User Learning, "Sticky Information," and User-Based Design

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ABSTRACT

To design new products and services that are accurately responsive to user needs, need information and solution information must be brought together with problem-solvers at a common location. Traditionally, this problem has been addressed by transferring need-related information to manufacturer-based product and service developers - a very successful approach under many conditions. However, this approach inevitably encounters difficulties when information related to user needs is changing rapidly due to learning by users, and/or is "sticky" - very costly or impossible to transfer from users to manufacturers.

In this paper we first show that user needs often do change rapidly, and that information related to user needs often is sticky. We then show via a model and evidence that under some such conditions it can pay to base product or service design activities partially or totally at user sites ("user-based design") rather than at manufacturer sites. We discuss the implications of these findings for marketing research methods .

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1. Introduction

When marketing research is used as an input to product and service design, it is serving as a component in the innovation process. During the last several years, the view of the innovation process held by innovation researchers has evolved from one in which innovation process activities were assumed to be centered in the manufacturers of new products and services, to one in which product and service development activities are seen as distributed between users and manufacturers as a function of innovation-related economic incentives. In this paper, we present the implications of this new view of the innovation process for the design of marketing research methods and the practice of marketing research.

We begin by showing three patterns in the allocation of product and service development tasks between users and manufacturers (section 2). Next we discuss two variables that significantly affect the relative cost-effectiveness of each pattern (section 3) and offer a model of the conditions under which each pattern would be most effective (section 4). Finally, we discuss the implications of these findings for marketing research methods (section 5).

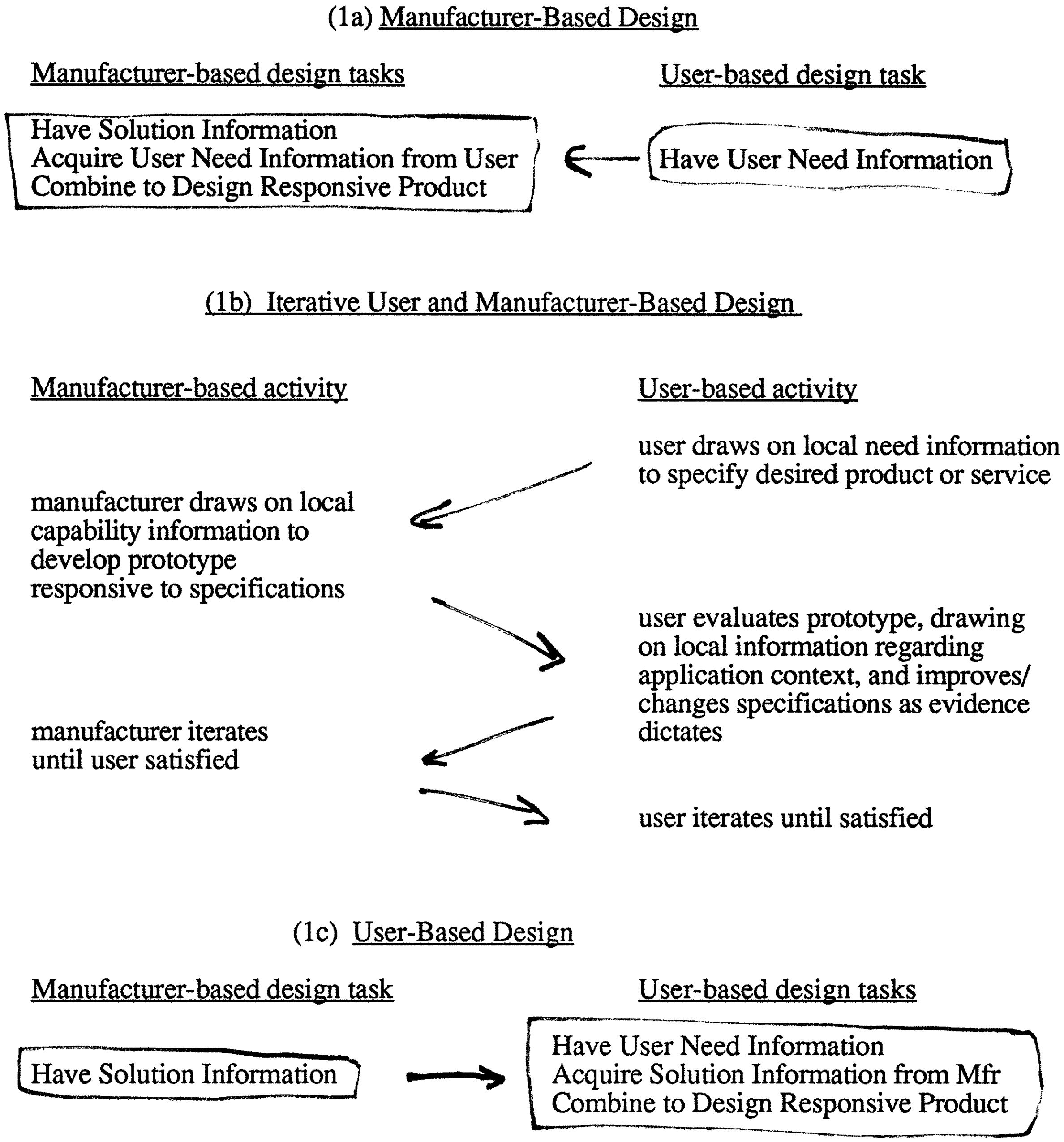
2. Patterns in the Location of Innovation Process Tasks

To develop new products and services that are accurately responsive to user needs, designers must have access to both need information and solution information. These two types of information are located, at least initially, in physically different places - with need-related information being located initially at user sites, and information on solution technologies being located initially at manufacturer sites.

Traditionally, innovation process scholars have taught that manufacturers are the appropriate site for the problem-solving work of product and service design. Implementation of that traditional model of the innovation process involves the transfer of need-related information from users to manufacturers via methods developed in the field of marketing research. Development is then carried out by manufacturer-based designers who draw on the need information that has been transferred to them plus solution information already located at the manufacturer site to create a new product or service that is responsive to user need. We term this subdivision of innovation process tasks between user and manufacturer "manufacturer-based design" (figure 1a).

