Chapter 1

From Models to the Management of Diffusion

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1.1 Introduction

A better understanding of why and how innovations are adopted (or not) can help us to develop more realistic business plans and public policies.

Diffusion is the means by which innovations are translated into social and economic benefits. We know that the impact of the *use* of innovations is around four times that of their *generation* (Geroski, 1991, 1994). In particular, the widespread adoption of *process* innovations has the most significant benefit (Griliches, 1984): technological innovations are the source of productivity and quality improvements; organizational innovations are the basis of many social, health and educational gains; and commercial innovations create new services and products (Bessant and Tidd, 2007; Tidd and Bessant, 2009). However, the benefits of innovations can take 10–15 years to be fully effected (Jaffe, 1986), and in practice most innovations fail to be adopted widely, so they have limited social or economic impact. There are many barriers to the widespread adoption of innovations, including:

- Economic — personal costs versus social benefits, access to information, insufficient incentives;

- Behavioral — priorities, motivations, rationality, inertia, propensity for change or risk;
- Organizational — goals, routines, power and influence, culture and stakeholders; and
- Structural — infrastructure, sunk costs, governance.

The title of this book, *Gaining Momentum*, was chosen to reflect an important omission in most treatments of diffusion. The term "momentum" is often used simply to indicate some critical mass of adoption or threshold level, or a successful marketing or communication campaign. Most studies are concerned only with the rate of adoption or the final proportion of a population that adopts an innovation. However, diffusion, like momentum, should be treated as a vector in that it has both magnitude and *direction*. The direction of the diffusion of innovations needs more attention: how and why different types of innovations are adopted (or not). This is critical for innovations which have profound social and economic implications, such as those affecting development, health and the environment.

In this chapter, we review what we know about the diffusion and adoption of innovations, identify some of the shortcomings of research and practice, and finally suggest some ways to better understand and manage this critical part of the innovation process. We begin with a brief review of the research in the field, beginning with the pioneering work of Rogers and other sociological approaches, through treatments in the economics literature and finally the most recent insights from marketing. Next, we identify some of the key themes to emerge from these studies, and also some of the common weaknesses. The chapter concludes with a discussion of two contemporary issues in the understanding and management of the diffusion of innovations: dealing with risk and uncertainty, such as the unintended consequences of adoption or non-adoption, through experimentation and learning; and the central role of networks in the diffusion and evolution of innovations.

1.2 Disciplinary Research on Diffusion

Conventional marketing approaches are adequate for promoting many products and services, but are not sufficient for the majority of innovations. Marketing texts often refer to "early adopters" and "majority adopters", and even go so far as to apply numerical estimates of these, but these simple categories are based on the very early studies of the state-sponsored diffusion of hybrid-seed varieties in farming communities, and are far from universally applicable. To better plan for innovations, we need a deeper understanding of what factors promote and constrain adoption, and how these influence the rate and level of diffusion within different markets and populations.

Rogers' (2003) definition of diffusion is used widely: "the process by which an innovation is communicated through certain channels over time among members of a social system. It is a special type of communication, in that the messages are concerned with new ideas" (p. 5). However, there are no generally accepted definitions of associated terms such as "technology transfer", "adoption", "implementation", or "utilization". Diffusion usually involves the analysis of the spread of a product or idea in a given social system, whereas technology transfer is usually a point-to-point phenomenon. Technology transfer usually implies putting information to use, or more specifically moving ideas from the laboratory to the market. The distinction between adoption, implementation and utilization is less clear. Adoption is generally considered to be the decision to do or acquire something, whereas implementation and utilization imply some action and adaptation.

The literature on diffusion is vast and highly fragmented. However, a number of different approaches to diffusion research can be identified, each focusing on particular aspects of diffusion and adopting different methodologies. The main contributions have been from economics, marketing, sociology and anthropology. Economists have developed a number of econometric models of the diffusion of new products and processes in an effort to explain past behavior.

Prediction is a common theme of the marketing literature. Marketing studies have adopted a wide range of different research instruments to examine buyer behavior, but most recent research has focused on social and psychological factors. Developmental economics and rural sociology have both examined the adoption of agricultural innovations, using statistical analysis of secondary data and collection of primary data from surveys. Much of the anthropological research has been based on case studies of the diffusion of new ideas in tribes, villages or communities. Most recently, there has been a growing number of multi-disciplinary studies which have examined the diffusion of educational, medical and other policy innovations.

The economists' view of the innovation process begins with the assumption that it is simply the cumulative aggregation of individual, rational calculations (Hall, 2005). These individual decisions are influenced by an assessment of the costs and benefits, under conditions of limited information and environmental uncertainty. An underlying assumption is that adoption represents a sunk cost and so any net benefit is perceived to be positive, but that under uncertainty about the future benefits of adopting an innovation, there is an option value in postponing adoption, which will slow diffusion. However, this perspective ignores the effects of social feedback and learning and externalities. The initial benefits of adoption may be small; but with improvement, re-invention and growing externalities, the benefits can increase over time and the costs decrease. These increasing returns from positive feedback are particularly evident with innovation clusters and networks, in which standards and complementary assets are important. This self-sustaining dynamic can result in inferior innovations and standards becoming "locked in" prematurely. Conversely, failure to establish standards and complementary innovations can slow or prevent diffusion.

Everett Rogers originally published his seminal book, *Diffusion of Innovations*, in 1962, and has since revised it every 8–10 years to reflect developments in the field. Over that period, the focus has shifted from the initial interest in rural sociology, in particular the promotion of adoption of innovations in agriculture, through public health and education in developed and developing economies, and most recently more narrow marketing and economic quantitative research on the adoption of specific technologies and products (especially consumer durables, such as mobile telephones, and pharmaceuticals).

Rogers (2003) conceptualizes diffusion as a social process in which actors create and share information through communication. Reflecting its roots in rural sociology and early interest in the adoption of agricultural innovations, the emphasis of this approach is on the roles of opinion leaders and change agents working within social structures and systems. Therefore, a focus on the relative advantage of an innovation is insufficient, as different social systems will have different values and beliefs, which will influence the costs, benefits and compatibility of an innovation, and different social structures will determine the most appropriate channels of communication as well as the type and influence of opinion leaders and change agents. In summary, this model of diffusion has five significant elements: an *innovation*, which is *communicated* through certain *channels* over *time* by members of a *social system* (emphasis in original).

