineers and others, not the environmental experts. EPS, a life-cycle analysis tool, is used to build new competencies among design engineers. The life-cycle view and the EPS analysis framework also link the various goals and targets that VCC has established. The MOTIV chemical database makes information available to the design engineer and not just EH&S specialists. This has helped reduce the number of chemicals used at AB Volvo. Volvo Dialogue, a general environmental training program, increases the understanding and appreciation of every Volvo employee. In order to implement the environmental policy, all employee behavior, attitudes, and values must be modified. VCC seeks change through education. Finally, education provides a common vocabulary for all employees.

Suppliers. Volvo requires its approximately 500 suppliers to know Volvo's environmental policy and to establish and maintain an environmental management system of their own that is "in the spirit" of Volvo's. The director of the Environmental Competence Center said that no time frame was put on the suppliers, but a Volvo brochure released in summer of 1996 implies a time frame. If suppliers fail to establish an EMS in the spirit of Volvo's, they will be dropped.

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[50]VCC had published a brochure three or four times per year, titled "Clear Facts," to generate information on environmental issues. This publication has been discontinued.

According to the director of the Environmental Competence Center, the suppliers were openly astonished that Volvo was being so tough.

Some suppliers, now that they are aware of Volvo's specifications and priorities, are improving Volvo's specifications and making Volvo aware of the environmental effects of these specifications. So information is flowing in two directions. This is similar to the outcome of employee training as well and is considered a sign of progress.

THE ENVIRONMENTAL PRIORITIES STRATEGIES LIFE-CYCLE ASSESSMENT

Life-cycle analyses, whether quantitative or qualitative, are an integral part of any design-for-environment program. These analyses, however, often prove difficult, particularly in the case of complex products that require systems integration. EPS in particular is important to Volvo's program in that the methodology gives design engineers a framework to assess the environmental impacts of their design decisions and material choices. In this way, it builds new competencies and aids analysis. Significantly, EPS also helps environmental managers and design engineers select strategic areas to focus additional analyses and to make investments. Because life-cycle analyses are so important to design-for-environment and EPS is important to the Volvo program, this section provides additional information on how EPS was developed and the underlying methodology.

In the early 1980s, members of the Federation of Swedish Industries began to cooperate on environmental issues.[51] This led to the development of five environmental handbooks and common tools:

- A handbook for managing environmental compliance.
- Special issue pieces, such as one on global warming.
- An environmental auditing guide.

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[51]At this time, environmental issues were getting more attention and the member companies were not well positioned to deal with them. So the federation began to cooperate on these issues in addition to previous interests and extend their cooperation on lobbying efforts to other issues (Almgren, 1996).

- A report on product stewardship principles (English version will be published soon).
- EPS development.

EPS is a life-cycle analysis tool. It has a database on environmental impacts (energy, emissions, waste generation) for various materials and industrial processes and software models for product and process design. Results called environmental load indices are calculated for various materials and processes. These load indices can be measured in units per kilogram, square meter, or piece (environmental load units, ELUs) and are based on the environmental effect in five general categories: biodiversity, human health, production, resources, and aesthetic values.

Origins and Approach

EPS has been developed through the cooperation of industry members, a trade association, and university researchers. Working groups are staffed by individuals from Chalmers Technical Institute, IVL (the Swedish environmental research institute), the Federation of Swedish Industries (a lobbying organization), and Volvo. The EPS system, including the database and model, will now be managed by the Life-Cycle Institute, housed at the Chalmers Technical Institute, also referred to as a Competence Center, which has just been established.[52] Future development will focus on the database because the methodology has been fairly well established. On average, 12 Swedish companies are involved at any point.

Development of the system began in 1991, but initial discussions date to 1989–1990. At the original meeting, several companies decided to develop the EPS system together to aid decisionmaking on environmental issues in new product design. These companies had begun to realize that the focus of environmentalists had shifted from production emissions to products. If products were required to be more environmentally sound, companies would have to possess the analytic tools to address these issues, but the companies had no data to perform an environmental inventory. Gunnar Westerlund of

[52]The institute is funded with university, government, and industry contributions.