In the "distributed" model of the innovation process (von Hippel 1988), it is understood that the firms that use industrial products and services, and individual users of consumer products and services as well, can sometimes have adequate incentives to develop products and services to fulfill their own needs. Such user-developed innovations can then become the conceptual basis for commercially successful products and services later produced by manufacturers.

The addition of users as a plausible site for innovation enables two additional patterns for bringing need information and solution information together with problem-solvers at a common location. Each involves a different subdivision of innovation-related tasks between user and manufacturer, and involves the transfer of different information between these two parties as well.



(1a) Manufacturer-Based Design

Manufacturer-based design tasks
- Have Solution Information
- Acquire User Need Information from User
- Combine to Design Responsive Product

User-based design task
- Have User Need Information

(1b) Iterative User and Manufacturer-Based Design

Manufacturer-based activity	User-based activity
	user draws on local need information to specify desired product or service
manufacturer draws on local capability information to develop prototype responsive to specifications	
	user evaluates prototype, drawing on local information regarding application context, and improves/ changes specifications as evidence dictates
manufacturer iterates until user satisfied	
	user iterates until satisfied

(1c) User-Based Design

Manufacturer-based design task
- Have Solution Information

User-based design tasks
- Have User Need Information
- Acquire Solution Information from Mfr
- Combine to Design Responsive Product

Figure 1: Three patterns of design activities seen among users and manufacturers of products and services.

"Iterative user and manufacturer-based design" (Figure 1b) involves an iterative shifting of problem-solving activity between user(s) and manufacturer(s) as information and/or problem-solving resources located at these two sites is drawn upon by problem solvers. Iteration between the two sites occurs - rather than a one-time access to each site - because problem solving in general (Barron 1988, 43-47) and technical problem solving in particular (Marples 1961, Allen 1966) has trial and error as a prominent feature. If and as each cycle of a trial and error process requires access to information or other resources located at more than one site, iterative shiftings of problem solving activity among these sites will occur as problem solving proceeds.

"User-based design" (Figure 1c) involves a user(s) developing a new product or service to satisfy his or her own need. The process begins with the transfer of solution information to users. User-based designers then combine that solution information with their own internal need data, and design responsive new products or services for themselves.

All three of the patterns just described do occur in real-world product and service development. Manufacturer-based design is the guiding assumption in many early marketing research methods, and can still be seen in many fields. In the field of software development, for example, it is known as the "waterfall" method. In that method, systems analysts begin the development of a new software product by meeting with users at the start of a project to determine user needs and agree on a written product requirements specification. Manufacturer-based developers then worked isolated from further user contact until the completed product is delivered months or even years later (Zelkowitz 1980, 1037).

Modern market research methods tend to implement iterative user and manufacturer-based design, with manufacturer-based activities being given heavy emphasis. Iteration is visible in method steps that require developers to return to users for more data during the course of a development project. For example, a method may prescribe that new product concepts developed on the basis of initial inputs from users be presented to additional user groups one or more times as part of a testing and refinement process (Urban and Hauser 1992).

The method of "rapid prototyping," initially developed for use in software development but now found in other fields as well, is an iterative method that gives user-based activities more prominence. Software manufacturers using the method respond to initial user need inputs by quickly developing and delivering to users (usually within weeks) an inexpensive, easy to modify, working model that simulates important components of the functionality of the proposed new software. Users then learn by using the prototype in their own setting on their own data and clarify their needs, in part by drawing on their tacit knowledge and experience (Gronbaek 1989, 114-16). Users then relay requests for change or new features to the software developers, who respond by drawing on their own sticky information and tools to make modifications to the prototype. Some of these modifications are minor, such as altering report formats, and some are major, such as implementing a new feature or modifying the basic structure of the prototype (Feld 1990, 14). A revised prototype is then sent to the user, and this process of iteration between developer and user is repeated until an acceptable fit between need and solution is found.

User-based design can be seen wherever and whenever users assemble "systems" of their own devising. They may acquire the solution information they need for user-based design by drawing on solution "kits" supplied by a manufacturer for that purpose or by assembling the solution information and components and tools they need from a range of manufacturers and other sources. As an illustration of the former approach, consider Object Oriented Programming languages (OOPs). Manufacturers of OOPs basically are in the business of creating and selling "user-friendly" software development tool kits.

User-based designers acquire these kits and use them to design software products for themselves that are responsive to their own needs. As an illustration of the latter approach, consider the design activities of production engineers who select and assemble equipment supplied by manufacturers into a customized production system. Similarly, consider the design activities of individual consumers who may select and purchase manufacturer-supplied components such as telephone answering machines and note pads and computers and desks and chairs and integrate these into a home office work place of their own design.

3. Economics of Innovation Process Patterns: Two Key Factors

Innovation is an economic activity, and individuals and firms will engage in product and service development if and as they expect that activity to "pay." The profit side of this cost-benefit equation has been explored elsewhere in terms of the relative ability of users, manufacturers and others to capture - to "appropriate" - the benefits their innovations may generate (von Hippel 1988). The cost side of the equation is currently being explored, and to date two factors have been identified that appear to play important roles in the relative cost-effectiveness of the three innovation process patterns we have just described. These factors are the presence of multiple-site learning during the course of a given innovation project, and the cost of transferring sticky information from site to site during the course of that project.

Interdependent, Multiple-Site Learning

When a manufacturer-based designer is the only problem-solver active on a new product or service development project, he or she is in the same position as a scientist or engineer asking a question of "nature." These problem solvers know that the answer they seek may be complex and hard to puzzle out. But they also know that answer will not change as they work due to the actions of other problems solvers. For example, engineers building the first rockets did not know all they needed to know about the stresses the rockets would encounter during flight. But they did know that nature would remain stable as they learned more, and that the correct answer would not change half way through the project. In contrast, a use environment populated by and/or affected by autonomous problem solvers offers no such assurance. Under such conditions the use environment and thus the nature of the desirable solution that the designer is seeking to provide may well change during or after completion of the design process.

