The dominant role of “local” information in user innovation: The case of mountain biking

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ABSTRACT

In a study of innovations developed by mountain bikers, we find that user-innovators almost always utilize “local” information – information already in their possession or generated by themselves - to assess the need for and to develop solutions for their innovations. We argue that this finding fits the economic incentives operating on users. Local need information is the most relevant to user-innovators, since the bulk of their innovation-related rewards typically come from in-house use. Local solution information that is already “in stock” is preferred because it can be applied to innovation-related problem-solving at a relatively low cost.

Our findings suggest that innovation development is distributed among users in an economical way: user-innovations tend to be developed by “low-cost providers.” It also suggests that the likely function and solution type employed in most user innovations can be predicted on the basis of preexisting user activity patterns and stocks of solution-related information. This in turn opens the way to new methods for efficiently screening user populations for the presence of innovations of any specified type.

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1.0: Introduction and overview

Firms that manufacture products and services have an incentive to develop innovations that appeal as strongly as possible to as wide a customer base as possible in order to enhance their innovation-related profits. Research into the incentives operating on user-innovators, however, leads us to hypothesize that this category of innovators will display a very different pattern.

Prior research has shown that users that develop new products and services typically profit only from their own, in-house use of their innovations. This is because users that seek to benefit financially from diffusion of an innovation to other users in a marketplace must obtain some form of intellectual property protection followed by licensing. Both are typically costly to attempt, and have very uncertain outcomes (Harhoff et al 2002). If users *do* derive their innovation-related benefit only from in-house use of their innovations, they should find it rational to ignore the general needs of the marketplace in favor of developing innovations that are very precisely tailored to serve their own specific needs. The innovations they develop to serve their own needs may, of course, also prove to serve a more general demand by happenstance.

In this paper we examine the specificity with which innovations developed by user-innovators address their in-house needs. To do this, we compare the characteristics of a sample of user-developed innovations in mountain biking equipment with the direct need experience of the users developing them. We find a close relationship: user-innovators do tend to develop innovations to serve precisely their own needs. They do not do this out of ignorance of the market: user-innovators in our sample have an accurate understanding of the breadth of potential marketplace demand for the innovations that they have developed.

In addition to finding that user-innovators do not stray significantly from attempting to solve their own in-house needs, we also find that user-innovators tend to use only their own pre-existing stocks of solution-related knowledge to develop their innovations. In other words, we find that innovators largely rely upon both need and solution information that is “local” to them to generate their innovations. (We define local information as that an innovator already has “on site” prior to innovating, or generates on site during the course of innovation development.)

Reliance on local need and solution information has the effect of sharply reducing innovators’ innovation-related costs. With respect to need information, consider that users encountering a need for an innovation during activities that they engage in “anyway,” in effect discover that need at no incremental cost. If they also can test solutions that they may develop to that need during the course of activities engaged in and rewarded for non innovation-related reasons, they also have a “free” test laboratory for solution development. A similar argument holds with respect to solution-related information. If a user employs only solution information that he or she already has “in stock,” and that was acquired and paid for on the basis of some unrelated prior activity, that user’s investment in a solution is correspondingly reduced.

In sharp contrast, if a user decides to stray from his or her own chosen activity in order to develop innovations of interest to others with needs that are different from his own, the cost properly assignable to innovation suddenly jumps. In other words, users operate in a “low-cost innovation zone” when they develop innovations precisely responsive to problems they encounter in the normal course of their activities, and that they address by using solution information already in hand.

These findings have interesting implications for the innovation process. First, as we noted earlier, the focus of users on developing innovations to satisfy their own needs differs fundamentally from the general assumption that innovators will want to develop innovations that will sell to the largest possible market. That assumption, we find, does not fit the reward conditions affecting user-innovators. Second, the fact that users tend to concentrate on addressing their own specific needs using only information already in their possession suggests that users that are well-equipped from an information point of view to develop a given innovation will be tend to be the ones developing it. When there is a wide dispersion of heterogeneous need and solution information, an innovation process that is distributed over many users can be an economical one.

Third, and with respect to practical applications of these findings, it seems likely that interested others – whether users or manufacturers - should be able to predict the specific application area user-innovators will address and also the general nature of the solution information they will draw upon. (This would not be the case, or would be the case to a lesser extent if we had discovered that users engaged in active search for non-local problem or solution-related information.) For example, one can predict that some fraction (say 20%) of leading-edge mountain bikers who are pushing the limits of downhill biking practice and who also are orthopedic surgeons will innovate applying their specialized orthopedic knowledge to address the equipment and technique problems that they personally encounter. This in turn should enable interested others, for example manufacturers, to develop more efficient methods for screening users to identify innovations of particular value to themselves.

In this paper we first review related literature (section 2). Next we review our research context and methods (section 3). Findings are presented in section 4 and implications developed and discussed in section 5.

2. Literature review

General impracticality of obtaining intellectual property protection for innovations

To benefit financially from diffusing their innovations to others, user-innovators that do not wish to manufacture their innovations for the marketplace themselves must license them. And to license, they must first gain some form of intellectual property protection. However, the ability of innovators to obtain effective intellectual property protection is weak in most fields.

In most subject matters, the most appropriate form of legal protection is the patent grant. However, researchers have found that the protection actually afforded by patents is weak in most fields – with the exceptions being chemicals and pharmaceuticals. In most fields it has been found that innovators that license do not obtain much income from doing so. In line with this finding, firm executives in most fields do not view patents as a very effective form of protection for intellectual property. With respect to the first point, Taylor and Silberston (1973) examined the impact of British and foreign patents in a very rich study of 44 British and multinational firms selected from five broad "classes" of industrial activity. They found that these firms gained relatively little from licensing, when benefits were computed as licensing fees and/or other considerations received minus patenting and licensing costs incurred by the innovating firm. Wilson (1975) studied data on royalty payments submitted by some U.S. corporations to the U.S. Securities and Exchange Commission in 1971 on Form 10K. He too, found corporate returns from licensing to be generally low.

The low returns from the licensing of patented knowledge found by Taylor and Silberston and by Wilson could in principle be caused either by weakness in protection afforded by patents or by a patent licensor or licensee disinclination to license. Research by several authors indicates that the correct interpretation is that protection afforded by the patent system is itself generally weak, and that innovators in most fields probably could not expect to benefit from licensing their patented knowledge even if they chose to do so (Scherer 1959, Taylor and Silberston 1973, Levin et al 1987, Mansfield 1968 and 1985, Cohen et al. 2000).