Volvo was instrumental in the development of EPS. He had a desire and a need to bring scientific, objective analysis into product design decisions. His most recent experience arose from a debate and lack of agreement concerning the use of plastic or metal for a part. Westerlund knew what the designers needed and he helped establish ground rules for the EPS to meet these needs.

Approximately 10 (likely 12) companies—Asea Brown Boveri (ABB), Akzo Nobel, Chemistry, Electrolux, Ericsson, Statoil, STORA Kopparberg, Tetra Pak, and Volvo, among others—cooperated on the EPS development, which included establishing an extensive materials database as well as the model. Their objective was to develop a comprehensive, easy-to-use tool that a designer could use to make quick design trade-offs based on the ecological impacts of product design choices. Two important factors that contributed to the success of the EPS project were support of experienced, senior management on the industrial side (e.g., the Volvo Group Vice President) and knowledgeable scientific researchers. Generally, industry members worked with the scientists to build consensus on the model ground rules and system boundaries. The scientific details were left to the scientists.[53]

The early design stage was targeted for an analysis tool because, at this stage, high-leverage opportunities can be found, a significant impact on environmental performance can be achieved, cost-effective changes can be made, and the summation of many "little" changes (changes without the specific intent of making a "green" product) can still have a large impact. To ensure that these early decisions were made with the proper information, the methodology had to be as comprehensive as possible. And in order to enable design engineers to use the tool in a practical sense, it had to generate simple results quickly and provide information that is easy to use, because too much information would add confusion. In the early design phases, many different product options are considered and analysts can quickly get overloaded with information. For this

[53]We repeatedly heard that five individuals spearheaded this effort. The two leading scientists mentioned in our conversations were Sven-Olof Ryding and Bengt Steen. The leading industrialist mentioned was Gunnar Westerlund of Volvo, who recently won an award for his contributions from the King of Sweden. Two others were not identified by name.

reason, EPS aggregates results for all the environmental effects into one number, called an environmental load unit. This approach is somewhat controversial, and the EPS has been criticized by many for aggregating the results on such a broad range of environmental impacts into one number. Again, EPS system developers wanted system transparency as well as straightforward results to balance the needs of product designers. Individual assumptions can be overridden if the design engineer prefers.[54]

The data collection and analysis process for developing EPS was extensive and time-consuming. Many of the existing data were old, in inconsistent formats, etc. The companies spent a lot of time establishing a common database structure. They did this sector-by-sector (iron and steel, forest products, manufacturing, textiles) and then the Environmental Research Institute decided which data to use. The database covers 10 to 12 different environmental effects, such as acidification, global warming, toxics, biodiversity (the most difficult to measure), and is continually being updated. Much of the scientific information in the model is rough, but the system developers' philosophy was to get a top-down structure and worry about the details later.

Methodology

EPS is an integrated system of the various steps in a life-cycle analysis. Active organizations in the LCA field, including SETAC and the International Standardization Organization (ISO), structure LCAs into three components: an inventory analysis, an impact assessment, and improvement analyses (SETAC, 1990, p. xviii; Ryding et al., 1993, pp. 3–4). EPS adds a fourth component—goal definition and scoping.

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[54]The British research community prefers to report at a more detailed level and then to let the engineers make the environmental trade-offs. EPS includes environmental priorities within the tool (using valuation) because design engineers are not necessarily experts on environmental issues (such as NO_X and SO_X emissions) and are focused on maintenance and disposal issues. AT&T/Lucent Technologies prefers a set of qualitative matrices that display all the environmental impacts as well as judgments about uncertainty.

- The goal definition and scoping component addresses the explicit reasons for performing the LCA, which can range from comparing products (for external use) to strategic planning (for internal use).
- The inventory analysis is the identification and accounting of environmental effects to include natural resource use and air, water, and soil emissions for a product.
- The impact assessment is the characterization of environmental effects on the environment and human health. It can be quantitative or qualitative and includes three phases: classification of impacts, characterization of emissions and use in the classification selected, and relative valuation of the various impacts (this is the most controversial element of an LCA).
- The improvement analysis component identifies (1) product characteristics, whether they be material use, design, operations, or something else, that offer greatest leverage for improvement and (2) the process for determining how to achieve those gains.

