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DIFFUSION OF TECHNOLOGICAL INNOVATIONS

BY

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Daryl Wong:

FACULTY COMMENTS

- Diffusion of innovation is one of those topics that sociologists, economists, marketing scholars, strategists and management of technology scholars all lay claim to. Unfortunately researchers in each area often pay little attention to what is going on in other areas. Daryl has done an excellent job at integrating ~~these~~ some of these literatures in a framework that is tractable and makes sense to MBAs!!
- In this day and age, every manager ~~and~~ ought to be very aware of the diffusion of innovation which can be both good and bad. This paper is a good start for such managers.
- Could have spent more time on diffusion to the market. But then, there wasn't enough space.
- Great job!

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ABSTRACT

This paper is concerned with the factors that affect the diffusion of technological innovations within an organization, between organizations, and from an organization to the market. First, it analyzes the existing literature on the diffusion of innovations, and then highlights the factors specific to technological innovations. With these factors in mind, it attempts to develop models for the three cases enumerated above, with primary emphasis on the case of diffusion within an organization. Finally, it highlights areas for potential study.

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INTRODUCTION

The study of diffusion of innovation has existed since the beginning of the Twentieth Century. For decades before World War II, theorists tried to explain how innovations spread from originators to followers. However, such studies had been limited to the sociological or anthropological fields. For instance, a 1943 study by rural sociologists Ryan and Gross examined the diffusion of hybrid corn usage in Iowa. In it, they attempted to identify the factors that affected the adoption of the hybrid corn by farmers. After months of research, they concluded that informal communication between originators and prospective adopters was the most effective way that innovative agriculture techniques could diffuse to target groups. Their theory established an initial paradigm for future research on the diffusion of innovations.

With its initial publication by Everett M. Rogers in 1962, *Diffusion of Innovations* became, and remains today, the definitive work for diffusion studies. The Rogers model focuses primarily upon on diffusion within an organization and between organizations. As a result of its robustness, it has served as a framework for various areas of innovation research. Briefly stated, this model asserts that the rate and success of an innovation diffusion depends on:

1. The benefits of the innovation, and
2. The characteristics of the organization receiving the innovation.

However, with the rapid pace of technological change, we must refine this model in order to understand how technological innovations diffuse.

In this paper, we will examine the diffusion of technological innovations both within and between organizations. First, we will examine the Rogers Model in greater detail, identify the additional paradigms required to explain the case of technological innovations, and then describe the stages of technological innovation diffusion. Finally, we will examine how technological innovations diffuse from an industry or organization to the market.

ROGERS MODEL FOR DIFFUSION OF INNOVATIONS

To restate, the Rogers Model attempts to describe innovation diffusion within an organization. In this model, the primary variable that affects diffusion is the aggregate benefit that an innovation represents to an adopter. In addition, there are secondary variables relating to the structure and beliefs of the adopting organization and the timeframe of the innovation.

Benefits of the Innovation

The aggregate benefit of innovation consists of the following attributes:

1. *Relative Advantage* is the degree to which an innovation is perceived as superior to the idea that it supercedes. From Rogers' opinion, this advantage is more subjective than objective. Therefore, perceived advantage could include not only economic factors but also social factors, convenience, or satisfaction with the innovation. A greater perceived relative advantage should result in faster adoption.
2. *Compatibility* is the degree to which an innovation is perceived as "matching" the existing organization in terms of its existing values, past experiences, and needs of potential adopters. Greater compatibility with an existing organization should lead to quicker adoption of an innovation. Incompatible innovations, or "red-zone" innovations, often require a change within the existing organization in order to facilitate adoption, thus slowing the process.
3. *Complexity* is the degree to which an innovation is perceived as difficult to understand and use. Again, the judgment of complexity is not necessarily an objective one, but subjective. If an organization perceives an idea as difficult to understand or to implement, it may not be implemented. Even if an idea can be implemented, it may require the organization to adopt new knowledge.
4. *Trialability* is the degree to which an innovation may be experimented with. If an organization or individual is able either to test the viability of an idea or to experiment with an idea in stages during implementation, it will develop skills and understanding about the idea. The greater potential to try an idea, the faster the adoption.
5. *Observability* is the degree to which the results of an innovation can be observed or demonstrated. If the results are easy to see, observers should be able to overcome their uncertainty about the innovation and adopt it. Therefore, the more observable an innovation, the faster the adoption.