The mere existence of users as an independent group of problem-solvers addressing a problem that can be interdependent with that being addressed by manufacturer-based designers creates the potential that needs for new products and services will change. This potential is often realized, because users often do have an incentive to engage in "system level" problem-solving that can affect the need for that new product or service.

Consider that individual products and services are components in larger systems. This is clearly visible in the instance of processing machines (which fit into larger processing systems) and in the instance of industrial components (which perform functions within larger products or services). It is also true, but perhaps less intuitively obvious, in the instance of consumer goods and services (Boyd and Levy 1963). For example, a fork is a component part of a user's system for eating, and a component as well of systems for conveying signals on social status and other matters. Similarly, a telephone-answering service or machine is a component of many consumers' complex personal systems for receiving and storing data.

Users and designers of systems value the functions or outputs of a system component only because of and in terms of its role in the system as a whole . That is, the "need" for a function(s) that such a product or service provides is a *derived* one. Thus, computer designers and operators may have an intensely felt need for magnetic hard disks. But this need is derived from the role these data storage components play in a computer system: they would have no need for computer disk drives absent computers. (A system can be seen as having many nested levels. Within each level, many components may be linked to form the next higher-level system. For example, a computer hard disk drive is a "system" assembled from components. In turn, such a disk drive is a component in a computer system, which in turn is a component in a data processing system, which in turn is a component in, for example, a telephone switching system, which in turn is a component in a telecommunications system, etc.. The argument we make here is independent of the system levels at issue.)

Needs for component products and services are stable or unstable as a function of design and use decisions made at other system levels. To illustrate, consider the design of a system and the design of a component to be used in it (a product or service) as two subproblems. If one wishes to make a functional change to the system, many solutions typically are possible. Some may involve changing the component, some changing the system, and some may involve changing both. In Figure 2 we categorize all possible solutions to the overall problem in terms of the interdependence of these two subproblems. Category 1 consists of solutions that involve changes to both the component and the system; category 2 consists of solutions that involve changes to the component (that is, the new product or service being developed) only; category 3 consists of solutions that involve changes to the system only.

		Innovation Involves Change to System?	
		Yes	No
Innovation Involves Change to System (Product or Service) Component?	Yes	(1) Need for component is *changed*	(2) Need for component is *stable*
	No	(3) Need for component is *stable*	(4) No innovation

Figure 2: A need for a product or service is derived from its role as a component in a higher-level system. The need for any given component can change as a result of changes made at the system level.

From Figure 2, we can see that needs for components will change in cases where problem-solving is going on in a higher-level system in a way that affects functional or physical component interfaces (e.g., the system-level problem-solving and component-level problem-solving are interdependent). Otherwise the need is stable. For example, if one wants to create a higher-performance personal computer, solution possibilities exist that will fall into categories 1, 2, and 3 of Figure 1 from the point of view of a manufacturer of a given system component - say, the microprocessor. Thus, one may change the design of the computer system in a way that changes the functional interfaces between system and microprocessor (category 1); or one may change the microprocessor while holding its interface to the rest of the system constant (category 2); or one may change the design of the computer system to improve performance, but in a way that keeps the functional and physical interfaces to the microprocessor stable - a category 3 solution from the point of view of a microprocessor designer.

Empirical evidence that user needs for component products and services do often change within a time frame relevant to developers comes from a variety of sources. Perhaps the most direct evidence comes from von Hippel and Tyre (1995, table 2) who, in a study of user-reported problems with novel process machinery, found that 5 of 22 cases involved users revising their need as a result of early field experience with the machines. These users then expressed their revised needs to developers as "problems" with the existing machines - even though those machines were performing according to the originally-planned specifications. Users presented revised needs to the manufacturers within a period ranging from one month to a few months after installation of the machines (ibid, table 3).

Table 1: When was need-related information available to machine designers regarding problems discovered during field use?

<u>Availability of need-related information</u>	<u># of problems affecting</u>		
	<u>Machine Type 1</u>	<u>Machine Type 2</u>	<u>Total</u>
(1) Information <u>existed</u> in user need specification or use environment when machine was designed:	7	8	15
(2) Need-related information was generated <u>after</u> machine was introduced to field by problem solvers who were:			
- (a) users working directly with machine	1	4	5
- (b) other problem solvers in the use environment	1	1	2
Totals	9	13	22

An example of a user need revised as a result of early product experience:

Location Adjustment Problem

> Each time a new board design was processed by the "component placing machine" [one of the novel machines studied - an automated robot arm designed to place electronic components on printed circuit boards], operators had to tell the machine where to put each of the components to be placed on the new board. They did this by entering the X and Y coordinates of each part location in the machine's computer memory. In case these coordinates required later adjustment, operators and machine designers both assumed that the operators would re-enter new X and Y coordinates.
>
> After the machine was installed in the plant, users discovered that they had to adjust X and Y coordinates very frequently. They also found that it was very cumbersome to do this by reentering new coordinates. Instead, they learned to make the needed adjustments via an obscure "move it over by X amount" command that was buried several layers down in a software menu on the machine's control panel. The problem [need] that users then brought to the attention of machine designers was: The "move it over by X amount command" is very hard to reach and use. Make a more convenient one! (Ibid p. 7)

Additional information regarding changes in user needs comes from Rosenberg (1982), who found that users "learn by using" new products and services in their use environments, and generate new needs and solutions as a result of that learning. Also, Hauschildt (1986) studied the decision processes of a sample of 308 firms deciding on the purchase or lease of a computer for internal use. He found that, although conventional decision process literature assumed that a well-defined goal would be specified at the start of a decision process, goals [needs for the new computer] were in fact continually set and reset during the computer selection process. This, he found, was because "The insight into possible solutions influences the [user firm] decision-makers' ideas of what they really want. The projection of a desired solution stimulates new problem-solving activities." (ibid, p12).[1]

"Sticky" Information

In all three innovation process patterns shown in figure 1, there is a requirement to transfer information from user to manufacturer or vice versa. This task can be difficult to accomplish adequately because information is sometimes very "sticky" - difficult to transfer.