The relative ineffectiveness of patents as a form of intellectual property protection in most fields is understandable. One important cause is the ease with which patents can be “invented around” in most fields. A second is that costs involved in obtaining patents, typically thousands of dollars, make patent protection economically unjustifiable for “minor” innovations. Yet empirical studies have shown that it is the cumulative effect of minor innovations that is responsible for most technical progress (Hollander 1965, Knight 1963).

Copyright is a low cost and immediate form of legal protection that is applicable to many forms of original writings and images – it “follows the author’s pen across the page.” In the US, courts have determined that the innovation-rich field of software is eligible for copyright protection because software may be regarded as a form of “writing.” Unlike the patent grant, copyright protection applies only to the specific writings embodying an innovation rather than to the underlying idea itself. Thus, copyright does not prevent someone from studying the novel functionality encoded in software and then creating original code to perform the exact same function. Therefore the level of protection copyright affords to software authors only reaches to the level of investment a would-be imitator must make to replicate the now known function in any given programming language. This protection can be substantial in the case of very large and complex programs such as Microsoft's Windows operating system. It can be quite low in the case of innovations having novel functionality that is easily understood and encoded in a software program of modest size.

Consider, finally, the practicality of protecting an innovation as a trade secret. Much intellectual property does not qualify for protection as a trade secret because it cannot simultaneously be kept secret and exploited for economic gain. And, even innovations that do meet this criterion are unlikely to remain secret for long. Mansfield (1985) studied a sample of 100 American firms and found that the period during which intellectual property can be kept secret in fact appears to be quite limited. He reports that "…information concerning development decisions is generally in the hands of rivals within about 12 to 18 months, on the average, and information concerning the detailed nature and operation of a new product or process generally leaks out within about a year."

Innovators' tendency to use "local" information primarily

Hayak (1945) was an early voice arguing against the common assumption by economists that economic actors possessed "perfect information." He argued that, to the contrary, it was simply common sense that people must vary in terms of the information that they possessed. The world is complex and fast-changing, and at least momentary and local variations in information available to decision-makers must exist.

The variation in information held by different parties is not simply a matter of information complexity and volume – it also results from the fact that information can be very costly to transfer from place to place. Such information "stickiness" can have a number of causes (von Hippel 1994). For example, it can be due to attributes of the information itself such as the way it is encoded (Nelson 1982 & 1990, Pavitt 1987, Rosenberg 1976 & 1982). Thus, as Polanyi (1958) pointed out, information can be "tacit." And/or information stickiness may be due to attributes of the information holders or seekers. For example, a particular information seeker may be less able in acquiring information because of a lack of certain tools or complementary information - a lack of "absorptive capacity" in the terminology of Cohen and Levinthal (1990). And/or, the availability of specialized organizational structures such as transfer groups (Katz and Allen 1988) can significantly affect the information transfer costs between and within organizations.

When information is sticky, a bias is created toward the use of local information over non-local information – simply because local information can be accessed more cheaply. This can in turn affect the character of innovations developed if local information differs in kind from more distant information. Ogawa (1998) showed this effect in a study of 24 equipment innovations. All were produced by NEC, a Japanese equipment maker, for Seven-Eleven Japan (SEJ), a major Japanese convenience store chain. His data showed that innovations requiring a rich understanding of needs (information local to users) tended to be carried out by the user, SEJ, while innovations involving rich understanding of new technologies (information local to NEC) tended to be carried out by NEC.

In a similar vein, Shane (2000), found a close relationship between the prior personal experiences of 8 innovators – by definition information local to each innovator – and the type of entrepreneurial opportunity discovered by each. The sample studied by Shane was linked to business opportunities related to an MIT "3-dimensional printing process." The link between prior personal experience and the nature of each opportunity discovered was quite clear. Thus, the entrepreneur that proposed using 3D printing to create custom-fitted orthopedic "artificial bones" for the medical and dental markets had a professional background in precisely these fields.

A study of user innovation in open source software by Franke (2002) shows a similar effect. Franke finds that personal experience – information that is local to the innovator - is a strong trigger for innovation. He points out that this finding makes sense from the point of view of attitude theory, which argues that attitudes towards an object will have a bigger impact on behavior if the subject has direct contact with the object. He notes that Regan and Fazio (1977) showed this effect in a classic study on students' housing shortage: if a student ever experienced a shortage himself the likelihood that an attitude like "we should do something about housing shortages" leads to actual behavior (like signing or organizing petitions) significantly rises.

Innovators’ focus on local information tends to be reinforced by the effect of “functional fixedness.” This effect simply means that the behavior of problem-solvers facing new situations tends to be entrained by their previous experiences with and responses to similar situations. Thus, it has been shown that experimental subjects who have been successfully using a complicated problem solving strategy are unlikely to devise a simpler one when this is appropriate (Luchins 1942). Also, subjects who use an object or see it used in a familiar way are strongly blocked from using that object in a novel way (Duncker 1945, Birch and Rabinowicz 1951, Adamson 1952). Furthermore, the more recently objects or problem-solving strategies have been used in a familiar way, the more difficult subjects find it to employ them in a novel way (Adamson and Taylor 1954). Finally, we see that the same effect is displayed in product development groups in firms, where the success of a group in solving a new problem has been shown to be strongly affected by whether solutions it has used to solve past problems will fit the new problem (Allen and Marquis 1964).

3: Research context and methods

Research context: mountain biking

The topic of this research is on the relationship between the information that is local to a given user-innovator and the type of innovation that individual develops. We chose to focus our empirical work on this matter on user innovation within the field of „mountain biking“. Our reason for this choice was simply that prior empirical work had shown a generally high level of user innovation in a number of sports-related fields (Shah 1999, Luthje 2002, Franke and Shah 2002). We anticipated that this general finding would also hold true in the field of mountain biking, which would enable us to collect the type of empirical data needed for this research.

Mountain biking involves bicycling on rough terrain such as mountain trails, and may also involve various other “extreme” conditions such as bicycling on snow and ice and in the dark (van der Plas and Kelly 1998). Mountain biking began in the early 1970’s when some young cyclists started to use their bicycles off-road. Existing commercial bikes were not suited to this type of rough usage, so these early users put together their own equipment out of strong old bike frames with balloon tires to which they added motorcycle lever-operated drum brakes for better stopping ability. They called their creations „clunkers“ (Penning 1998, Buenstorf 2002).

Commercial manufacture of mountain bikes began about 1975, when some of the early users of mountain bikes began to also build bikes for others. A tiny cottage industry developed, and by 1976 a half-dozen small assemblers existed in Marin County, California. In 1980, mountain biker Mike Sinyard took the next step and founded a company to bring the first mass-produced mountain bike to market (Benko 1999). In 1982, major bike manufacturers followed and started to produce mountain bikes and sell them at regular bike shops across the US. By the mid-1980's the mountain bike was fully integrated in the mainstream bike market. At about the same time, bicycle component manufacturers began producing components such as derailleurs, crank sets, tires and handle bars that were specifically designed for off-road use.