Secondary Factors

Diffusion is also affected by the following secondary factors.

1. *Communication Channels* are the means by which information travels within an organization. Such channels could be mass media or interpersonal ties. For example, members of an organization could gather new information through an official channel, such as a company policy statement, or through an informal one, such as a conversation at the cafeteria. As we shall discuss later in further detail, most people evaluate an innovation based upon the subjective opinions of either adopter or rejecters. As a result, Rogers concludes that diffusion is a social process.
2. A *Social System* is defined as a set of interrelated units that are engaged in joint problem solving to accomplish the same goal. The members can be individuals, informal groups, or subsystems within an organization. The activity that binds these members together is the seeking of a common goal. It is within this system that an innovation is evaluated. Depending upon the openness that a social system has towards new ideas, an innovation may be rejected or accepted, sometimes regardless of its benefits. As we shall examine later, the attitude of a social system towards innovation depends on several factors.
3. *Time* is the final factor affecting diffusion of an innovation. However, according to Rogers, the effect of time has several dimensions. First, the length of the "innovation-decision period"[1] influences the success or failure of an innovation. In many cases, a long evaluation period could prevent an innovation from being adopted if it can become obsolete within a short period of time. Secondly, an innovation's chances are affected by the relative time in which it is evaluated. For instance, many innovations that might have been rejected early in their lives could be adapted later when several other organizations have accepted them.

In summary, the Rogers Model states that the diffusion of an innovation depends on its aggregate benefit of a potential adopter, the communication channels and the social system that exist at an adopting organization, and the time when an innovation is evaluated. While this model describes diffusion for many types of innovations, technological innovations present challenges to an organization not fully explained by the model.

[1] The time required for a party to proceed through the Five Steps of the Innovation-Decision process: Knowledge, Persuasion, Decision, Implementation, and Confirmation. Everett M. Rogers, Diffusion of Innovation, 4th Edition, New York, The Free Press (1995), pp.20-21.

DIFFUSION WITHIN ORGANIZATIONS

As robust as it is, the Rogers Model cannot fully explain the factors that affect the diffusion of technological innovations. Especially in the area of information technology and biotechnology, the speed and the magnitude of innovation have increased dramatically. For instance, according to Moore's Law, the speed of microprocessors will double every 18 months. These two factors alone make successful diffusion of a technology throughout an organization extremely difficult. In this section, we will examine the factors that affect technological innovation diffusion.

Nature of the Innovation

With a technological innovation, its characteristics possess an even greater importance than assigned by the Rogers Model

First, the nature of the innovation's benefits becomes even more important in determining the success or failure of its adoption. If the benefits are easy for advocates to explain and for potential adopters to understand, then the change is more likely to be adopted. For instance, up until the mid-1990's, most personal computers could not operate many software packages at "optimum" speeds. Therefore, most consumers continued to purchase faster machines to reduce non-productive time, thus fueling the growth of hardware companies such as Intel. However, with most consumer software now no longer challenging current processors, consumers are no longer buying machines with cutting-edge microprocessors. If potential adopters cannot easily see benefits of a technological innovation, they might not implement it.

Second, the degree of a change that a new technology brings will either facilitate or hinder its adoption. Incremental innovations, or "green zone" innovations, require little new knowledge in order to implement them. Therefore, they are easier for an organization to adopt. On the other hand, radical innovations, or "Red Zone'[9] innovations, often require significant learning or organizational change to be implemented. Many companies are unable or unwilling to make such an investment. As a result, many Red Zone technological innovations are not adopted regardless of the benefits.