The "stickiness" of a given unit of information in any given instance is defined as the incremental expenditure required to transfer that unit of information to a specified site in a form usable by a given information seeker. When this cost is low, information stickiness is low; when it is high, stickiness is high. A full discussion of the causes of information stickiness has been provided elsewhere (von Hippel 1994) and will not be repeated here. Suffice it to say that the stickiness of a given unit of information is affected by attributes of the information itself (e.g. tacitness or other issues with respect to encoding), and also by attributes of and choices made by information seekers and information providers. For example, if a particular information seeker is inefficient or less able in acquiring information unit x , (e.g., because of a lack of certain tools or complementary information) or if a particular information provider decides to charge for access to unit x, the stickiness of that unit of information will be

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[1] Given our proposal that instability of needs has to do with problem-solving related to changes in system and system component it is interesting to note that Hauschildt found that the goal [need] formulations he documented did not deal only with the computer that was the system component being selected in the decision-making processes he studied; they dealt also with aspects of the computer-related system of the purchasing firm. Thus, 50% of the goal [need] reformulations he documented dealt with the nature of the computer software and hardware to be purchased; 23% dealt with organizational aspects of the firm purchasing the computer, and with clarifying subject matters to which the computer would be applied; 20% dealt with ancillary matters such as needed staffing, the nature of the room needed to house the computer, and terms of the contract to be made with the computer supplying firm. A final 7% did not fit neatly into any of the three categories just described (ibid p 7).

higher than it might be under other conditions (Cohen and Levinthal 1990, Griliches 1957, Mansfield 1968, Nelson 1982 &1990, Pavitt 1987, Rosenberg 1982, Teece 1977). Also, specialized personnel such as "technological gate-keepers" (Katz and Allen 1982, Katz and Tushman 1980) and specialized organizational structures such as transfer groups (Katz and Allen 1988) can significantly affect the cost of transferring a given unit of information between organizations.

Both need-related and solution-related information can be sticky. In what follows, however, we will focus on the transfer of need information and show the relevance of two common causes of high information transfer costs - the nature of information encoding and the amount of information that must be transferred from user to manufacturer - to the concerns of marketing research.

It is well understood that some information held by users is encoded in explicit terms, while other information is "tacit." Polanyi points out that many human skills and much human expertise are tacit, and illustrates the point by noting that "the aim of a skilful performance is achieved by the observance of a set of rules which are not known as such to the person following them" (Polanyi 1958, 49, italicized in original). For example, swimmers are probably not aware of the rules they employ to keep afloat, e.g., in exhaling, they do not completely empty their lungs, nor are medical experts generally aware of the rules they follow in order to reach a diagnosis of various symptoms. "Indeed," he says, "even in modern industries the indefinable knowledge is still an essential part of technology." And, Polanyi reasons, "an art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice..." - a relatively costly mode of transfer (ibid., 52,53).

Tacit information is important to market researchers and designers because both the use and the development of products and services generally involves human expertise or skill. For example, manufacturer-based designers who wish to develop a flotation aid for swimmers will be aided by knowing swimmers' tacit rules, so that their design can work in harmony with those rules. Similarly, a user - a swimmer - who wishes to design a flotation aid for swimmers will be aided by knowing some of the manufacturer-based designers' explicit and tacit information regarding practical and producible product design. Indeed, skills ranging from those associated with culturing cells in medical laboratories (Barley and Bechky 1994 p. 98-9) those involved in.making a cake ("fold the egg whites until they appear slightly stiff") or conducting a conversation via telephone ("he hesitated very slightly before answering - I think he may disagree with my suggestion") are also complex and partially held in tacit form by those possessing them. Therefore, we may expect that some key information related to many product and service development opportunities will be difficult to encode and transfer economically from user to manufacturer.

With respect to our second point, we observe that the cost of transferring information called for by a problem-solver from one location to another can be very high even when the needed information has a low stickiness per "unit" - simply because a great deal of such information may be needed by product and service designers. To understand why this is so, consider that a user's need and use environment and/or the solution skills and solution environment of manufacturer-based designers can contain a myriad of highly specific attributes. When this is the case, it will not be cost-effective to simply transfer all information related to one of these environments to the other. Nor will it be possible to identify and transfer to designers only that subset of information that they will find relevant during their problem-solving work. This is because the relevant subset of information is <u>contingent</u> upon the solution path designers take during their problem-solving work. And, since the problems designers work on are "ill-structured" ones[2], the path and outcome of their problem-solving work cannot be predicted in advance. As illustration of both points, consider a case drawn from von Hippel and Tyre (1995), which involves difficulties associated with transferring need-related information from a user environment to manufacturer-based designers.

Problem of the Yellow Circuit Board

> The design of the "component placing machine" [an automated robot arm designed to place electronic components on printed circuit boards] consisted of two major subsystems: a "machine vision system" that was used to determine the proper location for each integrated circuit being placed on a circuit board being processed; and a robot arm and hand that physically picked up the integrated circuits and placed them at those locations. The input to the machine vision system was a small video camera used to search for particular metalized patterns on the surface of boards being processed. In order for the vision system to function properly, it was necessary that the video camera be able to "see" these metalized patterns clearly against the background color of the board surface itself.

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[2] Well structured problems are defined as those for which one can precisely specify a process of trial and error that will lead to a desired solution in a practical amount of time (Reitman 1965, Simon 1973, Pople 1982). For example, a traveling salesman problem can be well structured, because one can precisely specify a generator of alternative solutions and a solution testing procedure that are guaranteed to eventually identify the best solution. However, "In general, the problems presented to problem solvers by the world are best regarded as ill structured problems. They become well structured problems only in the process of being prepared for the problem-solvers. It is not exaggerating much to say that there are no well structured problems, only ill structured problems that have been formalized for problem-solvers." (Simon 1973 p. 186).

