Case I
Reach Robotics Corporation

Steve, you know we were lucky in the '70s. . . . We had no competitive problems. . . . Price wasn't important in robotics. . . . I warned you last year that times have changed.

Company Profile

Brazos, Inc. is a major petroleum company located in Houston, Texas, and named after Brazos County, the original home of its founder and chairman, "Big Luke" Whitney. As early as the 1960s, Whitney concluded that diversification was imperative if Brazos were to have a sound long-term future. "A petroleum company," he said, "sooner or later will go drier than El Paso in August."

After considerable search and contemplation, Whitney and Brazos made the initial diversification move in 1971, when REACH, Inc. was acquired outright in a friendly takeover. REACH, located in Midland, Michigan, became an operating subsidiary (division) of Brazos. Whitney's management style for REACH was essentially one of hands-off. Whitney, who was Texas-congenial on the surface, but who would really raise hell when his managers faltered, saw his role with REACH as basically either "pocketing money or kicking tail," depending on how well the subsidiary was doing. Whitney recognized that involving himself in the day-to-day affairs of REACH was well beyond his competence.

REACH was a pioneer in painting equipment. One of its long-time customers was $39 Auto Paint Shops, for which REACH manufactured automated painting equipment. REACH's beginnings and growth were not unlike those of Brazos in some respects. REACH was founded and shepherded through its years of rapid growth by Lawrence Grafton, its 68-year-old president and chief executive officer.

During the late 1960s, Grafton moved REACH into robotics as a natural extension of its original business, particularly the work it did for $39

The data presented in this case regarding the robotics industry are generally factual. The REACH Corporation, however, is a fictitious company and represents a blend of the characteristics of several robotics firms. Any resemblance to any single producer in the industry is purely coincidental. Case prepared by John K. Ryans, Jr., and William L. Shanklin for use in executive development in high-tech firms.

Auto Paint Shops. In fact, it was success with $39 Auto Paint Shops that positioned REACH to become a supplier to the auto industry.

In 1967, Grafton was introduced to Stephen Palmer, a University of Michigan engineering professor who impressed Grafton with his ideas about using robots in painting processes. After working on a two-year research grant funded by REACH, Palmer joined the company full-time. Initially, he was REACH's R&D director. It was during this time that REACH expanded its expertise in robotics beyond spray painting applications, into such applications as welding, grinding, and sanding. (Currently, the company is evaluating the acquisition of robotized materials handling technology.) Subsequently, Palmer became REACH's vice-president of marketing and sales.

Thomas Green joined REACH in 1976 from Cincinnati Milacron as vice-president of new products and strategic planning. Green had earned an undergraduate degree in mechanical engineering from the Illinois Institute of Technology. Green's years with Cincinnati Milacron enabled him to obtain an executive master of business administration degree from the University of Cincinnati.

Throughout REACH, it was widely believed that either Palmer or Green would succeed Grafton as president. In recent years, Grafton's penchant for golf, especially golf near his Florida condo, kept him away from the Midland headquarters a great deal. And Grafton had long expressed his intent to step down by age 70—one and a half years away. Whether Palmer or Green was the heir apparent had probably not yet been decided by Grafton and Brazos. REACH's revenues had been growing adequately, if not spectacularly, in the first years of the 1980s. Moreover, the company's financial position looked to be in good order (see exhibits I-1 and I-2). Of the $162,659,136 in sales for 1982, about $14 million was accounted for by robotics. The remainder of its sales were derived from its painting equipment and related products.

The Industry

Unimation, Inc. is credited with having produced the first U.S. robot, in 1961, although active research in the area had been underway for more than a decade. In fact, America is credited with having had a fifteen-year robotics technology lead on the rest of the world by 1967—but, 1967 marks a critical turn in the industry. That year, Japan imported its first industrial robot, and by 1969, Kawasaki Heavy Industries was producing robots under a license from Unimation. The rest, of course, is history to followers of the robotics industry. Robots have caught on much more quickly in Japan, and Japan currently produces and employs the majority of the

Exhibit I-1

Brazos Corporation
REACH Division
STATEMENT OF INCOME
Years ended October 31, 1982, November 1, 1981 and November 2, 1980

96,000 [illegible]

	1982	*1981*	*1980*
Sales	$162,659,136	$159,178,207	$149,099,362
Operating costs and expenses:			
Cost of sales	83,995,572	78,954,483	70,562,369
Selling and administrative expenses	62,306,449	61,221,464	53,742,651
	146,302,021	140,175,947	124,305,020
Operating Profit			
Other income (expense):			
Interest—net	(520,047)	(1,569,703)	(1,302,899)
Currency exchange—net	(1,045,392)	(2,305,514)	413,867
Other—net	56,472	(854,663)	448,522
Income before income taxes	14,848,148	14,272,380	24,353,832
Income taxes			
Current	6,549,208	5,635,610	11,385,562
Deferred	(899,208)	(1,065,610)	(548,888)
	5,650,000	4,570,000	10,836,674
NET INCOME	$ 9,198,148	$ 9,702,380	$ 13,517,158

Exhibit I–2

Brazos Corporation
REACH Division
BALANCE SHEET
October 31, 1982 and November 1, 1981

	1982	1981
ASSETS		
Current assets:		
Cash	$ 11,176,403	$ 1,466,701
Receivables	33,328,384	33,787,696
Inventories	31,900,323	39,025,255
Deferred income taxes	3,874,316	3,070,394
Prepaid expenses	492,996	389,905
TOTAL Current Assets	80,772, 422	77,739,951
Property, Plant and Equipment—net	35,582,447	27,377,734
Intangible assets—net	1,529,399	2,041,834
Other assets	677,771	583,564
	$118,562,039	$107,743,083
LIABILITIES AND SHAREHOLDERS' EQUITY		
Current liabilities:		
Notes payable	$ 1,924,107	$ 1,065,996
Accounts payable	5,620,308	6,994,100
Income taxes	3,005,252	3,484,809
Accrued liabilities	14,428,671	12,939,587
Customer advance payments	2,037,786	3,114,855
Current maturities of long-term debt	695,040	701,379
Current obligations under capital leases	806,312	721,628
TOTAL Current Liabilities	28,517,476	29,022,354
Long-term debt	18,130,573	10,298,190
Obligations under capital leases	1,268,478	1,259,779
Deferred income taxes	668,337	726,895
Equity		
Brazos Holdings	12,500,468	11,805,362
Cumulative translation adjustments	(12,664,443)	—
Retained earnings	60,141,150	54,630,503
TOTAL Shareholders' equity	69,977,175	66,435,865
	$118,562,039	$107,743,083

world's output. For example, the U.S. robot market totalled more than $90 million in 1980, compared to $382 million in Japan. Forecasts call for Japan to account for 62.3 percent market share of the $3.45 billion robotics market in 1990.

According to U.S. Department of Commerce data, over 50 U.S. firms currently manufacture industrial robots, and the number is growing. These robotics companies fall into three broad categories:

1. established robot producers that either began in the field (Unimation) or entered early on the basis of their machine tool/processing system emphasis (Cincinnati Milacron, Prab Robots, and others);
2. venture capital groups, typically smaller operations spurred by innovation and the prospect of growth (Automatix, Inc., Advanced Robotics Corporation, Mobot, and so forth); and
3. major corporations (GE, IBM, Westinghouse) with an existing high technology emphasis seeking both to parlay their related strengths into a share of the robotics boom and to support, through robotics development, their other interests in factory automation.