A life-cycle analysis will not necessarily employ all four of these components. What is included depends on the first—the goal of the LCA. All four of these components are included in EPS.

Ground rules were agreed on between industry and scientists and are aligned with principles of sustainability. They have developed the following set of principles for EPS, which are easier to communicate than the mathematical details of the model:

- Be comprehensive, that is, include all environmental effects for the safeguard subject areas. Report results simply, summarized in a common measure (called an environmental load unit).
- Treat all generations and areas of the world equally (use a zero discount rate).
- Employ the precautionary principle to environmental threats (e.g., consider global warming even though the effect has not been proved definitively).
- Provide a baseline as a default scenario to simplify the analysis during design. Adjust it locally as needed to reflect the specific needs of the user.

- Maintain transparency by exposing all assumptions clearly and use linearity wherever possible to maintain simplicity.[55]
- Include uncertainty explicitly; build it up from uncertainty about individual parameters and factors; and display cumulative uncertainty.
- Weight "safeguard" subjects with willingness-to-pay studies to provide valuation of the estimated environmental impacts.

The EPS uses average risk assessment methodologies to relate risk to results, such as human mortality or loss of biodiversity (versus CO_2 emissions or global warming potential), in the five safeguard subjects: biodiversity, human health, production, resources, and aesthetic values. Input parameter sensitivity analyses are performed and these average risks are calculated using Monte Carlo techniques. For example, so many kilograms of SO_2 emissions reduce tree coverage on average by X hectares, which increases human mortality by X percent. Willingness-to-pay is then used to weight the effects in the safeguard subject areas aggregated into an environmental load unit, the model output, so that it would take one ECU (euro, or European currency unit) to reduce the effect by one ELU. Results are reported as environmental load units because monetized values can be both misleading and misused (e.g., analysts may attempt to apply a discount rate to it). Moreover, developers wanted users to realize that there was more behind the numbers than just dollars.

It was important to EPS developers to relate risk to "end points," because individuals can better relate to and value more-specific outcomes. But this was tricky because all the relationships between materials, the associated processes employed, and the environmental effects must be accounted for. For example, each material and process that contributes to acidification must be identified and then the contribution of acidification to each of the safeguard

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[55]Linearity is not consistent with threshold effects or many congestion-style effects common to environmental issues. These can be accommodated by changes in the baseline scenario if the designer knows to do this. The long-term goal is to develop, in effect, an intelligent decision support tool that would take care of such problems automatically. Until then, designer intervention is important. Poisons generally have threshold levels, so if the emissions are below these levels the calculations are not performed. Carcinogens have linear dose-responses.

subject areas must be estimated. In this case, it was estimated that acidification contributes to 15 percent of the biodiversity loss in Sweden. As much science as was available was used to guide these relationships; otherwise either simple relationships or models were developed, or an educated judgment was made. The system developers used global, regional, or local data, when available. Otherwise they used Sweden-based data to represent the world.[56] The developers hope that advances in scientific knowledge will inform and improve these estimates over time.[57]

Natural resources are valued at the cost of re-creating them or substituting for them if their supply were exhausted. For example, EPS developers have estimated how much it would cost if copper were depleted and had to be extracted from the earth's crust. This would involve mining, crushing, etc., including the expenses for vegetable oil, wood, acid for leaching, and processing, for a total of ECU56 per kilogram. This, and not market prices or forecasts, is the value placed into EPS for the natural resource of copper. This procedure cannot necessarily be used with all metals as they cannot all be reclaimed. Rare-earth minerals are more difficult to deal with than other metals and minerals. The value to future generations of going without a resource that cannot be replaced is what is applied to today's use, because the market has no scarcity value. Sometimes resource exhaustion may take much longer than 100 years (a long time for companies, a short time for science).[58] EPS is about sustainability, the fundamental goal underlying this model, and so the natural resources are included in this way.