Rogers contrasts this rich sociological perspective to the more narrow instrumental approaches, and warns that the "bias in marketing diffusion studies may lead to highly applied research that, although methodologically sophisticated, deals with trivial diffusion problems" (p. 90). Clearly, the motivations, questions, methods and foci of the research and practice of innovation diffusion are varied. However, we need to distinguish between the disciplines and methods used to understand and influence the diffusion of innovation, from the motivation and focus of such work. For example, sociological methods have been applied to segment markets and sell more products, whereas marketing techniques have been used successfully to promote beneficial social and health changes.

It is true that many more recent economic and marketing studies have typically focused on the diffusion of a specific technology or product, but an innovation may also be an idea, information, belief or practice. This includes the patterns of adoption of a philosophy, religion or doctrine (such as Marxism), or a management practice (such as Six Sigma or lean production), or changes in attitude and behavior (such as changes in lifestyle, exercise and diet). Similarly, the diffusion of many technologies or products also requires the adoption of complementary beliefs or practices, for example training or education. This can demand clusters or networks of interrelated innovations to be adopted to fully benefit. Moreover, the ordering or sequence of related innovations can influence diffusion, and prior innovations can restrict or promote adoption. In this way, an innovation may evolve over the process of diffusion through the adaptation and re-invention by users. Re-invention is more common where the focal innovation has a broad range of potential uses and can be adapted for different applications or contexts, or where local ownership and control are necessary or desirable.

The time dimension is important, and many studies are particularly interested in understanding and influencing the rate of adoption. It can take years for a new drug to be prescribed after license, a decade for a new crop variety, or 50 years for educational or social changes. This leads to a focus on the communication channels and the decision-making criteria and process. Generally, mass marketing media channels are more effective for generating awareness and disseminating information and knowledge, whereas interpersonal channels are more important in the decision-making and action stages. Rogers distinguishes between three types of decision-making relevant to the adoption of an innovation:

(1) *Individual*, in which the individual is the main decision-maker, independent of peers. Decisions may still be influenced by social norms and interpersonal relationships, but the individual makes the ultimate choice. For example, the purchase of a consumer durable such as a mobile telephone.
(2) *Collective*, where choices are made jointly with others in the social system, and there is significant peer pressure or formal requirement to conform. For example, the sorting and recycling of domestic waste.
(3) *Authoritative*, where decisions to adopt are taken by a few individuals within a social system, due to their power, status or expertise. For example, the adoption of enterprise resource planning (ERP) systems by businesses, or hospital management systems by hospitals.

Based upon an idealized diffusion curve, Rogers proposes five ideal types of adopters for the purpose of segmentation: innovators, early adopters, early majority, late majority and laggards. Many models and most marketing texts go further and (wrongly) assume a normal distribution, and assign the resultant proportion of the adopting population: 2.5%, 13.5%, 34%, 34% and 16%, respectively. Innovators are characterized as being technically sophisticated and risk-taking, and as a result are atypical; early adopters, in contrast, are more integrated with and respected by peers, and help to reduce perceived uncertainty for latter adopters. The early majority are well-connected in the social system and include opinion leaders; the late majority are more skeptical, and adoption is more the result of peer pressure and economic necessity. Finally, laggards, despite the label, have the least innovation bias and are the most rational of adopters.

Rogers argues that the innovativeness of potential adopters is a continuous variable, and that the five ideal types are abstractions. However, Moore (1991) takes a different view and makes the case for a significant "chasm" between the early adopters and the majority that must be overcome for mass market, high-technology products. Rogers' five categories are used widely in marketing, but a simpler two-fold distinction between early and late adopters is also common. Generalizations of the contrasting characteristics of early and late adopters are commonplace, but are often crude caricatures rather than empirical taxonomies, and reflect a strong innovation bias. For example, Rogers makes the assertion that early adopters are more educated, literate, intelligent and upwardly socially mobile, as well as less dogmatic and fatalistic, than late adopters. Consider this claim when you next meet someone with the very latest mobile telephone and sports shoes! Clearly, more subtle segmentation is necessary on a case-by-case basis. Cross-country comparisons of diffusion reveal that cultural factors play an important role. For example, high individuality limits the influence of imitation and contagion mechanisms; whereas high power distance, a measure of the hierarchies, promotes diffusion, possibly because innovations may be adopted faster within class strata (Van den Bulte and Stremersch, 2004). Similarly, at the national level, "industriousness" and "need for achievement", measured by the ratio of Protestants to Catholics in a country (!), speed up the diffusion of new consumer durables (Tellis *et al.*, 2002).

There is much evidence that opinion leaders are critical to diffusion, especially for changes in behavior or attitude (see Exhibit 1.1). Therefore, they tend to be a central feature of social and health change programs, such as sex education. However, they are also evident in more routine examples of product diffusion, ranging from sports shoes to hybrid cars. Opinion leaders carry information across boundaries between groups, much like knowledge bridges. They operate at the edge of groups, rather than from the top; they are not leaders within a group, but brokers between groups. In the language of networks, they have many weak ties rather than a few strong ties. They tend to have extended personal networks, be accessible and have high levels of social participation. They are recognized by peers as being both competent and trustworthy. They have access and exposure to mass media. Whether they are more innovative than peers is less clear. Rogers suggests that in a social system that favors change, opinion leaders tend to be more innovative; but in a social system with norms which do not support change, opinion leaders will not necessarily be innovative. A common mistake made by change agents is to choose opinion leaders who are too innovative compared to the social system, making the opinion leaders too atypical to act as a model and promote change.

Exhibit 1.1. Evolution of Hybrid Cars

The car industry is an excellent example of a large, complex socio-technical system which has evolved over many years, such that the current system of firms, products, consumers and infrastructure interact to restrict the degree and direction of innovation. Since the 1930s, the dominant design has been based around a gasoline (petrol)- or diesel-fueled reciprocating combustion engine/Otto cycle, mass produced in a wide variety of relatively minimally differentiated designs. This is no industrial conspiracy, but rather the almost inevitable industrial trajectory, given the historical and economic context. This has resulted

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in car companies spending more on marketing than on research and development. However, growing social and political concerns over vehicle emissions and their regulation have forced the industry to reconsider this dominant design, and in some cases develop new capabilities to help create new products and systems. For example, zero/low-emission targets and legislation have encouraged experimentation with alternatives to the combustion engine, whilst retaining the core concept of personal, rather than collective or mass, travel.