A select listing of the leading U.S. robot producers and their shares of U.S. market is shown in exhibit I–3. Currently, foreign producers account for a small fraction of total sales, since foreign producers tend to be busily engaged in meeting local demands. Japan was exporting less than 3 percent of its production, but targeted a 15 percent figure for 1985. Since Japan's Ministry of International Trade and Industry (MITI) has placed a high priority on the infusion of robots into Japanese industry in order to improve production, a leasing arrangement has been established that should give a greater boost to Japanese robotics industries. Other countries involved in robotics production include: West Germany, Sweden, the U.K., France, and Italy. France, in particular, has given extensive government support to the advancement of technology in the field. Finally, a recent characteristic of the industry has been a number of intercountry joint

Exhibit I–3
U.S. Robot Producers: Domestic Sales and Market Share, 1980–81

Company	*1980*		*1981*	
Unimation/Westinghouse	$40.00	(44.4%)	$ 68.00	(43.8%)
Cincinnati Milacron	29.00	(32.2)	50.00	(32.3)
DeVilbiss	5.00	(5.5)	6.50	(4.2)
Asea, Inc.	2.50	(2.8)	9.00	(5.8)
Other[a]	13.50	(15.1)	21.50	(13.9)
Total	$90.00	(100.0%)	$155.0	(100.0%)

Source: U.S. Department of Commerce.
[a]Including REACH, Copperweld, etc.

(France) and Cybotech (U.S.) offer just one example, as do Siemens AG (West Germany) and Allis-Chalmers (U.S.). Exhibit I–4 summarizes both current and forecasted U.S. sales and production.

The REACH Organization

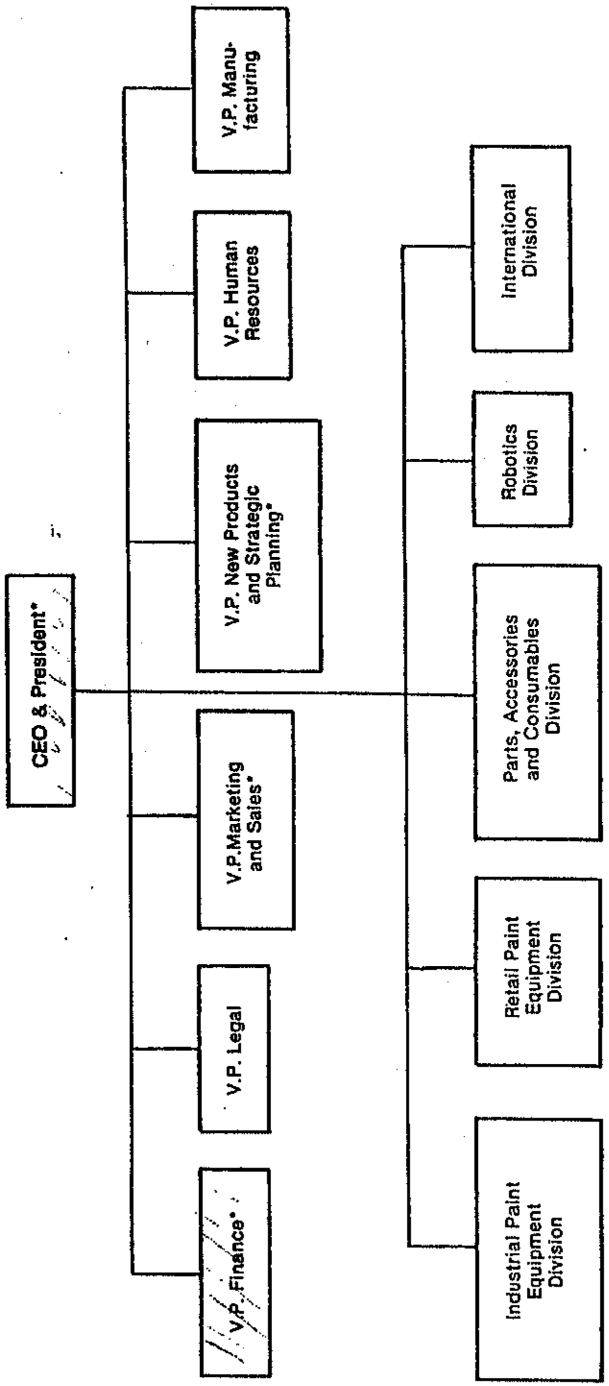
REACH and its various divisions had evolved organizationally over the years into the structure shown in exhibit I–5. Reporting to Grafton, the CEO and president, were six functional vice-presidents of finance, legal, marketing and sales (Palmer), new products and strategic planning (Green), human resources, and manufacturing. Grafton had selected three of these vice-presidents (finance, marketing and sales, and new products and strategic planning) to serve with him on the company's four-member Executive Policy Committee. Thus, in reality, these three vice-presidents wielded more clout than their nominal peers in legal, human resources, and manufacturing.

Also reporting directly to CEO Grafton were the general managers of

Exhibit I–4
U.S. Robotics Industry

	1980	*1981*	*1982*	*1983[a]*	*1985[a]*	*1990[a]*
Sales ($ millions)	90	155	205	270	540	2070
Production (units)	1450	2100	3075	4000	7715	32350

Source: Robots VI Conference, Projections
[a]Including REACH, Copperweld, etc.



*Member of Executive Policy Committee.

Exhibit I–5. Organization of REACH Corporation

REACH's five operating divisions. Grafton's span of control of 11 managers reporting to him directly had been some concern, but Grafton preferred to function as both chief executive officer and chief operating officer. In his view, if capable and strong managers were put into the 11 positions, he could delegate to them without worrying about the need to become too "hands-on" and involved in day-to-day decisions. In REACH's structure, the corporate vice-presidents exercised functional authority whenever comparable functions existed within the divisions. Specifically, the vice-presidents of finance, marketing and sales, and manufacturing had functional counterparts within the divisions, whereas the vice-presidents of legal and human resources did not. These latter two corporate activities were centralized and handled legal and personnel matters for all the divisions. While the Vice-President for New Products and Strategic Planning did not have an identical function within any of the REACH divisions, he definitely exercised functional authority over aspects of both divisional marketing and R&D. Indeed, there had been some confusion over the proper purview, within the divisions, of Vice-President of Marketing and Sales Palmer and Vice-President of New Products and Strategic Planning Green.

The organization of REACH's robotics subsidiary was nearly identical to that of its sister divisions, with the exception of the international division. Exhibit I-6 shows the basic organization, with more detailed attention given to the marketing component.

REACH's Marketing Strategy and Tactics (Robotics Division)

REACH originally employed its industrial paint equipment sales force to handle its robotics line. Very quickly, REACH management recognized that the robotics purchaser often had limited (or no) knowledge about the potential uses of this new high-tech product category. In fact, REACH's design engineers often spent extensive time working with prospective customers, since the paint equipment salesmen lacked the engineering know-how to complete the sale. Yet, initial sales were too small (and infrequent) to develop a specialized sales force.