Mountain biking enthusiasts did not stop their innovation activities after the introduction of commercially-manufactured mountain bikes. They kept pushing mountain biking into more extreme environmental conditions and also continuously developed new sports techniques involving mountain bikes (Mountain Bike Magazine 1996). Thus, some began jumping with their bikes from house roofs and water towers and developing other forms of acrobatics. As they did so, they steadily discovered needs for improvements to their equipment and, as we shall see in this paper, many responded by developing and building improvements for themselves. Also, users prototyped specialized infrastructure: for example, jumping from rooftops evolved into jumping from platforms specially built for that purpose. Over time, the more generally-valued of these innovations would spread among the user community and some of these would eventually be produced commercially by manufacturers.

During the past 20 years, the commercial market for mountain bikes and related gear has grown to a significant size. In the U.S., total retail sales in the bicycle market were $5.89 billion in 2000, including bicycles, related parts, and accessories through all channels of distribution (National Sporting Goods Association 2002). Approximately 65% of these sales were generated in the mountain bike category. This category is defined by the industry as consisting of traditional mountain bikes and „comfort bikes“ - modified mountain bikes featuring soft saddles, a more upright riding position and slightly easier gearing.

Sample selection and data collection methods

Our goal was to find a sample or samples of mountain bikers containing a usefully-large number of innovating users. We knew from our study of the history of the field that innovating users were traditionally found among "off-road" users of mountain bikes rather than among "comfort bike" users. Detailed discussions with experts in mountain biking focused our search still more by informing us that the "North Shore " of the Americas, ranging from British Columbia in Canada to Washington State in the U.S., was a current "hot spot" in mountain biking where new riding styles were being developed and where the sport was being pushed towards new limits.[1]

We next searched the Internet and identified 29 mountain biking clubs that were based in the North Shore region. We also discovered two unmoderated mountain biking forums on the Internet, the Transcend Magazine Forum (www.topica.com/lists/downhill/read), and the Topica Downhill Mailing List (www.transcendmagazine.com/). These forums were not restricted to North Shore users. However, both forums were founded by mountain bike activists from that region and recruit a significant part of their members from the North Shore. As a result, we decided to try and obtain data from both members of North Shore mountain biking clubs and contributors to the mailing lists of these two on-line forums.

To assemble our sample of mountain bike club members, we randomly selected 10 of the 29 North Shore clubs we had identified. We then contacted the presidents of 8 these clubs to describe our study and ask whether they would be willing to participate. (Two of the clubs could not be contacted after several attempts.) Of the 8 clubs

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[1] To obtain expert advice at various points during the course of our study, we identified a group of expert user informants by posting a request for assistance on the largest internet forums devoted to mountain biking. We then initiated email conversations with 16 who seemed to us to be the most expert. In addition, we gained important contextual information from telephone interviews with bike shop owners, with 2 officials of mountain biking associations, with one 1 small-scale manufacturer of mountain bikes and with 3 active mountain bikers who had recently invented mountain bike equipment.

contacted, 5 were found appropriate for our purposes and were also willing to participate. (Two clubs were founded recently and had only a few members, and one club was exclusively for children.)

Data collection from club members was done with the help of the club presidents. Each was asked to e-mail a cover letter and a link to our online-questionnaire to club members. In the five clubs taken together, 255 users were contacted in this way. We received 112 responses and had to exclude 6 non-usable responses, leading to 106 usable responses (see table 1). The gross response rate is 41,6%. This quite high percentage can be explained by the use of the clubs presidents as bridging persons. A request to participate in a survey is more likely to yield a response when a respected insider is asking.

Table 1: Response rates for two samples of mountain bikers

	Sample 1: Members of MTB clubs	Sample 2: Members of MTB online-forums	
	all reached members in the clubs	all members of the forums	active members of the forum (at least one posting)
Base	255	1,209	436
Responses	106	185	185
Response rate	41.6%	15.3%	42.4%

In the case of the two Internet forums devoted to mountain biking we began by contacting the organizers of each. Both proved willing to support the survey by posting a request to participate on their forums. Taken together, the two Internet forums had 1,209 members. After posting the request we received 185 answers. The directly-calculated response rate from forum members is therefore 15.3 %. However, viewing all members of the forum as potential respondents may be unduly conservative. Posting of one’s name on a forum list is easy and often does not indicate that an individual is an active member or is even continuing to visit the forum. Indeed, many listed “members” have never posted a comment on-line. If we therefore more realistically define active members of the two forums as those having posted at least one message within the six months before the survey, we find that only 469 of the members of the two forums were active. Our response rate among active members was therefore 42.4%. This figure is in the range of response rates achieved with the club members in sample 1. As in that case, the active support of the forum organizers probably was helpful in raising the response rate to this relatively high level.

Online questionnaire

Both of our samples of mountain bikers were asked to respond to an online-questionnaire. When compared to traditional mail surveys, the advantages of an online survey are, among others, higher speed and lower costs (Lescher 1995; Dahan and Hauser 2002). In the instance of our sample members, contact via email and use of an online questionnaire does not raise issues of access or representativeness. The officials of the 5 clubs in our sample reported that almost all members have e-mail and access to the internet. This was (by definition) also true for members of the two online forums contacted.

We designed a draft questionnaire based upon our own research interests as refined by previous research findings and information obtained from interviews with expert users in the mountain biking field (c.f. footnote 1). As a pilot test, we then sent our draft to these experts and asked them to fill it out and then provide feedback on its content and design. Based on this feedback, we then developed a final version incorporating several modifications that improved both the clarity of the questions and the logical structure of the questionnaire.

The questionnaire sent to our sample of users was divided into two major parts. The first part covered questions about each respondent's particular use experiences (intensity of riding, terrain, outside conditions, riding abilities) and technical knowledge (theoretical knowledge, practical skills, knowledge from other fields). The second part was addressed only to users that reported that they had an idea for an innovation or had actually developed one. This section dealt with the characteristics of and circumstances surrounding "the most important" innovation the users had developed (some had developed more than one). Thus, innovating users had to describe the problem they had identified and the type of solution they had conceived of to solve the problem. Finally, respondents also were asked to rate their ideas with respect to a number of criteria (e.g. newness, usefulness, market potential).

Open-ended questions were used to collect much of our information because, as was revealed in our exploratory interviews, there is a great diversity in user experience, technical knowledge, and user-developed innovations as well.

Coding

Answers to open-ended questions posed in our questionnaire regarding use experience were assigned to mountain biking activity categories using the scheme shown in table 2. The categorization of activities was developed with the assistance of the mountain biking experts mentioned earlier (c.f. footnote 1).