Ill structured problems may involve an unknown "solution space" (a precisely specifiable domain(s) in which the solution is known to lie). They may also involve unknown or uncertain alternative solution pathways, inexact or unknown connections between means and ends and/or other difficulties. Ill-structured problems are solved by a process of first generating one or more (typically several) alternative solutions. These may or may not be the best possible solutions - one has no way of knowing. These alternatives are then tested against a whole array of requirements and constraints (Marples 1961, Simon 1981 p.149). Test outcomes are used to revise and refine the solutions under development, and - generally - progress is made in this way towards an acceptable result.

> The vision system functioned properly in the lab when tested with sample boards from the user plant. However, when it was introduced into the factory, it sometimes failed. Development engineers came to the field to investigate, and found that the failures were occurring when boards that were light yellow in color were being processed.
>
> The fact that boards being processed *were* sometimes light yellow was a surprise to the machine developers. Factory personnel knew that the boards they processed varied in color, but had not volunteered this information because they did not know that the developers would be interested. Early in the machine development process, they had simply provided samples of boards used in the factory to the machine development group. And, as it happened, these samples were green in color. On the basis of the samples, developers had then (implicitly) assumed that all boards processed in the field were green. It had not occurred to them to ask users, "how much variation in board color do you generally experience?" Thus, they had designed the vision system to work successfully with boards that were green.

In retrospect, one can say that the product (a process machine in this case) being developed failed to meet user expectations because an element of information about the use environment had not been transferred from user to manufacturer. Why had it not been? After all, the information on board color variations was known to the users. To understand the difficulties that can attend transferring the "obvious," consider first that the aspect of the use environment at issue in the yellow board case was a very narrow and specific one. That is, the problem with the board was not that it had "physical properties," nor that it had a color. The problem was precisely that the boards were yellow, and a particular shade of yellow at that. Since a circuit board - indeed, most components - have many attributes in addition to color (shape, size, weight, chemical composition, resonant frequency, dielectric constant, flexibility, etc., etc.) it is likely that market researchers seeking to collect all of the information about the user and use environment required to design the product in a way that was precisely responsive to the need would have to analyze a very large (perhaps unfeasibly large) number of potentially problematic items and interactions to achieve this.

Note next that the problem caused by the yellow color of the board was *contingent* on the particular solution to the component placing problem selected and developed by the engineer, and this was only done during the problem-solving work of engineering design. That is, the color of printed circuit boards in the user factory became relevant only when engineers, during the course of their development of the component placer, decided to use a vision system in the component-placing machine they were designing; the fact that the boards were yellow only became relevant when the engineers chose a video camera and lighting that could not distinguish the metalized patterns on the board against a yellow background. Since engineers often change the alternatives they are developing during the course of their development work (Marples 1961, Allen 1966), it follows that the relevance to designers of any particular item of information bearing on product or service needs - or potential solutions to those needs - can also change frequently during the development process.

4. Modeling the Relative Efficiency of Innovation Process Patterns

Assume that the pattern of innovation process activities will be selected that minimizes the sum of user and manufacturer problem-solving and information transfer costs for a given project, other things being equal. Then, we can model the relative efficiencies of user-based, manufacturer-based, and iterative user-manufacturer design as follows:

$$\frac{\text{User-based design costs}}{\text{Mfr-based design costs}} = \frac{(I_m S_m + D_u)}{(I_u S_u + D_m)}$$

In this model (I_u) is the amount and (S_u) the stickiness of user-based need information that must be transferred from user to manufacturer if the problem is to be solved via manufacturer-based design. (I_m) is the amount and (S_m) the stickiness of manufacturer-based solution information that must be transferred from manufacturer to user if the problem is to be solved via user-based design. (Note that the information at issue is not *all* need-related or solution-related information required by user or manufacturer-based project designers, but rather only to that portion of the required information that is *not already in the designer's possession,* and so must be transferred to him or her during the course of the project.) Finally, (D_u) is the cost of problem-solving activities which are carried out at the user location in the case of user-based design, and (D_m) the cost of such activities which must be carried out at the manufacturer location in the case of manufacturer-based design.

The relative efficiency of user-based and manufacturer-based design in a particular instance is provided directly in the model just presented. The relative efficiency of iterative user and manufacturer-based design for a given project is determined by periodic recalculation of model values as project work progresses, in order to determine the points at which shifting between user-based and manufacturer-based design activities will be cost-effective.[3]

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[3] If both user-developed designs and manufacturer-developed designs diffuse equally well or poorly, then the equation given earlier holds independent of market structure considerations. If diffusion efficiency differs, however, the relative number of users and manufacturers interested in a given design affects market-level efficiencies for user-based vs manufacturer-based design. Suppose, for example, that several or many users (n) have an identical need for a given new product or service. Suppose further that users who design a solution would absolutely refuse to share their design information, while manufacturers who undertake manufacturer-based design would share that information freely by selling the product or service embodying it. In that case, the equation given earlier would change to:

$$\frac{\text{User-based design costs}}{\text{Mfr-based design costs}} = \frac{(I_m S_m + D_u)}{(I_u S_u + D_m)/n}$$

on a per user basis. In other words, under such conditions the relative efficiency of manufacturer-

If we assume that users and manufacturers interested in a given project will try to minimize their joint innovation-related costs, our model can help us to think through the relative cost-effectiveness of user-based vs manufacturer-based design in any given case. As a schematic illustration, suppose we face the new product design task of creating a new generation of Dynamic Random Access Memory chips for use in computers (DRAMs). Assume that the *novel* user need information required by manufacturer-based DRAM designers in that case is relatively small in amount and relatively non-sticky - essentially consisting, let us say, of "make it function like the last generation - but faster and cheaper, please." In contrast, the solution information required to create a new generation of DRAM chips is very rich and complex and, since DRAMs are at the frontier of the chipmaking art, will be held partially in tacit form in the minds of talented design and process engineers. Thus, we judge that $I_mS_m > I_uS_u$ in this instance.