Therefore, from the early 1970s through 1978, REACH used industrial distributors to identify and qualify prospects, handle the initial presentation, and complete the sales. The interim technical or application—specific stage of the sale was handled by REACH design engineers. By 1978, however, it was recognized that 80 percent of REACH's robotics sales were to the Big Three auto producers and a small handful of automobile industry suppliers.

Following the lead of Unimation and Cincinnati Milacron, now indus-

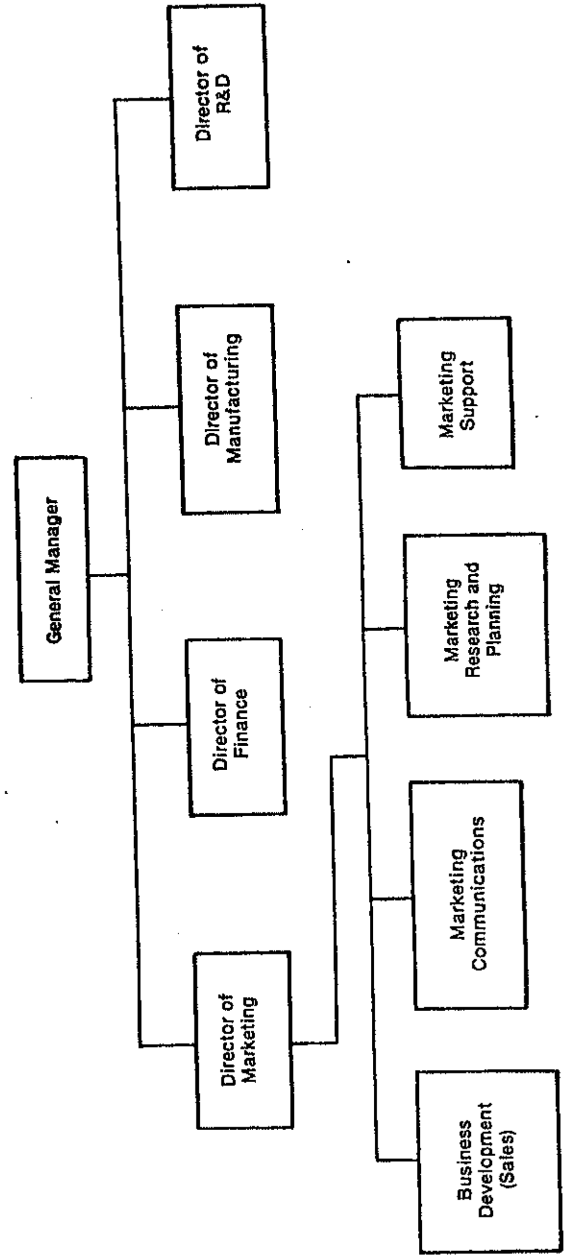


Exhibit I-6. Organization of REACH Robotics Subsidiary Marketing Function try leaders, REACH developed its own sales force of five applications engineers in September 1978, to handle its major clients (automotive). These five applications engineers were responsible for both the selling and the design-specific function, since the price of the product was dependent on the amount of modification needed to meet the buyers' requirements. (If the modifications and special requirements were too technical, the applications engineers would draw on the expertise of REACH's R&D department.) The remainder of REACH's customers (and the identification of new customers) remained the primary responsibility of the three industrial distributors that were retained after the reorganization.

Product

The early automated paint-spraying process that provided REACH's initial growth has long since evolved into a highly complex system. Even today, REACH is recognized as the state-of-the-art leader in that segment of the industry. In robotics, REACH had a similar early edge when Palmer joined the company and headed its R&D wing. As R&D costs increased during the 1970s, the company's Executive Policy Committee formed a product strategy that called for REACH to assume what might be termed a "followership" or imitator role in the industry. Grafton stated, in a meeting in 1975, that REACH could not expect to do everything in the way of R&D that the Cincinnati Milacrons, Unimations, and DeVilbisses were doing without seeking assistance from its parent; a step that he was unwilling to take. Rather, the company chose to depend on the modifications made for the auto industry and other top customers to trigger new products (and adaptations) and to stay close to the state-of-the-art via its "followership" role in the industry. "We want to lead in applied, not pure research," was Grafton's exact statement. As a result, REACH has remained competitive, but has not been the industry innovator, except in particular applications breakthroughs. Its percentage of sales directed to R&D has, therefore, remained close to the industry average.

Distribution

At present, the Robotics Division still employs the channel of distribution described in the previous section. Its current applications engineering group now numbers six and the United States is divided into two geographic zones (east and west) with an applications engineering manager overseeing each zone. Typically, each applications engineer is now teamed with a design engineer when a specific proposal to a buyer is being made; fewer and fewer

orders are routine, with most sales requiring the development of technical specifications for each prospect. REACH's application engineers (and design engineers) often work closely with the buyer's production managers in the development of an optimum automated system. The applications engineers are compensated through a combination salary-plus-annual-bonus system.

Promotion

REACH Robotics has dramatically increased its advertising budget in the past five years in order to match the efforts of its competition. The division has a marketing communications manager, who reports directly to the division's Director of Marketing and, via matrix, to the corporate promotion director, who is part of the staff of the Vice-President for Marketing and Sales. The division has a promotional budget of 2½ percent of the past year's sales, or $350,000. The budget is used mainly for trade journal advertising, brochures (direct mail), and trade show participation. For example, the company ran a two-page, four-color spread in all six 1982 issues of *Robotics Today* and in three issues of *Production Engineer*. This campaign's theme reflected the company's long experience in working with its customers to improve their productivity by helping them select the right robot.

The promotional budget for the Robotics Division is somewhat higher than those of the other divisions. However, this reflects the increased competitiveness in the robotics industry today.

Marketing Research

The Robotics Division does a limited amount of marketing research. Its three ongoing sources of information are (1) feedback from customers via its sales force; (2) information cards employed at trade shows; and (3) data obtained via media "bingo" cards. The latter two sources have twofold purposes. The trade show information cards provide useful basic industry data on the companies completing the cards and also help REACH to evaluate participation in the particular trade show. The "bingo" cards provide similar information on the companies completing them and help to determine the readership of the magazine or journal in which the advertisement appeared. The company information that REACH's marketing staff obtains from the cards (trade show or "bingo") includes the size of the company, its industry, geographic location, and so forth. If the data are maintained on a long-term basis, it will help REACH's marketing staff track changes in the demand for robots. To date, REACH has never employed the services of a marketing research firm to conduct special studies for the company.

Pricing

Price was not a factor in the sale of robots in the early 1970s; a 100 percent, or greater, profit margin was not uncommon. Gradually, as competition entered, the buyer gave more attention to price, especially for routine purchases. ("Routine purchases" refers to sales that required little, if any, product modification.) Like most of the industry leaders, REACH tended to stress service, reliability, and its ability to adapt its robots to the customer's needs, or non-price competition. Less than 20 percent of its sales to date have involved a standard product, requiring extensive line adaptation instead. However, major buyers, such as GM and Ford, are tending more and more to provide their own specifications and to need only minimum interface with REACH design engineers. In these instances, the company is being forced to submit bids for the projects. The company's position is now to meet its competitors' prices for standard products, with much of the profit being maintained in the sale of parts, accessories, and consumables.