Table 2: Categories of mountain biking activities

1 Preferred terrain	2 Predominant outside conditions	3 Focus on particular riding abilities
11 Fast Downhill Tracks (steep, drops, fast)	21 darkness, night riding	31 jumps, drops, stunts, obstacles
12 Technical Single Tracks (up & down, rocky, jumps)	22 snow, ice, cold	32 technical ability/balance
13 Smooth Single Tracks (hilly, rolling, speed, sand, hardpack)	23 rain, muddy conditions	33 fast descents / downhill
14 Urban and streets	24 heat	34 endurance
	25 extreme heights / altitude	35 climbing
		36 sprint

Coding of respondents use experiences was done independently by the first author and two additional coders selected by him. To test intercoder reliability among these three coders, the Cohen’s Kappa coefficient for each coders input for each dimension of user experience and technical knowledge was calculated (Cohen 1960). This measure takes into account that a certain percentage of corresponding assignments can be expected in a random coding. Thus, this coefficient is stricter than the simple pairwise intercoder reliability. Using the categories in table 2, Cohen’s Kappa was on average

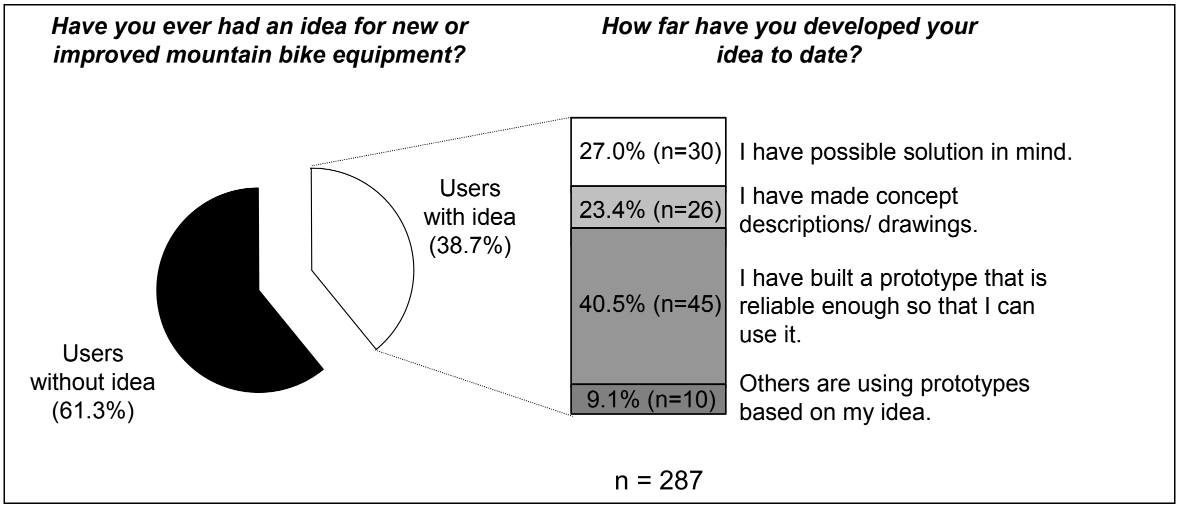
83,9% for user experience (0,82 for preferred terrain, 0,88 for outside conditions, ,and 0,83 for particular riding abilities).

Coding of the relationship between each innovator's sub-field of use experience, and the mountain biking activity to which that user's innovation primarily applied was carried out by a single coder - the first author. The reliability of this coding was then tested by asking 10 expert users to independently perform the same coding task for a random subsample of 23 of our 111 user innovations. (The 10 experts selected were the core members of two racing teams that engaged in mountain biking on a semi-professional level. All devoted a large amount of their own time to mountain bike riding; none had a relationship to any of the innovators or innovations in our sample.) The procedure used was to present the descriptions of the 23 ideas to each expert during the course of a personal interview. Each was then asked to associate the users' inventions to the specific functions and sub fields of application shown in table 2. An acceptable level of agreement between the authors' and the expert users' coding was achieved. For the ten expert users the Cohen's Kappa coefficients range between 0,77 and 0,86. The overall level of agreement for the random sample of 23 user innovations was 81%.

4: Findings

A significant number of individuals responding to our questionnaire reported having developed ideas for new or improved mountain biking equipment. Thirty eight percent of our 287 respondents reported having developed one or more such idea. Of these, 40.5% reported building and personally using a prototype embodying their idea, and 9.1% of the inventing users reported that their innovative idea had been adopted and put to use by other mountain bikers (figure 1). It is possible that the level of user innovation in our sample overstates the actual level of innovation in our population of mountain bikers: innovators may have been more likely than non-innovators to respond to our questionnaire. However, members of our sample were dedicated bikers, and Franke and Shah (2002) report similar levels among serious practitioners of the four diverse sporting fields they studied: sailplane flying, canyoning, bordercrossing and cycling by individuals with physical disabilities. (Luthje (2000) finds a lower level (10%) among recipients of specialized mail-order catalogs for outdoor sporting products.)

Figure 1: Frequency of idea and prototype generation by serious mountain bikers



Respondents typically characterized their ideas or innovations as relatively moderate improvements utilizing fairly routine solution technologies (table 3). Twenty four percent considered their ideas to be totally new products, and only 13% thought that their solutions incorporated "high technology" or new technology. This type of relatively incremental innovation is characteristic of the mountain biking field. Ever since the introduction of the mountain bike – itself a modification of the general biking equipment then in use - the predominant innovation pattern has involved incremental and minor novelties, with technological progress mainly consisting of accumulated improvements and minor modifications to the same basic design (Buentsdorf 2002). Three examples of needs and solutions drawn from our sample are illustrative:

- Problem encountered by user in "stunt" riding: "When doing tricks that require me to take my feet off the bike pedals in mid-air, the pedals often spin, making it hard to put my feet back onto them accurately before landing." Solution devised: "I have added a foam ring around the pedal axle near the crank. This adds friction, and prevents the pedals from free-spinning when my feet are off."
- Problem encountered by user riding in extreme conditions: "When riding on ice, my bike has no traction and I slip and fall." Solution devised: I increased the traction of my tires by getting some metal studs used by the auto industry for winter tires. Then I selected some mountain biking tires with large blocks of rubber in the tread pattern, drilled a hole in the center of each block and inserted a stud in each hole."
- Problem encountered by user related to racing: "You need to try out different "lines" on a race course [the precise path that your bike will travel] and compare

> them to figure out which is the fastest." Solution developed: "I mounted a thumb-activated stopwatch next to my bike's handlebar to be able to conveniently and accurately time each line tested."