Thirdly, the origin of a technological innovation will affect its adoption. While most technological organizations purport themselves to be creative organizations that accept all ideals, many also have strong "Not Invented Here" syndrome. Case after case has shown that organizations will accept technological changes that have internal origins and will reject those external ones. A classic case if that of Microsoft's reaction to the explosion of the Web in the 1990's. While the Web represented a huge change in the IT world, Microsoft initially ignored it as a threat to the Intel-Microsoft model of the self-contained "mainframe on a desk." Only after the explosive growth of Web applications and of Netscape Communications did the Microsoft team realize the magnitude of the threat posed. Therefore, if a technological innovation is external to an organization, change advocates must be prepared to change the minds of critics.

Nature of Knowledge Required

Even if the benefits of a technological change are clear, adoption can be affected by type of knowledge required to understand and adopt the innovation. In this case, we need to understand the difference between explicit and tacit knowledge.

Innovations that require explicit knowledge may be easier to adopt. Knowledge is *explicit* if it is easily codeable, either in written or verbal format.[2] For instance, a person can learn to play a musical instrument by reading a book. However, the potential level of proficiency is limited.

In the case of a technological change, adopters can learn about a change through journals, books, lectures, or design drawings. However, the scope of the knowledge gained, or of the benefits communicated, is limited by the means of the communication (bandwidth). A document may only address a few benefits while ignoring other potential applications for an innovation. Therefore, while an innovation communicated explicitly will have a greater chance of being adopted, the potential benefits might be fewer, possibly weakening the case of adoption.

[2]Allan Afuah, Innovation Management - Strategies, Implementation, and Profits, New York and Oxford, Oxford University Press (1998), pp. 24-25 & 58-59.

On the other hand, innovations requiring the exchange of tacit knowledge will be more difficult for a party to understand and adopt. Knowledge is *tacit* if it is uncoded and non verbalized.[3] For instance, while a person can study books to learn an instrument, one can only really become a musician by playing with other musicians. In a sense, much tacit knowledge is acquired only by doing and by interacting with experts.

With a tacit technological innovation, adopters need to have the innovation explained and demonstrated to them in order to understand and to realize its full potential. Here, formal and informal interpersonal networks are extremely important in the transfer of such knowledge. For instance, 3M's microreplication technology, originally developed to manufacture plastic Fresnel lenses, found applications in adhesives and abrasives only after its developers communicated its benefits to other scientists within the organization.[4] While some of the knowledge communicated was explicit, much was tacit that had to be communicated through potential adopters seeing then experimenting with the manufacturing process. Therefore, we can conclude that, while tacit knowledge is more difficult to communicate than explicit knowledge, tacit communication has a much broader bandwidth for the discovery of new, unintended uses.

Adoption Externalities

Finally, an organization is more likely to adopt a technological innovation if it results in other benefits not directly related to the innovation itself. Such benefits may appear immediately, or may take the form of options. For instance, when companies migrated from mainframe to client-server IT structures, they benefited immediately from lower capital investments required to diffuse computing technology throughout their organizations. However, greater benefits were often derived from adoption externalities. By taking advantage of the technological innovation of PCs and client-server technology, companies could access an ever-expanding catalog of software applications not found on mainframe platforms. For an advocate of a new technology, identifying and quantifying

[3] Afuah, pp. 24-25.
[4] Nitin Pai, Stephen Pawl, Daryl Wong, and Carlos Zavala, "3M-Making Waves with Microreplication," University of Michigan Business School (1997), pp. 7-8.

its adoption externalities can make the difference between organizations adopting or rejecting an innovation.

THE ROLE OF THE ORGANIZATION

While the characteristics of a technological innovation play a key role in its diffusion, the characteristics of the potential adopting organization have equal importance to the innovation itself. Too often, technological innovations that could have been adopted were rejected because of the lack of "fit" with the adopter. Because a technological innovation is often are extremely expensive to evaluate and implement, it must fit, or it will fail to be adopted. In this section, we will describe the ideal organization from the standpoint of Strategy, Structure, Systems, and People (S^3P).[5]

Strategy

Generally speaking, any innovative organization must continuously evaluate new technological innovations. This openness to innovation must be specifically articulated in its business strategy. At companies that rely on technology to maintain their competitive advantages, technological innovation is an integral part of their philosophies and corporate vision. With R & D expenditures exceeding $2.3 billion (7% of revenue) in 1997, Intel pursues technological innovation at a breakneck pace, bringing new technologies to market at the expense of its existing products. 3M maintains a corporate goal of "generating 30% of sales from products introduced within the previous four years." With a strong corporate commitment to technological innovation, an innovation has a much higher probability of adoption.