Current Situation at REACH

In late November 1982, Lawrence Grafton's Thanksgiving holiday became less pleasant when he received this succinct handwritten note, via Federal Express, from "Big Luke" Whitney about REACH's profit trend: "Net income off 48% since 1980. Recession's been hard on capital equipment . . . but not that bad. Will see you shortly. LW"

Tom Green had already sent a note to the other members of REACH's Executive Policy Committee urging an immediate meeting to consider the company's deteriorating profit picture. Grafton had also directed his five divisional general managers to explore the diagnosis and prognosis for their business units. He was particularly concerned with the Robotics Division. REACH's top management had realized for some time that the paint equipment lines of business were mature "cash cow" types, whereas robotics was intended to be the high-growth "star" that carried REACH upward and onward in the 1980s and beyond.

In mid-December 1982, REACH's Executive Policy Committee convened specifically to discuss robotics. Grafton, who had adjourned to Florida for a golfing hiatus, was not present. As was typical, the Executive Policy Committee meeting rather quickly became a heated dialogue between

Palmer and Green. Within fifteen minutes after the coffee had been poured, Tom Green was following his usual blunt, aggressive approach: "Steve, you know we were lucky in the 1970s. . . . We had no competitive problems. . . . Price wasn't important in robotics. . . . I warned you last year that times have changed." (See exhibit I–7.)

Steve's retort was unexpectedly low key for him: "Tom, calm down for a minute and take a look at our industry position. Our $8.5 million in sales for 1981 put us number four in the industry, and I grant you, was a far cry from the totals for Milacron and Unimation. But, we beat DeVilbiss and pushed Asea. This year, our February sales to the auto producers was so big, we are likely to move up even further. My bet is that when the industry data for '82 are published, we will be number three. Not bad for an industry still in the growth stage. Why rock the boat?"

"Steve, maybe its our differences in background, but I feel we have to begin to take a long-run view on this industry. The word at last year's trade show supports this opinion that some new, tough competition is coming along. And we are relying very heavily on a few key customers. I don't need to 'what if' you to death and I know you get tired of hearing me . . . but let me say again that I think we need to take a close look at the market. Perhaps, there are some market segments we should attack. Is our distribution approach adequate? I feel that Reg Gardner [Robotics Division general manager] may be a bit complacent. He needs to tell us where we should be going." At this point Randall Logan, Vice-President of Finance, saw his opportunity to cut in: "Guys, we are going to get nowhere today like this. I think we ought to bring Gardner before the group and see what he has in mind. This is like trying to make an investment without even knowing what a company's R.O.I. is. Why not have Gardner meet with us during the first week in January and let's hope Larry [Grafton] can make the meeting." Without further dialogue on the robotics situation, the meeting ended with a discussion of the annual company Christmas party to be held at the Sheraton Hotel the following Thursday.

Exhibit I–7

Memorandum

TO: Executive Policy Committee DATE: January 18, 1982

FROM: Tom

SUBJECT: Industrial Marketing article (January 1982)

I think the attached raises some significant issues regarding the Robotics Division's future direction. What do you think?

On January 5, 1983, Reg Gardner was not at all unhappy to be called to the meeting with the Executive Policy Committee. Churning over in his mind, as he drove toward the ten-story reflective-glass headquarters building that had won an architectural award for Maze and Franklin Associates in 1980, were a number of concerns and puzzling questions. What was happening to the robotics industry? What had seemed to be a competitive comaraderie—it had been fun to go to the trade shows—had recently become all business. Several fellow company heads had even told him confidentially that they might pull out—Nordson for one. And the battle for patents and the number of foreign companies made things difficult. But what had surprised him most was the comment made by Ben Schooler, the applications engineer handling the Detroit area, at the Christmas party. Ben had said "Things seem to be cooling at our prime "Big Three' auto customers. None of the engineers will give me any ideas about how to improve our manipulators." I'm going to tell the committee that our $14 million sales for 1982 may be difficult to match a year or two down the road. I really need Tom's and Steve's inputs.

All of the Executive Policy Committee were present for the meeting, a fact that was not lost on the group and a reflection of the seriousness of the meeting. A well-tanned Larry Grafton opened with the following statement: "I think the thing that impressed 'Big Luke Whitney the most when he had Brazos acquire us was that we represented the future with our robotics area. Things are at a plateau in the paint equipment area and with the high dollar, we can't expect our international division to bail us out by giving more growth overseas; so that leaves robotics and why Reg is here today. Steve, do you or Tom have anything to add?"

Steve quickly took the lead by saying, "Larry you are absolutely correct. This industry is forecast to hit $2 billion in 1990, compared to its $200 million size today. It may be a little costly in terms of short-term profits, but I think all we need to keep things rolling is to do more of what has gotten us where we are today. Among other things, I would like Reg to tell us how he might use more dollars for advertising and sales people. . . . I mean application engineers."

Before Reg could answer, Tom interjected: "Larry, as you might guess, Steve and I are on opposite sides of the fence on this one. I think, with a market that is expected to increase tenfold by the end of the decade, we need to take a longer-term look at our situation. Will this growth mean new market segments, important product changes, or what? I hate to see us look for more colorful Band-Aids, when we may need to tourniquet. What do you think, Reg?"

Now Reg knew how it felt to be caught in between the proverbial rock [illegible]

was quiet until Randy Logan said "I think that what we need is an outside perspective. Who are some good marketing consultants to contact?" About that time, Jeannie Shepard, Grafton's secretary, knocked on the door and handed him a message . . . and it appeared the meeting was at an end.

At Issue

Assume that your consulting group is in the position of advising REACH's Executive Policy Committee on what to do about the Robotics Division. *Some*, but not necessarily all, of the issues that the consulting group should consider addressing are these:

1. How can REACH Robotics (RR) best go about identifying market segments?
2. How might RR stimulate and evaluate ideas for commercially successful new products or product modifications? Should RR be competition-oriented and watch what competitors do, be customer-directed and rely on buyers for suggestions, be R&D-driven and let R&D people come up with new product developments, or just how should RR proceed?
3. What kinds of information does RR need to make these types of decisions? How can the information be obtained and by what techniques? How often should it be obtained? By whom?

As a consulting group, follow up on the issues (stemming from the January 5 meeting). In particular, your assignment is to identify in detail all alternatives and indicate and support the alternative you recommend that RR take. The time is now January 18, 1983. You need to provide some direction for the company to take within one month. The annual International Symposium on Industrial Robots/Robots 7 will be held in Chicago on April 17–21, 1983.

CHAPTER 5

Life-cycle environmental management and product innovation: the case of the Volkswagen Audi Group

Andy Gouldson

INTRODUCTION

> One of the most crucial tasks facing us in the future will be to design both industrial processes and products in such a way that the possibility of undesirable impacts on the environment is precluded – insofar as is technically possible – from the very outset. It is vital that we should not place undue strain on our natural resources, for only then can we safeguard the company's long-term prospects.