Next, with respect to design costs, note that the design of a new generation of DRAMs requires experiments carried out on complex and costly laboratory equipment. DRAM manufacturers already have much of the needed equipment and related expertise in use and available for a DRAM design project: DRAM users do not. On this basis we may reason that $D_m < D_u$ in the case of DRAM design. Placing these values in our model leads us to conclude that DRAM design would be more economically carried out via manufacturer-based rather than via user-based design.

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based design at the level of a market would increase as the number of potential users of a given product or service design increases In fact, however, there may well be no major difference in the rate of diffusion of design information developed by users or by manufacturers. It has been found that detailed information on user-developed processes and process machinery diffuses to rival users in a matter of months (Mansfield 1985). Further, "lead user" market research studies have shown users generally willing to share their design information with inquiring manufacturers (Urban and von Hippel 1988, Herstatt and von Hippel 1990). Once user design information has been transferred to even a single manufacturer, further diffusion can occur via the same route as that taken by manufacturer-developed design information - by the sale of products or services that embody it.

As a second, contrasting illustration, suppose that the design task in question is the creation of a surgical tool - a curved-wire probe with a loop at the end to be used by surgeons as a tool to aid in the removal of plaque from the walls of certain arteries during heart operations. In this case we may reason that the relevant solution information (consisting, let us say, of how one bends and forms the grade of wire used in such surgical tools) is relatively small in amount and non-sticky. In contrast, it is likely that the user-based need information is both voluminous and largely tacit, consisting of the complex interactions between the surgeons' skill and the characteristics of patients' bodies and arteries and of plaque. Thus, we conclude that $I_mS_m < I_uS_u$ in this case.

Testing and adjusting proposed designs for the probe involves problem-solving under real or very realistic operating theatre conditions. Such conditions are routinely available to practicing heart surgeon users, but not to instrument manufacturers. Therefore it is likely that ($D_m > D_u$). Placing these values in our model then leads us to conclude that this surgical instrument design task will be most economically carried out via user-based design rather than via manufacturer-based design.

On the basis of our model we may speculate that users engaged in user-based design and manufacturers engaged in manufacturer-based design will tend to develop innovations with different characteristics. Thus, other things being equal we would expect users to develop innovations having on average a "richer" need content than those developed by manufacturers. A study by Riggs and von Hippel (1994) is suggestive in this regard. The authors studied the development of 64 significant improvement innovations affecting two types of scientific instrument. They found (table 2) that 82% of the innovations that allowed users to do qualitatively new types of things were developed by users while, in sharp contrast, 87% of innovations that increased instrument convenience and reliability were developed by manufacturers. (Innovations that improved the instruments along dimensions known to be desirable, such as sensitivity and resolution, were developed by users and manufacturers with equal frequency.) Information stickiness was not measured in this study, but it seems likely that the need-related information required by problem-solvers was stickiest for innovations in the first category. If so, the preponderance of innovations by users in this category - that is, innovations developed by problem-solving activities carried out at user sites - is what we would expect given efforts to minimize information transfer costs.

Table 2: Source of scientific instrument innovations by nature of improvement effected (Riggs and von Hippel (1994 table 3)

Type of improvement provided by innovation	Innovation developed by: %User	%Mfr	(n)
(1) New functional capability	82%	18%	17
(2) Improvement to convenience or reliability	13%	87%	24
(3) Improvement to sensitivity, resolution or accuracy	48%	52%	23
		Total	64

Note that the information addressed by our model is not *all* need-related or solution-related information required by user or manufacturer-based project designers, but rather only to that portion of the required information that is *not already in the designer's possession,* and so must be transferred to him or her during the course of the project. To illustrate this distinction, consider a design project to create a cake mix having a new flavor. New cake mixes are often developed using a manufacturer-based design process. Yet, the user need-related information relevant to cake mix development is clearly very rich and complex, and arguably involves a significant amount of sticky information that must somehow be transferred from users to manufacturer-based designers.

For example, to design an acceptable cake mix, designers must understand in detail what a cake is and what it should look like; understand the role it plays in meals and social occasions; understand how it is eaten and so forth. They must also understand what users expect a "cake mix" to be, understand the nature of the baking skills users possess, the nature of the kitchen equipment commonly available to users, etc.. Despite this need for complex and sticky need-related information, manufacturer-based designers may have no difficulty creating a successful cake mix. Both designers and users share a rich cultural context which includes cakes and cake mixes, and so the designers already know the great bulk of the need-related information they will require. Under these conditions, therefore, the information that is *not* already in the designer's possession and so must be transferred from user to designer may be relatively limited and non-sticky - consisting, for example, only of user perceptions and preferences regarding the proposed new cake mix flavor.

5. Implications for Marketing Research Methods

We now have an understanding of two major variables, multi-site learning and the costs of transferring sticky information, that can affect the relative costs of user-based design, manufacturer-based design and iterative user-manufacturer-based design. We have also seen that each can be the mechanism of choice under some conditions. If this is so, it would seem useful to develop and/or improve the marketing research methods related to the execution of each. We first explore the idea that it will in general be desirable to convert product and service design problems that are appropriate to iterative user and manufacturer-based design "as given" into subproblems that are each appropriate to either user-based design or manufacturer-based design. Next, we consider possible improvements to the marketing research methods associated with manufacturer-based and user-based design.

Learning to Reduce User-Manufacturer Iteration

On the face of it, one might judge that user-based design or manufacturer-based design would be the most cost-effective way to execute a given design problem when learning is important at only one site, and when information needed by designers is sticky only at that same single site. For projects involving information that is sticky at both sites and/or learning during a project at both sites, one might reason that iterative user and manufacturer-based design would be the most cost-effective approach to the location of design activities. But we propose that it will be useful to avoid user-manufacturer iteration for all projects - because there are inevitably costs and time lags associated with starting up and shutting down problem-solving activities - and iterative user and manufacturer-based design may incur these costs several times in the course of a single project. We further propose that one can avoid intersite iteration by *reframing* design problems that appear to call for such iteration as originally proposed. This is done by converting problems of this nature into subproblems that each require access to only one such site.

