



*The International Center for Research
on the Management of Technology*

The Marketing and R & D Interface

**Abbie Griffin¹
John R. Hauser²**

**October 1991
Revised February 1992**

WP # 48-91

Sloan WP# 3350-91-MSA

¹ Assistant Professor of Marketing and Production Management,
The University of Chicago

² Kirin Professor of Management, Sloan School, MIT

Forthcoming, *Handbook: MS/OR in Marketing*, Gary L. Lilien
and Jehoshua Eliashberg, Eds., (Elsevier Science Publishers:
Amsterdam, The Netherlands), 1992.

© 1992 Massachusetts Institute of Technology

Sloan School of Management
Massachusetts Institute of Technology
38 Memorial Drive, E56-390
Cambridge, MA 02139-4307

To succeed in today's marketplace, many corporations must engender cooperation between the marketing and the R&D (Research and Development) functions.

It wasn't always this way. In earlier times, most families were self-contained. Various family members cooperated to produce yarn, weave cloth, sew garments, build furniture, forge utensils, and even build their own living quarters. When people gained experience they became craftsmen, experts with the skills to produce goods that could be sold to others in order to pay for other consumable goods and services. But still the expertise could be centralized in a single person who knew (or developed) the technology of production, the process of production, and the means to market the goods to others. For example, the blacksmith knew where to get the raw materials, how to light and maintain the forge fire, and how to shape the metal. Customers sought out the blacksmith and explained their needs. He asked questions, understood their needs, and produced the product. If he did these tasks well, he lived well. If he failed at any of these tasks, he starved. The marketing and the R&D functions were integrated in the activities of the blacksmith. Market feedback was quick, obvious, and persuasive.

Even today, in entrepreneurial firms, the producer-inventor combines the knowledge of what is needed with how to produce it. But as the firm grows the functions of marketing and of R&D become specialized. Scientists are hired to maintain and develop the technology, marketing specialists are hired to sell the product or, in some cases, to talk to customers and communicate product benefits. Over time these groups grow apart, each expert at their own function, but less aware and sometimes quite critical of the other's contribution. As integration and communication among these critical functions decreases, their abilities to produce successful products decreases and the firm suffers.

This chapter addresses the issues of marketing and R&D cooperation, integration, and communication. It illustrates how empirical research and OR/MS methods have contributed to a better understanding and managing the interface. In section 1 we examine cross-functional responsibilities to understand better what information and tasks are shared. In section 2 we cite scientific studies which suggest that communication and cooperation between marketing and R&D are critical success factors of product policy. In section 3 we seek to understand why communication and cooperation are difficult. In section 4 we review academic models of the marketing/R&D interface. In section 5 we present approaches to encourage communication and cooperation. In section 6 we turn to a relatively new technique, Quality Function Deployment (QFD), which has proven to be successful in improving the marketing/R&D interface. We present scientific evidence of QFD's affect on communication (section 7), compare the documented short-term and long-term benefits (costs) of QFD (section 8), and discuss the marketing implementation of QFD (section 9). Section 10 summarizes this chapter.

1. CROSS-FUNCTIONAL RESPONSIBILITIES

In 1967 Lawrence and Lorsch (p. 11) defined the level of integration between two corporate functions as:

... the quality of the state of collaboration that exists among departments that are required to achieve a unity of effort by the demands of the environment.

To understand the need for cooperation, we must understand the tasks which require cooperation "to achieve a unity of effort by the demands of their environment." Table 1 is a partial list of tasks in which the outcome is superior if marketing and R&D each provide input. Some of these tasks are core tasks upon which the success of the enterprise rests, for example, setting new-product goals and understanding customer needs. These are listed as shared responsibilities because they usually require cooperation throughout the period of the task and the combined expertise of both functional groups¹. Other tasks are listed as marketing-dominant or R&D-dominant. In these tasks most of the expertise to complete the task resides within one group; the other functional group is called upon for consultation, usually in a discontinuous manner during critical periods in the task.

Of the three categories in table 1, shared-responsibility tasks are the most difficult to manage because maintaining the balance of inputs over the duration of the task is extraordinarily difficult, yet key to new-product success (Cooper 1983). Function-dominant responsibilities are easier to manage. Because the primary expertise resides within one functional group, that group can marshal the resources (time, money, and people) to accomplish the task. Work relationships are often well-established and the task fits within the normal scheme of functional effort. On the other hand, the dominant function may have difficulty obtaining input from the contributing function if the contributing function does not share in the rewards and recognition for successful completion of the task.

For example, we have listed "trouble-shooting problems customers have with current products" as a marketing-dominant responsibility. These tasks require effort at random intervals over the lifetime of a product (unless the product has a serious flaw), occurring most frequently when someone uses the product in ways for which it was not intended. Customer support (marketing) is usually called upon to solve the problem and often can do so. However, if the problem pushes the frontier of product use, marketing may not have the expertise to solve the problem so R&D is called in. However, this request may be disruptive to research on the next generation of the product. (Problems rarely occur at convenient times and places.) Furthermore, marketing may blame R&D for the problem occurring in the first place and R&D may resent marketing for being unable to handle the problem. Thus, seeds of discontent between the functions are sown. On the other hand, such frontier-pushing, leading-edge users can be the source of new-product ideas (von Hippel 1986) and should not be overlooked. Like so many other tasks, the right rewards, incentives, and recognition are necessary to ensure that the task is completed in a timely manner with the appropriate inputs from both functions.

Consider the R&D dominant task, "identifying and fixing design flaws for future releases

¹In the past, "understanding customer needs" was usually delegated to the marketing function. Recently corporations have come to recognize the centrality of this task: it is a task that requires expertise from both groups. We expand upon new techniques to address this task later in this chapter.

<p>SHARED RESPONSIBILITIES</p> <ul style="list-style-type: none"> · understanding customer needs · setting new product goals · matching technological solutions to customer needs · establishing the core benefit proposition for new products · next generation product improvement · resolving engineering-design and customer-need tradeoffs <p>MARKETING DOMINANT RESPONSIBILITIES</p> <ul style="list-style-type: none"> · finding and assessing new applications for products and technologies · trouble-shooting problems customers have with current products · training new users · producing accurate product literature and manuals · selecting advertising claims <p>R&D DOMINANT RESPONSIBILITIES</p> <ul style="list-style-type: none"> · establishing long-term R&D directions · keeping abreast of competitive developments · identifying and fixing design flaws for future releases of current products
--

Table 1. Examples of Tasks Requiring Marketing and R&D Cooperation

of products." The bulk of the effort in this task resides in the "fixing" portion of the task. It is normally R&D's responsibility to fix these flaws. But the earlier these flaws are identified and cataloged, the earlier R&D can seek solutions. Very often, the customer input which identifies flaws comes in through the marketing function. Not only can marketing identify these flaws through their customer contacts, they can provide priorities (which bugs cause the worst grief for the customer) and, potentially, they can identify user solutions (von Hippel 1978). While it is R&D's responsibility to fix the flaws, it is everyone's responsibility to satisfy the customer. This task is important and requires coordination because each function controls only a part of the solution.

Finally, consider the shared responsibility of "establishing the core benefit proposition for a new product." The core benefit proposition (CBP) is the short list of strategic benefits that the product provides to customers and an indication of how the product provides these benefits (Urban and Hauser 1980). It includes the basic benefits that define the category of products as well as the unique benefits that the new product provides better than competition. In essence, the CBP defines the new product. Clearly, a good CBP requires marketing input to determine

the critical benefits that customers demand as well as R&D input to determine how to provide the benefits. Selecting the right benefits and solutions from the set of potential benefits and solutions requires close cooperation throughout the new-product development process.

The complexity of developing the CBP is illustrated in figure 1, which is a synthesis by Dougherty (1989) from Bonnet (1986), Clark (1985), Cooper (1983), and Roberts (1988). We have modified it slightly by listing, at the bottom of the figure, the formal labels for a sequential product-development process as described in Urban and Hauser (1980). Notice the similarity between the informal stages of Dougherty's description of the processes as observed and the formal stages of Urban and Hauser's pedagogical summary. The key difference is the complex interactions inherent in the observed process.

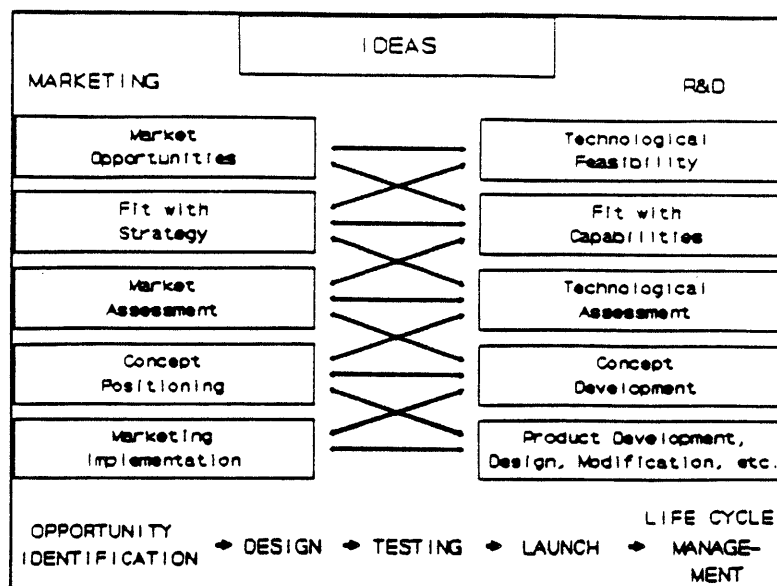


Figure 1. Linking Technological Possibilities and Market Opportunities (From Dougherty 1989 and Urban and Hauser 1980.)

Figure 1 depicts an ideal model of the process of "needs-linking" that leads to a CBP. As drawn, each stage of new-product development from opportunity identification to design to testing to launch requires the coordination of inputs from both marketing and R&D. Naturally, as the product is developed inputs are combined and many phases are iterated. The final process is often much more integrative than figure 1. (For example, see Dougherty 1987.) However, at minimum, figure 1 illustrates that both marketing and R&D have roles in all phases of new-product development.

Technology and market choices are neither independent nor static; they cannot be analyzed separately and they evolve as new solutions become available, as customer needs evolve, as competitors offer their new products, and as governmental and environmental constraints change. But if the business opportunity has been identified and if the product meets user needs then it is more likely to succeed (Rothwell, et. al. 1974, Cooper and Kleinschmidt 1986).

Table 1 provides examples of the many responsibilities that require marketing and R&D interactions. In each of these interactions money, materials, information, and technical expertise must flow across the boundaries between the functional areas (Ruekert and Walker 1987). We explore now scientific evidence that suggests that such flows are critical to the success of new-

product development.

2. COOPERATION, WHEN IT OCCURS, LEADS TO SUCCESS

Cross-functional cooperation takes time, resources are stretched thinly, and in encouraging cross-functional communication we run the danger of allowing amateurs (marketing in technology, R&D in customer relations) to limit the effectiveness of experts in getting a job done. On the other hand, intuition suggests that when the tasks of marketing and R&D are performed separately in a corporation, cooperation between the two groups enhances new-product success. Few, if any, of the tasks in table 1 could be accomplished successfully without inputs from and cooperation between both functional groups. Furthermore, figure 1's needs-linking process requires harmonious, effective communication. Each group understands and respects the other and provides the other group with the information they need to complete their responsibilities in a timely manner.

In table 2 we have summarized some of the extensive scientific evidence that relates to cooperation between marketing and R&D. In each case the researchers either support or are consistent with the hypothesis that cooperation enhances success². More importantly, the evidence is strong, consistent, common to a variety of methodologies, and seemingly applicable in both services and products and in both consumer and industrial markets. Few, if any, management principles are based on such persuasive evidence.

To help the reader appreciate this body of research we give three examples. One example is based on in-depth, ethnographic studies of a relatively few projects; another is based on a large-sample survey, and a third is based on a variety of longitudinal studies over a period of ten years.

Dougherty (1987) studied pairs of successful and unsuccessful new-product projects at industrial firms, consumer firms, and service firms by a combination of retrospective interviewing and examining the paper trails of the projects. She then combined her qualitative data to develop a three-point scale to measure the amount of communication during the new-product development. She measured this communication for nine topics. Four topics related to the user (product use, politics of the buying center, customer needs, and delivery); four topics related to marketing strategy (customer segments, competitive activity, marketing actions, and prices), and the final topic measured communication about the physical characteristics of the product or service.

²Of course, cooperation can be formal or informal, but as Feldman and Page (1984, p. 53) state "More than many other activities in a company, product planning is a 'people process.' Its multi-layered, cross-functional, interdisciplinary character places great demands on the human skills of creativity, negotiation, and perseverance." Moore (1987, p. 12) also finds smaller divisions allow informal contact which facilitates new-product development.

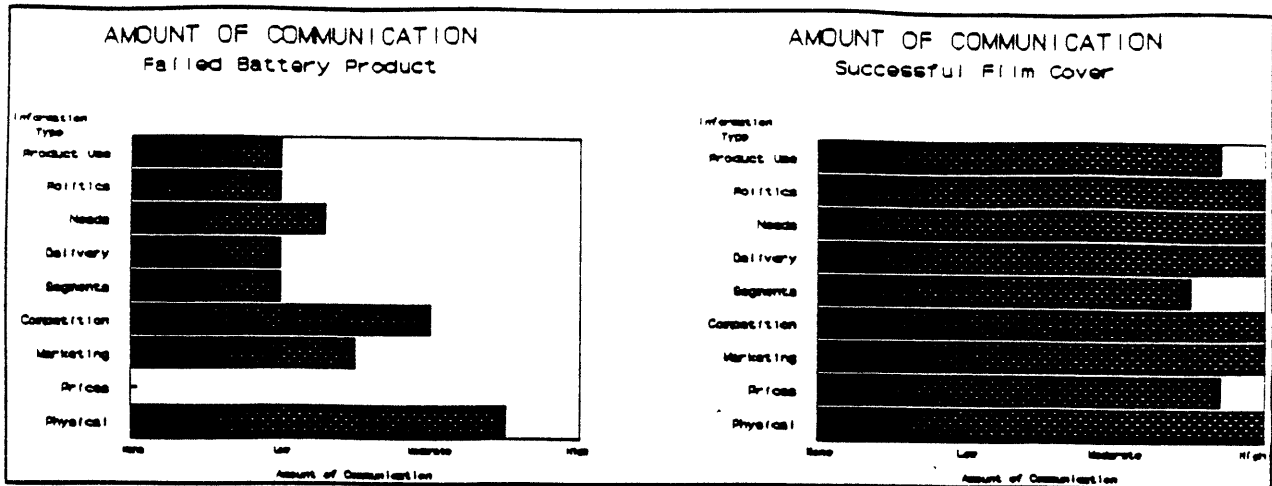


Figure 2. Amount of Communication on Two New Product Projects at the Same Firm
(Adapted from Dougherty 1987.)

Figure 2 presents one of the head-to-head comparisons in Dougherty’s data. In this case, as in other pairs in her data, there was sporadic communication among failed project team members and uniformly strong communication among team members involved in the successful project. Of course, there might be a reverse causality (people get excited about successes and talk more) and her data is based on a small sample of qualitative judgments, but it is suggestive of how communication enhances success.