Structure

Such a technologically innovative strategy must translate into an organizational structure that permits effective communication, evaluation, and adoption of an innovation. We can evaluate an organization's structure by the following six factors:[8]

[5] Afuah, pp.222-238.

[6] Warren S. Hensch, "Research & Development - High-Tech Leaders Pour Record Amounts into New Technology Development to Stay Ahead," Computer Reseller News. Volume 16 Number 6 (June 1996), p. 4.

[7] Pai, pp. 4.

[8] Rogers, pp. 379-381.

Centralization can hinder an organization's innovativeness. If an organization has a very few dominant leaders, new ideals can be easily stifled. Stifling can occur no matter how innovative the leader. One can look at to the case of Intel's erroneous dismissal of the "sub-$1000" PC market in 1997 to see how Andy Grove's force of personality caused Intel's management team to misjudge the magnitude of this competitive threat. As a result, competitors such as AMD, who had not given Intel much competition in the past, now challenge Intel's dominant position.

Complexity, or level of expertise of staff, enhances innovativeness. If a staff has a strong level of expertise, it will be more likely to develop internal innovations. To maintain a high level of innovativeness, Intel commits substantial funds to hiring and retaining electrical engineering talent. However, a high level of expertise does not necessarily translate into a high level of cooperation. Oftentimes, the quest for individual achievement among groups of high achievers can hinder cooperation and coordination. In its worst case, the Not-Invented-Here Syndrome can hinder innovation.

Formalization within an organization can hinder innovativeness. In this case, formalization is the degree to which an organization emphasizes formal roles, rules or procedures. In terms of innovation, such a dependence on rules favors incremental innovations over radical ones because these changes do not require new knowledge, structures, or procedures to be adopted. In other words, formalization encourages Green Zone innovations. However, many technological changes are Red Zone innovations requiring new knowledge or structures. As a result, formalization can prevent the adoption and subsequent diffusion of new technologies.

Interconnectedness within an organization encourages innovativeness. Interconnectedness is the degree to which different members of an organization are linked by informal means, primarily by interpersonal networks. As stated previously, many technological innovations contain high amounts of tacit knowledge. Such knowledge is exchanged more easily through informal, rather than formal, communication networks. These networks also facilitate consensus building amongst potential adopters and testing of innovations. Without a high level of interconnectedness within a firm, tacit knowledge is extremely difficult to exchange.

Organizational Slack encourages innovativeness. In this case, organization slack refers to the uncommitted resources that an organization has available for innovation study. While an organization may have the will to innovate, it may lack the resources to do so. According to Rogers, the primary area of slack is capital; however, other areas could include corporate attention, people, or time.

Systems

An innovative strategy must also be reflected in the systems of an organization. Systems may include performance measurement and incentive systems, communications systems, and others. 3M have developed innovative incentive systems that foster innovativeness. Recognizing the contributions of its scientists, 3M maintains separate management and scientific promotional paths, referred to as the "Dual Ladder System."[9] This system ensures that both scientists and managers are rewarded for excellence. It also gives awards to employees who develop outstanding innovations. Finally, it encourages communication within its technical community by sponsoring technology fairs, conferences, and other forums. Such systems make the communication and evaluation of technological innovations much easier.

People

Finally, the last component that can advance or hinder innovation is people. Even if an organization has a forward-looking leadership that has established the organizational structure and systems to encourage innovation, it will fail if it lacks innovative people. These people must have the expertise and forward-looking attitude to evaluate and adopt innovations. If this level of sophistication is absent, any attempts at innovation will fail

Summary

As we have seen, the nature of the adopting organization can enhance or hinder the chances of diffusion as much as the innovation's characteristics. Therefore, any organization's leadership must understand how well an innovation matches with its constraints. If there are significant barriers internally, it must assume that organizational changes must be made to increase the chances of successful adoption.