As a schematic illustration of reframing, suppose that a pipe manufacturer is given the job of designing a special pipe that must cross a busy construction project, and suppose that this pipe must be manufactured with many precisely-located turns and bends to avoid interfering with sites of present and potential construction activity. Clearly this problem, framed in this way, is appropriate for iterative user and manufacturer-based design. Information about the pathway the pipe must follow is sticky - complex and unpredictably changing as construction proceeds - so transfer of accurate need information to the manufacturer would be quite costly. Nor can the manufacturer easily transfer solution information to the user - information related to the process of designing curves into the pipe is also quite sticky, requiring an understanding of shapes that can be cast successfully in a metal foundry. The result will clearly be a lot of iteration between user and manufacturer before the design is gotten right.

However, consider that we can reframe the original problem into two subproblems: (1) how to design a flexible pipe that can be bent by users at field sites without compromising its ability to function and, (2) design of a pathway across the construction site for the pipe that will not interfere with construction activities. The pipe manufacturer can now address problem (1), design of a flexible pipe, by drawing only on sticky information located at the manufacturer site, while the user can address problem (2), locating the pipe, by drawing only on information located at the user site. Thus, this reframing of the problem eliminates the need to iterate between user and manufacturer during problem-solving in order to gain access to sticky information.

As a real world case of reframing, consider the problem-solving work involved in designing an integrated circuit for a custom application. In this design problem, two sticky data bases are central to the problem-solving work: (1) information at the circuit user locus involving a rich and complex understanding of both the overall application in which the custom integrated circuit will play a role and the specific function required of that circuit; (2) information at the circuit manufacturer locus involving a rich and complex understanding of the constraints and possibilities of the silicon fabrication process that the manufacturer uses to produce integrated circuits.

Traditionally, custom integrated circuits were developed via an iterative user and manufacturer-based design process involving a circuit user possessing sticky need information and an integrated circuit manufacturer possessing sticky information about designing and producing custom integrated circuits. That process began with a user specifying the functions that the custom chip was to perform to a circuit design specialist employed by the integrated circuit manufacturer. The chip would then be designed at the manufacturer locus, and an (expensive) prototype would be produced and sent to the user. Testing by the user would typically reveal faults in the chip and/or the initial specification, responsive changes would be made, a new prototype built, and so forth.

More recently, the Application Specific Integrated Circuit (ASIC) method of making custom integrated circuits has come into wide practice. In the ASIC method, the overall problem of designing custom circuits has been reframed into two new subproblems which each draw on only one locus of sticky information, thereby eliminating the need to iterate between two such sites in the design process. The manufacturer of ASICs draws on its own sticky information to develop and improve the fabrication processes in its manufacturing plant, a "silicon foundry." The manufacturer also draws on its own sticky information to design "standard" silicon wafers that contain an array of unconnected circuit elements such as logic gates. These standard circuit elements arrays are designed by the manufacturer to be interconnectable into working integrated circuits by the later addition of custom interconnection layers designed in accordance with the needs of specific users.

The design of the custom interconnection layer is carried out by users in a user-based design process with the aid of a user-friendly Computer-Aided Design (CAD) software package supplied by the manufacturer. This package contains both user-friendly design tools and information about the solution capabilities of the silicon foundry that are relevant to the users' design task. With the aid of this software, users can design a custom interconnection layer design to meet their specific application needs and yet stay within the production capabilities of the manufacturer's silicon foundry. The software also allows the user to simulate the function of the custom circuit under design, and to conduct trial-and-error experiments. Taken together, these capabilities allow the user to both design a circuit, and to refine need specifications and the desired circuit function through an iterative process that draws only on sticky information located at the user site.

Instances of problem reframing - motivated, we speculate, by a desire to escape the costs and time lags associated with iterative user and manufacturer-based design - can be seen in a number of fields. The development of "desk-top publishing," to replace iterative problem-solving between a graphic designer and an author, is one such example. More generally, there is a trend in software (Feld 1990) and other fields towards "empowering users" by reframing products and service design problems in such a way as to create the possibility for user-based design activities that can be conducted independent of the manufacturer. (For example, software manufacturers might create a line of user-friendly programming "tool boxes." Users would then draw on their own sticky information to create software precisely adapted to their needs.) Such reframings offer a way for manufacturers to seek economies by producing standard products, while at the same time enabling users to carry out the problem solving needed to adapt these to specific local needs and conditions.

Improving Methods for Manufacturer-Based Design

Marketing research methods that implement manufacturer-based design (figure 1a) have been developed to a high level of sophistication. Nonetheless, as our model suggests, the range of situations for which this approach is cost-effective can be increased by improving the ability of these methods to (1) collect and (2) analyze sticky information. A number of methodologists are working on various approaches to this problem.

First, we note that need-related information used in manufacturer-based product and service development is often collected via individual and/or group interviews and/or questionnaires. These methods clearly have only a limited ability to transfer information that is sticky because it is poorly-encoded (e.g., tacit information) or involves a great deal of detail - and yet we have seen that manufacturer-based designers will often require the transfer of information having precisely these characteristics. Some investigators are working to improve the effectiveness of interview and questionnaire procedures with respect to these matters. (Thus, Zaltman (1993) has improved interviewers ability to collect non-verbal information during interviews by asking interviewees to bring along and comment upon relevant visual materials.)