Users developing innovations reported that they gained a high personal benefit from using their innovations in their own mountain biking activities. On average, they also thought that quite a few people would buy their innovations if they were commercially available (table 3).[2]

Table 3: Characteristics of user-developed innovations

Rating dimensions	Mean	% of innovations with high or very high agreement
Newness [a)]	3.49	24.1%
Technical Sophistication [b)]	2.61	12.9%
Personal Benefit [c)]	5.39	66.1 %
Market Potential [d)]	4.32	31.2%

n=109 ; 7-point-rating scales were used
[a)] 1=small improvement / modification of existing product; 7=totally new product
[b)] 1=low-tech solution / known technology; 7= high tech solution / new technology
[c)] 1=personally benefit very little; 7=personally benefit very much
[d)] 1=few people would adopt if commercially produced; 7=many people would adopt if produced

Of course, a user's appraisal of the general appeal of his or her own innovation might well involve a significant positive bias. We tested this possibility by having a subset of the users' innovations also evaluated by 10 mountain biking experts who had no relationship to the innovators or innovations in our sample. We found that, although user-innovators did evaluate the commercial potential of their innovations slightly more

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[2] Likely sales volumes of innovations appealing to "many" mountain bikers is not clear. One can get a flavor of likely volumes, however, based upon the following market-related information. Sporting Goods Manufacturers Association (SGMA) estimates that in 2001 there were approximately 8 million people who went off-road mountain biking in the United States. Of these, about 2 million are "frequent riders," riding on at least 25 occasions a year on traditional or modified mountain bikes ("comfort bikes"). A $50 innovation purchased by 10% of frequent riders would thus generate $1 million in sales. Purchase of a $50 item of equipment seems reasonable: According to a survey of USA Cycling Association frequent riders spend an average of $1,212 per year in bikes/cycling equipment.

positively than did the independent experts, the level of difference was not statistically significant.[3]

Increasing specialization in an innovator's mountain biking interests was associated with a *decrease* in the number of other users that could potentially benefit from the innovation developed and a decrease in its market potential as well. As the number of mountain biking specialties in which an innovator is active increased, so did the breadth of applicability of his or her innovation (table 4).

Table 4: Impact of user's specialization on general usefulness of his innovation

Correlation coefficients	Usefulness of the innovation for other users [b)]	Market potential of the innovation [c)]	% of users who experience the problems/needs the innovation solves [d)]
Level of specialization in product use [a)]	- .265 ***	-.116*	-.214**
No. of different disciplines of MTB	.037 (n.s.)	.177*	.226**

*n = 108; Pearson correlation coefficients, * p < .1; ** p<.05; *** p<.01*

a) *6-point-rating scale (1=all-rounder; 6 = particular strength)*
b) *7-point rating scales (1= useful for a very small group of riders; 7=useful for all people active in MTB)*
c) *7-point rating scales (1= few people would adopt if commercialized; 7=many people would adopt if commercialized*
d) *Measured in %*

4.1: Differences in experience and technical skill between innovators and non-innovators

Users that reported having ideas for improving mountain biking equipment differed significantly from those without such ideas on a number of measures of

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[3] To conduct this test, we asked the aforementioned 10 expert users to evaluate a random sample of 23 idea descriptions provided by the innovating respondents. Since the 10 experts were engaged in mountain biking on a semi-professional level they had a good understanding of the purpose and utility of the innovations developed by our sample of users. They also all worked part-time at bike shops, and so had a good understanding general user needs – at least from that vantage point. Via an interview, the experts were presented with concept descriptions of the ideas and were asked to rate the potential of the ideas concerning their usefulness for mountain bikers and their market potential (number of adopting users if commercially available). The same scales were used in these interviews as in the survey responded to by the innovating users. We then compared the self-rating of the developers of these 23 innovations with those of the independent experts. Due to the small sample, we used a non-parametric test (the Wilcoxon-Signed-Rank-Test) and determined that the null hypothesis - that the distribution of user-innovator and user-expert ratings are equal - is not rejected.

experience and technical skills. Those with ideas (50% having also built prototypes) spent more hours per week in mountain biking, had been active in their sport for a longer time, and were active in more different mountain biking specialties such as jumping and endurance riding. They also participated more frequently in races, rode to a greater extent on challenging terrain and under extreme outside conditions and were more focused on particular riding abilities. They also reported a higher level of technical knowledge with respect to how their mountain biking equipment functions and how to fix it than did those not reporting ideas for improvements (table 5).

Table 5: Differences in use experience and technical knowledge between those with and without ideas for improved mountain biking equipment

	Users *with* improvement ideas [a)]	Users *without* improvement ideas[b)]	Difference[c)]
Aspects of use experience			
Hours per week in MTB	12.9	9.0	P<.001
Years of MTB	8.4	6.3	P<.001
No. of different disciplines of MTB	1.9	1.4	P<.001
Participation in MTB races [d)]	3.8	2.3	P<.001
Riding in challenging terrain [e)]	4.32	3.82	p<.01
Riding under extreme outside conditions [e)]	3.96	3.06	P<.001
Focusing on specific riding ability [e)]	3.03	2.29	P<.001
Aspects of technical knowledge			
Know-how about equipment functionality [d]	6.10	4.37	P<.001
Ability to fix equipment [d)]	6.32	5.09	P<.001
Relation to others with repair abilities [d)]	5.89	5.66	n.s.
Knowledge about tools and repair facilities [d)]	6.36	5.74	P<.001

a) means (n=111): b)means (n=176)
c)two-tailed t-test for independent samples
d)measured on 7-point-rating-scale (1 = never; 7 = very often)
e)measured on 6-point-rating-scale (1 = never; 6 = very often)

It seems reasonable that generating ideas for desirable new improvements has to do primarily with the nature and intensity of a respondent's use experience. In contrast, going on to the stage of building prototypes should also be associated with a respondent's level of technical skill. To test this idea we used a multinomial LOGIT model to examine the differences between three subgroups in our sample of respondents: (a) users having no idea for an improvement to mountain biking equipment; (b) users who have a need and a general type of solution in mind; and (c) users who have built and used reliable prototypes embodying their ideas (c.f. figure 1 categories).[4] The results in table 6a show the degree to which the independent variables can explain why users initiate new product development instead of remaining totally passive (are in group b rather than a). The results in table 6b show the degree to which our variables can explain why users develop reliable prototypes instead of just generating ideas and concepts (are in group c rather than b). All measures indicate a good fit with the estimation model. The rate of correct classification of respondents into the three subgroups is 77.1%. The Proportional Chance Criterion (PCC) is significantly lower at 52.6%.