Figure 3 illustrates the type of evidence generated by the large scale surveys in table 2. In this study, Cooper (1984a, 1984b) surveyed 122 organizations on 66 strategic variables. He factor analyzed the 66 variables to obtain 19 strategic dimensions which he then cluster analyzed the organizations to obtain five basic organizational strategies. Figure 3 plots the centroids of the clusters on two axes: the success rate and the percent of company sales from new products. Some firms achieved a high success rate by taking few chances, but they did not succeed in the sense of generating sales. On the other hand, some firms, particularly high-technology firms, were able to achieve sales at the cost of many failures. The one group of firms that had consistent success, in terms of both the percent of new products that made it in the marketplace and sales generated by those new products, was the group that balanced the

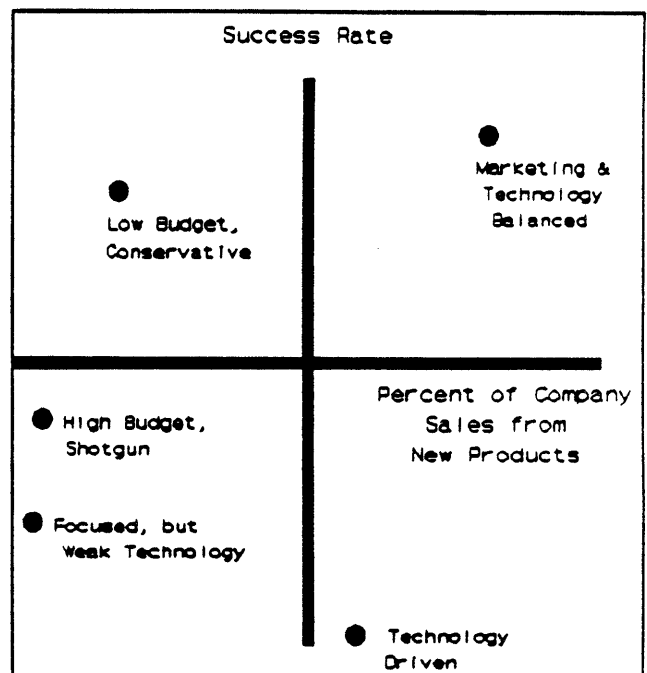


Figure 3. Comparison of New-Product Strategies
(Adapted from Cooper 1984.)

RESEARCHER(S)	SAMPLE	TYPE OF FIRM	EVIDENCE (Partial list)
Cooper (1983)	58 projects	Industrial	Projects which balance marketing and R&D inputs have a higher rate of success.
Cooper (1984)	122 firms	Electronic, heavy equipment, chemicals, materials	Management strategies which balance marketing and R&D have a greater percentage of new product successes and greater percentage of their sales coming from new products.
Cooper and de Brentiani (1991)	106 projects	Financial services	Synergy (e.g., fit with the firms expertise, management skills, and market research resources) was the number one correlate of success. (Correlation = 0.45.)
Cooper and Kleinschmidt (1987)	125 firms 203 projects	Manufacturing	Market synergy and technological synergy are both significantly related to success.
Dougherty (1987)	5 firms 16 projects	Industrial, consumer, and services	More communication and communication on all relevant topics separated successful projects from unsuccessful projects.
de Brentiani (1989)	115 firms 276 projects	Financial services, management services, transportation, communication.	Sales, market share, and reduced costs are correlated with communication between functions. (Correlation with sales and market share = 0.38, correlation with reduced cost = 0.29.)
Gupta, Raj, and Wilemon (1985)	167 firms 107 R&D managers 109 marketing managers	High-technology	Lack of communication was listed as the number one barrier to achieving integration among marketing and R&D.
Hise, O'Neal, Parasuraman, and McNeal (1990)	252 Marketing Vice Presidents	Large manufacturing firms	High level of joint effort in new product design is a significant factor in determining success. This is true for both industrial and consumer good companies.
Moenaert and Souder (1990)	Literature review	Products and services	Integration of functions is positively related to innovative success.
Pelz and Andrews (1966)	1311 scientists and engineers	Scientists and engineers	Positive relationships between the amount of interaction and performance.
Pinto and Pinto (1990)	72 hospital teams 262 team members	Health services	Strong relationship between cross-functional cooperation and the success (perceived task outcomes and psychosocial outcomes) of the project. (Correlation = 0.71.)
Souder (1988)	56 firms 289 projects	Consumer and industrial	The greater the harmony between marketing and R&D, the greater the likelihood of success.
Takuchi and Nonaka (1986)	6 projects US and Japan	Consumer and industrial	Cross-fertilization and self-organizing teams led to success

Table 2: Examples of the Scientific Evidence that Suggests that Communication among Marketing and R&D Enhances New-Product Success

marketing and technology functions through better communication and cooperation. Their products had a "high degree of fit and focus."

Finally, table 3 illustrates that communication is more than just talk. In a ten-year study of 289 projects, Souder (1988) provides evidence that interfunctional harmony (communication and cooperation, not just communication) is a strong correlate of new-product success. For example, he found that the groups really needed to cooperate on the project -- too much social interaction at the expense of professional interaction was harmful because it prevented objective criticism.

Research investigating the relationship between R&D and marketing communication and product development success is extensive in amount and virtually univocal in support. Additional research has demonstrated that communication and integration, while

desirable, is not always easy to achieve due to a number of inherent barriers between the groups. We now explore barriers that exist which make communication difficult and which discourage cooperation between the functions of marketing and R&D.

State	Percentage of Projects in Each State Exhibiting Each Outcome		
	OUTCOME		
	Success	Partial Success	Failure
Harmony	52%	35%	13%
Mild Disharmony	32%	45%	23%
Severe Disharmony	11%	21%	68%

Table 3. Communication vs. Success
(From Souder 1988, Table 3)

3. BARRIERS TO COMMUNICATION AND COOPERATION

There are many barriers to successful communication between marketing and R&D. As Moenaert and Souder (1990, p. 96) summarize "empirical research indicates that disharmony between marketing and R&D is the rule, rather than the exception." We now explore some of the reasons for this disharmony, starting with the people themselves and moving into differences in firm-related barriers to cooperation and communication.

Personality

When Saxberg and Slocum (1968) studied marketing and R&D personnel in American corporations, they found inherent personality differences between the groups. These differences are summarized in table 4. Some of these differences are stereotypes, many may have changed since 1968, and many may be unique to the American culture. but these differences do caution us that there may be some social distance between marketing and R&D. These differences may be due to the influence of education, the corporate reward systems, the differing goals, and/or self-selection by people in one field or the other. But the stereotypes, when they exist, can be formidable barriers between the groups. Even if the stereotypes are not based in fact, if one or the other group believes in them, this belief alone can become a barrier to mutual understanding.

For example, Gupta, et. al. (1986b), in a sample of marketing and R&D managers at 167

R&D TRAITS	MARKETING TRAITS
<u>Goals and Aspirations</u>	
<ul style="list-style-type: none"> • Knowledge as a source of value to mankind • Research for research's sake • Peer evaluation and recognition 	<ul style="list-style-type: none"> • Organizational survival and growth • All activities relevant to firm's objectives • Organizational recognition
<u>Needs</u>	
<ul style="list-style-type: none"> • Autonomy • Peer recognition, creative environment • Continuing education and development • Support for advancing knowledge in society 	<ul style="list-style-type: none"> • Plans, procedures, policies, rules • Organizational recognition • Team work • Increased organizational status
<u>Motivation</u>	
<ul style="list-style-type: none"> • Service to mankind • Publications • Professional recognition • Patents with name attached • Freedom to solve problems, advance knowledge 	<ul style="list-style-type: none"> • Rewards and sanction system with pay and advancement through the organization

Table 4. R&D and Marketing Stereotypes (Saxberg and Slocum 1968.)

high-technology firms, found that the two groups were more socio-culturally similar than table 5 would suggest -- they found differences mainly in time orientation. Furthermore, this difference was true whether or not marketing and R&D were well-integrated in the firm. On the other hand, Gupta, et. al. found that cultural barriers were two of the four most frequently stated barriers to cooperation. This suggests that the true barrier may be a perceptual barrier of stereotypes rather than a barrier of actual cultural differences. In either case, the barrier exists.

Personality or stereotype barriers may be the most difficult of all communication barriers to reduce or eliminate (Block 1977). Thus, the firm should seek means by which the groups can work together effectively. Among other things, this implies mechanisms for gaining understanding of persons in the other function and their capabilities and building trust between persons in each function.

Cultural Thought-worlds

Marketing and R&D personnel often differ in their training and background. Marketing professionals are drawn primarily from business schools, often with a prior liberal arts background, while R&D professionals are drawn primarily from engineering and science schools. The training in business schools focuses on general problem solving combining data

and intuition to make decisions that lead to profitable performance of the firm. The training in engineering schools is technological problem solving with a goal of developing better solutions to technical problems. The training in schools of science focuses on the scientific method of hypothesis generation and testing. These "world views" are reinforced in the corporate cultures of the functional departments (Dougherty 1987, Douglas 1987).

<u>Dimension</u>	<u>Functional Position</u>	
	<u>Marketing</u>	<u>R&D</u>
Time Orientation	Short	Long
Projects Preferred	Incremental	Advanced
Ambiguity Tolerance	High	Low
Departmental Structure	Medium	Low
Bureaucratic Orientation	More	Less
Orientation to Others	Permissive	Permissive
Professional Orientation	Market	Science
Professional Orientation	Less	More

Table 5. Marketing and R&D Differences (adapted from Lorsch and Lawrence 1965, Gupta, et. al. 1986b, and Dougherty 1987.)

Lawrence and Lorsch (1967) first publicized the cultural differences between marketing and R&D. Table 5 summarizes the differences that they and subsequent researchers have documented. (See also Gupta, et. al. 1986, Ruekert and Walker 1987, and Souder 1987.) Basically, marketing prefers a short time horizon of incremental projects. They focus on the market, can accept a high degree of ambiguity and bureaucracy, and feel a professional loyalty to the firm. By contrast, R&D prefers a long time horizon of advanced projects. They focus on scientific development with a loyalty to their scientific profession. They have a low tolerance for ambiguity and bureaucracy. Naturally, these rules do not apply to every individual professional or even to every marketing or R&D department, but they do indicate trends that researchers have been able to identify.

The result of these differences is that marketing and R&D run the danger of developing self-contained societies, or thought-worlds, in which they reside. Even though each function works for the same corporation with the same overall corporate goals, the lens through which each function interprets those goals differs. More importantly these thought-worlds mean that marketing and R&D may have difficulty understanding one another's goals, solutions, and tradeoffs. To work together they must understand and appreciate the other's thought-world.

Language

As separate thought-worlds develop, language barriers also arise. Marketing has and uses

its own set of technical terms and R&D uses different technical terms. For example, when an automobile customer says he wants quick acceleration, the engineer may interpret this in terms of the time it takes the car to go from 0 to 60 mph, or the horsepower of the engine, or the gear-ratio. The consumer might be really concerned with merging into traffic from a yield sign or making a light at rush hour. However, if the appropriate context for quick acceleration is not made clear by marketing, the engineer will add some (possibly inappropriate) context to the customer comment, for example, acceleration during highway driving. When this misunderstanding occurs, customer needs and engineering solutions can disconnect even though each group thinks they are talking about exactly the same thing. As another example, consider word processing on a personal computer. The computer manufacturer might think in terms of millions of instructions per second (MIPS) or disk access time, while the software developer might think in terms of keystrokes to accomplish a task. On the other hand the user might be more concerned with being able to remember how to do the task, how input is made (keyboard vs. function keys vs. cursor vs. mouse), and being able to see the screen respond as fast as the user can type. The subtle differences in language often imply vastly different solutions and make the difference between a successful and an unsuccessful project.

Even the level of detail used by each group varies. For example, the marketing department of a liquid dishwashing detergent manufacturer may find that consumers want the product to "clean my dishes better." Such a statement may be adequate for an advertising strategy, but R&D wants to know what kind of dishes, under what conditions, what dirt has to be removed, and in what type of water. Different solutions can be developed if the consumer judges "clean" by spots on the dishes, spots on the glasses, a shine on the dishes, the fragrance after the wash, the amount of bubbles during the washing process, or, and this is a true story, the size and shape of the bubbles. In automobiles, marketing may discover that the consumer wants easy-to-use controls, but R&D needs much more detailed information if they are to make the necessary tradeoffs in placing controls for lights, turn signals, wipers, radio, heater, air conditioner, cruise control, windows, and locks. If each group does not understand customer needs at the level of detail that they need to do their job, they become frustrated with the communication process.

Organizational Responsibilities

Organizational barriers arise due to different task priorities and responsibilities, from measures of **success** which do not support integration (short-term profit, current market share, etc.), and from a **lack of top management support** to reward integration. While these factors are clearly under top management control, the possibility of organizational change in and of itself can create barriers. Middle managers who have risen to where they are under the previous criteria now have to learn to play by different rules to continue to rise in the organization. Given that they have become proficient and successful under the old system, many are reluctant to change to new operating rules, philosophies, or informal goals. The confusion and angst can cause resistance to any "outsiders" and thus reduce cooperation among marketing and R&D.

Physical Barriers

Physical barriers frequently isolate marketing from R&D in U.S. firms. Long distances between the groups make face-to-face communication inconvenient and create delays in decisions. Meetings must be planned; serendipitous information transfer or clarification in the halls or around the water fountain and coffee machine does not occur. For example, in a seminal study (Allen 1986, chapters 8 and 9) suggests that the probability that two people communicate one or more times per week drops off rapidly with the distance between their offices³. For example, at a distance of 10 meters, the probability drops to less than 10%.

This physical separation can become acute. It is not uncommon for R&D facilities to be located on "campuses," which are actually in different cities than the marketing offices. For example, at General Motors the marketing offices are in downtown Detroit or at the divisional headquarters (e.g., Flint, MI) while the R&D facility is located in Warren, MI. At a major computer company, the marketing offices are located in a northern state while the R&D effort is headquartered in a southern state. In other firms, time zones separate marketing from R&D. Such separation decreases chance meetings and social encounters which can be extremely productive in creative problem solving and mutual understanding.

Physical isolation of groups also exacerbates other barriers to communication. Isolation solidifies the separate thought worlds, encourages short-cut jargon-filled language development, and heightens perceptions of personality differences.

The general outcome of the personality, cultural, language, organizational, and physical barriers between marketing and R&D means that communication and cooperation are difficult to achieve. As Kotler (1991, p. 699) summarizes "marketers see the R&D people as impractical, long-haired, mad-scientist types who don't understand business, while R&D people see marketers as gimmick-oriented hucksters who are more interested in sales than in the technical features of the product. These stereotypes get in the way of productive teamwork." Such misunderstanding can lead to strong "Not-Invented-Here" (NIH) attitudes, where each function supports the data and work generated from within their own group. If we contrast these barriers with the scientific evidence that communication between marketing and R&D is one key success factor in developing new products and generating sales, we see that such barriers must be addressed, and either eliminated or circumvented, if the firm is to be profitable in the long term.

The next section reviews academic models which have been proposed for studying marketing/R&D interactions by both management scientists and behavioral researchers. Section 5 reviews approaches to enhance communication and cooperation and section 6 reviews one approach, developed in industry, which has been successful in enhancing the success of new-

³The study is based on 512 researchers in 7 U.S. laboratories. Allen estimated the following equation, $P(c) = 0.522/S + 0.026$, where $P(c)$ is the probability that two persons communicate one or more times per week and S is the separation between their offices in meters.

product development by improved communication and cooperation.