Second, we note that interview and questionnaire methods can only hope to elicit the information that respondents themselves possess. This is a problem when important need and use-environment information is not be visible to or understood by users - and so cannot be reported by them. (For example, a bicycle rider may not be aware of the types of surfaces he or she rides upon - is the surface of her favorite bike path sometimes slightly oily or sometimes covered with a thin layer of dust? Yet this information would be vital to a designer who is seeking to design a bicycle tire that will "stick to the road" under surface conditions encountered by the rider.) This problem is being addressed by the development of methods for collecting information during actual visits to customer sites (Holtzblatt and Jones 1990, Shiba et al 1993). Such methods can improve market researchers' ability to collect both contextual information and information that is held in tacit form by users. Holtzblatt and Jones (1990 p. iii) explain the benefits of customer visits (included in their "contextual inquiry" method) as follows:

> "The contextual inquiry approach is based on field research techniques, and focuses on interviewing users in their own context as they do actual work.... If we just ask customers what they need, they are unable to tell us. Customers are experts in their work, but they usually cannot articulate the key elements of their work. Similarly, if we only observe customers' actions, we might misinterpret the meaning of their actions. ... Whenever we design, we have assumptions about the nature of the customers' work and how technology solves their problems. These assumptions can be blind spots that keep us from seeing information that challenges our assumptions. Contextual inquiry provides a way to align our understanding with customers' understanding. We expand our entering understanding by probing things we do not understand, behavior that surprises us, and problems behind solutions that customers offer. We share our interpretations with customers to create a shared understanding .

Finally, we note that the ability of any given technique for collecting information from users and transferring it to manufacturer-based designers can be affected by the type of users selected for examination. Information is not distributed uniformly across all users in a marketplace. Lead users, for example, tend to know more about a given need than do routine users, because they have a higher incentive to generate that knowledge. More generally, we can expect that method development related to segmenting users by what and how much they know will lead to improvements in the information collection capabilities of manufacturer-based methods.

After need-related information is collected, it is analyzed by manufacturer-based market researchers. Current analytical methods tend to strip much of the richness from need-related data that is collected from users, and some are working on methodological improvements that can reduce such losses. We can illustrate the problem by reference to "multiattribute" analytical methods (Lancaster 1971, Silk and Urban 1978, Shocker and Srinivasan 1979, Urban and Hauser 1992) that are frequently used in quantitative marketing research today.

Multiattribute analysis begins when the records of user interviews, site visits, etc. are examined by a market researcher. The researcher's goal is to encode this qualitative information in the form of about 20 scalable, independent component attributes which can be analyzed quantitatively. (The method used by the analyst to identify or create the set of component attributes is typically some formal or informal type of content analysis. The number of attributes identified is limited to about 20 to make succeeding analytical work more tractable.) Once a set of attributes has been specified, the stage for quantitative analysis has been set. A consumer's perception of any particular product in the category can then be expressed quantitatively terms of the amounts of each attribute the consumer perceives it to contain, and the difference between any two products in the category can be expressed as the differences in their attribute profiles. Potential wants and demands for a product or service containing any mix of component attributes can also be determined by including consumer data on the importance and desirability of each of the component product attributes in the analysis.

It will be clear to the reader that quantitative analyses of this type can produce very useful findings. It will also be clear, however, that the analyses are based on only a small portion of the information that collected or collectable from users. Current efforts to improve the richness of information actually transferred to manufacturer-based designers of new products and services tend to involve supplementing information generated by quantitative analyses with rich qualitative information collected by means such as customer visits. Procedures such as QFD (Hauser and Clausing 1988) and Customer Requirements Analyses (Shiba et al 1993) can then be used to help designers and marketers to integrate and manage both types of information during the problem-solving work of product and service design.

Improving Methods for User-Based Design

In user-based design (figure 1c), information regarding needs for new products and services is both generated within and used within user firms. This means that manufacturers that produce products and services created via user-based design can do so without having to understand the user needs they satisfy. (For example, in the ASIC process of integrated circuit design and manufacture that we reviewed above, circuit manufacturers were able to produce circuits that were accurately responsive to user needs without themselves having to understand those needs.) If the traditional role of manufacturer-based marketing research is to understand user needs, what tasks can or should it adopt in the case of user-based design? We suggest two: (1) the identification and screening of user innovations; (2) the induction of desired types of user innovation.

Manufacturer-based methods for identifying user innovations are useful because users design and fabricate products and services to serve their own needs, and may have no incentive to inform manufacturers regarding their accomplishments. Manufacturer-based methods for screening user innovations are needed because innovating users tend to assess the value of the products and services they develop exclusively in terms of within-company service: They typically do not know or care whether manufacturers would find it profitable to sell related products commercially. The "lead user" method is one methodological approach to serving both of these functions. It first identifies a subset of lead users who are both experiencing a need that is being or will be experienced by others, and who have a high incentive to find a solution for that need - and so may innovate. Innovations created by these lead users are then identified and screened to determine their utility to other user segments in the intended market (von Hippel 1986, Urban and von Hippel 1988, Herstatt and von Hippel 1990).

Manufacturers can influence the rate and direction of users' innovative activity by appropriately affecting the experience of users with respect to a trend of interest, and/or by affecting the incentives of users to innovate in desired ways. With respect to influencing experience, Urban (19--) has begun to consider how one might "accelerate" user learning by providing a selected group with a partial simulation of a predicted future state of interest. Von Hippel and Finkelstein (1979) have demonstrated the effect of incentives on user innovation by showing that manufacturers of a given type of product (specifically, automated blood analyzers) can increase the amount of user innovation dedicated to improving that product by designing the product to be easily modifiable and/or by creating tools and component kits that make desired types of innovation easier for users to accomplish. (Of course, manufacturer-designed tools and kits such as the objects in object-oriented programming have limits with respect to the range of conditions they can address. Does this not mean that manufacturers attempting to stimulate user-based design must study user needs after all - if only to determine the kinds of tools innovating users will find desirable? Possibly, but not necessarily. Preliminary research suggests to us that manufacturers often devise such tools by simply responding directly to user requests that specify what is wanted, rather than by researching user needs.)

6. Conclusion

In this paper we have presented three patterns in the partitioning of product and service development tasks among users and manufacturers, and have also presented an initial exploration of the conditions under which each might be appropriate. We think that these patterns and the related implications for market research methods are interesting and perhaps important. We hope that others will be inclined to join with us in further research and exploration on this general topic.

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