For example, the zero-emission law passed in California in 1990 required manufacturers selling more than 35,000 vehicles a year in the state to have 2% of all vehicle sales as zero-emission vehicles by 1998, 5% by 2001 and 10% by 2003. This most affected GM, Ford, Chrysler, Toyota, Honda and Nissan, and potentially BMW and VW, if their sales increased sufficiently over that period. However, the USA automobile industry subsequently appealed, and had the quota reduced to a maximum of 4%. As fuel cells were still very much a longer-term solution, the main focus was on developing electric vehicles. At first sight, this would appear to represent a rather "autonomous" innovation, i.e. the simple substitution of one technology (combustion engine) for another (electric). However, the shift has implications for related systems such as power storage, drivetrain, controls, weight of materials used, and the infrastructure for re-fueling/re-charging and servicing. Therefore, it is much more of a "systemic" innovation than it first seems. Moreover, it challenges the core capabilities and technologies of many of the existing car manufacturers. The American manufacturers struggled to adapt, and early vehicles from GM and Ford were not successful. In contrast, the Japanese were rather more successful in developing the new capabilities and technologies, and new products from Toyota and Honda have been particularly successful.

However, zero-emission legislation was not adopted elsewhere, and more modest emission reduction targets were set. Since then, hybrid petrol-electric cars have been developed to help reduce emissions.

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These are clearly not long-term solutions to the problem, but do represent valuable technical and social prototypes for future systems such as fuel cells. In 1993, Eiji Toyoda (Toyota's chairman) and his team embarked on project G21: "G" stands for global, and "21" stands for the 21st century. The purpose of the project was to develop a small hybrid car that could be sold at a competitive price in order to respond to the growing needs and eco-awareness of many consumers worldwide. A year later, a concept vehicle was developed called the Prius, taken from the Latin for "before". The goal was to reduce fuel consumption by 50%, and emissions by more than that. To find the right hybrid system for project G21, Toyota considered 80 alternatives before narrowing the list to 4. Development of the Prius required the integration of different technical capabilities, including, for example, a joint venture with Matsushita Battery.

The prototype was revealed at the Tokyo Motor Show in October 1995. It is estimated that the project cost Toyota US$1 billion in R&D. The first commercial version was launched in Japan in December 1997 and, after further improvements such as battery performance and power source management, introduced to the American market in August 2000. The fuel economy is 60 MPG for urban driving, and 50 MPG for motorways — the opposite consumption profile of a conventional vehicle, but roughly twice as fuel-efficient as an equivalent Corolla. From the materials used in production, through driving, maintenance and finally its disposal, the Prius reduces CO_2 emissions by more than a third, and has a recyclability potential of approximately 90%. The Prius was launched in the USA at a price of US$19,995, and sales in the USA were 15,556 in 2001 and 20,119 in 2002. However, industry experts estimate that Toyota was losing some US$16,000 for every Prius it sold because it costs between US$35,000 and US$40,000 to produce. Toyota did make a profit on its second-generation Prius launched in 2003, and on other hybrid cars such as the Lexus range in 2005, because of improved technologies and lower production costs.

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Hollywood celebrities soon discovered the Prius: Leonardo DiCaprio bought one of the first in 2001, followed by Cameron Diaz, Harrison Ford and Calista Flockhart at the 2003 Academy Awards. British politicians took rather longer to jump on the hybrid bandwagon, with the leader of the opposition, David Cameron, driving a hybrid Lexus in 2006. In 2005, 107,897 cars were sold in the USA, about 60% of global Prius sales, and four times more than the sales in 2000 and twice as many in 2004. Toyota plans to sell a million hybrids by 2010.

In addition to the direct income and indirect prestige the Prius and other hybrid cars have created for Toyota, the company has also licensed some of its 650 patents on hybrid technology to Nissan and Ford, which are expected to launch hybrid vehicles in 2010, and Ford plans to sell 250,000 hybrids by 2010. Mercedes-Benz showed a diesel-electric S-Class at the Frankfurt Auto Show in autumn 2005. Honda has developed its own technology and range of hybrid cars, and is probably the world leader in fuel cell technology for vehicles.

Sources: Pilkington and Dyerson (2004); [Anonymous] (2004); Naim (2005); Taylor (2006); [Anonymous] (2006).

1.3 Models of Diffusion

Research on diffusion attempts to identify what influences the rate and direction of the adoption of an innovation. The diffusion of an innovation is typically described by an S-shaped (logistic) curve. Initially, the rate of adoption is low, and adoption is confined to so-called "innovators". Next to adopt are the "early adopters", then the "early majority" and "late majority", and finally the curve tails off as only the "laggards" remain. Such taxonomies are fine with the benefit of hindsight, but provide little guidance for future patterns of adoption (Geroski, 2000).

Hundreds of marketing studies have attempted to fit the adoption of specific products to the S-curve, ranging from television sets to new drugs. In most cases, mathematical techniques can provide a relatively good fit with historical data, but research has so far failed to identify robust generic models of adoption. In practice, the precise pattern of the adoption of an innovation will depend on the interaction of demand-side and supply-side factors:

- *Demand-side factors* — direct contact with or imitation of prior adopters, adopters with different perceptions of benefits and risks.
- *Supply-side factors* — relative advantage of an innovation, availability of information, barriers to adoption, feedback between developers and users.

The epidemic S-curve model is the earliest model and is still the most commonly used. It assumes a homogeneous population of potential adopters, and assumes that innovations spread via information transmitted by personal contact, observation and the geographical proximity of existing and potential adopters. This model suggests that the emphasis should be on communication, and on the provision of clear technical and economic information. However, the epidemic model has been criticized because it assumes that all potential adopters are similar and have the same needs, which is unrealistic.

The probit model takes a more sophisticated approach to the population of potential adopters. It assumes that potential adopters have different threshold values for costs or benefits, and will only adopt beyond some critical or threshold value. In this case, differences in threshold values are used to explain different rates of adoption. This suggests that the more similar potential adopters are, the faster the diffusion.

However, adopters are assumed to be relatively homogeneous, apart from some difference in progressiveness or threshold values. The probit model does not consider the possibility that the rationality and profitability of adopting a particular innovation might be different for different adopters. For example, local "network externalities", such as the availability of trained skilled users, technical assistance and maintenance, or complementary technical or organizational innovations, are likely to affect the cost of adoption and use, as distinct from the cost of purchase.