This statement, taken from Volkswagen Audi Group's 1992 Annual Report, could come from the environmental policy of any company. It recognises that continued economic viability relies on continued environmental viability, and in a very broad sense it commits the company to some level of environmental innovation and development.

However, many environmentalists suggest that the car, the core product of VW, has a greater impact on global sustainability than any other consumer product manufactured on this planet (Ekins *et al*, 1992). Is it possible therefore that a company which manufactures such a damaging product can ever come close to realising the goal of precluding environmental damage from the outset?

The very essence of the environmental debate is reflected in the polemic surrounding the environmental impacts of the automobile industry. In terms of sustainability at least, the ideal remains that society avoids environmental damage by demanding and being supplied with products which are compatible with the goals of sustainability. Clearly this ideal requires fundamental changes in societal thought and economic structure. In relation to sustainable mobility, it will require a change in the reliance that society places on the car, and a strategic U-turn in the operations of the oil and automotive industries, two of the most powerful multi-national industries in the world. While we are waiting to arrive at this utopia, companies such as VW, based on the drive for competitive advantage, are taking steps to improve the environmental performance of both their products and processes.

PRODUCT ENVIRONMENTAL IMPACT

The world now has more than 400 million cars, consuming over 200 billion gallons of oil each year and contributing 17 per cent of global CO_2 emissions (Ekins *et al*, 1992). In the UK, motor vehicles account for 80 per cent of lead emissions, 85 per cent of carbon monoxide, 45 per cent of nitrous oxides and 28 per cent of hydrocarbons (Rees, 1991). In all, cars produce over 1,000 types of chemical emission (Friends of the Earth, 1988).

In addition to their direct environmental impact, motor vehicles and their supporting infrastructure are responsible for significant land use, habitat destruction and loss of amenity. Cars are also associated with significant health and safety impacts. In the UK, for example, 6,000 people are killed and 300,000 injured each year on the roads (Rees, 1991).

The key environmental impacts in the life cycle of a motor vehicle relate to the use of the product because of the massive amount of environmental damage done through the burning of non-renewable fossil fuel and the consequent output of pollutants from that process. But there are also significant areas of environmental impact in product manufacture. As a major manufacturing industry, the automotive industry faces the common issues of resource consumption and waste generation. The market size, structure and product complexity of the automotive industry dictate that automotive manufacturers are also partially responsible for the environmental impact of their suppliers, and for all those impacts associated with servicing the product throughout its lifetime. The post-consumer disposal of automobiles also contributes significantly to the waste disposal problems which are now ubiquitous throughout the industrial world.

Therefore, as manufacturers of a product which generates an onerous environmental impact throughout much of its life, the automotive industry is beginning to be held responsible for the environmental impact of its product from cradle to grave.

CONSUMER PRESSURES

Clearly, governments and individuals are concerned about the impact that motor vehicles have on the environment. However, despite the level of the impact, the scale of the public response in relation to consumption and voting patterns has as yet been minimal. In the UK, notwithstanding increases in the cost of cars, fuel, tax, or congestion, car ownership and use have doubled between 1968 and 1988 (Ekins *et al*, 1992), and are predicted to increase by between 83 per cent and 142 per cent by 2025 (Rees, 1991). Therefore, irrespective of the growth in environmental awareness and concern amongst its customers, the automotive industry as a whole has not been subjected to significant degrees of green consumerism.

While the environmental concern of consumers does not impact on the apparently unrelenting demand for cars, it does drive companies such as VW to develop and maintain an innovative lead in the environmental performance of their product. Competition is intense to supply the characteristics that consumers demand from the increasingly homogenised products of the automotive industry. These characteristics include functionality, comfort, style, safety, efficiency and environmental friendliness. However, to date, environmental considerations remain a relatively minor component of the purchasing decision for automobiles. It is not only the producer which holds responsibility for the environmental impact of the product, the environmental concerns of society are evidently not impacting on the demand that the individual offers to the automotive industry.

Nevertheless, regarding their environmental performance, individual companies and products are subjected to more intense scrutiny than the industry as a whole. Substitutability is greater between automotive brands and models, than between private vehicles and alternative forms of transport. The amount of 'product loyalty' awarded to road transport has therefore offered significant market power to the industry as a whole, while individual manufacturers strive to develop the aspects of environmental performance which may form one of the many ingredients of competitive advantage.

GOVERNMENT PRESSURES

The reticence or inability of the consumer to substitute the use of cars for other forms of transport has had a profound influence on the transport policies which governments have adopted. In many countries, in the absence of an effective and affordable public transport network, there is little public, and hence governmental, support for measures which seek to lessen the use of cars. Furthermore, governments throughout the world have been reluctant to impose extra costs or regulations on the use of road transport due to its economic and social significance. Governments have also been effectively lobbied in many instances by the combined economic power of the oil, automotive and construction industries. As a result, the automotive industry has escaped the major controls which the life-cycle impact of its product would appear to warrant.

As with any major industry, however, automotive manufacturers are subject to the range of health, safety and environmental regulations that now face all industries in the Western world. Their productive efficiency relies on their ability to develop meaningful strategies to address issues of environmental compliance, stakeholder pressure and competitiveness.

For the purposes of this study, however, emphasis will be placed on the efforts of the Volkswagen Audi Group in the field of product development and life-cycle environmental management. While mention will be made of the internal environmental management strategies that VW are developing, VW are currently implementing environmental auditing pilot studies for internal production processes, the detailed results of which are not yet known. As a result, a broad overview of the environmental management strategies applied in VW's production processes will be offered, while greater emphasis will be placed on the responses developed by VW to the complex life cycle of the car, particularly in relation to product design and disposal.

THE BACKGROUND TO VOLKSWAGEN

Volkswagen was established in 1938 and, since then, through the Volkswagen Audi Group, which includes Volkswagen, Audi, SEAT and SKODA, the company has grown to control 9 per cent of the world market and 17.5 per cent of the Western European markets for automobile production. The Volkswagen Group now produces 3.4 million vehicles per year, around 65 per cent of which are manufactured in Germany. The group manufactures in 12 countries throughout the world and employs 273,000 people directly. Prior to its review of its suppliers in 1993, VW purchased from around 3,000 suppliers, and has an annual turnover of DM 53.2 billion.

EARLY INITIATIVES IN ENVIRONMENTAL PROTECTION AT VOLKSWAGEN

Due to water shortages in the region surrounding VW's major manufacturing facility in Wolfsburg, Germany, environmental considerations have played a central role in the production process since the plant's construction in 1938. Since this time, production processes have been based on the minimisation of water use through the development of water recycling processes. An ethos of efficient resource use has therefore been present since the company's founding.

However, environmental considerations in the production process were not widely recognised as an operational concern until the late 1980s. As in many companies prior to the advent of widespread environmental awareness, environmental management issues were implicitly monitored and controlled through day-to-day production and health and safety management practices. Similarly, efforts to improve product environmental performance through vehicle fuel efficiency were motivated by economic rather than environmental

concerns. Therefore to state that environmental management strategies are only now emerging throughout VW's activities would be a misrepresentation. The inherent links between economic efficiency and environmental performance have ensured that, where environmental costs and benefits are internal to the firm, the environmental performance of both production and the product have been optimised for many years but have only recently been recognised and communicated as such.