As can be seen in table 6a, the LOGIT coefficients of the variables associated with use experience are, with one exception, positive and significant. That means that the higher the amount and "extreme nature" of use experience, the more probable that a user has ideas and concepts for new or improved products. The same is true for technical knowledge. Note, however that one variable related to technical knowledge – relation to others with repair abilities - does not have significant explanatory power.

In table 6b a different pattern emerges when we compare the users that only developed an idea/concept with those that developed a reliable prototype. None of the variables measuring aspects of use experience can explain why a user decides to actually develop his idea or concept into a working prototype. However, we see that bikers that did develop prototypes had significantly higher technical knowledge than those who did not.

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[4] Since the endogenous variable is ordinal, the independent variables in table 5 can be combined in a multinomial LOGIT model (Agresti and Finlay 1997, Aldrich and Nelson, 1984). To assess the level of multicollinearity (linear dependence of exogeneous variables among themselves) we examined the correlation matrix and observed the impact of exclusion of most highly-correlated variables on the model estimation. As a result, one variable associated with technical knowledge ("ability to fix equipment") was excluded from further analysis.

Table 6: A LOGIT model shows that moving beyond an idea to the actual building of a working prototype is significantly affected by users' levels of technical skill

Table 6a user initiates idea and concept development rather than remains totally passive

Variables of user background	LOGIT-coefficient[5]	Standard error	Wald statistic
Aspects of use experience			
Hours per week in MTB	**0.06**	0.03	3.87 (p<0.05)
Years of MTB	**0.18**	0.05	12.99 (p<0.001)
No. of different disciplines of MTB	**0.46**	0.22	3.81 (p<0.05)
Participation in MTB races d)	**0.28**	0.11	5.37 (p< 0.05)
Riding under extreme outside conditions e)	**0.29**	0.12	3.59 (p<0.05)
Focusing on specific riding ability e)	**0.16**	0.15	1.17 (n.s.)
Aspects of technical knowledge			
Know-how about equipment functionality d	**0.51**	0.16	10.22 (p<0.001)
Relation to others with repair abilities d)	**0.06**	0.16	1.02 (n.s.)
Knowledge about tools and repair facilities d)	**0.39**	0.18	4.83 (p<0.05)
Constant	**-6.34**	1,23	26.52 (p<0.001)

Table 6b user develops reliable prototype rather than just develops ideas and concepts

Variables of user background	LOGIT-coefficient	Standard error	Wald statistic
Aspects of use experience			
Hours per week in MTB	**-0.03**	0.027	0.92 (n.s.)
Years of MTB	**-0.02**	0.05	0.13 b(n.s.)
No. of different disciplines of MTB	**0.27**	0.24	1.31 (n.s.)
Participation in MTB races d)	**0.03**	0.12	0.07 (n.s.)
Riding under extreme outside conditions e)	**0.07**	0.16	0,19 (n.s.)
Focusing on specific riding ability e)	**0.04**	0.15	0.07 (n.s.)
Aspects of technical knowledge			
Know-how about equipment functionality d	**0.63**	0.27	5.60 (p<0.05)
Relation to others with repair abilities d)	**0.40**	0.17	5.88 (p<0.05)
Knowledge about tools and repair facilities d)	**0.74**	0.34	4.79 (p<0.05)
Constant	**-5.82**	2.21	6.94 (p<0.01)

-2 log likelihood= 330.64, p = 0.92; Likelihood-Ratio=192,45 (df=18, p<0.001); McFaddens R^2*= 0.37; n=280.*

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[5] In this survey a positive LOGIT coefficient indicates that it is more likely that a user generates an idea for innovations (table 6a) or develops a a reliable prototype (table 6b) if the corresponding factor takes high values. The coefficient itself indicates the change of the Logit of the dependent variable if the independent variable changes in one unit (Aldrich and Nelson 1984).

4.2: Relationship between specific user need and solution information and innovation content

Taken together, the two findings in section 4.1 support the view that use experience primarily drives the development of ideas and general solution concepts. Then, the level of a user's personal technical knowledge explains why some users stop at the idea/concept stage while others go on to build a prototype. In this section we explore these findings more deeply by determining how *closely* innovating users' experiences and technical capabilities are linked to the types of innovations they develop.

Fit between specific user experiences and innovation function

With respect to experience, innovators report that their innovative ideas were triggered by direct and repeated *personal experience* with a problem associated with mountain biking (table 7). Repeated experience can be helpful in isolating an item in a continuous flow of events as „a" problem. It can also be helpful for prototype development: Repeatedly experiencing the same problem creates a laboratory for repeated trial-and-error experimentation in the field.

Table 7: Experience-related triggers of user innovations

	Mean	Median	% of users
"How did you recognize the problem/need solved by your idea? Because of your personal experience or because you learned that other riders experienced it?" [a)]	2.15	2	84.5% rather personal experiences
"How did you recognize the problem/need? As a result of frequently repeated experience or as a result of a single incident?" [b)]	2.07	2	87.3% rather frequently repeated experience

n=110

[a)] 6-point-rating-scale (1=because of my personal experiences; 6=because other riders experienced it)

[b))] 6-point-rating-scale (1=very frequently repeated experience; 6=single incident)

Users' assertions that their innovations are triggered by problems they personally encounter in mountain biking can be indirectly tested by comparing the function of each idea or innovation developed by each user with that user's declared special biking interests. To make this comparison, we used our table 2 listing of specialized activities in the mountain biking field. The respondents answers with regard to their special interests as well as their written descriptions of their innovations' function showed a strong association (table 8). (As was discussed in section 3, coding procedures with respect to both of these matters were tested and proven reliable.)

Table 8: Applicability of innovation to sub field of special interest to innovator

	Dimensions of mountain biking activity			
	Preferred terrain	Predominant outside conditions	Particular riding ability	**Total**
Number of user innovations associated with the particular dimension of biking activity	82	59	52	**193**
Percentage of these innovations applicable to at least one subfield mountain biking activity of special interest to the innovator.	94,0% (77)	95.0% (56)	88.5% (46)	**92.7% (179)**

A comparison of the functions of user-built prototypes with the special interests of our user-innovator respondents show that mountain bikers do indeed tend to develop prototypes useful for the specific kind of mountain biking that they personally perform (table 7). Very rarely does an innovation lie exclusively in fields of product use where the innovating user has no personal experience.

To illustrate what we mean by a close link between user experience and innovation content, consider the example of knee-activated brake levers drawn from our sample. Knee-activated braking levers can provide greater braking power than the handbrakes traditionally used in mountain biking. The knee lever developer reported that he rode his bike primarily in very mountainous terrain. On long descents, he found that continuously applying his hand brakes created such a strain on his hands and upper arms that muscle fatigue was seriously affecting his safety. By creating a way to activate his brakes using his knees, he was able to utilize his much-stronger leg muscles for braking and thus avoid fatigue.