Also, it is unrealistic to assume that adopters will have perfect knowledge of the value of an innovation. Therefore, Bayesian models of diffusion introduce lack of information as a constraint to diffusion. Potential adopters are allowed to hold different beliefs regarding the value of an innovation, which they may revise according to the results of trials to test the innovation. Because these trials are private, imitation cannot take place and other potential adopters cannot learn from the trials. This suggests that better-informed potential adopters may not necessarily adopt an innovation earlier than the less well-informed ones, which was an assumption of earlier models (Griffiths and Tenenbaum, 2006).

The most influential marketing model of diffusion was developed by Frank Bass in 1969, and has been applied widely to the adoption of consumer durables. The Bass model assumes that potential adopters are influenced by two processes: individual independent adopters are initially influenced mostly by media; and later, adopters are more influenced by interpersonal communication and channels. The addition of these two adoption processes generates the famous bell-shaped diffusion curve, or cumulatively, the S-curve.

Slightly more realistic assumptions, such as those of the Bass model, include two different groups of potential adopters: innovators, who are not subject to social emulation; and imitators, for whom the diffusion process takes the epidemic form. This produces a skewed S-curve because of the early adoption by innovators, and suggests that different marketing processes are needed for the innovators and subsequent imitators. The Bass model is highly influential in economics and marketing research, and the distinction between the two types of potential adopters is critical in understanding the different mechanisms involved in the two user segments.

The main models of the diffusion of innovations were established by 1970 (Meade and Islam, 2006). These were developed to explain historical data, rather than to predict or manage future diffusion. More recently, attempts have been made to develop models which incorporate the effects of active marketing efforts, and how these influence the market potential and probability of adoption. For example, the generalized Bass model (GBM) introduces a factor representing "current marketing effort" into the hazard function, or probability of adoption. Such models tend to provide better forecasts for the diffusion of consumer durables. The Norton–Bass model (1987) adapts the Bass model for cases where there are successive generations of a product or technology, for example mobile phones. In such cases, a new generation can lead to incremental adoption by new market segments, and in addition may result in substitution or upgrading by adopters of earlier generations. This model has been applied to the diffusion of a wide range of electronic devices, industrial processes and pharmaceuticals (Norton and Bass, 1992).

The "critical mass" or "take-off" is the point after which diffusion becomes self-sustaining. The term is borrowed from physics, where it is used to describe the point at which a nuclear chain reaction occurs. In diffusion, the point is usually less explosive, but can mark a significant increase in adoption and changes in the mechanisms driving adoption. For example, many information and communication technology (ICT) innovations follow this pattern as their value increases with interaction. Research on the diffusion of 25 different ICT innovations found that external influence and imitation were the main drivers of adoption, rather than internal individual factors (Teng *et al.*, 2002). Such innovations become more valuable as the number of users increases, creating so-called "network externalities" and clusters of complementary innovations. The Internet reached this point in the mid-1990s, following developments in HTML and web browsers. Similarly, bandwagons can occur beyond the critical mass, where peer pressure or fashion becomes more important than other mechanisms.

Bandwagons may occur where an innovation is adopted because of pressure caused by the sheer number of those who have already adopted an innovation, rather than because of individual assessments of the benefits of an innovation (see Exhibit 1.2). In general, as soon as the number of adopters has reached a certain threshold, the greater the level of ambiguity of the innovation's benefits, the greater the subsequent number of adopters. This process allows technically inefficient innovations to be widely adopted, or technically efficient innovations to be rejected. Examples include the QWERTY keyboard, originally designed to prevent professional typists from typing too fast and jamming typewriters; and the DOS operating system for personal computers, designed by and for computer enthusiasts.

Exhibit 1.2. Diffusion of Management Fads and Fashions

Over the past 40 years, we have seen many apparent panaceas for the problems of becoming competitive. Organizations are constantly seeking new answers to old problems, and the scale of investment in the new fashions of management thinking has often been considerable. The original evidence for the value of these tools and techniques was strong, with case studies and other reports testifying to their proven value within the context of origin. But there is also extensive evidence to suggest that these changes do not always work, and in many cases lead to considerable dissatisfaction and disillusionment. Examples include:

- total quality management (TQM);
- business process re-engineering (BPR);
- best practice benchmarking;
- networking/clustering;
- knowledge management; and
- disruptive or open innovation.

New management practices diffuse in less than optimal ways. They often begin with a large, public firm developing or adapting some new method, technique or tool (e.g. Six Sigma began at Motorola, lean production began at Toyota). The apparent benefits of such innovations are observed by other firms, and adopted or adapted. However, if imitation was the only mechanism driving adoption, such innovations would be restricted to specific sectors or countries and would diffuse slowly. The equivalent of the role of mass media in the Bass model are the popular business journals and case studies written by business schools. Critical mass requires further codification of ideas and practices, through professional associations and active change agents such as management consultants. Finally, the innovation becomes a full bandwagon. Further pressure is created by peers and stakeholders to adopt the latest "modern" management practices to remain competitive. Many public sector organizations also feel under pressure

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to adopt, and have been criticized for "fad-lag", i.e. adopting out-of-date management fashions. The problem with this process is that, however worthy the original innovation may be, it becomes diluted and taken out of the original context and so may offer limited value or indeed be dysfunctional.

What is going on here demonstrates well the principles behind behavioral change in organizations. It is not that the original ideas were flawed or that the initial evidence was wrong. Rather, other organizations assumed that they could simply be copied, without the need to adapt, customize, modify or change them to suit their circumstances. In other words, there was no learning or progress towards making them become routines as part of the underlying culture within the firm.

Sources: Alexander and Korine (2008); Tidd and Bessant (2009).

Bandwagons occur due to a combination of competitive and institutional pressures (Abrahamson and Plosenkopf, 1993). Where competitors adopt an innovation, a firm may also adopt it because of the threat of lost competitiveness, rather than as a result of any rational evaluation of benefits. For example, many firms adopted business process re-engineering (BPR) in the 1980s in response to increased competition, but most failed to achieve significant benefits (Isaksen and Tidd, 2006). The main institutional pressure is the threat of lost legitimacy, for example, being considered by peers or customers as being less progressive or less competent.

The critical difference between bandwagons and other types of diffusion is that the former require only limited information to flow from early to later adopters. Indeed, the more ambiguous the benefits of an innovation, the more significant bandwagons are on rates of adoption. Therefore, the process of diffusion must be managed with as much care as the process of development. In short, better products do not necessarily result in more sales. Not everybody requires a better mousetrap.