As with most other companies, environmental issues emerged as critical strategic issues in their own right in the late 1980s. At this time, the first public pressure was exerted on VW in relation to the proposed development of a new vehicle paint shop in Wolfsburg. Although all employees are assigned environmental obligations, VW now employs a department of over 100 staff with explicit environmental responsibilities. Aside from the advance of public pressure, VW recognises that its environmental performance inherently relates to both its operational efficiency, for instance through waste management, and to its public relations record.

MINIMISING THE OVERALL ENVIRONMENTAL IMPACT

VW's environmental management strategies implicitly seek to minimise the overall impact of both the product and the process of its manufacture. In theory, some form of life-cycle assessment (LCA) should be utilised to collect and analyse the information with which decision makers can address the impact of a product (including its manufacture) from cradle to grave. While a formal framework of LCA has not been applied, VW are seeking to address the environmental impact of the main areas of their supply chain and product life cycle. Thus, strategies of varying intensity are in place to improve environmental performance in each of the major stages of the life cycle as illustrated in Figure 5.1. An assessment of the initiatives that have been or are being developed in each of these stages follows.

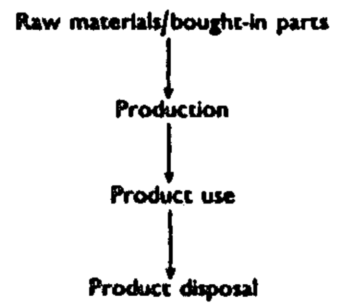


Figure 5.1 Stages of the product life cycle

DIFFUSION OF ENVIRONMENTAL COMMITMENT TO SUPPLIERS

VW has recently established a framework for the assessment of the environmental performance of its 3,600 dealers in Germany. VW Audi partners have access to the VW Audi Environmental Consultancy Service which offers advice on environmental performance, particularly in relation to the technologies and techniques available to VW Audi dealers and their workshops suppliers which can reduce their environmental impact.

Another initiative also seeks to recognise those suppliers which maintain high environmental standards through the incorporation of environmental criteria into the quality assessment of suppliers. Suppliers and dealers are assessed in relation to both internal (VW) and external (legislative) standards to ensure that they comply both with the law and with VW's own policies. However, as yet, no supplier or dealer has been refused a contract as a result of poor environmental performance alone.

Further, in line with its policy of waste avoidance before reduction, reduction before re-use and re-use before disposal, VW actively seeks to use material inputs which are both recycled and upon disposal will be recyclable. The selection of material inputs clearly relates to the strategies that are being developed by VW to design recyclability into the product and to set up the necessary infrastructure to collect and recycle its used products. Analysis of these initiatives is offered below.

ENVIRONMENTAL MANAGEMENT IN THE PRODUCTION PROCESS

Initiatives which today would be given an environmental label have been under way within the main production facility since its inception in 1938. The main focus of early environmental initiatives in the production process related to water usage. Since 1973 VW has reduced its consumption of mains water by 40 per cent. Of a total consumption at the Wolfsburg plant of 27.67 million m^3 in 1990 (the equivalent to the consumption of 7 million people), only 3.5 million m^3 came from fresh drinking water. As part of this system of water recycling, each unit of drinking water is subsequently used six times as process water. The plant has now achieved a total water recycling rate of 87.3 per cent.

Notable process changes have also been made in relation to energy use and its associated air emissions. The extruding, casting, welding, grinding, sticking and painting of metals and plastics in automobile manufacture consume considerable amounts of energy and can generate air pollution problems relating both to the health and safety of workers within the plant and to the community outside it.

The production plants within Wolfsburg, Hanover and Kassel in Germany

together have energy-generating capacity of 691 MW of electricity and 1,265 MW of heat. In total, production in VW consumes 740,000 tonnes of coal, 10,000 tonnes of heating oil and 260,000 tonnes of natural gas each year. Therefore, it goes without saying that energy efficiency initiatives within VW are well established. In Wolfsburg, VW's combined heat and energy generation, which is economically and environmentally more efficient, also supplies electricity and community heat to the surrounding populations. Within the plant, at all external temperatures above $-5°C$, the factory is sufficiently heated through heat exchangers driven by surplus process heat. Clearly, such a scheme has both economic and environmental benefits, and fits in with VW's policy to apply the best available technologies at all points, which, in the long run, are seen to be more efficient.

To improve the environmental performance of its energy demand, low sulphur content fuels are used, and traditional coal-burning furnaces are being replaced with fluidised bed coal burners which are considerably more efficient and less polluting. Additionally, flue gas desulphurisation and catalytic conversion are used to reduce sulphur dioxide and nitric oxide emissions. Air emissions are also electrostatically precipitated to reduce dust emissions, the collected dust is then used within the construction industry. Sulphur dioxide emissions have been reduced by 72 per cent in the last 20 years, and dust emissions have fallen by 59 per cent. The investment of time and money which has enabled the development of better technologies in the production process has ensured that VW exceeds many of the relevant emissions standards. Air emissions are constantly monitored and controlled to assure continued compliance.

The development of environmental auditing methodologies

On a wider level, day-to-day operational management has also included regular auditing of quality, waste management, and health and safety. A variety of initiatives have been, and continue to be, developed, and VW is currently formulating an environmental audit methodology for use in all of its sites. At present the environmental audit programme only covers German facilities, although once the pilot project is concluded and the audit methodology is refined, it is planned that the scheme will be extended to apply to other sites.

Rather than seeking to fine-tune existing systems, the audit methodology seeks to address information gaps in areas of poor performance and to uncover integrated solutions to efficiency, quality and environmental management issues within VW. Due to the early stages of the environmental audit programme, as yet no new technologies or management practices have been implemented as a result of its findings, but VW is clearly willing to act on these issues in the future.

Although the environmental audit programme could eventually have external benefits, it is essentially driven by internal motivations for information-gathering and dissemination. It is important to recognise, however, that in its main facility VW employs some 55,000 staff, so the networking of information is not a simple task. Nevertheless, the results of the audit will be disseminated throughout the company. This will reinforce the company-wide environmental protection training programme that has been established in order to develop the attitudes which VW recognises as a vital component of efficient environmental protection. Indeed, VW views its training programme as a more efficient strategy for environmental protection than the application of new technologies. While currently there are no schemes to recognise and reward environmental initiatives within the company, VW is considering introducing such a scheme to foster commitment to environmental performance amongst the whole workforce.

In relation to the external communication of the audit programme, it is envisaged that the audit results will be verified by external consultants, and that VW will eventually register some of its facilities under the EC eco-management and auditing registration scheme.

ADDRESSING THE ENVIRONMENTAL IMPACT OF THE PRODUCT

As outlined above, the major area of environmental impact for the automotive industry is the impact of the product in use. It is quite possible that the entire future of the automotive industry depends on its response to this issue, particularly as any advances in the environmental efficiency of each individual product will be offset by the rapid growth in the overall number of cars on the road throughout the world.

Governmental responses to the threat of global warming alone are therefore likely to be a fundamental strategic issue for the automotive industry, although to date the powerful lobbying activities of the world's fossil-fuel-dependent industries to slow down global responses to the threat of global warming, have been severely criticised (Leggett, 1993). Obviously, few companies would reveal any support that they might offer to such lobbying activities.