Fit between specific user technical knowledge and innovation solution

Innovators in our sample indicated that they already had the knowledge they needed to develop the type of technical solution embodied in their innovation, either from their profession or from mountain biking or other hobbies. Only 15.6% of our innovators strongly agreed that they had acquired new knowledge to develop the solution to their problem (table 9).

Table 9: How did you obtain the information needed to develop your solution?

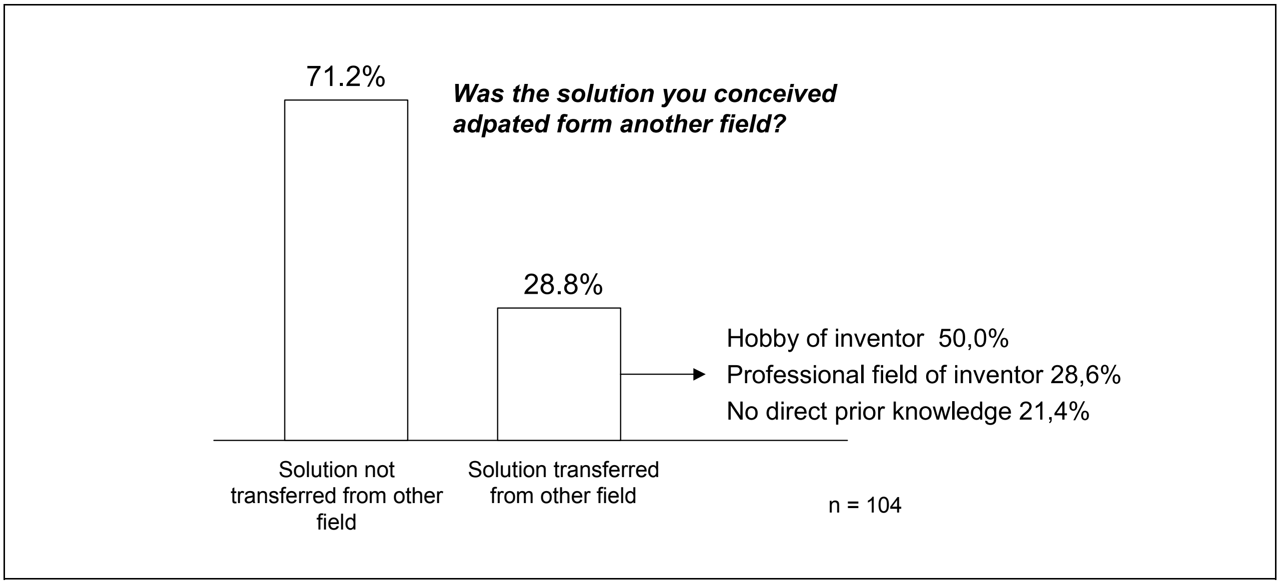
	Mean	Median	Very high or high agreement
"I had it due to my professional background." [a)]	4.22	4	47.5%
"I had it from mountain biking or another hobby." [b)]	4.56	5	52.4%
"I learned it to develop this idea."	2.11	2	15.6%

n=61; all responses were measured on a 7-point-rating-scale (1=not at all true; 7=very true)

This general finding is supported by responses to another question we posed to our sample of user-innovators. We asked whether the innovation was adapted from a field *outside* of mountain biking (for example, the automotive field) – and, if so, whether the users had professional or hobby-related direct experience in that field (figure 2). Similarly to the findings regarding acquisition of need-related information, direct personal experience was reported to be involved in 78,6% of the instances where a user drew a solution from a field outside of mountain biking. In 50,0% of the cases the other field involved another hobby of the innovator (e.g. motocross). In 28,6% of the cases, the other field was related to the innovators' profession (e.g. medicine).

- Example: "I'm a human movement scientist working in ergonomics and biomechanics. I used my medical experience for my design. I calculated a frame design suitable for different riding conditions (downhill, climb). I did a CAD frame design on Catia and conceived a spring or air coil that can be set to two different heights. I plan to build the bike next year."

Figure 2: Was solution transferred from a field outside of mountain biking?



User solution concepts transferred from another field do not significantly differ from the rest with respect to their newness or technical sophistication.

In only 21,4% of the cases did user-innovators *not* have direct prior experience with the solution-related technology used. In almost all of these, the innovators knew about the solution through friends active in the external field. Only one respondent indicated that information was obtained from an external field by a systematic scanning of different information sources. Again, the findings show that inventors primarily develop solutions that are related to their personal experience, knowledge and skills.

5.0: Discussion

In this paper we have found that the innovations developed by users are motivated by each user-innovator's own personal and repeated experiences with a need for improved mountain biking equipment. We also find that innovating users typically draw upon only their own existing stock of solution information to develop a solution to the problem they experience: only 16% of our user-innovators agreed that they learn new solution information in order to develop their idea. In essence, therefore, we find that a user's personal patterns of product usage and needs directly encountered – his or her "local" information – strongly affects the function of the innovations he develops. That user's pre-existing local stocks of technical knowledge and skills will then determine the type of solution that will be developed.

This finding is important both with respect to advancing our understanding of the nature of user innovation and also with respect to a very practical matter for manufacturers and others that may be interested in benefiting from innovations developed by users: Efficient identification of innovations of a specific function and type that users may have developed.

Some users can develop innovations much more cheaply than others

Why do users tend to develop precisely what they want for themselves rather than designing for a larger market? As we noted in our introduction, this pattern can be understood both in terms of users' innovation-related costs and also in terms of the benefits that users can reasonably expect from innovating.

With respect to innovation costs, consider first that mountain bikers generally engage in a particular pattern of mountain-biking activity because they enjoy it: it is a recreational activity for them. Repeated specialized play and practice leads to improvement in related specialized skills. This in turn may lead to a discovery of a problem in existing mountain biking equipment. As an example, recall the problem encountered by the user in our sample who specialized in "stunt" riding: As that user reported: "When doing tricks that require me to take my feet off the bike pedals in mid-air, the pedals often spin, making it hard to put my feet back onto them accurately before landing." Taking one's feet off the pedals while in mid-air is necessary to perform certain stunts – like twisting the bike sideways in the midst of a jump. However, the stunt rider needs to reestablish contact with the foot pedals before landing in order to have good control over the bike and to move smoothly into the next maneuver.

One can appreciate that such a problem is only encountered when a user has gained quite a high level of skill at jumping and at performing tricks in mid-air: bikers do not risk taking their feet off the pedals until they are fairly skilled jumpers. Once the problem *has* been encountered and recognized, however, a skillful user can re-evoke the same problematic conditions at will during ordinary practice. The result is creation of a "free" test laboratory for trying out and comparing different solutions to that problem.