Finally, there are more sociological and psychological models of adoption that are based on interaction and feedback between the developers and potential adopters (Williams and Gibson, 1990). These perspectives consider how individual psychological characteristics such as attitude and perception affect adoption. Individual motivations, perceptions, likes and dislikes determine what information is reacted to and how it is processed. Potential adopters will be guided and prejudiced by experience, and will have "cognitive maps" which filter information and guide behavior. Social context will also influence individual behavior. Social structures and meaning systems are locally constructed, and therefore highly context-specific. These can distort the way in which information is interpreted and acted upon. Therefore, the perceived value of an innovation, and thus its subsequent adoption, is not some objective fact, but instead depends on individual psychology and social context. These factors are particularly important in the later stages of diffusion. For example, lifestyle aspirations, such as exercising more and adopting a healthy diet, have created the opportunity for many new products and services.

Initially, the needs of early adopters or innovators dominate, and therefore the characteristics of an innovation are most important. Innovations tend to evolve over time through improvements required by these early users, which may reduce the relative cost to later adopters. However, early adopters are almost by definition atypical; for example, they tend to have superior technical skills. As a result, the preferences of early adopters can have a disproportionate impact on the subsequent development of an innovation, and can result in the establishment of inferior technologies or the abandonment of superior alternatives.

The choice between the different models of diffusion and factors which will most influence adoption will depend on the characteristics of the innovation and the nature of potential adopters. The simple epidemic model appears to provide a good fit to the diffusion of new processes, techniques and procedures; whereas the Bass model appears to best fit the diffusion of consumer products. However, the mathematical structure of the epidemic and Bass models tends to overstate the importance of differences in adopter characteristics while underestimating the effect of macroeconomic and supply-side factors. In general, both these models of diffusion work best where the total potential market is known, that is, for derivatives of existing products and services rather than for totally new innovations.

1.4 Factors Influencing Adoption

Numerous variables have been identified as affecting the diffusion and adoption of innovations, but these can be grouped into three clusters: characteristics of the innovation itself; characteristics of individual or organizational adopters; and characteristics of the environment. Characteristics of an innovation found to influence adoption include relative advantage, compatibility, complexity, trialability and observability. Individual characteristics include age, education, social status and attitude to risk. Environmental and institutional characteristics include economic factors such as the market environment and sociological factors such as communications networks. However, whilst there is a general agreement regarding the relevant variables, there is very little consensus on the relative importance of the different variables, and in some cases disagreements over the direction of relationships.

1.4.1 *Characteristics of an innovation*

Diffusion rates of different innovations are highly variable. In predicting the rate of adoption of an innovation, five factors explain 49–87% of the variance: relative advantage, compatibility, complexity, trialability and observability. However, the contextual or environmental factors are also important, as demonstrated by the fact that the diffusion rates for the same innovation in different contexts also vary significantly.

1.4.1.1 *Relative advantage*

Relative advantage is the degree to which an innovation is perceived as better than the product it supersedes, or competing products. Relative advantage is typically measured in narrow economic terms like cost or financial payback, but non-economic factors such as convenience, satisfaction and social prestige may be equally important. In theory, the greater the perceived advantage, the faster the rate of adoption.

It is useful to distinguish between the primary and secondary attributes of an innovation. Primary attributes, such as size and cost, are invariant and inherent to a specific innovation, irrespective of the adopter. Secondary attributes, such as relative advantage and compatibility, may vary from adopter to adopter, being contingent upon the perceptions and context of adopters. In many cases, a so-called "attribute gap" will exist. An attribute gap is the discrepancy between a potential user's perception of an attribute or characteristic of an item of knowledge and how the potential user would prefer to perceive that attribute. The greater the sum of all attribute gaps, the less likely a user is to adopt the knowledge. This suggests that preliminary testing of an innovation is desirable in order to determine whether significant attribute gaps exist. Not all attribute gaps require changes to the innovation itself — a distinction needs to be made between knowledge content and knowledge format. The idea of pre-testing information for the purposes of enhancing its value and acceptance is not widely practiced.

1.4.1.2 *Compatibility*

Compatibility is the degree to which an innovation is perceived to be consistent with the existing values, experience and needs of potential adopters. There are two distinct aspects of compatibility: existing skills and practices, and values and norms. The extent to which the innovation fits the existing skills, equipment, procedures and performance criteria of the potential adopter is important, and relatively easy to assess. But, compatibility with existing practices may be less important than the fit with existing values and norms (Leonard-Barton and Sinha, 1993). Significant misalignments between an innovation and an adopting organization will require changes in the innovation or organization, or both. In the most successful cases of implementation, mutual adaptation of the innovation and organization occurs

(Leonard-Barton, 1990). However, few studies distinguish between compatibility with values and norms, and compatibility with existing practices.

The extent to which the innovation fits the existing skills, equipment, procedures and performance criteria of the potential adopter is critical. Few innovations initially fit the user environment into which they are introduced. Significant misalignments between the innovation and the adopting organization will require changes in the innovation or organization or, in the most successful cases of implementation, mutual adaptation of both. Initial compatibility with existing practices may be less important, as it may provide limited opportunity for mutual adaptation to occur.

In addition, so-called "network externalities" can affect the adoption process. For example, the cost of adoption and use, as distinct from the cost of purchase, may be influenced by the availability of information about the technology from other users, the availability of trained skilled users, technical assistance and maintenance, and the availability of complementary innovations (both technical and organizational).

1.4.1.3 *Complexity*

Complexity is the degree to which an innovation is perceived as being difficult to understand or use. In general, innovations which are simpler for potential users to understand will be adopted more rapidly than those which require the adopter to develop new skills and knowledge.

However, complexity can also influence the *direction* of diffusion, not just the rate of adoption. Evolutionary models of diffusion focus on the effect of "network externalities", i.e. the interaction of consumption, pecuniary and technical factors which shape the diffusion process. For example, within a region, the cost of adoption and use — as distinct from the cost of purchase — may be influenced by the availability of information about the technology from other users, the availability of trained skilled users, technical assistance and maintenance, and the availability of complementary innovations (both technical and organizational).

1.4.1.4 *Trialability*

Trialability is the degree to which an innovation can be experimented with on a limited basis. An innovation that is trialable represents less uncertainty to potential adopters, and allows learning by doing. Innovations which can be trialed will generally be adopted more quickly than those which cannot. The exception is where the undesirable consequences of an innovation appear to outweigh the desirable characteristics. In general, adopters wish to benefit from the functional effects of an innovation, but avoid any dysfunctional effects. However, where it is difficult or impossible to separate the desirable from the undesirable consequences, trialability may reduce the rate of adoption.