4. ACADEMIC MODELS OF THE MARKETING/R&D INTERFACE

Managing the marketing/R&D interface changed dramatically in the mid-1980s. Firms started feeling intense competitive pressures to reduce new-product-development cycle times and manufacturing lead times and to increase their success rate for new product introductions. During this time frame many firms experimented with flatter management structures, cross-functional teams, and cross-discipline management processes. By changing the way corporations manage the marketing and R&D functional groups these innovations have led to new perspectives in the academic literature. By the same token, research prior to this period, which assumes hierarchical corporate structures with separate (and sometimes isolated) functional groups, is being reassessed in light of these interfunctional innovations. This section focuses on the academic research which recognizes the interfunctional perspective. We review but briefly research on management within the functions.

Academic research since 1986 on the marketing/R&D interface has been performed by several different disciplines and has produced three different types of work. By far the largest body of work, reviewed in section 2 of this chapter, studies the balance between marketing and R&D and the level of communication or integration between marketing and R&D. It is primarily published in the management-of-technology and product-development literatures, with some articles appearing in the organizational-studies literature.

In addition, several researchers have attempted to model all or part of the interaction process. Both behavioral as well as management science approaches have been taken to model the interactions and relate them to either the success of their outputs or the effectiveness of the interactions. This section of the chapter reviews both efforts.

Management Science Approaches

The major published contributions by management science methods address optimization within a function. The models and simulations assume that any information or inputs required from another function will be available and provided when they are needed. These models are important, **in part, because they suggest which information will be needed to optimize a function. Naturally, we expect that the models will evolve and improve based on the consideration of cooperation among functions.**

*R&D Management Science*⁴. Lucas (1971) started a major stream of R&D-oriented management science research. Lucas investigated whether a firm should make an investment in an R&D project, and, if it should invest, what should be the optimal spending policy. He

⁴We thank an anonymous reviewer for bringing this stream of literature to our attention.

developed four abstract models for evaluating and controlling investment levels in an R&D project over a time horizon, where the objective is to obtain the conditions which maximize the expected value of the project's present value. His models manipulate whether the completion time is known or a random variable and whether costs are constant or variable but controllable. This work has been extended by Aldrich and Morton (1975) to allow the possibility of time dependent returns using continuous-time dynamic-programming methods. Mehrez (1983) also extended the original ideas to allow for changes in returns from the project, to measure the expected value of perfect information (which allows analysis and solidification of the market uncertainties which affect returns) and defines a set of optimal spending policies for a number of different objective functions.

A later stream of research models R&D investment strategies in terms of how much a firm should invest in R&D, given that competitors are also investing in a particular innovation. Reinganum (1982) models how investment levels depend upon the availability of perfect patent protection and the number of firms simultaneously targeting a particular innovation. Under perfect patent protection her model suggests (1) that the pace of technology investment is increased if the payoffs to the innovator are greater and (2) if more firms join the R&D race then each firm increases its investment. See further analyses in Lee and Wilde (1980), Loury (1979), Kamien and Schwartz (1972), and Park (1987). Finally, a new stream of research, which has begun to use agency theory to set incentives for the manufacturing/marketing interface (Porteus and Whang 1991), might be extended to the marketing/R&D interface.

Marketing Science. There is a stream of research called product optimization. See Hauser and Simmie (1981), Green and Krieger (1992), Kohli and Sukumar (1990), and Schmalensee and Thisse (1988). This research begins with an assumption that R&D has already decided on a basic approach and must select from a set of features a product that has the best profit potential. A model of market response is estimated (either a perceptual map as in Hauser and Simmie, a conjoint model as in Green and Krieger, or a demand model as in Schmalensee and Thisse) that allows the researcher to predict, for every feature combination, the demand for the product. In some cases competition is considered explicitly while in others the analyst must perform a number of "what-if" analyses. Because the features are specified it is possible, in theory, to determine the production cost for each feature combination. Then, by searching over feature combinations based on the models of demand and cost, the analyst can recommend the feature combination with the best profit potential. These models do not address how R&D decides on which features to include in the first place, nor do they provide guidance on how to encourage creative new-product solutions.

For example, consider the case of a firm designing a spirometer. (A spirometer measures lung capacity.) Some of the basic needs of spirometry users (physicians and hospitals) are that the spirometer provides "convenient-sized output," "good printout quality," and "easy-to-interpret diagnostic information." In 1990, spirometers used either a 4¼" thermal printer or an 8½" x 11" letter-quality printer. If the design were limited to these options, conjoint analysis could present users with the choice of these options (vs. other features) and quantify the importance of a letter-quality printer relative to a thermal printer. If the cost of providing each

were known, the researcher could balance sales and cost to select the better printer. However, such an analysis is appropriate only if the new-product team has already limited the set to these features.

Later in this chapter we review a method to decide on which features to consider. An important aspect of this method is that it deals with the more basic needs, such as "easy-to-interpret diagnostic information." By dealing with the more basic needs, the new-product team is encouraged to consider creative solutions. For example, when Puritan-Bennett introduced its revolutionary Renaissance spirometry system, it made it possible for the physician to use the printer that was already in the office. See Hauser (1992) for details on this case.

These marketing science models are quite effective once the final set of product features has been selected and thus are a complementary approach to the marketing/R&D interface approaches discussed later in this chapter.

Behavioral Models

Two groups of researchers have begun to develop behavior-based, conceptual models of marketing and R&D's interactions. They, and others, have begun testing the validity of their models in both U.S. and international firms.

Gupta et al. (1986a) propose a model and 13 propositions for studying the R&D and marketing interface in product development. (See Figure 4). According to the authors' model the degree of integration for which the firm should strive depends on the organization's strategy (prospecter, analyzer, defender or reactor) and the perceived environmental uncertainty within which the firm operates. Higher environmental uncertainty and strategies targeting leading-edge technology or product positions lead to an increased need for R&D/marketing integration. A pilot study of survey-generated results produced inconclusive findings (Gupta, et al., 1986c).

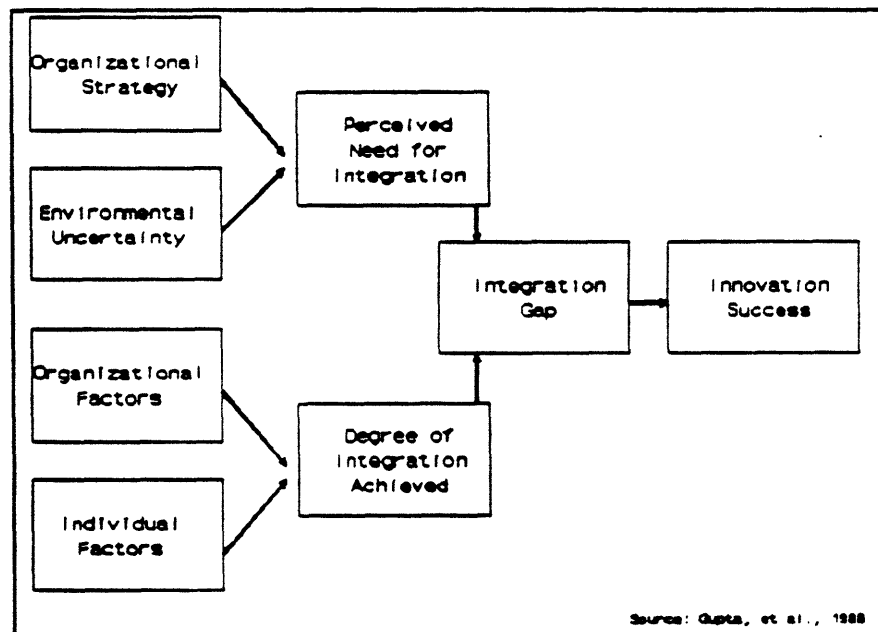


Figure 4. Model for Studying the Marketing/R&D Interface

Parry and Song (1991) tested the constructs of Gupta et al.'s model by surveying 411 Japanese high-technology firms to determine which, if any, of the hypotheses appeared to hold. They found that Japanese managers perceive a higher need for the integration of marketing and R&D when firms emphasized opening up new markets and new product areas ("prospector" firms, Miles and Snow, 1978). This need was higher than that for firms which pursued more cautious innovation routes ("analyzers"). In turn, analyzer firms see more need for integration between marketing and R&D than firms who place little emphasis on innovation ("defenders"). In a sample of 274 R&D managers and 264 marketing managers, Song (1991) found the correlation between the stated ideal level of integration and the achieved level of integration to be 0.55.

Parry and Song also found that high consumer demand uncertainty and high rates of technological change drive managers to believe that they need better marketing/R&D integration, and that these uncertainties have a more significant impact on the perceived need for marketing/R&D integration than do uncertainties about competitor strategies. They also found relationships between perceived levels of integration and

- the quality of R&D and marketing relations (self-stated),
- the business experience of R&D personnel,
- the encouragement by management to take risks, and
- the value that management placed on integration.

The survey has been replicated for US chemical firms, but the results are not yet in final form (Norton, et al., 1992). This research team plans to repeat the survey for German chemical firms and compare the results to those obtained for US and Japanese firms.

Ruekert and Walker (1987) provide another perspective. They offer a framework and 14 propositions for examining how, how effectively, and why marketing personnel interact with personnel in other functional areas in planning, implementing, and evaluating marketing activities. The authors have transformed each proposition into testable constructs and have tested parts of the framework by using survey responses from marketing, R&D, manufacturing, and accounting personnel in three different divisions of one *Fortune 500* firm.

Like Gupta, et al. (1986a), Ruekert and Walker (1987) start with the firm's organizational and working environments. However, in their model, these starting factors feed into the organizational and structural processes which lead to integration (See Figure 5). Their framework predicts (1) psycho-social outcomes in terms of level of conflict and perceived effectiveness and (2) functional outcomes in terms of goal accomplishment for interactions between marketing and R&D and between marketing and other functions within the firm.

Ruekert and Walker predicted that more interdependence, more task and work similarity, more formal between-group interactions, and more influence between groups would lead to higher transaction flows (flows of resources, work, and assistance), less conflict, and higher perceived effectiveness between the groups. Even in this small pilot study, they found support for

their basic proposition that marketing and R&D interaction results from and is influenced by perceived resource dependencies in getting their jobs done. The more one function believes they depend on the other, the greater the amount of interactions and resource flows across the functional boundaries and the more influence the information providing group has over the other group.

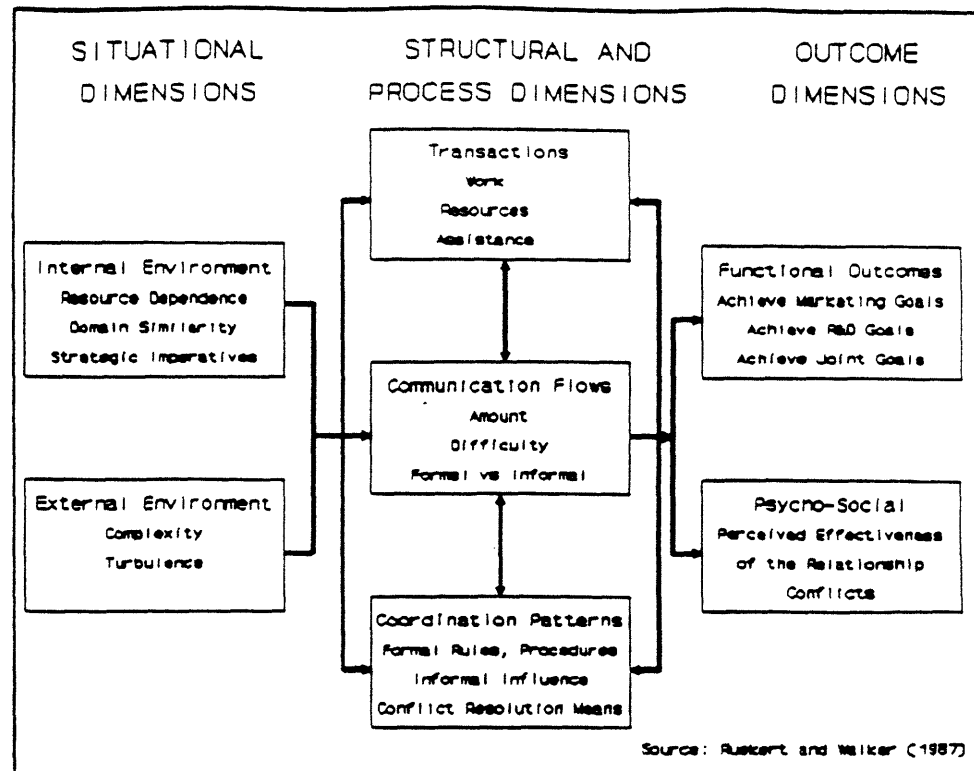


Figure 5. A Framework for Assessing Marketing's Interaction with R&D

Both models (Gupta, et. al. and Ruckert and Walker) relate greater perceived effectiveness between marketing and R&D to the organization structure and behavior across the functional groups. The model of Gupta, et al., (1986a) may prove useful in analyzing the appropriate level of marketing/R&D integration, given a firm's strategy and environment. It might be used to explain how firms with different levels of marketing/R&D integration can all be successful from an innovation-producing point of view. Ruckert and Walker's (1987) model may be more appropriate for analyzing interfaces within one company, or within a set of companies facing similar environments, using similar strategies. This model may prove useful in determining whether a particular technique a company employs for integrating across the two groups has actually changed anything. The model can be used to diagnose which aspects of integration a company might try to develop a technique to improve.

Research Challenges

R&D Management Science. The real challenge in this field of research is the application and improvement of the models. Interesting and provocative theory has been developed to indicate what R&D should do to optimize its decisions. Through application these models might be made more practical so that they are accepted widely. The other challenge is integration with marketing science to reflect the interfunctional cooperation that becoming important in industry.

Marketing Science product optimization. These models are very effective once a set of features is chosen. The challenges are to integrate them with the techniques to select the features in a cooperative marketing/R&D world. More importantly, there are opportunities to extend the models to deal with the formal identification of more fundamental customer needs. (The models might also be extended to incorporate manufacturing considerations and customer-satisfaction feedback.)

Behavioral models. The behavioral models provide conceptual guidance as to how the marketing/R&D interface operates. Table 2 suggests that cooperation and communication are important to new-product success and that communication is best directed at the responsibilities listed in table 1. The models of Gupta, et al., (1986a) and Ruekert and Walker (1987) are early attempts to explain how personal, corporate, and environmental factors may impact a firm's ability to integrate marketing and R&D.

Researchers are starting to test the validity of these models with both U.S. and Japanese firms. If this research is successful, it will help companies select techniques and methods to achieve the level of cross-functional integration that is appropriate to the firm's strategies and environmental conditions. This is important research that has the potential to change the marketing/R&D interface. The most important directions for these models are their development through application in use and their extensions to consider the interfunctional aspects of the marketing/R&D interface.

5. APPROACHES TO ENHANCE COMMUNICATION AND COOPERATION

The academic research is just beginning to explore new theories to enhance the communication and cooperation between marketing and R&D. On the other hand, industry has faced this problem for a number of years, and there is much we can learn from the research on management practice. There are five general approaches cited by Shapiro (1987), Ruekert and Walker (1987), and Allen (1978). Companies have been using these approaches to attempt to integrate the efforts of marketing and R&D:

- relocation and physical facilities design,
- personnel movement,
- informal social systems,
- organizational structure, and
- formal integrative management processes.