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[56]At about this time (starting in 1989), United Nations Environmental Program reports were being published, and they provided useful information.

[57]All input sources are documented in Excel spreadsheet notes. The models use the linear form of average probabilities and apply uncertainty bands to probabilities. Subjective judgments are used to estimate uncertainty bands (for example, factor 10 of log-normal distribution). Uncertainty is introduced in many ways—parameter estimation, exposure pathways, pharmokinetics, willingness-to-pay, etc.—and includes future regulations. Optimization routines deal with harm, not the willingness to pay.

[58]Eventually everything is regenerative (species come and go, minerals come and go) in the long run. But this time horizon is so much larger than human time scales that costs for living without a resource may be so large that they approach infinity and in effect the resources are depleted.

The various environmental impacts are combined into one number using valuation weights. Not many life-cycle assessments include valuation. Valuation is not universally seen as appropriate for life-cycle assessment. The valuation weights in EPS are based on willing-to-pay data and are normalized so that the output, an environmental load unit (ELU), is equivalent to one euro (ECU). Willingness-to-pay values were drawn from an inventory of all such studies relevant to global, regional, and local areas where the data were available. EPS developers found it relatively easy to find willingness-to-pay data for health effects and much more difficult to find such data for bio-diversity loss and mineral extraction (iron ore or copper ore). The developers' main source for the hard-to-determine biodiversity data were Swedish expenditures on natural spaces and parks (approximately SKr800 million per year) and Norwegian university studies. The developers feel that valuation is an important contribution of EPS. While other LCA models may be stronger on the natural sciences side, EPS provides guidance on weighting or valuing the environmental impacts. EPS developers felt that willingness-to-pay is the only systematic means for weighting various environmental impacts. However, getting reasonably accurate estimates for these values is extremely difficult. Despite these uncertainties, some regulators in Sweden were comfortable with the willingness-to-pay valuation. In part, this is because of the abundance of studies performed in preparation for a new packaging law. These studies were used to calibrate EPS, so now the regulators are comfortable with the system. This was actually one of the areas of agreement between the regulators and industry.

Environmental scenarios are part of the methodology. The baseline is the present situation and today's technologies and practices (e.g., how pollutants or chemicals are currently disposed of and the associated effects). This tool does not forecast the future but is a series of "what if" analyses.

Experience with EPS

Approximately three years after project start, the EPS has been used by most of the companies to varying degrees as a function of their product lines. While all participating companies have used EPS to some extent, Volvo has been the most active.[59] Member companies, such as ABB, Electrolux, and the STORA Kopparberg Group, are not using EPS in a way consistent with the guiding principles. For one, they often modify the assumptions regarding valuation, especially of natural resources. This is partially because companies generally view five- to ten-year time horizons as long; while science views 100 years as short. However, the public may pressure companies through regulations, so in the long run companies should be prepared. In addition to the modifications regarding natural resource valuation, companies would like to see EPS report emissions and natural resource use separately. Some separate the results for the safeguard subjects and focus on a particular area. However, EPS combines them as a consequence of its established ground rules. Volvo, the most active EPS user, does not use EPS for all designs. It looks at the various emissions, not just the aggregated ELU. And it uses different baseline scenarios.

Engineers are happy with the system. It is easy to use, and the engineers get a lot of satisfaction contributing to environmentally sound products. While methodologies are more product-specific, the supporting EPS database is easily transferable. This database is available to any entity, including the U.S. DoD. In effect, EPS provides a national materials database. In contrast, such U.S. databases as Franklin and Associates database are commercially developed and owned. The EPS developers have not done a lot to promote EPS and to encourage design engineers and others to use it.