While VW does not accept that the phenomenon of global warming is as yet proven, it is committed to improving the fuel efficiency of its products as rapidly as possible. As VW perceives the traditional characteristics of product differentiation to be diminishing in its market, competitive edge through technical standards of environmental performance will become a more significant selling point. For the industry as a whole, its commitment to the advancement of product efficiency may well determine the extent to which it is regulated in the future. As self-regulation rather than government regulation is the preferred option, this gives an added incentive for the automotive industry to continue its efforts to improve product efficiency.

It is fortunate that the automotive industry can respond to the combined threats of global warming and intense government regulation by harnessing the economic self-interest of its customer. Product fuel efficiency, economic

efficiency and environmental efficiency are synonymous for the industry's consumers, and the forces of competition will dictate that every major automotive manufacturer implements meaningful research and development programmes to address these common issues. It is doubtful whether this scale of commitment into the research and development of clean technologies would be afforded under any system other than the capitalistic structure of the multinational automotive industry.

VW has prided itself on its position as a leader of product innovation in the industry. Environmental management strategies in this respect are two-pronged. Firstly, initiatives relating to the fuel efficiency of its cars, and secondly, developments to design-in product recyclability and to encourage the necessary infrastructures to allow product recycling. Each of these issues will now be addressed in turn.

FUEL EFFICIENCY

VW states that its central aim in developing technologies for environment-friendly products is to reduce fuel consumption in order to conserve fossil-fuel energy sources and to cut CO_2 emissions. The drive for improved product efficiency is supported by a research and development programme which, in 1992, had a budget of DM 3 billion and employed some 14,000 staff. VW has been able to reduce the average fuel consumption of its motor vehicles by 25 per cent over the last ten years and, largely as a result of the adoption of catalytic converters, hydrocarbons and nitrogen oxide emissions have been reduced by 90 per cent.

VW accepts that increases in the price of oil, for instance, as a result of the implementation of a carbon/energy tax, would increase the incentives to develop alternative fuel sources, although it suggests that significant increases in the price of fossil fuels would be necessary to sever the strong bond between consumers and their cars. In the absence of such changes in the relative prices of different fuels, VW is developing alternative technologies for use in particular circumstances. In Brazil, for example, in the early 1970s, VW developed engines powered by ethanol fuels derived from sugar cane, and has since built over 2 million cars to run on this alternative fuel source. Although the life-cycle carbon balance of ethanol fuel is better than that of petrol (that is, in aggregate it contributes less to the greenhouse effect) the wider adoption of bio-fuels is restricted by both climatic and land-use considerations.

VW is also cooperating with various other companies, including electricity utilities, battery manufacturers and other vehicle manufacturers to develop technologies for the use of electrical energy in transport, particularly in relation to public transport in inner city areas where local air quality is a significant environmental problem. Once more, the automotive industry is in an ideal position to resource and undertake research into the technologies which will be needed in the future to develop truly sustainable patterns of mobility.

There is evidence to suggest that legislative and regulatory standards are driving technical innovation in the motor industry in this respect. In California, for example, where local air quality is a significant problem, 2 per cent of all vehicles must be 'zero-emissions vehicles' (ZEVs) by 1998, and 10 per cent by 2003. Although these targets may force the development of more efficient technologies, a central problem associated with electrically-powered transport remains. Specifically, the electricity must be generated and this in turn has associated environmental impacts. Nevertheless if, in the future, energy-generating capacity shifts towards more renewable sources of electricity, the potential for sustainable mobility will be considerably enhanced by the technology-forcing standards adopted in areas such as California. Furthermore, as the USA has driven product standards in the automotive industry in the past, for instance in relation to catalytic converters, these targets may provide a strategic insight into the future of product standards for the car industry. Some commitment to research and development in this field is therefore wise.

At present, however, VW does not foresee a time when the focus of its product moves away from fossil fuels and towards bio-fuel sources or electrically-powered cars. Rather, VW is striving to increase the fuel efficiency of traditional fossil-fuel-driven engines. Indeed, VW has been responsible for a number of milestones in the advancement of fuel-efficient technologies in the automotive industry. VW was the first manufacturer to develop and market small diesel engines for cars, and has developed the diesel catalyst and the turbo diesel engine which, with low emissions, can now provide fuel efficiencies of 46.2 miles per gallon at a speed of 103 mph. More generally, technological developments in standard production engines have enabled an average 25 per cent reduction in fuel consumption over the last ten years.

Besides more environmentally-friendly engines, which are already in full-scale production, VW has developed a number of other technologies which are currently being market-tested. The main advance has been the development of the 'Automatic Momentum Gearbox' (AMG). The AMG, which is being tested on the Eco-Golf, automatically disengages the transmission and cuts off the engine whenever the drive power from the engine is not used, so the car only continues to roll under the force of its own momentum. This enables zero fuel consumption and zero emissions over long periods of day-to-day use, particularly within urban areas. The AMG only re-engages and restarts the engine when the accelerator pedal is pressed again. In daily operation, the Eco-Golf requires 20 per cent less diesel fuel and emits 10 per cent to 20 per cent less pollutants in its exhaust.

The market success of product innovations such as these depends very much on the reaction of the consumer. There is intense discussion within VW on the likely response of consumers to the AMG. VW is also considering a programme of customer education to encourage the successful introduction of the product to the market. Nevertheless, unless there is a favourable reaction from the consumer, the diffusion of cleaner technologies, such as this, will be curtailed for economic reasons. Clearly it is vital that VW adopts both a market-led and market-leading strategy in the development of new product technology and educate the consumer about its new product innovations.

The patenting and successful introduction of technologies such as the AMG into the market will afford VW a considerable competitive advantage through protected product differentiation. Should technologies such as the AMG be rejected by the consumer, the automotive industry can rightly claim that it has developed cleaner technologies and that the barrier to the improved environmental performance of its product is the consumer. Potentially this is a powerful argument to dispel the prospect of future regulation for the automotive industry, suggesting that the emphasis of regulation should be placed on the consumer rather than the producer.

PRODUCT RECYCLING

One of the major life-cycle environmental impacts of the car is in its final disposal. Indeed, the automotive industry could be criticised for the planned obsolescence of its product, whereby motor vehicles are designed to last for a limited period only, thereby assuring regularly renewed market demand for the industry. Clearly such a policy, whether explicit or implicit, would contribute significantly to the waste disposal problems associated with the industry and its product.

However, there is growing evidence that VW, and the automotive industry more generally, are developing the products, technologies and infrastructure necessary for effective recycling of the industry's product waste. The partial recycling of scrap cars has been under way for many years through vehicle dismantlers and scrap metal dealers. More recently, issues of life-cycle assessment, product stewardship and legislative developments such as the German Packaging Ordinance, which demands that suppliers of packaging materials arrange for their re-collection and recycling, have encouraged industry to develop strategies for recycling. As a result of the German legislative framework for waste recycling, German automotive manufacturers, including VW, are emerging as the market leaders in the global automotive industry in product innovation to encourage recycling. It is important to stress however that recycling initiatives are not only being developed in response to legislative pressure, they are also due to the adoption of product stewardship policies in the automotive industry and the effects of increased stakeholder pressure.