[9] Pai,pp. 5.

STAGES OF DIFFUSION WITHIN AN ORGANIZATION

Having evaluated the factors affecting the diffusion of technological innovations, we will now examine the stages that such innovations must pass through in order to diffuse fully into an organization. First, we will describe the initiation stages of innovation, and then describe its implementation.

Initiation

The initiation of an innovation can take two forms: push initiation and pull initiation. While technological innovations can be of either type, most radical new technologies are pull innovations that pose greater challenges to successful diffusion.

Push Innovation

With a Push Innovation, a problem pushes an organization to find a solution. As one can guess, push innovations appear more frequently than pull innovations. Despite their frequency, such innovations generally are not radical, but are incremental. The primary reason is that the innovators are constrained by the boundaries of the problem at hand. These innovations generally are initiated in the following fashion:

1. *Agenda Setting,* where a performance gap or problem triggers the search for an innovative solution,
2. *Matching,* where several potential innovations are tested for the fit with the problem. In its strictest sense, matching would involve the exchange of mostly explicit knowledge.

Situations that result in push innovations often do not stimulate substantial technological innovations. Not only do constraints hinder the creative process, but the reactive nature of the innovation also hinders creativity. Most often, such innovations develop in a time-critical environment. In summary, push innovations are quick, focused solutions that are incremental in nature.

Pull Innovations

In contrast to push innovations, pull innovations are solutions in search of problems in an organization. Because these innovations are conceived in an environment without the boundaries of an existing problem, the innovator can be much more creative, not only in discovering it but in finding applications or problems to solve. Pull innovations generally are "initiated" in the following stages:

1. *Discovery* can occur either by attempting to solve a problem and getting an unintended innovation or just by basic research.
2. *Matching*, where advocates of an innovation find potential applications. Because innovation has different benefits for different situations, advocates must communicate tacit knowledge to each potential adopter.

Clearly, this initiation process is much more difficult than that for push innovations, as both innovators and potential adopters have no specific goals of solving specific problems. In addition, because the innovator must diffuse tacit knowledge, the matching process is much longer also. However, because an innovator can be creative, a technological innovation developed in this environment can be a radical one that could solve many different problems. One need look no farther than the multitude of applications for 3M's microreplication technology to see how pull innovations can offer robust solutions for many problems.[10]

Implementation

Innovations not only adapt to existing organizational and industrial arrangements, but they also transform the structure and practice of these environments.

Van de Ven, 1986 [11]

[10] Innovations include light-enhancing films for laptop displays, reflective highway signs, adhesives, and abrasives. Pai, p. 1.

[11] Andrew Van de Ven, "Central Problems in the Management of Innovation," Management Science, Volume 32, Number 5 (1986), pp. 590-607.

This statement made by Andrew Van de Ven, a renowned expert in organizational change, reflects the fact that both an innovation and an organization must change in order to facilitate the successful adoption of an innovation. As a result, a technological innovation cannot be implemented quickly. Instead, an adopting organization must proceed through the following steps.

Redefining & Restructuring

The first step in implementation is Redefining and Restructuring. As one would expect, this step is the most difficult because either the innovation or the organization need to change in order to be successful.

The simpler option of the two is to change the innovation. We can equate this option to a Green Zone innovation discussed previously. Generally speaking, changing an innovation is easier to execute, but changes may strip an innovation of some of its benefits. Such potential degradation is very likely with many technological innovations that embody radical changes. We can look to the explosion of Enterprise Resource Planning at many companies as an example. Most companies adopt ERP systems because they can allow the transparent sharing of information between all functions. However, they often try to make the ERP system mimic the old legacy systems in order to preserve the knowledge investment made already. As a result, information flow becomes more opaque, thereby reducing the benefits of ERP. Clearly, an organization is limited in how much it can change an innovation.