EPS has limited application to regulatory policy, although Volvo used results on automobile recycling to negotiate inclusion of energy recovery. The EPS use of average probabilities and globally relevant data means that it is not particularly applicable to local problems. The use of average probabilities would skew results if, say, the transport mode, exposure pathways, or geography could have dramatic effects on harm done, such as in the case of arsenic. To use EPS for

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[59]In contrast, Tetra Pak, a packaging company, did not use it much. This is because Tetra Pak needed greater accuracy than the EPS valuation system provides. It had been doing life-cycle assessments for a while, had its own database, and so was experienced with life-cycle assessments in general. It needed greater visibility into the parameters and had to make trade-offs at a more detailed level than provided by EPS. Tetra Pak and STORA used EPS for a beverage carton.

regulatory policy that addresses local needs, data and load conditions would have to be collected and developed for the unique aspects and environmental impacts of the locality. However, for some global or far-reaching issues, such as ozone, society must set direct limits through regulations, in which case EPS, as is, may be relevant.

Relationship to ISO and Other Governance Structures

There is no straightforward relation between EPS and ISO 14040, because EPS preceded ISO. However, EPS experience has been communicated to the ISO 14040 technical committee. While EPS fits the developing ISO framework, there is a debate on whether or not valuation belongs in an LCA. Clearly, the EPS developers feel that, if valuation is transparent, it is permissible to include in an LCA. There is also no connection between EPS and EMAS, which is oriented toward production facilities' emissions, not product design.

According to its developers, industry views the EPS as useful for only one purpose, making product development more environmentally sound. They do not think that it is suitable for regulatory purposes, which require greater specificity. EPS may be used for eco-labeling programs as long as the uncertainties and inaccuracies are communicated. U.S. industry in general would probably strongly disagree with using LCAs for eco-labeling.

AB VOLVO GOALS AND ACTION PROGRAM

In 1993, Volvo Group Executive Committee implemented the "Environment 95" action program to run to the end of 1995. The program consists of goals for 20 different areas. Progress toward goals is evaluated annually, and progress is summarized. A new program, emphasizing the environmental impact of products, EMS, production processes, and communications will be implemented in 1996.

The 20 goals established in 1993 are listed in Table A.2. See Volvo's 1995 Environmental Report for an assessment of progress toward its goals and more detailed remarks.

Table A.2

Goals of the Volvo "Environment 95" Program

	Goal	Progress[a] (percent)
1	Establish a well-developed environmental organization, with clearly defined line and managerial responsibilities for environmental affairs.	50
2	Establish environmental councils in companies and plants.	75
3	Implement regular training and information programs in environmental affairs for various personnel categories.	75
4	Implement the EPS system of life-cycle assessment as a design aid and decisionmaking instrument at different levels.	25
5	Complete a first round of environmental audits in all production units.	75
6	Establish an environmental communications strategy with the environmental message as a key element.	75
7	Prioritize and seek environmental optimization in industrial processes for energy, volatile organic solvents, water pollution, chemical use, and waste.	75
8	Monitor the environmental performance of suppliers, stipulating environmental policy and auditing conditions in applicable cases.	25
9	Implement a plan where alternative CFCs, halons, 1,1,1-trichloroethane are available. 50% progress on CFCs, 75% on halons, 100% on 1,1,1-trichloroethene.	75
10	Ensure one unit in each truck engine family complies with Euro 2 standards.	100
11	Develop test series of distribution trucks burning natural gas or alcohol.	100
12	Introduce an environmental concept truck for urban delivery applications.	100
13	Ensure that at least one variant per model family in the VCC meets the strictest environmental requirements in the European incentive system.	25
14	Ensure that VAC's small gas turbines have the lowest emission levels on the market.	75
15	Ensure VPC is the first marine engine manufacturer to have five diesels emission-approved for operation on Lake Constance.	100
16	Develop and establish recycling system for vehicle parts and materials in Sweden.	50
17	Publish scrapping manuals for (a) cars and (b) trucks.	(a)100[b] (b) 25[c]

Table A.2—Continued

	Goal	Progress[a] (percent)
18	Participate in demonstration projects of both cars and goods delivery truck in built-up urban areas.	100
19	Develop navigation, positioning, and communications systems for installation in demonstration vehicles and for commercial sale.	100
20	To be, and considered, one of the mot environmentally aware companies in the transport sector.	75

[a]Approximate degree of progress toward goal. 100 percent indicates that the goal has been completely realized.

[b]From 1975.

[c]From 1978.