Relocation and Physical Facilities

Some firms have changed their physical facilities to promote communication. We have already seen that communication drops off rapidly with distance. One solution is to relocate

people so that the distance between marketing and R&D is reduced. This provides the opportunity for, but does not by itself generate, coordination or even communication.

Allen (1986) has experimented with different layouts which enhance communication. Not only has he found that communication increases with team co-location, but he has found additional increases when the group works in non-territorial spaces. Informal meeting places, with accessible black boards or white boards and free coffee, located at strategic points throughout buildings enhance informal (and productive) communication. Little⁵ suggests that lounge spaces with traffic generators such as refrigerators, copiers, fax machines, and small libraries bring people together and encourage the exchange of ideas. Corning's Decker Engineering building in Corning, NY and Steelcase's Headquarters building in Grand Rapids, Michigan have been designed around Allen's architectural axioms to enhance communication⁶.

Providing communication opportunities through physical proximity must also be complemented by providing groups with techniques which foster the development of cross-functional relationships.

Personnel Movement

Human movement between functional groups is one effective technique to improve the transaction flow across functional boundaries (Roberts 1987, Roussel, et. al. 1991, pp. 163-173). People moving from one function to another bring with them contextual information which may be important in understanding why certain decisions are made even though there is no formal documentation. They also bring with them the person-to-person contacts and friendship-based links to people in their old groups. These links improve the probability of both formal and informal communication and cooperation.

As a product or service moves toward commercialization, personnel can move with the project. This downstream transfer moves experience and know-how into the receiving function to aid in problem-solving and reduces the impression that the downstream function is "stuck" with the post-transfer problems. Similarly, upstream transfers enable the upstream group to anticipate downstream problems. It creates the impression that the downstream group has inputs and ownership in the project.

However, transferring personnel between closely-related technical disciplines or between engineering and manufacturing is far easier than shifting personnel between marketing and R&D. As indicated earlier, the skills, knowledge, language, and culture required by each function create barriers that are difficult to overcome. There are some solutions. Companies may at

⁵John D. C. Little of M.I.T., personal communication.

⁶So have the common areas in for both the Management of Technology Group and the Marketing Group at M.I.T.'s Sloan School of Management. Informal observation by the authors suggests that the change in physical facilities has had a major effect on cooperative research. Both groups are considering co-location of research personnel.

times find and hire those rare individuals with dual skill sets, or they may induce some of their personnel to obtain training in both areas -- the creation of "Management of Technology" programs at many leading universities is a sign that such training is occurring. Companies can also consider transfers where a marketing professional spends part of his (her) time in an R&D group as an advisor or an R&D professional spends part of his (her) time in the marketing function. Such transfers should be temporary to ensure that skills are not eroded, but they can be valuable in the transfer of perspectives without asking a professional to do a job for which he (she) has not been trained. See also discussion in Takeuchi and Nonaka (1986).

Informal Social Systems

Both Moore (1987, p. 12) and Feldman and Page (1984, p. 50) suggest that informal contact is important and often substitutes for formal new-product processes. While cultural differences between marketing and R&D raise barriers to cooperation, informal social networks can provide contact outside a development team, especially to those functions which are ancillary to the team. Such informal social contacts may have the requisite expertise to contribute to solving a particular problem or may identify who has the expertise. Unfortunately, group-culture change often requires a catastrophic crisis which demands change for survival (Schein 1985). Although it is difficult to force such networks to develop, managers can provide opportunities through cross-functional dinners and picnics, athletic leagues and tournaments, community volunteer projects, and other recreational activities. Retreats often serve the dual purpose of problem-solving and generating social networks. However, retreats must be planned carefully to encourage the informal social system. They can be counterproductive if viewed as an inefficient use of time.

Organizational Structure

Table 6 lists six characteristics of an organization that lead to improved cooperation between marketing and R&D. In a study of 80 technology intensive companies, Gupta and Wilemon (1988) found each of these characteristics correlate highly with credibility and cooperation. Any organizational structure should incorporate these characteristics if it is to succeed at fostering cooperation. We explore three organizational structures that have been proposed.

Coordinating groups. Lorsch and Lawrence (1965) advocate creating coordinating groups. Permanent coordinating groups consist of personnel who have a balanced perspective which enables them to work effectively with several specialist groups over a long period of time. Temporary cross-functional committees resolve problems between functional groups and encourage achieving specific goals. However, in case-based research Lorsch and Lawrence report mixed success. Such groups do have the potential to address the issues of table 6 if they are focused on encouraging joint efforts rather than simply resolving conflicts. Supporting part of Gupta, et al.'s interaction model, Lorsch and Lawrence also found that identical structures performed differently across organizations with different strategies and operating within different environments.

Project or program teams. Marquis and Straight (1965) advocate placing all functional contributors in the same group under a single leader. Project or program teams encourage the exchange of information, provide a degree of formalization, value cooperation, and provide a joint reward system. Such a project organization maximizes coordination and control toward a specific goal, but runs the risk of greater centralization. One long-term flaw with project-based organizations is that, by removing specialists from their supportive functional groups, these specialists react less with colleagues in their own technical or market-based discipline. If the project duration is too long, the technical skills and the knowledge base of the team members erodes, especially when the technology base or market structure is changing rapidly (Roberts 1987).

Product champions. Moore (1987, p. 14) stresses that product champions are important to the success of new-product development. Such champions develop networks of informal contacts to make sure that information is transferred between marketing and R&D and that both functions contribute to the process. Of course product champions need "protectors" who can intercede to defend the champion and to secure resources and "strategists" to focus the champion on the goals of the organization. See discussion in Urban and Hauser (1980, pp. 540-546).

Matrix organizations. Babcock (1991) reports that a number of firms have implemented matrix organizations in an attempt to maintain functional specialization while improving cross-functional performance. Functional specialists reside in their functional groups and report to a functional manager, but they also report on a "dotted-line" basis, frequently part-time, to one or more project leaders who need their particular expertise during some phase of a project. In theory, the project leader performs the integrating function by encouraging information exchange, providing formal reporting procedures, joint rewards, and assigning value to cooperation. However, personnel often find it difficult to balance time spent in a functional group with time spent on the cross-functional teams. Different individuals may infer different priorities from their functional and cross-functional managers. Without good coordination, such matrix organizations run the risk of becoming just "paper" matrices (Roberts 1987).

CHARACTERISTIC	EXPLANATION
1. Harmonious operating characteristics	Discuss important issues, resolve conflicts early, work together
2. Formalization	Clear performance standards, clear responsibilities, well-defined guidelines
3. Decentralization	Issues resolved quickly by "local" knowledge
4. Innovativeness	Supports new ideas, tolerates failure, is responsive to change
5. Cooperation is valued	Provides opportunities to exchange views and perspectives
6. Joint reward system	Both marketing and R&D share in success (and do not blame the other for failure)

Table 6. Organizational Characteristics that Enhance Cooperation (Gupta and Wilemon 1988)

Each of these organizational structures has the potential to improve marketing/R&D coordination and communication and each has worked in a variety of circumstances. However, a formal organization is not sufficient by itself to generate cooperation and communication. It must be supported by other means, such as personnel co-location, moving personnel across functions, and formal management processes.

Formal Management Processes

The most visible joint task requiring cooperation between marketing and R&D is new-product development. Urban and Hauser (1980) synthesize many of the new-product development processes into a sequence of opportunity identification, design, testing, launch, and profit (life cycle) management. While, on paper, such phased development processes encourage cooperation between the functions, these processes usually assign specific responsibilities to one of the functional groups and encourage timely input from the other. For example, Urban and Hauser's decision flow chart (chapter 18, page 538) describes parallel decisions and development within functional areas. Similarly, Dougherty's synthesis in figure 1 suggests parallel responsibilities with communication across boundaries. See also the review in Kotler (1991, chapter 12).

More recently, processes have been developed which combine the inputs of marketing, R&D, and even manufacturing, into a joint decision making process. Hayes, et. al. (1988) and Takeuchi and Nonaka (1986) suggest that such overlapping development processes enhance communication and reduce barriers to cooperation. An ideal process would include:

- a cross-functional effort led by an experienced business manager,
- a stable, possibly autonomous, team throughout the whole project,
- extensive overlapping of project phases and problem-solving with early release of preliminary information to all functional groups and transfer of lessons learned,
- progress which is measured by task completion, not time progression, and
- cross-functional relationships based on trust and mutual respect, with conflicts addressed early and at low levels, that is, by the team itself, not upper managers.

Griffin's (1991) research on managing the process of product development suggested that an ideal process would

- explicitly structure decision-making processes across functional groups,
- build a solidly-organized, highly motivated team, and
- move information efficiently from its origin to the ultimate user.

In the next section we review in depth one formal integrative process, Quality Function Deployment, that has been adopted widely and which has been proven to enhance communication between marketing and R&D. Sections 7 and 8 present research which demonstrates how QFD improves the process of new product development. Section 9 describes how QFD's use has implications for the way marketing research is performed in firms, and provides suggestions as

to how management science research can improve QFD's application.

6. QUALITY FUNCTION DEPLOYMENT -- ONE PROCESS TO ENCOURAGE INTERFUNCTIONAL COOPERATION

Quality Function Deployment (QFD) is one formal management process that has been developed to integrate marketing and R&D. It was developed in 1972 at Mitsubishi's Kobe shipyard, brought to the United States by Ford and Xerox in 1986 and, in the last five years, has been adopted widely by Japanese, United States, and European firms⁷. Hauser and Clausing (1988) claim that in some applications it has reduced design time by 40% and design costs by 60% while maintaining and enhancing design quality⁸. Many US firms who have adopted QFD claim that it has improved relations between marketing and R&D by focusing their efforts on providing information and designing products and services that satisfy customer needs.

QFD begins with an interfunctional team that includes marketing, R&D, and other functions, such as manufacturing. The team works together under a team leader to focus on either product improvement or product development following the suggested practices of ideal processes listed above. We believe QFD works because it provides procedures and processes to enhance communication between, and structure decision-making across, marketing and R&D and because it provides a translation mechanism from the language of the customer to the language of the engineer. It overcomes many of the barriers to communication listed earlier in this chapter. The enhanced communication leads to reduced cycle time.

QFD uses four "houses" to integrate the informational needs of marketing, engineering, R&D, manufacturing, and management. Applications begin with the first house, the House of Quality (HOQ). We begin by describing the HOQ, which is shown conceptually in figure 6.

One way to look at the HOQ is as a translation between the marketing input (customer needs, customer-need importances, and customer perceptions) and the language of R&D (design attributes and engineering measures) through a relationship matrix. However, we want to stress that the HOQ (as well as QFD) is an integrative process in which marketing and R&D participate as equal partners in all aspects of the communication process including the identification of customer needs and their relationship to design attributes. Much of the benefit of the HOQ comes from the mutual understanding of the problem and of one another that comes as marketing and R&D work together for a joint solution. With this in mind we describe first

⁷ Among the firms reporting applications in 1989 were General Motors, Ford, Navistar, Toyota, Mazda, Mitsubishi, Procter & Gamble, Colgate, Campbell's Soup, Gillette, IBM, Xerox, Digital Equipment Corp., Hewlett-Packard, Kodak, Texas Instruments, Hancock Insurance, Fidelity Trust, Cummins Engine, Budd Co., Cirtex, Yasakawa Electric Industries, Matsushita Densko, Komatsu Cast Engineering, Fubota Electronics, Shin-Nippon Steel, Nippon Zeon, and Shimizu Construction.

⁸ These estimates are derived from Japanese companies using QFD.

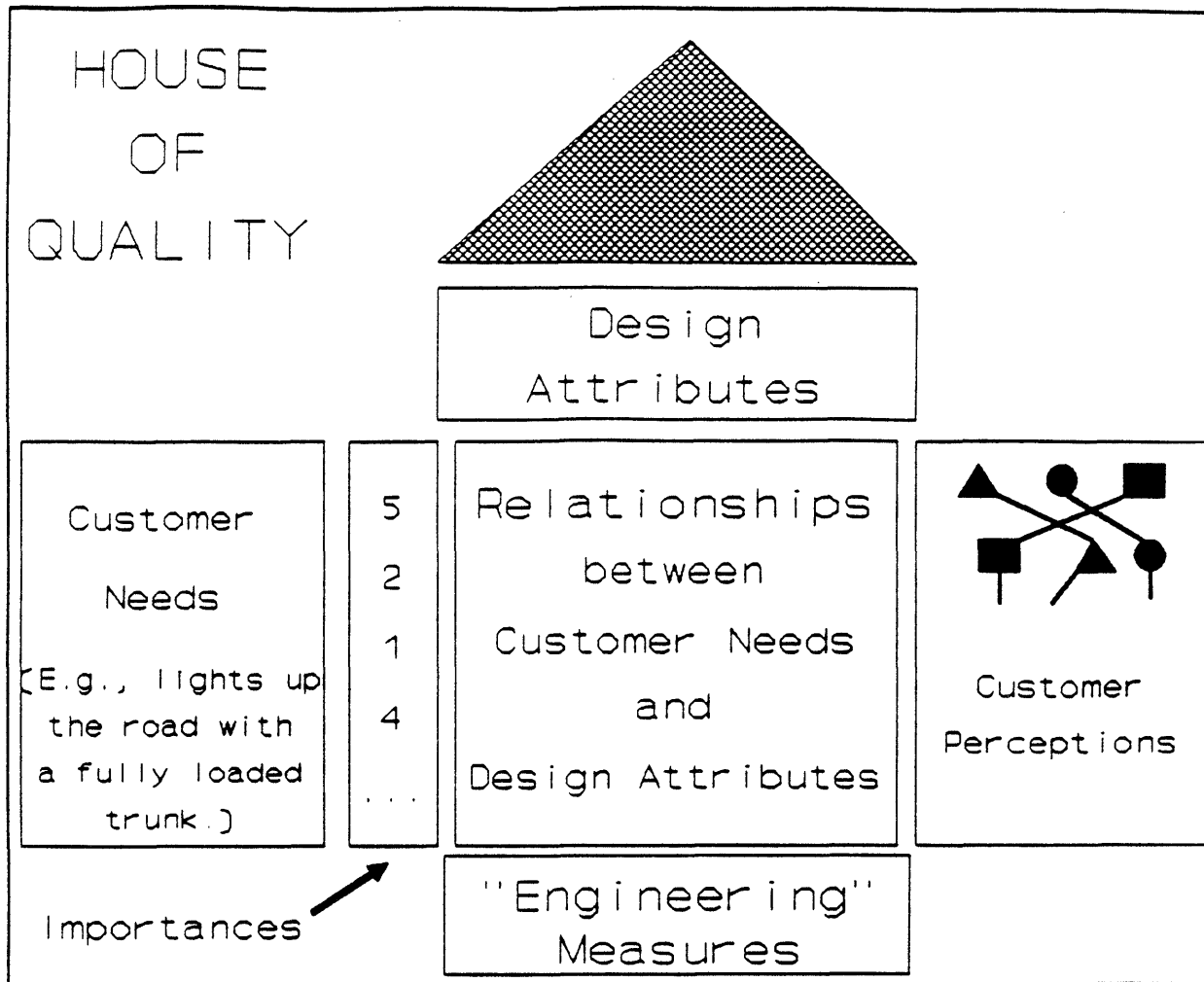


Figure 6. The House of Quality in QFD (from Griffin and Hauser 1992)

what is normally considered the marketing-side input, the voice of the customer.