Traditionally, there is a range of factors which impede the development of recycling initiatives. These factors include the lack of economies of scale in collection and recycling for many products (particularly for mixed or contaminated waste streams), the instability of market prices for waste materials, the low and variable quality of recycled products, and hence the lack of an end-market. In combination, these factors combine to discourage recycling activity. However, for a range of reasons, the automotive industry is in a very strong position to overcome these barriers and to develop successful recycling initiatives.

Firstly, the industry and individual producers within it are of a sufficient scale to allow economically viable collection, dismantling and recycling facilities. Further, the size and nature of the product ensures that the industry's product waste is not contaminated through mixing with other materials from other waste streams. In the case of many waste streams, this is a situation which normally increases recycling costs and reduces the quality of the recycled product. While the size and nature of the product favours recycling in the automotive industry, it should be noted that, traditionally, motor vehicles are made up of a wide range of components and materials and are therefore difficult to dismantle, separate and recycle. Nevertheless, scale economies and product reformulation can counteract the difficulties associated with the collection, dismantling and recycling of complex products. VW have undertaken feasibility studies to analyse the possibilities for a regional or supra-regional waste collection association. They have also been developing technologies and techniques for dismantling, cleaning and recycling waste materials in order to generate the highest possible quality of recycled product.

Secondly, car manufacturers are increasingly utilising recycled materials in vehicles which are designed to be easily dismantled and recycled upon disposal. Clearly, the automotive industry could ultimately be both the supplier and consumer of the waste material through recycling and re-using its own product waste. As a result, it is in a possibly unique position to ensure that the materials selected, and the methods of recycling, meet the necessary specifications to make vehicle recycling a feasible option. VW recognises that the success of vehicle recycling depends on the design of the product. This relates to the ease of dismantling, cleaning and reprocessing, considerations which benefit from a reduced number of raw materials used in manufacture. VW has responded to this issue in a number of ways, notably by increasing the proportion of polypropylene in the total amount of plastics used in each vehicle from 25 per cent to 50 per cent, thereby simplifying dismantling, unifying waste streams and generating a recycled product of a relatively higher quality than that which might be achieved if a greater mixture of plastics were used.

Thirdly, the industry is able to ensure that an effective and assured demand is generated for the waste product, potentially enabling the materials life cycle for the car to be closed (see Fig. 5.2), although in reality it is unlikely that 100 per cent recycling rates will be achieved. By buying back its recycled product waste, the industry is able to avoid a major obstacle to recycling that is experienced in many other industries, namely the lack of a stable market for recycled materials. As the leader of a number of recycling initiatives, VW is able to cooperate with other companies downstream in the life cycle of its product, to encourage them to recycle. Without this vertical cooperation in the market, the prospects for growth in the automotive recycling sector would be greatly diminished.

Fourthly, deliberate and planned obsolescence followed by efficient waste

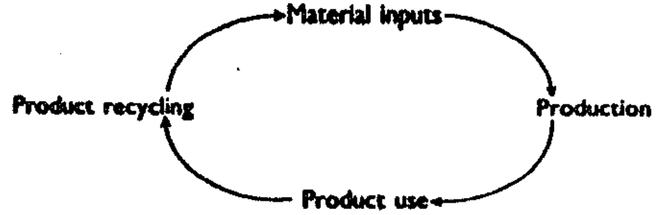


Figure 5.2 Materials life cycle for the car

collection and recycling effectively encourages car manufacturers to 'lease' materials to consumers for the life cycle of the product. Given the rapid advances in fuel efficiency, this allows the industry to periodically re-instal the best available technologies and hence to address one of the most significant environmental impacts of the car, namely its consumption of fossil fuels. Conveniently, this also provides a regularly renewed source of demand for the industry. Companies such as VW are therefore seeking to encourage waste minimisation and the continual application of the best available technologies by extending the life cycle of the materials used rather than the product itself. VW for example is seeking to develop the use of aluminium in vehicle manufacture, not only to reduce weight and hence increase fuel efficiency, but also to facilitate more efficient recycling which would eventually offset the extra raw materials costs associated with aluminium in the first cycle of its use.

The development of recycling activities such as those developed by VW can be seen to have a range of underlying motives. Firstly, they respond to the growing problem of waste disposal and may therefore be seen to be a proactive response to impending environmental legislation. Secondly, they offer a response to increased stakeholder pressure to adhere to the principles of product stewardship by accepting responsibility for the product from cradle to grave. Thirdly, they allow the automotive industry access to valuable recycled material inputs. Fourthly, they address potential criticism relating to the disposability and limited life cycle of the car. By offering to regularly update the road transport stock with the best available economic and environmental technologies, the automotive industry can be seen to be addressing key environmental concerns while assuring the future of its market. Recycling strategies such as those of VW have therefore translated a potentially significant market threat into a potentially equally significant opportunity through the development of proactive environmental management strategies.

CONCLUSIONS

It is clear that companies such as VW are committed to improving the environmental performance of both their products and the process of their manufacture. The potential for the wider adoption of environmental management strategies is enhanced in many cases by the overlap between the economic self-interest of both the producer and consumer, and the environmental imperative that society has collectively placed on the automotive industry to lead the way in developing sustainable modes of personal mobility. High standards of environmental performance within the automotive industry will therefore become an integral part of the industry's future economic success. Through innovation at all stages in its product life cycle, VW has emerged as a market leader in the field of environmental performance in the automotive industry.

Arguably, given current economic structures, harnessing the forces of self-interest and capitalism to drive environmental improvement is the only way society can develop the scale of response needed if we are to achieve sustainability. While undoubtedly companies such as VW are committed to environmental improvement for altruistic as well as commercial reasons, it is far from clear whether the products of the automotive industry are compatible with the long-term goal of sustainability. Given time, it is clear that VW and the automotive industry more generally will build, and should be encouraged to build, on the significant progress made to date, and continue to move towards sustainability. The question that remains is whether such an industry could ever arrive at the elusive goal of sustainability, and how much time it should be given in which to try.

Questions for discussion

1 Why is it important to examine the design of industrial processes and products if a company is committed to environmental improvement?

2 To what extent is VW using life-cycle assessment in evaluating the environmental impact of its products?

3 How is VW pushing environmental improvement up and down the supply chain?

4 Outline VW's audit methodology.

5 VW has put a lot of emphasis on the recyclability of their cars. Explain how they have improved this. Do you consider that recyclability in itself is a sufficient measure to improve the environmental performance of cars?

6 Do you consider that the car industry can ever arrive at the goal of sustainability?

Note: For further information on the topics raised in this chapter, please refer to Chapters 7 and 8 of *Environmental Management and Business Strategy* by Richard Welford and Andrew Gouldson (Pitman Publishing, 1993).

References

Ekins, P., Hillman, M. and Hutchison, R. (1992) *Wealth Beyond Measure*, Gaia Books, London.
Rees, A. (1991) *The Pocket Green Book*, Zed Books, London.
Friends of the Earth (1988) *The Environment – The Government's Record*, Friends of the Earth, London.
Leggett, J. (1993) 'Climate Change and the Insurance Industry', *European Environment*, Volume 3, Part 3, June.