Developers of an innovation may have two different motives for involving potential users in the development process. First is to acquire the knowledge from users needed in the development process so as to ensure usability and add value. Second is to attain user "buy-in", that is, user acceptance of the innovation and commitment to its use. The second motive is independent of the first, because increasing user acceptance does not necessarily improve the quality of the innovation. Rather, involvement may increase users' tolerance of any inadequacies. In the case of point-to-point transfer, both motives are typically present.

However, in the case of diffusion, it is not possible to involve all potential users, and therefore the primary motive is to improve usability rather than attain user buy-in. But even the representation of user needs must be indirect, using surrogates such as specially selected user groups. These groups can be problematic for a number of reasons. Firstly, they may possess atypically high levels of technical knowledge, and therefore may not be representative. Secondly, where the group must represent diverse user needs, such as both experienced and novice users, the group members may not work well together. Finally, when user representatives work closely with developers over a long period of time, they may cease to represent users and instead absorb the developers' viewpoint. Thus, there is no simple relationship between user involvement and user satisfaction. Typically, very low levels of user involvement are associated with user dissatisfaction, but extensive user involvement does not necessarily result in user satisfaction.

1.4.1.5 *Observability*

Observability is the degree to which the results of an innovation are visible to others. The easier it is for others to see the benefits of an innovation, the more likely the innovation will be adopted. The simple epidemic model of diffusion assumes that innovations spread as potential adopters come into contact with existing users of an innovation.

Peers who have already adopted an innovation will have what communication researchers call "safety credibility", because potential adopters seeking their advice will believe that they know what it is really like to implement and utilize the innovation. Therefore, early adopters are well positioned to disseminate "vicarious learning" to their colleagues. "Vicarious learning" is simply learning from the experience of others, rather than direct personal experimental learning. However, the process of vicarious learning is neither inevitable nor efficient because, by definition, it is a decentralized activity. Centralized systems of dissemination tend to be designed and rewarded on the basis of being the source of technical information, rather than for facilitating learning among potential adopters.

Over time, learning and selection processes foster both the evolution of the technologies to be adopted and the characteristics of actual and potential adopters. Thus, an innovation may evolve over time through improvements made by early users, thereby reducing the relative cost to later adopters. In addition, where an innovation requires the development of complementary features, for example a specific infrastructure, late adopters will benefit. This suggests that, instead of a single diffusion curve, a series of diffusion curves will exist for the different environments. However, there is a potential drawback to this model. The short-term preferences of early adopters will have a disproportionate impact on the subsequent development of the innovation, and may result in the establishment of inferior technologies or the abandonment of superior alternatives. In such cases, interventionalist policies may be necessary to postpone the lock-in phenomenon.

From a policy perspective, high visibility is often critical. However, high visibility, at least initially, may be counterproductive. If users' expectations about an innovation are unrealistically high and adoption is immediate, subsequent disappointment is likely. Therefore, in some circumstances, it may make sense to delay dissemination or to slow the rate of adoption. However, in general, researchers and disseminators are reluctant to withhold knowledge.

Demonstrations of innovations are highly effective in promoting adoption. Experimental, private demonstrations or pilots can be used to assess the attributes of an innovation and the relative advantage for different target groups, and to test compatibility. Exemplary, public demonstrations can improve observability, reduce perceived complexity, and promote private trials. However, note the different purpose and nature of experimental and exemplary demonstrations. Resources, urgency and uncertainty should determine the appropriate type of demonstration. Public demonstrations for experimental purposes are ill-advised and are likely to stall diffusion.

In the case of systemic or network innovations, a wider range of factors have to be managed to promote adoption and diffusion. In such cases, a wider set of actors and institutions on the supply side and demand side are relevant, in what has been called an *adoption network* (Chakravorti, 2003, 2004a, 2004b). On the supply side, other organizations may provide the infrastructure, support and complementary products and services that can promote or prevent adoption and diffusion. For example, in 2008 the two-year battle between the new high-definition optical disc formats was decided not by price or any technical superiority, but rather because the Blu-ray consortium managed to recruit more film studios to its format than the competing HD DVD format. As soon as the uncertainty over the future format was resolved, there was a step-change increase in the rate of adoption.

On the demand side, the uncertainty of potential adopters as well as communication with and between them need to be managed. Whilst early adopters may emphasize technical performance and novelty above other factors, the mainstream mass market is more likely to be concerned with factors such as price, quality, convenience and support. This transition from the niche market and needs of early adopters through to the requirements of more mass markets has been referred to as "crossing the chasm" by Moore (1991, 1998). Moore studied the successes and many failures of Silicon Valley and other high-technology products, and argued that the critical success factors for early adopters and mass markets were fundamentally different but most innovations failed to make this transition. Therefore, the successful launch and diffusion of a systemic or network innovation demand not only attention to traditional marketing issues such as the timing and positioning of the product or service (Lee and O'Connor, 2003), but also significant effort to demand-side factors such as communication and interactions *between* potential adopters (Van den Bulte and Lilien, 2001).

The continued improvement in health in the advanced economies over the past 50 years can be attributed in part to the supply of new diagnostic techniques, drugs and procedures, and also to changes on the demand side, such as increases in the levels of education, income and service infrastructure. However, the focus of innovation (and policy) in health care is too often on the development and commercialization of new pharmaceuticals, but this is only part of the story. This is a clear case of systemic innovation, in which firm and public R&D are necessary but not sufficient to promote improved health. The adoption network includes regulatory bodies, national health assessment and reference pricing schemes, regional health agencies, public and private insurers, as well as the more obvious hospitals, doctors, nurses and patients (Atun *et al.*, 2007). However, too often the management and policy for innovation in health are confined to the regulation of prices and the effects of intellectual property regimes. There is a clear need for new methods of interaction, involvement and engagement in such cases (Flowers and Henwood, 2008).