The Voice of the Customer

Identifying customer needs. The voice of the customer begins with identifying customer needs, which are listed on the left side of the house. A customer need is a description, in the customer's own words, of the benefit which he, she, or they want fulfilled by the product or service. For example, for an automobile headlight, a customer need might be "lights up the road with a fully loaded trunk." Note that the customer need is not a solution, say halogen headlights, or a physical measurement of the need, say illumination at 20 feet, but rather a more detailed description of what the customer wants the headlight to do. This is a key distinction between QFD and more traditional marketing inputs to R&D. If the team focuses on solutions too early, they miss creative opportunities. For example, if, in the early 1950's, an automobile transmission team had set a customer need as a "smooth clutch" rather than "easy shifting," they

might have overlooked the invention of an automatic transmission. Similarly, if the team focuses too quickly on physical measurements, they may miss an understanding of all of the influences on customer needs. For example, a customer's perception of how well a headlight "lights up the road" might depend upon illumination, characteristics of the windshield, interior lighting, the targeting of the lens, etc.

Customer needs are identified by talking to real customers facing real problems. For example, focus groups or experiential one-on-one interviews allow customers to explain how they use a product and how they would like to use a product under different usage scenarios. (We discuss methodological implications in section 9 of this chapter.)

Normally, discussions with customers identify 100-400 customer needs including basic needs (what the customer just assumes a headlight will do), articulated needs (what the customer will tell you that he, she, or they want the headlight to do), and excitement needs (those needs, which, if they were fulfilled, would delight and surprise the customer). However, it is difficult for a team to work with 100-400 customer needs simultaneously.

Structuring the needs. To make customer needs manageable, they are structured into a hierarchy of primary, secondary, and tertiary needs. The primary needs, also known as strategic needs, are generally the five-to-ten top-level needs that set the strategic direction for the product. Secondary needs, also known as tactical needs, are elaborations of the primary needs -- each primary need is usually elaborated into three-to-ten secondary needs. These needs indicate more specifically what can be done to fulfill the corresponding strategic (primary) need. A typical list of 20-30 secondary needs is quite similar to the 20-30 "customer attributes" that are common in marketing research. But, the voice of the customer goes beyond the customer attributes of marketing research to explore the tertiary needs, also known as operational needs. The tertiary needs provide detailed requirements to R&D, so that they can deliver the benefits the customer wants. For example, if R&D wants to design a headlight that lights up the road, they might ask "Is the customer driving in the city or on a country road?," "Is the customer driving at dusk or late at night?," "Is the trunk loaded or empty?," "Are the high-beams on or off?," "Is it raining, snowing, foggy, or clear?," etc. The tertiary needs address these questions and articulate what the customer wants in each of many specific conditions. It is this last lower level of customer needs that provides the translation from a product or service strategy to a detailed product or service design. It is this last lower level that provides the means of communicating between marketing and R&D.

Importances of the needs. Customers want their needs fulfilled, but some needs have higher priorities than others. These priorities help the QFD team make decisions which balance the cost of fulfilling a need and the benefit to the customer. For example, if it is equally costly to fulfill two needs, then the need which the customer rates as more important should be given higher priority. Importances are usually based upon survey measures.

Customer perceptions. Customer perceptions describe how customers evaluate "our" product and competitive products in terms of the products' abilities to fulfill the customer needs.

By understanding which products fulfill customer needs best, how well those customer needs are fulfilled, and whether there are any gaps between the best product and "our" product, the QFD team can provide goals and identify opportunities for product design. Furthermore, by comparing customer perceptions to a team's perceptions of a product, the team can overcome organizational biases. Customer perceptions are measured for each customer need, usually through a formal survey.

While customers are the primary sources of the marketing-side inputs to the HOQ, engineers provide the bulk of the technical and performance inputs to QFD. We now turn to the steps required in assembling the technical inputs to QFD.

The Voice of the Engineer

Design attributes. To fulfill customer needs, the product (or service) must fulfill measurable requirements. For example, a headlight might have as design requirements target values for illumination (in candle power), coverage (in square meters), and power consumption (in watts). It might have design characteristics specified under a variety of conditions, conditions which match those voiced by the customer. These design measures are listed at the top of the house. They are measured in physical measurement units that become targets for an R&D design. However, they are not product solutions. Solutions come in the second house of QFD. If solutions are specified too early, the R&D process becomes constrained to existing solutions and new, creative directions may be missed.

Engineering measures. Just as we measured competitive products with respect to customer needs, so do we measure competitive products on the physical units specified by the design attributes.

Relationship matrix. The QFD team judges which design attributes influence which customer needs. Each element of the relationship matrix indicates how much (if at all) each design attribute affects each customer need. The idea is to specify the strongest relationships leaving most of the matrix blank (60-70% blank). While it is possible to complete experiments to measure elements of the matrix, the majority of applications are based on team judgments which synthesize the combined expertise of the team and any "hard" data that may have been collected.

Roof matrix. Finally, the roof matrix, shown as cross-hatched lines in figure 4, quantifies the physical interrelations among the design attributes -- a brighter headlight requires more electrical power and thus impacts other subsystems in the car.

Using the House of Quality

The House of Quality encourages cooperation between marketing and R&D by requiring each functional group to quantify and articulate their inputs and assumptions. QFD links the language of the customer to the language of the engineer. By specifying the language of the

customer (marketing) and the technical language of design (R&D) and the means to translate one to another (relationship matrix), the HOQ prevents misunderstanding and forces each group to clarify their own thought-world. If the entire team participates in the HOQ, all team members understand and accept these inputs and relationships.

Once the HOQ is complete, the team can use the inputs and the relationships to establish design targets, that is, specific performance values of the design attributes which the product will try to deliver. To make these decisions the team considers the cost and difficulty of achieving these targets, the influence of these targets on other design attributes, the influence of these targets on fulfilling customer needs (relative to competition), and any other relevant input of which the team is aware.

Perhaps in the future researchers will develop means to automate the HOQ while maintaining its ability to encourage creativity and foster interfunctional communication. In the applications with which we are familiar the HOQ works best as a means of communication that does not supplant the team's judgments and instincts. It can be used in parallel with more formal "what-if" analyses that quantify the cost and/or demand impacts of design decisions and it can be followed with a more-formal marketing-science product optimization model. But such applications have yet to appear in the published literature.

The Other Houses of QFD

If the first house links customer needs to design attributes, the second house links design attributes to solutions. For example, in the second house design attributes (illumination) are placed on the left side of the house and solutions, such as the type of headlight, the electric system that drives it, the control system in the car, the dashboard switches, the housing and closure system for the headlight, are placed at the top of the house. This house is often known as the parts-deployment house, or simply, the second house. In developing the second house, the QFD team tries to list as many alternative solutions as possible so that the best combination can be chosen to deliver the design attributes. When the second house is linked to the HOQ, these solutions are based on customer needs.

QFD recognizes that design solutions are not enough. The product must be built or the service delivered. Furthermore, marketing and R&D are not the only functions that need to be integrated. The third house links engineering solutions to process operations, thus coordinating marketing and R&D with manufacturing and service delivery. Finally, a fourth house links process operations to production requirements to complete the cycle. Together the four linked houses ensure that the customer's voice drives the entire design and manufacturing (service delivery) process and that all relevant functional areas work together toward the same goal.

This completes our short description of QFD. For a managerial discussion of QFD see Hauser and Clausing (1988); for a participant-observer ethnography of thirty-five projects at nine firms see Griffin (1989); for details and case studies see Clausing (1986), Eureka (1987), King (1987), Kogure and Akao (1983), McElroy (1987), and Sullivan (1986), as well as collections

of articles by Akao (1987), and the American Supplier Institute (1987).

In the remainder of this chapter, we present the first major research results from investigating QFD's use in the US. In section 7 we present results indicating that QFD improves communication between marketing and R&D. In section 8, we suggest when QFD does and does not work and suggest that the greatest benefits of QFD are long-term rather than short-term improvements in time and cost. Finally, in section 9 we examine the marketing research implications of QFD.

7. QFD IMPROVES COMMUNICATION BETWEEN FUNCTIONS

In studying product-development communications, we have compared QFD to a traditional "phase-review" process at a large automobile manufacturer (Griffin and Hauser 1992). One development team used QFD; the other used a phased process in which they reviewed development as the project passed certain checkpoints. The teams were chosen to be matched as closely as feasible. Both teams resided in the same organization, developing components of comparable technical complexity, with about the same number of parts, and which serve similar functions in an automobile. Both products are manufactured by outside suppliers, but are designed by the automobile manufacturer (OEM, "original equipment manufacturer"). Both teams report to the same manager two levels up and contain roughly the same number of team members with roughly the same experience. In both cases the team leader was committed to the process being used.

During the 15-week period of observation team members reported on their communications by completing, on a randomly chosen day each week, a one-page form. Following a method developed by Allen (1970, 1986), the names of potential communication partners were listed as rows on the form and the potential topics of communication were listed as columns. The team member simply indicated at the end of the day with whom he (she) had communicated and about what. In total the response rate was 85% with a reliability⁹ of 94.7%.

Section 2 of this chapter suggests that communication among marketing and R&D enhances success in product development. If

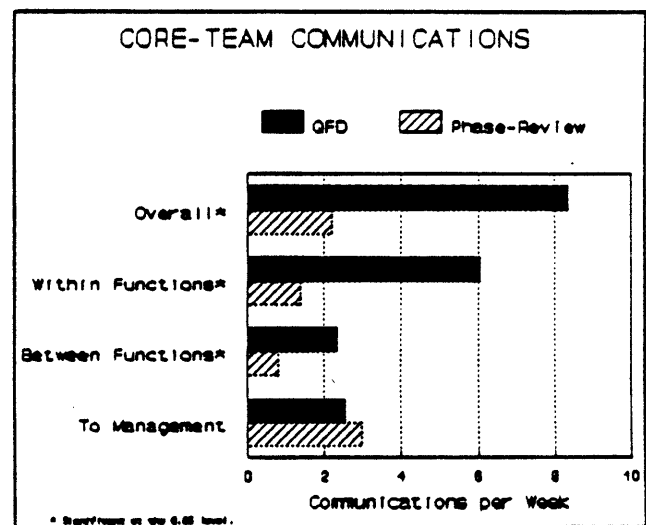


Figure 7. Communication Comparison
(from Griffin and Hauser 1991a)

⁹A response is considered reliable if person *i* reports communicating with person *j* and person *j* independently reports communicating with person *i*.

we add manufacturing to marketing and R&D we have a "core team" within the QFD or phase-review teams. Figure 7 compares the communication patterns of the core QFD and the core phase-review teams. QFD led to more communication, more communication within functions, and more communication between functions. However, QFD reduced slightly the communication from the core team to management. When we examined more detailed patterns (see figure 4 in Griffin and Hauser 1992) it suggested a pattern of QFD team members communicating directly to one another rather than going through a management loop. If indeed management was serving primarily as a communication conduit, then this would imply that the QFD pattern of communication was more efficient.

Figure 8 compares the topics discussed. Both teams focused primarily on design issues. In part this was because communication on design issues is a key correlate of new-product success (Hise, et. al. 1990) and, in part, because design was the focus during the period of our observation. More importantly for the comparison between teams, there was more communication about design, customer needs, and market information by the QFD team. On the other hand, the phase-review team allocated more effort to planning. Thus, figure 8 is consistent with the hypothesis that QFD allows the team to focus on "doing" rather than "planning to do."

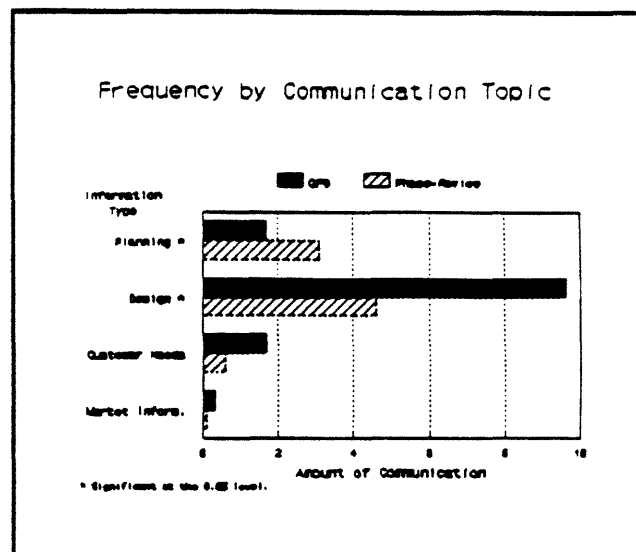


Figure 8. Comparison of Communication Topics (from Griffin and Hauser 1991a)

Naturally, figures 7 and 8 are based on a single comparison at one manufacturing company. They are consistent with intuition and suggest that QFD may indeed provide a means to enhance communication and, by implication, the success of the marketing/R&D interface. Our own qualitative experience in over twenty applications suggests that such communication gains are typical. We have observed that QFD and the House of Quality encourage marketing and R&D to understand one another and to focus on customer needs¹⁰.

¹⁰These applications include computers (main-frame, mid-range, work stations, and personal), software, printers, cameras, airline service, paints, surgical instruments, diagnostic instruments, office equipment, consumer products, tools, retirement plans, movie theaters, health insurance, distribution networks, automobiles, automobile subsystems, and automobile components.

8. QFD CONTRIBUTES TO LONG-TERM DEVELOPMENT IMPROVEMENTS

Many US managers have promoted QFD based on the potential for decreased design costs and decreased time to market. However, the philosophy of QFD is one of incremental improvements with payoffs coming over the long term. To determine whether QFD could provide either short-term and/or long-term benefits and to determine when QFD does and does not work, Griffin (1991) studied nine of the two-dozen US companies using QFD in 1987. In total 35 projects were studied. These projects included components, subsystems, and complex systems for products, services, and software. They varied on the number of customers (few to many) and the amount of change (incremental to "clean sheet").

The research combined retrospective interviews with members of the QFD teams, interviews with senior managers who could evaluate the success of the projects and the incremental advantages and disadvantages of QFD, and real-time observation of nine of the thirty-five teams as they used QFD.

We begin by evaluating the short-term impact of QFD. Short-term benefits, if they occur will be changes in the cost and the time required to develop new products or improvements in the products themselves. Based on team-member and manager evaluations and quantitative measures (when available), Griffin assigned each project to one of four categories in terms of short-term, tactical success. The categories were:

- *Tactical success.* Measurable project improvements.
- *Failure.* The process was abandoned or rejected.
- *Mixed success.* Some performance aspects improve; others are worse.
- *No change.* Projects exhibit no short-term changes from expected performance.

Tactical Success Category	No.	% with Strategic Benefits
Tactical Success	7	100%
No Change	7	100%
Mixed Results	8	100%
QFD Failures	4	50%
No Information	9	56%
TOTAL	35	83%

Table 7. Successes and Failures in Sample

The indicators of tactical short-term success were product performance (improved feature performance, increased quality levels, or increased customer satisfaction) and commercial process improvements (decreases in commercialization time and cost). A project is labeled as successful if at least one measure is better and no measure is worse.