The utility of such a laboratory can be appreciated in the context of our example. Here, the user reported devising the following solution: "I added a foam ring around the pedal axle near the crank. This adds friction, and prevents the pedals from free-spinning when my feet are off." This solution was developed by trying out multiple ideas and then iteratively refining the solution approach chosen. After all, the user-innovator needed to determine the best type of foam to use, how much to use, where should it be located, how stiff it should be, etc.. In other words, the user *needed* a very effective test laboratory – and had one available at no incremental cost - when developing a solution to a problem encountered during the normal course of his own activities, activities selected and "paid for" by rewards unrelated to innovation.

In sharp contrast, if the user decides to stray outside his own chosen activity in order to develop innovations of interest to others with needs that are different from his own, the cost properly assignable to innovation suddenly jumps. To gain an equivalent-quality context for innovation, such a user must invest in developing personal skill related to the chosen innovation topic. Only in this way will he gain an equivalently-deep understanding of the problems relevant to practitioners of that skill, and acquire a "field laboratory" appropriate to developing and testing possible solutions.

A similar argument holds with respect to solution-related information. If a user employs only solution information that he or she already has "in stock" that was acquired and paid for on the basis of some unrelated prior activity, the user's investment in a solution is correspondingly reduced. This holds even when the solution information is quite specialized and costly to acquire, as when a mountain biker has a professional background in orthopedic surgery or advanced engineering materials.

In sum, users operate in a "low-cost innovation zone" when they develop innovations precisely responsive to problems they encounter in the normal course of their activities, and that they address by using solution information already in hand. (This same logic is applicable to corporate users of innovations - and to manufacturers and other types of innovators as well - with respect to the type of activity they engage in "anyway," and that are amenable to solutions drawing upon their in-house store of solution-related knowledge. The low-cost arena of innovation and "field laboratory for free" will differ according to the arena of activities practiced. In the case of manufacturers, for example, this arena probably will include innovations having to do with the improvement of production processes in use.)

Of course, if increased reward were in prospect, it is reasonable that users could be induced to develop more generally-applicable innovations. What would be the compensating reward for developing an innovation less useful to oneself but more useful to others? There might be monetary and/or prestige gains from doing so. With respect to monetary gains, it has been shown in the general case (Harhoff et al 2002), and also specifically in the case of sports equipment (Shah 1999), that user-innovators have little realistic opportunity to profit from licensing their innovations for sale to others. Direct financial benefit from diffusion of an innovation to other users in a marketplace typically requires some form of intellectual property protection followed by licensing. Both matters are costly to attempt, with very uncertain outcomes. Gains in prestige from developing a generally useful innovation certainly do exist. Indeed, reputational gains have been posited a major reason for contributions to open source software projects (Lerner and Tirole 2002). However, empirical studies of user motivations for contributing to open source software do not find it to be a major motivator (Lakhani and Wolf 2001, Niedner et al 2000).

As a consequence, personal benefit from "in-house" use is the major likely source of an innovator's reward. In this case, rationally-anticipatable benefits should be highest for precisely those innovations where personal use benefit is highest. If an innovator deviates from his or her personal preference in order to make an innovation more appealing to others this personal use benefit will of course drop. The net result is a narrow, low-cost, high-benefit peak where users can encounter, develop and test ideas as a low-cost adjunct to activities carried out for other reasons. Therefore, our innovators are only following the rational course of action when they design innovations for themselves. We note that they do appear to be succeeding at this task: recall that our respondents report gaining a high level of personal benefit from personal use of their innovation.

Practical applications

What are the implications of a pattern of many users with heterogeneous interests and skills – a significant fraction of whom innovate? It suggests a distributed model of innovation in which we can view the population of users as many potential sites for innovation. Given heterogeneity, many such sites will have different characteristics with respect to both low-cost need information arising from activities engaged in for reasons other than innovation and pre-existing solution information that is low cost because it is already "in stock." Users that experience a need will be incented by that need to create a responsive solution. Some of these will also have a proclivity to innovate and existing solution capabilities that are a useful fit for the contemplated innovation. In such cases, development and use of a prototype innovation may be triggered.

Given a user population that is both large and heterogeneous with respect to need and solution types, the result will be a large number of diverse innovations being generated. (On the basis of our study data, about 50% of 38% - about 20% - will create and personally use prototypes.) Some of these will prove to be of general interest to other users in the activity, and so may reward commercial production and general distribution. (For example, an innovator might need a better bike light to accommodate a need experienced in a very specialized activity - night-time jumping – but perhaps many people also have a (lesser) need for better lighting at night.)

How can manufacturers and/or users identify specific innovations of potential value to themselves? On the basis of our findings, it seems likely that interested others – whether users or manufacturers - should be able to use information on the characteristics and backgrounds of users to predict the specific application area and innovation solution type some will develop. (This would not be the case, or would be the case to a lesser extent if users engaged in active search for either problems or solutions.) For example, one should be able to predict that some fraction (say 20%) of leading-edge mountain bikers who are pushing the limits of downhill biking practice and who also are orthopedic surgeons will innovate applying their specialized solution knowledge to address the equipment and technique problems that they are personally encountering.

As we saw, the innovations developed by all-around mountain bikers have a bigger present market potential. However, this does not necessarily implies that manufacturers should primarily rely on “generalist” users and automatically reject the ideas of specialized bikers. The trends in the mountain biking field are strongly that today’s extreme is adopted by center of the market riders after an elapsed time of approximately 4 to 6 years. Thus, extreme rider innovations tend to be lead user innovations that might not represent the current market needs but will be more general in the marketplace in the foreseeable future. More specialized and extreme users can therefore be seen as an important source of innovation to mountain biking commercializers.

Methods for searching for user-developed innovations of particular interest developed to date include the “lead user process,” a method that uses telephone networking to identify users and user-developed innovations having specified characteristics (von Hippel et al 1999, Lilien et al 2002). Open source software uses a different method. User-developed innovations are posted on the Internet within any of hundreds of thousands of open source programs and can be – not very efficiently - searched for by knowledgeable experts.

Neither of these extant methods utilizes information on user interests and backgrounds as useful inputs to the search for user innovations of particular interest to specific searchers. However, the findings we have developed here suggest that method development utilizing this type of information for screening purposes might be feasible and economical. Data mining methods and existing data bases might, for example, allow efficient identification of “all members of mountain biking clubs that are also orthopedic surgeons.” Once identified, such narrow segments of the user population might then be economically screenable for innovations of potential interest.

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