1.5 Towards a Process for Managing Diffusion

Diffusion research and practice has been criticized for an increasingly limited scope and methodology. For example, economic and marketing studies have focused narrowly on the diffusion of consumer durables such as mobile phones, in contrast to the pioneering work on the adoption of health, educational and agricultural innovations. Rogers (2003) identifies a number of shortcomings in diffusion research and practice:

(1) Diffusion has been seen as a *linear*, *unidirectional communication* activity in which the active source of research or information attempts to influence the attitudes and/or behaviors of essentially passive receivers. However, in most cases, diffusion is an interactive process of adaptation and adoption.
(2) Diffusion has been viewed as a *one-to-many communication* activity, but point-to-point transfer is also important. Both centralized and decentralized systems exist. Decentralized diffusion is a process of convergence as two or more individuals exchange information in order to move toward each other in the meanings they ascribe to certain events.
(3) Diffusion research has been preoccupied with an *action-centered and issue-centered communication* activity, such as selling products, actions or policies. However, diffusion is also a social process that is affected by social structure, position and interpersonal networks.
(4) Diffusion research has used *adoption as the dependent variable* — the decision to use the innovation, rather than implementation itself. Hence, adoption is seen as a consequence of the innovation. Most studies have used attitudinal change as the dependent variable, rather than change in overt behavior.
(5) Diffusion research has suffered from an implicit *pro-innovation bias*, which assumes that an innovation should be adopted by all members of a social system as rapidly as possible. Therefore, the process of adaptation or rejection of an innovation has been overlooked, and there have been relatively few studies of how to prevent the diffusion of "bad" innovations.

Rogers makes the important point that the diffusion of an innovation may not be economically or socially desirable, or conversely anti-diffusion programs may seek to limit or prevent the adoption of "bad" innovations. However, the research and practice of innovation diffusion has an inherent pro-innovation bias: marketing studies seek to promote the sale and purchase of products, and social programs seek to promote changes in behavior and practice. This "source bias", whereby diffusion researchers and practitioners side with the promoters of an innovation, can result in individual blame for rejection, non-adoption or late adoption of an innovation. Many apparently individual decisions to reject or adopt late are locally rational, or are more the result of systemic conditions than individual choice. For example, surveys of the European Union consistently reveal that around half of the population do not support innovation and change, as broadly defined. Such widespread beliefs cannot simply be labeled as "regressive" by firms and policy-makers. Therefore, we need a better framework for anticipating and managing the consequences of the adoption or rejection of an innovation by a social system:

(1) Desirable versus undesirable consequences, depending on the functional and dysfunctional aspects of an innovation within a specific social system;
(2) Direct versus indirect consequences, due to second-order effects or time delays; and
(3) Anticipated versus unanticipated consequences, due to ignorance, complex interactions or uncertainty.

1.5.1 *Unintended consequences: dealing with risk and uncertainty*

At the group or social level, many factors influence our perception and response to risk. How managers assess and manage risk is also a social and political process. It is influenced by prior experience of risk, perceptions of capability, status and authority, and the confidence and ability to communicate with the relevant people at the appropriate times (Genus and Coles, 2006). In the context of managing innovation, risk is less about personal propensity for risk taking or rational assessments of probability, and more about the interaction of experience, authority and context. In practice, managers deal with risk in different ways in different situations. General strategies include delaying or delegating decisions, or sharing risks and responsibilities. Generally, when managers are performing well and achieving their targets, they have less incentive to take risks. Conversely, when under pressure to perform, managers will often accept higher risks, unless these threaten survival.

Studies confirm that measures of cognitive ability are associated with project performance. In particular, differences in reflection, reasoning, interpretation and sense making influence the quality of problem formulation, evaluation and solution, and therefore ultimately the performance of research and development. A common weakness is the oversimplification of problems characterized by complexity or uncertainty, and the associated simplification of problem framing and evaluation of alternatives (Tenkasi, 2000). This includes adopting a single prior hypothesis, selectively using information that supports this hypothesis, devaluing alternatives, and maintaining the illusion of control and predictability. Similarly, marketing managers are likely to share similar cognitive maps, and tend to make the same assumptions concerning the relative importance of different factors contributing to new product success (such as the degree of customer orientation versus competitor orientation) and the implications of relationship between these factors (such as the degree of interfunctional coordination) (Tyler and Gnyawali, 2002).

At the individual, cognitive level, risk assessment is characterized by overconfidence, loss aversion and cognitive bias (Westland, 2008). Overconfidence in our ability to make accurate assessments is a common failing, and results in unrealistic assumptions and uncritical assessment. Loss aversion is well documented in psychology, and essentially means that we prefer to avoid loss rather than risk gain. Finally, cognitive bias is widespread and has profound implications for the identification and assessment of risk. Cognitive bias results in us seeking and overemphasizing evidence which supports our beliefs, thus reinforcing our bias, but at the same time leads us to avoid and undervalue any information which contradicts our view (Gardner, 2008). Therefore, we need to be aware of and challenge our own biases, and encourage others to debate and critique our data, methods and decisions.

So, the evidence indicates the importance of cognitive processes at the senior management, functional, group and individual levels of an organization. More generally, problems of limited cognition include (Walsh, 1995):

- *Reasoning by analogy*, which oversimplifies complex problems;
- *Adoption of a single, prior hypothesis bias*, even where information and trials suggest this is wrong;
- *Limited problem set*, i.e. the repeated use of a narrow problem-solving strategy;
- *Single outcome calculation*, which focuses on a simple single goal and a course of action to achieve it, denying value trade-offs;
- *Illusion of control and predictability*, based on an overconfidence in the chosen strategy, a partial understanding of the problem and limited appreciation of the uncertainty of the environment; and
- *Devaluation of alternatives*, emphasizing negative aspects of alternatives.

In most organizations, risk has become a negative term — something which should be minimized or avoided — and implies hazard or failure. This view, particularly common in the policy domain, is enshrined in the "precautionary principle" and the many regulatory regimes it has spawned, which, as the title suggests, promotes wherever possible the avoidance of risk taking (Fischoff, 1995; Renn, 1998; Stirling, 1998).

However, this interpretation perverts the nature of risk and opportunity, which are both central to successful innovation, and promotes inaction and the status quo rather than improvement or change. The term "risk" is derived from the Latin for "to dare", but has become associated with hazard or danger. We must consider the risks of success as well as the risks associated with *not* changing (Sunstein, 2005). Berglund (2007) provides a good working definition of risk in the context of innovation, as "the pursuit of perceived opportunities under conditions of uncertainty".