In addition to the short-term benefits, team members and managers reported long-term

strategic benefits by answering two open-ended questions: "What did QFD do for this project?" and "What benefits did using QFD produce?" Many of the teams reported intangible benefits such as "better understanding of customer needs," or "better cross-functional relationships." Such benefits may have their payoffs over many years and many projects.

Table 7 reports the percent of projects with short-term and with long-term benefits. Notice that while only 27% reported a clear tactical success, 83% reported long-term strategic advantages. These long-term advantages are summarized in table 8. Based on tables 7 and 8 we infer that QFD is better at providing (perceived) long-term rather than short-term benefits to the firm and that firms should guard against asking too much too soon from QFD in terms of quantifiable outcome measures.

	# of Projects
PROCESS BENEFITS	
Make Rational Decisions	18
Improve Information Flow	16
Solidify Design Early	13
Forge Cross- Functional Relationships	4
PROJECT BENEFITS	
Meld Team Together	9
Produced a Change	7
Captures Knowledge	7
NON-SPECIFIC VALUE	
Would/Did Use QFD Again	9
"Liked it;" Saw Value	3

Table 8. Strategic Benefits Reported

Griffin also investigated project characteristics which might be associated with short-term QFD successes and failures. These variables are summarized in table 9.

One key variable is whether firms treated QFD as an investment or a cost. All successful projects considered QFD an investment in people and information while all failures treated QFD as an expense which must be incurred, but should be minimized. The second key variable was commitment. For the successful projects, all the involved managers and team members were highly committed to using QFD as a process for development. In the less successful projects only one function (marketing, R&D, or manufacturing) was committed.

A third variable, the goal orientation of the project, seemed to be necessary, but not sufficient. Six of the seven successful QFD projects were undertaken to effect a specific change (solve a problem) in some aspect of the product or development process. However, two of the failed projects also had problem-oriented goals. Put another way, QFD is unlikely to improve short-term development outcomes when it is undertaken as a "demonstration" project to gain expertise with the method, or as a means to study a "generic" project for the entire product line, or as a means to improve process measures without a specific project goal.

Naturally, Griffin's qualitative study can provide at best hypotheses for further scientific comparison. For example, one might hypothesize that teams bought into QFD because it seemed to be providing success or that firms saw QFD as an investment because the payoffs (and success) was assured. Furthermore, the long-term benefits are based on perceptions of the

product-development team rather than "hard" sales or profit measures¹¹. However, Griffin's study suggests the working hypotheses that QFD requires a long-term perspective, a willingness to invest in people and process, and a goal-orientation.

	Total	Success	Fail	Mixed	No Change
WHO PUSHES QFD USE					
Top-Down	8	0	1	2	3
Bottom-Up	10	4	1	1	1
Neutral Other	17	3	2	5	3
LEVEL OF TEAM BUY-IN OR COMMITMENT					
High	10	7	0	0	2
Moderate	12	0	0	5	4
Low	13	0	4	3	1
GOALS FOR USING QFD					
Process-Oriented	20	1	2	5	5
Output-Oriented	14	6	2	3	2
CORPORATE ATTITUDE TO QFD					
Investment	21	7	0	7	3
Expense	14	0	4	1	4
NUMBER OF FUNCTIONS INVOLVED					
1 out of 4	2	1	0	1	0
2 out of 4	8	3	2	1	0
3 out of 4	15	1	2	5	5
4 out of 4	10	2	0	1	2
TEAM FAMILIARITY					
High	3	0	0	0	2
Moderate	14	5	2	4	2
Low	18	2	2	4	3

Table 9. Summary of Implementation Characteristics

¹¹Griffin completed her study in 1987. Since then, firms have improved their use of QFD and the marketing research inputs have become more efficient and effective. Based on personal observation, we feel that the success rate of QFD has improved for both the short-term and long-term. See Griffin and Hauser (1991) for nine vignettes of successful applications and Hauser (1992) for complete details on one application that increased potential sales by a factor of five while increasing customer satisfaction and reducing the cycle time of new-product development.

9. MARKETING IMPLICATIONS OF QFD

Although marketing should be involved throughout the QFD process, one key input from marketing is participation in identifying, structuring, and prioritizing the voice of the customer. Many of these tasks will be familiar to our marketing readers. For example, see the discussions in chapters 7-12 of Urban and Hauser (1980). For QFD the new challenge is the detail necessary at the tertiary (operational) level (100-400 customer needs), the desire to link the customer needs to design attributes, and the manner in which the customer needs are structured into primary, secondary, and tertiary levels (strategic, tactical, and operational levels). In this section we give examples of how marketing might provide the voice of the customer. Naturally, we can not review all of the techniques that are available, but this short review should give the reader an idea of current practice. For more details and scientific comparisons, see Griffin and Hauser (1991).

Identifying Customer Needs

Identifying customer needs relies upon qualitative research. For example, in the Vocalyst™ method¹² now used by a variety of service, industrial product, and consumer product firms, between 10 and 30 customers (per segment) are interviewed for approximately one hour each in a one-on-one setting. During the interview customers are asked to picture themselves using the product or service. As the customer describes his, her, or their experiences, the interviewer keeps probing, searching for more detailed explanations and more complete descriptions. Experiences are elicited and probed until the interviewer feels that no new needs will be identified. During the interview the customer is also asked to image future experiences and to indicate needs which should be fulfilled that are not now fulfilled. When necessary the interviews probe higher level needs and explore the means to achieve these needs. (Such explorations are known as laddering and/or means-end analysis. See Reynolds and Guttman 1988.) Other techniques involve focus groups (Calder 1979) and mini-groups of two-to-three customers.

Because practice is still developing there is much debate among practitioners. The two questions we hear often are: (1) Is it better to interview customers in groups or individually?, and (2) How many people (groups) should be interviewed?

Groups or one-on-one interviews. Many market research firms advocate group interviews (see also Calder 1979) based on the hypothesis that customers within groups will get ideas from one another and that the synergies will produce more and varied customer needs. On the other hand, if there are eight people in a focus group then, on average, each person talks for about 15 minutes. Some market research firms argue that 15 minutes may not provide sufficient time to probe deeply for a more complete understanding of the operational customer needs.

¹²Vocalyst is a trademark of Applied Marketing Science, Inc. of Waltham, MA. Experiential interviews are based on Griffin (1989) and Griffin and Hauser (1991). We are aware of other applications.

Figure 9 is one comparison of the productivity of focus groups and one-on-one interviews. The product category is a complex piece of office equipment and the users were experienced. Eight two-hour focus groups of 6-8 people each and nine one-hour interviews were undertaken. The entire set of data was analyzed by six people to produce a combined set of customer needs. Silver and Thompson (1991) then reanalyzed the data to determine, for each customer need and for each group or individual, if that group or individual had voiced that customer need. They used this data to determine, on average, how many customer needs would have been voiced by one person or group, by two people or two groups, etc.

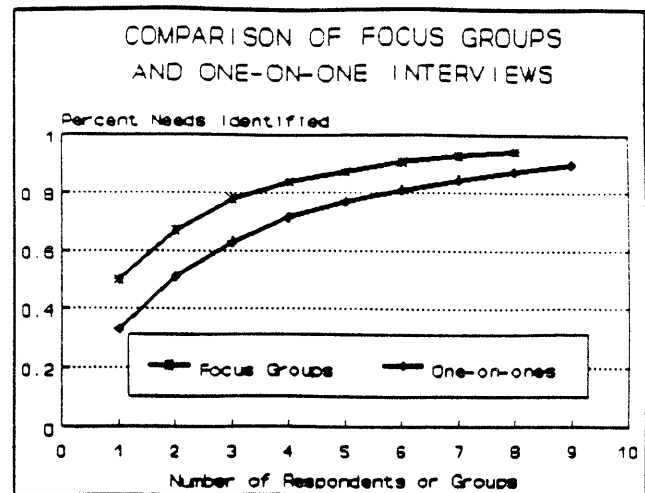


Figure 9. Focus Groups vs. One-on-One Interviews for Office Equipment (from Silver and Thompson 1991)

Figure 9 indicates that a focus group provides more needs than a single interview, but that two interviews provide about as many needs as a single focus group. As one manager said when he examined the data, it is almost as if an hour of transcript time is an hour of transcript time independently of whether it comes from a single interview or a focus group¹³. If it is less expensive to complete two one-hour interviews than one two-hour focus group, then figure 9 suggests that interviews may be more efficient. At minimum figure 9 suggests that the group synergies do not seem to be present.

How many customers. Figure 9 suggests that 10+ interviews might be sufficient for that high technology piece of office equipment, particularly if the one-on-one interviews are supplemented by telephone interviews to probe on issues the team may wish to have elaborated¹⁴. We do not yet know whether that conclusion generalizes for expert users. However, we know of one other detailed study for less-experienced users of a less-complex product, portable food-carrying devices, a.k.a. coolers.

In this study, 30 customers were interviewed. Again, a set of needs was identified and, for each need and each customer, we determined whether that customer would have given that need (Griffin and Hauser 1991). Because it was possible that 30 customers were not enough, we estimated a statistical model to determine how many needs were not identified by the thirty

¹³We note that this qualitative result can also be seen in the data reported by Fern (1982). He found that eight nominal 20-minute interviews with individuals produced 75% more ideas than one 100-minute eight-person focus group. In each case approximately 1.2 ideas were generated per minute of transcript time.

¹⁴As of this writing, a few market research firms are advocating such telephone supplements. Experience is sparse so we do not yet know whether such interviews live up to their promise.

customers. The results, given in figure 10, suggest that 30 customers give over 90% of the needs and that approximately 15 customers give about 80% of the needs.

Putting figures 9 and 10 together, we hypothesize that at least 10-20 interviews are needed, more if the users are less experienced, the product category is more complex, or a particularly broad market segment is being investigated.

Structuring Customer Needs

Because we work with a large number of attributes in QFD, means must be found to structure them into smaller groups of similar items which can be used by the development team to drive product design. Large random attribute lists overwhelm design teams - they don't know where to start or on which attributes to focus. Factor analysis, the standard marketing research techniques to structure attributes, is difficult to use because the large number of customer needs makes data collection difficult and because there is often ecological correlation which confounds correlation due to similarity¹⁵. Thus, Japanese and US firms have tended to use one of two techniques -- one based on the team's judgment and one based on statistical analysis of data collected from customers. We describe these techniques, affinity diagrams and customer-sort diagrams, which are used to structure customer needs into usable hierarchies.

Affinity diagrams. In most American and Japanese applications, customer needs are structured with affinity charts or K-J diagrams¹⁶, two variations of one of the "Seven New Tools" used in Japanese planning processes (King 1987). Affinity-charts are based on a process of group consensus in which the product-development team imposes structure on the customer needs. The advantage of an affinity chart is that it assures group buy-in to the structure; the disadvantage is that there is no assurance that the team's structure represents how customers make decisions.

Each team member is given a roughly equal number of cards, each bearing one need. One team member selects a card from his (her) pile, reads it aloud, and places it on the table

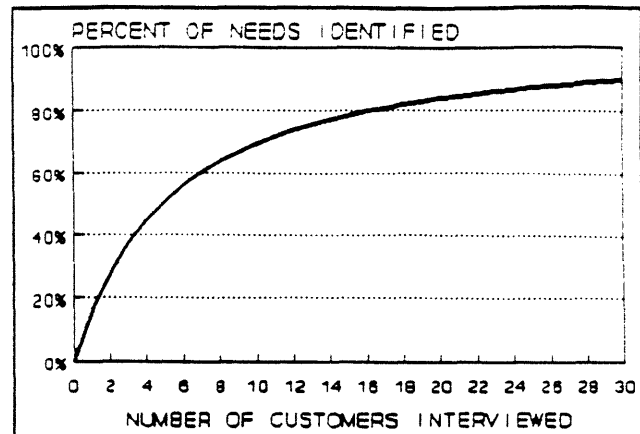


Figure 10. Predictions of Number of Needs Identified for Coolers (from Griffin and Hauser 1991b)

¹⁵For example, in an automobile, the total length is often correlated with engine size, legroom, and even the quality of the interior. Thus, when we survey people about needs that relate to length, engine size, legroom, and the interior we will find correlation even though these needs are quite distinct in the customer's mind. We do not rule out factor analysis; we only point out that it can not be used blindly.

¹⁶K-J is the registered trademark of Jiro Kawakita for his version of the affinity chart. For the remainder of the paper we use the more generic name.

(or wall). Other members add "similar" cards to the pile with a discussion after each card. Sometimes the card is moved to a new pile, sometimes it stays where it was first placed. The process continues until the group has separated all the cards into some number of piles of similar cards, where each pile differs from the others in some way. The team then structures the cards in each pile into a hierarchical tree with more detailed needs at lower levels, and more tactical and strategic needs at the upper levels. To label a higher-order need, say a secondary need to represent a group of tertiary needs, the group can either select from among the tertiary needs or add a new card to summarize the relevant tertiary needs. Throughout the process the team can rearrange the cards, start new piles, or elaborate the hierarchy.

Customer Sort. In a customer sort, customers are given a deck of cards, each bearing one need. They are asked to sort the cards into piles such that each pile represents similar needs and differs from the other piles in some way. The number of piles and the exact definition of similarity is left unspecified. After completing the sort, each respondent is asked to choose a single need, called an exemplar, which best represents each pile. From the sort data we create a co-occurrence matrix in which the i - j -th element of the matrix is the number of respondents who placed need i in the same pile as need j . We also label each need with the number of times it was chosen as an exemplar.

To develop a structured hierarchy we cluster¹⁷ the co-occurrence matrix. To name the clusters we use the exemplars. When there is no clearly dominant exemplar within a cluster, we either choose from among the exemplars in the cluster or add a label to the data.

Comparison. We have now completed formal comparisons of structures for a consumer packaged-good and for coolers. We have also completed a formal comparison for a high-technology product between affinity groups based on team input and affinity groups based on customer input. In addition we are aware of a number of comparisons that have been completed in the field for both consumer and industrial products¹⁸. Table 10 reports the primary-need labels for the cooler hierarchies. Notice that the customer-sort hierarchy used more categories, that the secondary and tertiary needs are more equally distributed among categories, and that the exemplars are more equally distributed. More importantly, most managers believe that the customer-sort hierarchy provides a clearer, more-believable, and easier-to-work-with representation of customer perceptions than does the affinity hierarchy. The affinity hierarchy seems to sort needs according to how one would build a cooler; the customer-sort hierarchy

¹⁷We have found that Ward's method, the average linkage method, and the complete linkage (farthest neighbor) provided similar structures in our data. See Griffin (1989). For example, when comparing a Ward's-based cluster solution and an average-linkage-based cluster solution, only 3% of the customer needs appeared in different primary groupings. Single linkage (nearest neighbor) led to "chaining" in which customer needs were merged to a large cluster one at a time. Because the difference between the three clustering algorithms is slight, we chose Ward's method for the comparisons in this chapter. It is used more often in industry (Romesburg 1984) and, when shown the three solutions, the management team believed that the Ward's structure was slightly superior to other two. (In Ward's method, clusters are merged based on the criterion of minimizing the overall sum of squared within-cluster distances.)

¹⁸Personal communication with Robert Klein of Applied Marketing Science, Inc.

seems to sort needs according to how one would use a cooler.