The more challenging option is to change an organization to fit the requirements of an innovation. Most technological innovations result in this type of Red Zone change. While changing an organization is much more difficult, more benefits can be realized as a result. Looking to the case of ERP systems again, an organization can get the full benefit of ERP only if it makes substantial changes to the way it does business. Among the many possible changes, a company could change its performance metrics, its accounting method, and its operational strategy to take advantage of new information. In the end, the greater benefits justify the changes.

We can conclude that the Redefining & Restructuring process is not altogether objective and procedural. Rather, it is a humanistic process of knowledge exchange and compromise with the goal of determining a technology's final form and function. This viewpoint is also known as the Social Construction of Technology.[12] To proceed successfully through this stage, a technical innovation must have the following sponsors:

1. *Champion* - A strong champion of a technological change is extremely important, especially for a Red Zone innovation. A champion must address technical, financial, and social uncertainty.
2. *Agent of Knowledge Transfer* - In the case of an internal innovation, the champion can also serve to transfer knowledge. However, for innovations originating outside an organization, another party, such as a consultant, may be required to transfer knowledge and facilitate redefining & restructuring. Consultants can more objectively develop restructuring plans without emotional attachment to the existing organization. In addition, a consultant can help to lower the "knowledge barriers" that could hinder the adoption and diffusion of an innovation throughout an organization.

The redefining & restructuring process can be long and difficult. However, if an organization recognizes the role of compromise in this process, then both the technological innovation and the organization can be changed to make diffusion within the organization a success.

Clarifying

The next phase in implementation is clarifying, in which an innovation is put into wider use across an organization. Often, the redefining stage only involves the input of advocates and key decision-makers and not those members lower in the organizational hierarchy. As a consequence, the benefits of an innovation, especially technological ones, are not obvious to low and mid-level

[12]Rogers, pp. 295-296.

users. Because such benefits can be reaped only if these members absorb the tacit knowledge to use new technologies, the only way to clarify these benefits is for an organization to implement a technology. As an additional benefit, an organization can see and remove any unintended affects of a technology.

Again, we can look to the case of ERP system implementation. Most of these systems require deliberate, staged rollouts into an organization, not a quick rollout that could be used for a more incremental innovation. Here, each area needs time to analyze the new technology to determine its impact. In addition, area members need to acquire the tacit knowledge in order to gain the benefits of the technology. If rollout is too rapid, members will not understand the technology and its effects. Then, the innovation may move in a circle between redefinition and clarification. In the worst case, such a situation could result in the failure to adopt the technology.

Clearly, the redefining and clarifying stages are not strictly sequential. Rather, they can take place at the same time, depending on the innovation involved. However, an organization cannot allow a technological innovation to move between redefining and clarifying indefinitely because it could lose some of its benefits in the process. In order to maintain a decisive strategy, an organization must discourage a long clarifying stage.

Routinizing

In this stage, an innovation is fully implemented by an organization, and the innovation loses its separate identity. At this point, the innovation becomes the status quo, and, many would argue, the diffusion of the innovation is complete. However, with many technological innovations, we can argue that routinizing cannot be completed as easily as Rogers asserts.

If new technological innovations appear quickly, organizations may choose to obsolete innovations that have not progressed fully through routinization. Again, we can look to the example of ERP systems. To date, many companies have committed millions of dollars and years of effort on ERP systems from SAP. However, this application manages information on a single enterprise level. With these same companies moving to supply chain models of business, such as the Toyota model, these ERP systems are not keeping pace. As a result, many companies may have to move away from these ERP systems before they have even been routinized.

Clearly, an organization must develop an innovation strategy that recognizes this "early obsolescence" problem. A potential preemptive strategy is to evaluate innovations constantly, both during and after routinization. With such a strategy, an organization can evaluate and, if judged beneficial, adopt newer technologies while minimizing investment in the now obsolete innovation.

Summary

From our analysis, it is clear that the process of internal innovation diffusion can be lengthy and expensive. To navigate through the initiation and implementation steps successfully, an organization must commit to an overall strategy of continuous innovation. Especially with "Red Zone" technological innovations, it must also commit significant capital and time to make an innovation work. While the risks of such strategy are high, failure to be innovative can cost an organization its business.