AFFINITY CHART				CUSTOMER SORT			
<u>PRIMARY NEED</u>	<u>SECD. NEEDS</u>	<u>TERT. NEEDS</u>	<u>EXEM-PLARS</u>	<u>PRIMARY NEED</u>	<u>SECD. NEEDS</u>	<u>TERT. NEEDS</u>	<u>EXEM-PLARS</u>
Price	4	0	2	Attractiveness	4	20	9
Container Utility	2	14	21	Carries Many Things	4	21	9
Phys. Characteristics	10	30	10	Maintains Temps.	5	39	6
Thermal Attributes	4	34	3	Right Size	3	29	7
Convenience	5	139	6	Easy to Move	2	23	6
				Convenience	2	29	1
				Works as Container	2	30	4
Total	25	217	42		22	201	42
Coeff. of Variation	0.6	1.4	0.9		0.4	0.2	0.5

Table 10. Comparing Affinity-chart and Customer-sort Cooler Hierarchies (from Griffin and Hauser 1991)

Based on our observations and our discussions with practitioners most of the speculation based on table 10 generalizes to the proprietary applications. The customer-sort hierarchy does tend to spread the needs and exemplars more equally and the resulting structure does seem to represent better how customers use the product rather than how firms build the product. Indeed, in *every* application which we have observed or have heard about, once the team saw the customer-sort hierarchy they felt that it, rather than the affinity diagram, was a better voice of the customer.

One argument in favor of the affinity hierarchy is that it encourages more involvement by the team and leads to greater "ownership" of the results. Faced with this criticism, recent applications of customer-sort methods have asked the team to complete the customer task in parallel with the customers. Both sets of data are analyzed and comparisons made. During the process the team begins to ask themselves: "I know how I would sort the customer needs, but how would the customer sort these same needs?" Such involvement leads to a greater appreciation of the results and a belief by the team that they "own" the results.

Providing Priorities for Customer Needs.

Providing priorities (importances) for customer needs, albeit for fewer needs than are necessary for QFD, has received much attention in the marketing literature. We refer the reader to Wilkie and Pessemier (1973), Lynch (1985), Shocker and Srinivasan (1979), Green (1984), and Hauser and Urban (1979). Rather than focusing on that literature, we again focus on those questions that are most common in the application of QFD: (1) Can we avoid new data collection by using frequency of mention in the qualitative research as a surrogate for importance?, (2) Do survey measures of importances have any relation to how customers make choices among products?, and (3) If frequency of mention is not a good surrogate, what is the

best survey measure?

Is frequency of mention a good surrogate for importance? It is a reasonable hypothesis that customers will mention most those needs that are most important. If this were true, then we could use frequency of mention as a surrogate for importance. To test this hypothesis we measured importances for the customer needs in figure 10 (coolers) with a nine-point self-rated importance scale. We then reanalyzed data in the same way, but for only the most important needs. The results are plotted in figure 11, where, for comparison, we have normalized the data so that 30 customers equals 100%. Figure 11 clearly suggests that important needs are no more likely to be mentioned by a customer than needs in general. Regrettably, frequency of mention does not appear to be a good surrogate for importance.

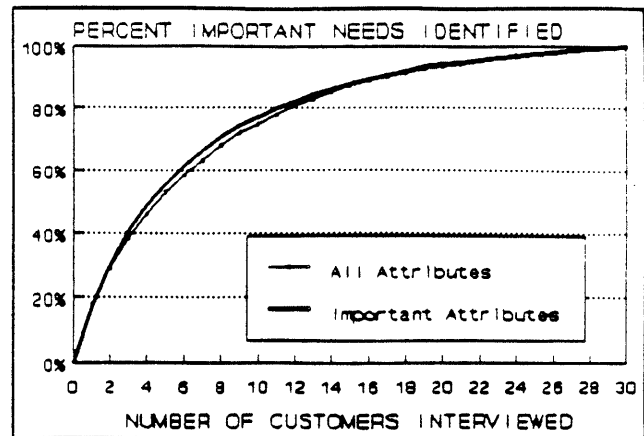


Figure 11. Important Needs vs. Total Needs (from Griffin and Hauser 1991b)

How do survey measures relate to customer choice? Table 11 reports one comparison of survey measures to customer interest and preference. In this study a major consumer-products company created seven product concepts, each of which emphasized improvement with respect to one of the seven primary needs that had been identified for the category. Consumers were then given the concepts and asked to express their interest in the concepts and their preference for the concepts. In addition, later in the survey they were asked to rate the importance of the customer needs. Three scales were used: (1) a *direct* nine-point rating scale, (2) a *constant-sum* scale in which customers allocated 100 points among the customer needs, and (3) an *anchored* scale in which customers allocated 10 points to the most important need and up to 10 points to all other needs. Each customer completed one set of scales. The sample size was 1600 customers per scale with response rates in the range of 75-78% for the three samples.

Table 11 reports that all three measures correlate highly with both interest and preference. While interest and preference are not actual choice, we do expect that they should be correlated with actual choice (should the concepts be developed into physical products) suggesting that all three measures of importance are reasonable in the sense that customers prefer those concepts that stress important needs.

What is the best survey measure? Table 11 is one of three formal comparisons which we have completed. In each case, there was general agreement among all of the survey measures. No clear winner has yet emerged. Qualitatively, we prefer the anchored scale, however one must be cautious in using either it or the constant-sum scale. In both of these scales the rated importance of the primary need is cascaded down as a multiplying factor for the corresponding secondary and tertiary needs. If the primary need is poorly worded, then any

	Interest	Preference	Direct	Anchored	Cons.-sum
Primary Need A	2	1	1	1	1
Primary Need B	1	2	3	2	2
Primary Need C	4	4	4	4	4
Primary Need D	6	6	6	5	5
Primary Need E	5	5	5	6	6
Primary Need F	7	7	7	7	7
Primary Need G	3	3	2	3	3
RANK Correlation with		Interest	0.89	0.93	0.93
		Preference	0.96	0.96	0.96

Table 11. Comparison of Interest and Preference with Importances (from Griffin and Hauser 1991)

measurement error affects *all* corresponding secondary and tertiary needs. For more details see Hauser (1991).

Research Challenges

Academic research on the use and improvement of QFD has just begun. There are many opportunities to improve the process through careful, scientific study. Hopefully, by building upon the rich history of field experience, researchers can make many incremental improvements which, if taken together, revolutionize the practice of QFD.

The Voice of the Customer. For example, Griffin and Hauser (1991) have used probabilistic models (beta-binomial models) to quantify how many customers needs are missed with a data collection and analysis procedure. These simple models can be extended to more complex analyses. Alternatively, researchers can use the models to explore differences among product categories and data collection techniques. For example, the total number of customer needs applicable to the product category might be affected by the product's inherent complexity (cars have more functions than shampoos) and the homogeneity of the respondent group (one niche segment will probably produce only some subset of the total needs for the entire market).

A factor worth exploring is the question of who to interview. Some respondents are extraordinarily articulate; others have difficulty expressing themselves -- the customer needs just trickle out. Even a very good interviewer sometimes has difficulty getting an inarticulate respondent to provide useful data. Also, a person's experience level in the product area may

affect the number of customer needs they can voice to an interviewer. For example, we have noticed that people who routinely rent and drive many different cars in the course of their frequent business travel can discuss their driving needs far more easily than the person who has driven only one car over the last several years. Clearly, the topic of leading-edge users bears investigating in the context of QFD.

Another challenge is the structuring of customer needs. We described above a formal clustering procedure based on judged similarity among customer needs. It is clear that clustering customer-sort data is superior to judgment-based affinity charts. However, we do not know what data collection is best, how best to correct for the fact that different customers use different numbers of piles, or what data analysis procedure is best.

The question of importance measurement for large numbers of customer needs is still open. Procedures such as conjoint analysis appear promising, but the state-of-the-art frontier for conjoint analysis seems to be about 50 features (Wind, et. al, 1989). More critically, conjoint analysis works best when features (whether a spirometer has a thermal printer or a dot-matrix printer) rather than customer needs are specified. We have seen proprietary applications where quantal choice (logit) models have been effective with between 10 and 20 customer needs, but in those applications the firm had access to a large data base in which customers could be observed making actual choices. Such revealed preference models are promising if one can deal with the collinearity that is inherent in the 100-400 customer needs that are typical for QFD.

The Relationship Matrix. The relationship matrix of a House of Quality, in which the impact design attributes have on customer needs are recorded, consists of somewhere between 10,000 to 100,000 cells. Each cell represents one interaction between a design attribute and a customer need. The relationships in these cells are currently identified by consensus of a cross-functional team in a series of working meetings. The results are thus the perceived relationships between these two parameters, not necessarily the actual relationships. An interesting and highly useful area of research would be to investigate a means for producing these relationships more efficiently and grounded in data rather than perception. We are aware of one proprietary study in which an automobile manufacturer measured over 100 features of competitive automobiles and over 50 customer needs on those same automobiles. They then attempted to use multiple regression to estimate the relationship matrix. While the study gave valuable insight to the firm, the collinearity in the regressions was severe and had to be modified with judgment. Certainly Bayesian techniques are worth exploring.

A Technical Importance Index. In QFD, importance priorities for design attributes are often derived by summing, across all customer needs, the level of interaction between the characteristic and the customer need multiplied by the importance of the customer need. Bordley and Paryani (1991) have developed a more complete index of design attribute importance which takes into account both the gap between current performance and the cost to close the gap, as well as the original values. While their technique presents some concerns as to the difficulty and length of time required to develop the series of additional data dictated by the method, they demonstrate through simulation that the highest priority design attributes from a small set of

disguised data are very robust to changes in assumptions about sales volume, strengths of relationships between design attributes and customer needs, and how correlations between design attributes affect customer feature delivery.

Summary. QFD is just one technique which may be used to improve the marketing/R&D interface. Other product-development processes as well as other general approaches can be used to improve the interaction and work flow across the interface. The research we have presented in this section demonstrates that while some initial inroads have been made into understanding and improving upon QFD, there is significant opportunity for research to contribute both to applying QFD better, and by extension, to improving the use of other techniques.

This completes our brief discussion of marketing's role to identify, structure, and prioritize the voice of the customer. This is one key role of marketing, but we want to emphasize that QFD only works well if marketing *and* R&D are involved throughout the QFD process.

10. SUMMARY

This chapter has reviewed some of the developments at the interface between marketing and R&D. We began by recognizing that many of the day-to-day tasks of product development require cooperation. Although some of these tasks are dominated by either marketing or R&D, many critical tasks such as understanding customer needs, setting product-development goals, matching solutions to customer needs, establishing the core benefit proposition, and resolving engineering-design and customer-need tradeoffs must involve marketing *and* R&D. We found that the scientific literature is persuasive in the conclusion that cooperation, when it occurs, leads to greater success and more sales from new products.

However, cooperation is not always easy. There are many barriers to both communication and cooperation. Marketing and R&D exist in different thought-worlds, each with their own language, culture, accepted goals, and accepted procedures. There is some speculation that personality and organizational barriers exist. In many cases, marketing and R&D are located in different buildings or cities such that communication is physically difficult.

Faced with these barriers firms have developed means to enhance communication. Organizational structures such as coordinating groups, project teams, and matrix structures have been set up to encourage communication. Personnel have been transferred among and within groups and physical facilities have been relocated. Firms have encouraged informal social systems and, in some cases, formal integrative management systems. Each approach has met with some degree of success, if they are accepted by the groups involved and if the groups really want to cooperate.

Of the formal management systems, Quality Function Deployment has met with the most

recent success. QFD attempts to enhance communication with an interfunctional group that meets regularly and uses the House of Quality (and subsequent Houses) to focus marketing, engineering, R&D, and manufacturing on the voice of customer. In particular, the House of Quality provides a direct link from customer needs to design attributes so that the language of the customer can be translated to the language of the builder. In one scientific study, we found that QFD did enhance communication within functions and between functions by encouraging team members to talk to one another directly rather than through management filters.

Further study of 35 projects in nine firms suggested that QFD provides strategic benefits in 83% of the projects and tactical short-term benefits in 27% of the projects. The key variables that seemed necessary for the success of QFD were (1) that firms viewed QFD as an investment rather than a cost, (2) that both management and team members were committed to QFD as a process, and (3) that QFD was used to solve a specific product or process goal.

Because this chapter appears in a marketing handbook, we closed with a review of the marketing input to QFD. The new challenge of QFD is the large number of customer needs (100-400) that are necessary to complete the communication link between marketing and R&D. This number of customer needs is an order of magnitude larger than the number of customer needs with which marketing research normally deals. As a result, it becomes important to use a qualitative research technique that is cost effective and which provides a reasonably complete set of customer needs. Our research suggests that experiential one-on-one interviews may be the most cost-effective method because greater depth is gained relative to focus groups.

Our research also suggests that customer input is critical in the structuring of the voice of the customer. When customers are asked to sort the customer needs, they tend to sort them to reflect how they use the product. When team members are asked to sort the customer needs, they tend to sort them to reflect how they build the products. If the goal is to satisfy the needs of the customer, it is clear that the customer-sort structure is the better representation.

Finally, our research suggests that importance ratings for the customer needs can be measured via surveys and that such measures correlate well with customer interest and preference. We have not yet identified a "best" survey measure but, regrettably, we do know that frequency of mention in the qualitative research is *not* a good surrogate for importance.

We believe that the marketing-R&D interface is important to profitability. To date there has been much research in the R&D literature and there has been much interest by industry. QFD, one formal technique, has spread rapidly throughout American and Japanese industries and we expect that trend to continue. But QFD is not just a process; it is a living, growing, and evolving set of tools to integrate and improve the marketing-R&D interface. We hope that research on QFD and on the interface continues. Perhaps ten years from now marketing and R&D will be fully integrated to the point where they work smoothly together for improved new products and greater long-run profits to the firm.

REFERENCES

- Akao, Yoji (1987), *Quality Deployment: A Series of Articles*, (Lawrence, MA: G.O.A.L., Inc.) Translated by Glen Mazur.
- Aldrich, Carole and Thomas E. Morton (1975), "Optimal Funding Paths for a Class of Risky R&D Projects," *Management Science*, 21, 5, (January), 491-500.
- Allen, Thomas J. (1970), "Communications Networks in R&D Laboratories," *R&D Management*, 1, 14-21.
- Allen, Thomas J. (1978), *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization*, (Cambridge, MA: The MIT Press).
- Allen, Thomas J. (1986), *Managing the Flow of Technology*, The MIT Press, Cambridge, MA.
- American Supplier Institute (1987), *Quality Function Deployment: A Collection of Presentations and QFD Case Studies*, (Dearborn, MI: American Supplier Institute, Inc.)
- Babcock, Daniel L. (1991), "Chapter 15: Project Organization, Leadership, and Control," *Managing Engineering and Technology*, Prentice Hall, Englewood Cliffs, NJ.
- Block, J. (1977), "Recognizing the Coherence of Personality," In D. Magnusson and N.S. Endler (eds.), *Interaccional Psychology: Current Issues and Future Prospects*, Wiley, New York.
- Bonnet, D. (1986), "Nature of the R&D/Marketing Cooperation in the Design or Technologically Advanced New Industrial Products," *R&D Management*, 16, 117-126.
- Bordley, Robert F., and Kioumars Paryani (1991), "Prioritizing Design Improvements Using Quality Function Deployment," General Motors Corporation Working Paper, submitted to *Management Science*.
- Calder, Bobby J. (1979), "Focus Groups and the Nature of Qualitative Marketing Research," *Journal of Marketing Research*, 14, (August), 353-364.
- Capon, Noel, and Rashi Glazer (1987), "Marketing and Technology: A Strategic Co-alignment," *Journal of Marketing*, 51, 1-14.
- Clark, Kim (1985), "The Interaction of Design Hierarchies and Market Concepts in Technological Evolution," *Research Policy*, 14, 235-251.

Clausing, Don (1986), "QFD Phase II: Parts Deployment," American Supplier Institute Publication, Warren MI.

Cooper, Robert G. (1983), "The New Product Process: An Empirically-Based Classification Scheme," *R&D Management*, 13(1), 1-13.

Cooper, Robert G. (1984a), "New Product Strategies: What Distinguishes the Top Performers?," *Journal of Product Innovation Management*, 2, 151-164.

Cooper, Robert G. (1984b), "How New Product Strategies Impact on Performance," *Journal of Product Innovation Management*, 2, 5-18.

Cooper, Robert G. and Ulricke de Brentani (1991), "New Industrial Financial Services: What Distinguishes the Winners," *Journal of Product Innovation Management*, 8, 75-90.

Cooper, Robert G., and Elko Kleinschmidt (1986), "An Investigation into the New Product Process: Steps, Deficiencies, and Impact," *Journal of Product Innovation Management*, 3, 71-85.

Cooper, Robert G., and Elko Kleinschmidt (1987), "New Products: What Separates Winners from Losers?," *Journal of Product Innovation Management*, 4, 169-184.

de Brentani, Ulrike (1989), "Success and Failure in New Industrial Services," *Journal of Product Innovation Management*, 6, 239-58.

Dougherty, Deborah (1987), "New Products in Old Organizations: The Myth of the Better Mousetrap," unpublished doctoral dissertation, Massachusetts Institute of Technology.

Dougherty, Deborah (1989), "Interpretive Barriers to Successful Product Innovation," Marketing Science Institute Report # 89-114.

Douglas, M. (1987), *How Institutions Think*, Rutledge and Kegan Paul, London.

Eureka, William E., (1987), "Introduction to Quality Function Deployment," Section III of Quality Function Deployment: A Collection of Presentations and QFD Case Studies, American Suppliers Institute Publication, January.

Feldman, Laurence P. and Albert L. Page (1984), "Principles vs. Practice in New Product Planning," *Journal of Product Innovation Management*, 1, 43-55.

Fern, Edward F. (1982), "The Use of Focus Groups for Idea Generation: The Effect of Group Size, Acquaintanceship, and Moderator on Response Quantity and Quality," *Journal of Marketing Research*, 19, (February), 1-13.

Glaser, B.G. (1967), and A.L. Strauss, *The Discovery of Grounded Theory*, Aldine Publishing, Chicago, IL.

Green, Paul E. (1984), "Hybrid Models of Conjoint Analysis: An Expository Review," *Journal of Marketing Research*, 21,2, (May), 155-169.

Green, Paul E. and Abba Kreiger (1992), "An Application of a Product Positioning Model to Pharmaceutical Products," *Marketing Science*, 11, 2, (Spring).

Green, Paul E. and V. Srinivasan (1990), "Conjoint Analysis in Marketing Research: New Developments and Directions," *Journal of Marketing*, 54, 4, (October), 3-19.

Griffin, Abbie (1989), "Functionally Integrating New Product Development," unpublished PhD thesis, Massachusetts Institute of Technology.

Griffin, Abbie (1991), "Evaluating Development Processes: QFD as an Example," University of Chicago Working Paper.

Griffin, Abbie, and John R. Hauser (1992), "Patterns of Communication Among Marketing, Engineering and Manufacturing -- A Comparison Between Two New Product Teams," accepted for publication *Management Science*, vol 38, No. 3, (March).

Griffin, Abbie, and John R. Hauser (1991), "The Voice of the Customer," Working Paper, Sloan School of Management, M.I.T., Cambridge, MA 02139.

Gupta, Ashok K., S.P. Raj, and David Wilemon (1986a), "A Model for Studying R&D-Marketing Interface in the Product Innovation Process," *Journal of Marketing*, 50(April), 7-17.

Gupta, Ashok K., S.P. Raj, and David Wilemon (1986b), "R&D and Marketing Managers in High-Tech Companies: Are They Different?" *IEEE Transactions on Engineering Management*, EM-33(1), 25-32, (February).

Gupta, Ashok K., S.P. Raj, and David Wilemon (1986c), "Managing the R&D/Marketing Interface," *Research and Technology Management*, March-April, 38-43.

Gupta, Ashok K., S.P. Raj, and David Wilemon (1985a), "The R&D-Marketing Interface in High-Technology Firms," *Journal of Product Innovation Management*, 2, 12-24.

Gupta, Ashok K., S.P. Raj, and David Wilemon (1985b), "R&D and Marketing Dialogue in High-Tech Firms," *Industrial marketing Management*, 14, 289-300.

Gupta, Ashok K. and David Wilemon (1988), "Improving the R&D/Marketing Interface," Working Paper, Syracuse University, Syracuse, NY, (February).

Hauser, John R. (1991), "Comparison of Importance Measurement Methodologies and their Relationship to Consumer Satisfaction," M.I.T. Working Paper, Sloan School of Management, Cambridge, MA, January.

Hauser, John R. (1992), "Puritan-Bennett, the Renaissance Spirometry System: Listening to the Voice of the Customer," M.I.T. Working Paper, Sloan School of Management, Cambridge, MA, January.

Hauser, John R., and Donald Clausing (1988), "The House of Quality," *Harvard Business Review*, (May-June), 63-73.

Hauser, John R., and Patricia Simmie, "Profit Maximizing Perceptual Positions: An Integrated Theory for the Selection of Product Features and Price," *Management Science*, Vol. 27, No. 2, (January 1981), pp. 33-56.

Hauser, John R. and Glen L. Urban (1979), "Assessment of Attribute Importances and Consumer Utility Functions," *Journal of Consumer Research*, 5, (March), 251-62.

Hayes, Robert H., Steven C. Wheelwright, and Kim B. Clark (1988), *Dynamic Manufacturing*, The Free Press, New York.

Hise, Richard T., Larry O'Neal, A. Parasuraman and James U. McNeal (1990), "Marketing/R&D Interaction in New Product Development: Implications for New Product Success Rates," *Journal of Product Innovation Management*, 7, 2, (June), 142-155.

Jewkes, John, David Sawers, and Richard Stillerman (1969), "The Individual Inventor," Chapter V in *The Sources of Invention (Second Edition)*, W.W. Norton & Company, New York, NY.

Kamien, Morton, I., and Nancy L. Schwartz (1972), "Timing of Innovations Under Rivalry," *Econometrica*, 40, 43-60.

King, Robert (1987), *Better Designs in Half the Time: Implementing Quality Function Deployment (QFD) in America*, (Lawrence, MA: G.O.A.L., Inc.)

Kogure, and Yoji Akao (1983), "Quality Function Deployment and CWQC," *Quality Progress*, 16:10, (October), 25-29.

Kohli, Rajeev and R. Sukumar (1990), "Heuristics for Product-line Design Using Conjoint Analysis," *Management Science*, 36, 12, (December), 1464-1478.

Kotler, Philip (1991), *Marketing Management*, Seventh Edition, Prentice-Hall, Inc., Englewood Cliffs, NJ.

Lawrence, Paul R., and Jay W. Lorsch (1967), *Organization and Environment*, Harvard Business School Press, Cambridge, MA.

Lee, Tom, and Louis L. Wilde (1980), "Market Structure and Innovation: A Reformulation," *Quarterly Journal of Economics*, 94, 429-436.

Lorsch, Jay W., and Paul R. Lawrence (1965), "Organizing for Product Innovation," *Harvard Business Review*, 109-120, (January-February).

Loury, Glenn C. (1979), "Market Structure and Innovation," *Quarterly Journal of Economics*, 93, 395-410.

Lucas, Robert E. (1971), "Optimal Management of a Research and Development Project," *Management Science*, 17, 11, (July), 679-697.

Lynch, John G., Jr. (1985), "Uniqueness Issues in the Decompositional Modeling of Multi-attribute Overall Evaluations: An Information Integration Perspective," *Journal of Marketing Research*, 22, (February), 1-19.

Marquis, Donald G., and D.L. Straight (1965), "Organizational Factors in Project Performance," MIT Sloan School of Management Working Paper.

McElroy, John, (1987), "For Whom are We Building Cars?," *Automotive Industries*, (June), 68-70.

Mehrez, Abraham (1983), "Development and Marketing Strategies for a Class of R and D Projects, with Time Independent Stochastic Returns," *R.A.I.R.O. Recherche Operationnelle/Operations Research*, 17, 1, (February), 1-13.

Miles, Raymond E., and Charles C. Snow (1978), *Organizational Strategy, Structure, and Process*, McGraw-Hill, New York, NY.

Moenaert, Rudy K. and William E. Souder (1990), "An Information Transfer Model for Integrating Marketing and R&D Personnel in New Product Development Projects," *Journal of Product Innovation Management*, 7, 2, (June), 91-107.

Moore, William L. (1987), "New Product Development Practices of Industrial Marketers," *Journal of Product Innovation Management*, 4, 6-20.

Norton, John A., Mark E. Parry, and X. Michael Song (1992), "The Impact of Firm Strategy, Environmental Uncertainty, and Organizational Structure and Climate on R&D-Marketing Integration in American Chemical And Pharmaceutical Firms," Working Paper, University of Chicago.

- Park, Jaesun (1987), "Dynamic Patent Races with Risky Choices," *Management Science*, 33, 12, 1563-1575.
- Parry, Mark E., and X. Michael Song (1991), "The Impact of Firm Strategy, Environmental Uncertainty, and Organizational Structure and Climate on R&D/Marketing Integration in Japanese High-Technology Firms," *Proceedings: 1991 Product Development Management Association International Conference*, Boston, MA 49-59.
- Pelz, Donald C., and F.M. Andrews (1966), *Scientists in Organizations*, Revised Edition, (Ann Arbor, MI: University of Michigan Press).
- Pessemier, Edgar A. (1986), *Product Management: Strategy and Organization*, (Robert E. Krieger Publishing Company, Inc.: Malabar, FL).
- Pinto, Mary Beth and Jeffrey K. Pinto (1990), "Project Team Communication and Cross-Functional Cooperation in New Program Development," *Journal of Product Innovation Management*, 7, 200-212.
- Porteus, Evan L. and Seugjin Whang (1991), "On Manufacturing/Marketing Incentives," 37, 9, (September), 1166-1181.
- Ray, M.L. (1982), *Advertising and Communication Management*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 157.
- Reinganum, Jennifer F. (1982), "A Dynamic Game of R and D: Patent Protection and Competitive Behavior," *Econometrica*, 50, 3, (May), 671-688.
- Reynolds, Thomas J. and Jonathan Gutman (1988), "Laddering Theory, Method, Analysis, and Interpretation," *Journal of Advertising Research*, 28, 1, 11-31.
- Roberts, Edward B. (1987), "Managing Technological Innovations: A Search for Generalizations," in Edward B. Roberts, ed., *Managing Technological Innovation*, Oxford University Press, Oxford, England.
- Roberts, Edward B. (1988), "What We've Learned: Managing Invention and Innovation," *Research and Innovation Management*, 31, 11-29.
- Romesburg, H. C. (1984), *Cluster Analysis for Researchers*, (Lifetime Learning Publications: Belmont, CA).
- Roussel, Philip A., Kamal N. Saad, and Tamara J. Erickson (1991), *Third Generation R&D: Managing the Link to Corporate Strategy*, (Harvard Business School Press: Boston, MA).
- Rothwell, R., C. Freeman, A. Horsley, V. Hervis, A. Roberston, and J. Crawford

(1974), "SAPPHO" Updated: Project SAPPHO Phase II," *Research Policy*, 32, 258-291.

Ruekert, Robert W., and Orville C. Walker (1987), "Marketing's Interaction with Other Functional Units: A Conceptual Framework and Empirical Evidence," *Journal of Marketing*, 51, (January), 1-19.

Saxberg, B. and J. W. Slocum (1968), "The Management of Scientific Manpower," *Management Science*, 14, 8, B473-B489.

Schein, Edgar H. (1985), *Organizational Culture and Leadership*, Jossey-Bass Publishers, San Francisco, CA.

Schmalensee Richard and Jacques-François Thisse (1988), "Perceptual Maps and the Optimal Location of New Products: An Integrative Essay," *International Journal of Research in Marketing*, 5, 225-249.

Shapiro, Ben P. (1987), "The New Intimacy," Harvard Business School Note, ICCH #788010 (October 1).

Shocker, Allan D. and V. Srinivasan (1979), "Multi-attribute Approaches for Product Concept Evaluation and Generation: A Critical Review," *Journal of Marketing Research*, 16, (May), 159-180.

Silver, Jonathan Alan and John Charles Thompson, Jr. (1991), "Understanding Customer Needs: A Systematic Approach to the 'Voice of the Customer,'" Master's Thesis, Sloan School of Management, M.I.T., Cambridge, MA 02139.

Siwolop, S. (1987), "R&D Scoreboard," *Business Week*, 134-155, (June 22).

Song, X. Michael (1991), "An Empirical Investigation of the Marketing/R&D Interface," Unpublished Ph.D. Dissertation, University of Virginia, Darden School, (August).

Souder, William E. (1978), "Effectiveness of Product Development Methods," *Industrial Marketing Management*, 7.

Souder, William E. (1987), "Managing the R&D/Marketing Interface," Chapter 10 in *Managing New Product Innovations*, Lexington Books, Lexington, MA.

Souder, William E. (1988), "Managing Relations Between R&D and Marketing in New Product Development Products," *Journal of Product Innovation Management*, 2, 6-19.

Sullivan, Lawrence P. (1986), "Quality Function Deployment," *Quality Progress*, 19(6), (June), 39-50.

Takeuchi, Hirotaka and Ikujiro Nonaka (1986), "The New New Product Development Game," *Harvard Business Review*, 66, 1, (January-February), 137-146.

Urban, Glen L., and John R. Hauser (1980), *Design and Marketing of New Products*, (Englewood Cliffs, NJ: Prentice-Hall, Inc.)

von Hippel, Eric (1978), "Successful Industrial Products from Consumers' Ideas," *Journal of Marketing*, 42, 1, (January), 39-49.

von Hippel, Eric (1986), "Lead Users: A Source of Novel Product Concepts," *Management Science*, 32, 7, (July), 791-805.

Webster, Frederick E., "The Changing Role of Marketing in the Corporation," Marketing Science Institute Report # 91-127, October.

Wiebecke, George, Hugo Tschirky and Eberhard Ulich (1987), "Cultural Differences at the R&D/Marketing Interface: Explaining Inter-Divisional Communication Barriers," *Proceedings of the IEEE Conference on Management and Technology*, Atlanta, GA.

Wilkie, William L. and Edgar A. Pessemier (1973), "Issues in Marketing's Use of Multi-attribute Attitude Models," *Journal of Marketing Research*, 10, (November), 428-441.

Wind, Yoram, Paul E. Green, Douglas Shifflet, and Marsha Scarbrough (1989), "Courtyard by Marriott: Designing a Hotel facility with Consumer-Based Marketing Models," *Interfaces*, 19, (January-February), 25-47.