DIFFUSION BETWEEN ORGANIZATIONS

Once an organization diffuses a technological innovation throughout itself successfully, it must decide if it wants to allow the innovation to diffuse to other organizations within its area of expertise. In this section, we will examine the factors that would result in a share/no share decision, and then the strategies that would be used to carry out this decision.

Sharing Technology

A firm should share a technology if it has the potential to create even more benefits for it. For a technological innovation, a firm may want to develop a standard within its industry. The case of Sun Microsystems' Java™ programming language provides an excellent example. Developed by a group of Sun Engineers, Java™ was designed to let computers and devices communicate with one another much more easily than with the current incompatible operating platforms. However, in order to operate most efficiently across platforms, programmers must develop applications with the same or very similar versions of Java ™. To encourage the use of Java™, Sun licenses it to developers for a nominal fee. If Sun is successful in establishing Java™ as the new standard for network computing and information exchange, it will be able to spread it into other application such as consumer electronics, thereby increasing is revenue stream and power over the market.

To share a technology, an organization could promote it actively. Such promotion could occur in trade publications or through other codeable means. The actual transfer of the technology could involve no transaction costs, or could involve nominal sales or licensing fees. However, for this method to be effective, the benefits and knowledge required for other organizations to use the technology should be explicit. In other words, other organizations should be able to understand the technology and its benefits relatively easily. If they cannot see the pluses of the innovation, they may not be convinced just by formal means of communication.

With most technologies, organizations must also engage in passive promotion. Because of the tacit knowledge required evaluating and implementing new technologies, knowledge sharing through interpersonal networks often works more effectively. As discussed previously, this fact is paralleled by the exchange of tacit knowledge within an organization. Oftentimes, such networks as trade groups or functional associations are more effective in reducing organizational barriers for knowledge exchange. With a combination of active and passive promotion, an organization can encourage a technological innovation to diffuse within an industry.

Not Sharing Technology

On the other hand, an organization should not share an innovation if it could lose the competitive advantage gained from the innovation. For instance, 3M has chosen not to release the details of its microreplication process because the technology allows 3M to produce products in several areas that its competitors cannot. If it did share this process, competitors could develop competing products, probably to the detriment of 3M's profit margins.

While an innovation cannot be kept from competitors indefinitely, an organization can engage in a block or a run strategy to slow diffusion, choosing to use either separately or together.

In a block strategy, an organization tries to stymie replication of an innovation by competitors. Often, companies resort to legal means to do so. Intel and 3M both use a complex system of copyrights, trademarks, and patents to protect the core technology innovations that allow them to develop and manufacture new products before their competitors. Such blocking is not limited to legal means. Organizations can set up compensation systems for key technological innovators to dissuade them from moving to competitors. By giving scientists equal promotional opportunities to managers, 3M's Dual Ladder System encourages employees to stay at 3M, thereby minimizing the loss of knowledge experts. An organization can also make use of its reputation and connections within an industry to discourage copying. While blocking may be effective for a period, it is not effective as the only long-term strategy because knowledge about innovations will leak out of an organization over time.

Often, an organization must also pursue a run strategy. With a run strategy, an organization must exploit a technological innovation as quickly as possible to maintain its lead over the competitor. Often, a firm must cannibalize existing technologies in such a strategy. Intel's business strategy is a classic block and run strategy. While it blocks competitors as discussed previously, it develops new products and processes at a breakneck pace. Often, it retires existing products at the plateau of their sales volume in order to bring new products to market. As a result, Intel has been able to release new products much sooner than its competition. In this case, Intel's run strategy has augmented its block strategy by eliminating those competitors who could not maintain the same pace of technological innovation.

Summary

In summary, an organization can derive benefits by not sharing a technological innovation. However, it must not divert too many resources to these efforts and away from its basic efforts at innovation. Therefore, an organization must engage in the block & run strategy described above, in which it simultaneously hinders the innovation efforts of competitors while it develops new products from its innovation. In addition, it must continue basic R & D to find new innovations. While such a strategy is expensive and requires total management commitment, an organization could lose its innovative advantage if it fails.

DIFFUSION TO THE MARKET

The final area that we will examine is the diffusion of a technological innovation to the market. Most of the studies of this diffusion are marketing diffusion models, the primary model being the Bass Forecasting Model. However, this model as conceived has severe limitations in explaining the diffusion of technology.

The Bass Model

Developed by Frank Bass in 1969, this model attempted to explain the diffusion of new consumer products to the marketplace. It was adopted quickly because it was the first that tried to predict the diffusion of a new product based upon a set of independent variables. According to Bass, a new product would diffuse in an S-curve pattern, with the following factors affecting the rate of introduction:

1. *Mass Media Communication*, where heavy promotion results in rapid product adoption by the market relatively early in its lifecycle,
2. *Interpersonal Communication*, where product knowledge exchanged result in expanding product adoption in the first half, then declining thereafter, and
3. *Index of Market Potential*, where a product's market potential affects the magnitude of the adoption S-curve.

Like the Rogers Model, the Bass Model has spawned many new theories and new areas of research that built the Marketing Diffusion tradition. However, it has several deficiencies in explaining the diffusion of technological innovations.

The Special Case of Technology Innovations

As is the case with the diffusion of a technological innovation within an organization, the nature of the innovation is primary variable affecting adoption by the market.

First, an organization should already know the nature of the knowledge required both to understand and to implement a technological innovation. If this knowledge is explicit, then the organization can rely upon formal communication channels to diffuse product information and stimulate adoption. For instance, when audio Compact Discs were introduced to the recorded music model, formal advertising worked because consumers understood that CDs had superior sound quality and never wore out. As a result, the CD became the medium of choice, eliminating the LP.

On the other hand, if such knowledge is tacit, then the organization will have to exercise the same, or greater, care that it took within its organization to allow time for tacit knowledge transfer. Often, an organization must actively encourage this transfer. For instance, with many software packages, the rate of adoption is quicker if there is an existing community of users in place. These organizations help provide tacit knowledge, such as specific installation knowledge or special user "tricks," that help potential adopters alleviate their uncertainty. Other user groups, such as the Berkeley Macintosh Users Group (BMUG), use their positions as experts in a field to help establish standards. However, an organization must remember that this knowledge transfer can result in slower diffusion that is possible with explicit knowledge.

Finally, an organization must also expect a much slower adoption rate if an innovation is in the Red Zone for the user. With such innovations, a user probably will have to learn new skills in order to derive maximum benefit. If this learning is perceived as too difficult or time-consuming, the user will probably not adopt without significant marketing efforts.

CONCLUSION

An organization that is competing in an industry highly dependent on technological innovation must understand how such innovations diffuse. As we have examined, such situations can be classified as diffusion within an organization, from an organization to another, and from an organization to the market. While we can apply the Rogers Model of Diffusion to explain the first two types and the Bass Model for the third, neither model adequately addresses the unique situation of technological innovations.

Common to these three cases is the great importance that the innovation's characteristics play. Clearly, the benefits of an innovation greatly affect its chances for successful diffusion. Such benefits can be judged not only in terms of the relative advantage that the innovation has, but also in compatibility with the organization and the complexity, trialability, and observability of its benefits. Interestingly, such benefits are not all objective; rather, most of these benefits are subjective ones judged through the eyes of the potential adopter.

It is this subjectivity that makes the adopter's organizational characteristics just as important in determining the success or failure of diffusion. An organization can be evaluated in terms of its S PE fit with the innovation. If a firm's strategy, structure, systems, and people all encourage the adoption of oftentimes radical technological innovations, then the firm should be more successful in diffusing such innovations. Such a framework can be applied if we look at organization-to-organization or organization-to-market diffusion. In either case, there must be an S^3PE fit.

As alluded to in this paper, the speed of technological innovation today represents the greater difficulty in understanding technological innovation diffusion. Because technology is changing so rapidly, organizations are forced to adopt new innovations, even as existing ones are still being implemented. It is in this area that more research is required. As technological change accelerates in the 21st Century, the abilities of organizations to understand and implement innovations will be challenged. Thus, new paradigms need to be developed to explain how such cognitive challenges will be met.

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