Research on returns to new technology indicates that the diffusion of very novel technology is associated with very high costs and uncertainty, but conversely mature technology provides limited opportunity (Heeley and Jacobson, 2008). This suggests a "Goldilocks" strategy of exploiting median-age technologies (in the relevant patent classes) which have reduced much of the very high cost and uncertainty, but retain significant scope for further development and commercialization. Similarly, a study of organizational innovation and performance confirms the need for this delicate balance between risk and stability. Risk taking is associated with a higher relative novelty of innovation (how different it is to what the organization has done before) and absolute novelty of innovation (how different it is to what *any* organization has done before), and both types of novelty are correlated with financial and customer benefits (Totterdell *et al.*, 2002). However, the same study concludes that:

> [I]ncremental, safe, widespread innovations may be better for internal considerations, but novel, disruptive innovations may be better for market considerations. . . . [A]bsolute novelty benefits customers and quality of life, relative innovation benefits employee relations (but) risk is detrimental to employee relations. [Totterdell *et al.*, 2002, p. 362]

In fact, many of the critical risks that need to be identified and managed are internal to organizations, rather than the more obviously anticipated external risks such as markets, competition and regulation (Keizer *et al.*, 2005). The inherent uncertainty in some projects limits the ability of managers to predict the outcomes and benefits of projects. In such cases, changes to project plans and goals are commonplace, being driven by external factors (such as technological breakthroughs or changes in markets) as well as internal factors (such as changes in organizational goals). Together, the impact of changes to project plans and goals can overwhelm the benefits of formal project planning and management (Dvir and Lechler, 2004).

This is consistent with the real options approach to investing in risky projects, because investments are sequential and managers have some influence on the timing, resourcing and continuation or abandonment of projects at different stages. By investing relatively small amounts in a wide range of projects, a greater range of opportunities can be explored (see Exhibit 1.3). Once uncertainty has been

Exhibit 1.3. The Value of Uncertainty

The real options approach has been used to evaluate R&D at both the project and firm levels. The idea is that investment in (or, more strictly speaking, spending on) R&D creates greater flexibility and a portfolio of options for future innovations, especially where the future is uncertain. Faced with uncertainty, managers can choose to commit additional resources to R&D to create an *option to grow*, or alternatively delay additional R&D to hold an *option to wait*.

This study (see source below) examined the different and combined effects of market and technological uncertainty on the financial valuation of firms' investments in R&D. The authors examined the behavior and performance of 290 firms over 10 years, and found that the relationship between R&D and firm valuation depended on the source and degree of uncertainty. They identified a U-shaped relationship between market uncertainty and R&D capital: increasing market uncertainty initially reduces the value of any unit of investment in R&D until a point of inflection, beyond which it augments the value. The higher the rate of market growth, the lower the point of inflection. Conversely, the relationship between technological uncertainty and R&D capital is an inverted U-shape. This suggests that investors put a limit on the value of technology hedging: at low levels of technological uncertainty, there is limited value in creating options; and at very high levels, the cost of maintaining many alternatives is too high.

Therefore, it is important to identify the main sources of uncertainty, technological or market, in order to make better decisions about the potential value of investments in R&D options.

Source: Oriani and Sobrero (2008).

reduced, only the most promising projects should be allowed to continue. For a given level of investment, this real options approach should increase the value of the project portfolio. However, because decisions and the options they create interact, a decision regarding one project can affect the option value of another project (McGrath and

Nerkar, 2004; Paxon, 2001). Nonetheless, the real options perspective remains a useful way of conceptualizing risk, particularly at the portfolio level. The goal is not to calculate or optimize, but rather to help identify risks and payoffs, key uncertainties, decision points and future opportunities that might be created (Loch and Bode-Greual, 2001). Combined with other methods, such as decision trees, the real options approach can be particularly effective where high volatility demands flexibility, placing a premium on the certainty of information and the timing of decisions.

1.6 Role of Innovation Networks

Different authors adopt different meanings, levels of analysis and attribute networks with different characteristics. For example, academics on the Continent have focused on social, geographical and institutional aspects of networks, and the opportunities and constraints these present for innovation (Camagni, 1991). In contrast, Anglo-Saxon studies have tended to take a systems perspective, and have attempted to identify how best to design, manage and exploit networks for innovation (Nohria and Eccles, 1992).

Whilst there is little consensus on the aims or means, there appears to be some agreement that a network is more than an aggregation of bilateral relationships or dyads, and therefore the configuration, nature and content of a network impose additional constraints and present additional opportunities. A network can be thought of as consisting of a number of positions or nodes — occupied by individuals, firms, business units, universities, governments, customers and other actors — and the links or interactions between these nodes. By the same token, a network perspective is concerned with how these economic actors are influenced by the social context in which they are embedded and how actions can be influenced by the position of actors.

A network can influence the actions of its members in two ways (Gulati, 1998). First is through the flow and sharing of information within the network. Second is through differences in the position of actors in the network, which cause power and control imbalances.

Therefore, the position an organization occupies in a network is a matter of great strategic importance, and reflects its power and influence in that network. Sources of power include technology, expertise, trust, economic strength and legitimacy (see Table 1.1). Networks are appropriate where the benefits of co-specialization, sharing of joint infrastructure and standards, and other network externalities outweigh the costs of network governance and maintenance. Where there are high transaction costs involved in purchasing technology, a network approach may be more appropriate than a market model; and where uncertainty exists, a network may be superior to full integration or acquisition.

Networks can be tight or loose, depending on the quantity (number), quality (intensity) and type (closeness to core activities) of the interactions or links. Such links are more than individual transactions, and require significant investment in resources over time. Historically, networks have often evolved from long-standing business relationships. Any firm will have a group of partners that it does regular business with — universities, suppliers, distributors, customers and competitors. Over time, mutual knowledge and social bonds develop through repeated dealings, increasing trust and reducing transaction

Table 1.1. Competitive dynamics in network industries.

	Type of network	
	Unconnected, closed	**Connected, open**
System attributes	Incompatible technologies	Compatible technologies across vendors and products
	Custom components and interfaces	Standard components
Firm strategies	Control standards by protecting proprietary knowledge	Shape standards by sharing knowledge with rivals and complementary markets
Source of advantage	Economies of scale, customer lock-in	Economies of scope, multiple segments

Source: Adapted from Garud and Kumaraswamy (1993).

costs. Therefore, a firm is more likely to buy or sell technology from members of its network (Bidault and Fischer, 1994).

Research has examined the opportunities networks might provide for innovation, and the potential to explicitly design or selectively participate in networks for the purpose of innovation, that is, a path-creating rather than path-dependent process (Galaskiewicz, 1996). A study of 53 research networks found two distinct dynamics of formation and growth. The first type of network emerges and develops as a result of environmental interdependence and through common interests — an emergent network. However, the other type of network requires some triggering entity to form and develop — an engineered network (Conway and Steward, 1998). In an engineered network, a nodal firm actively recruits other members to form a network, without the rationale of environmental interdependence or similar interests. Table 1.2 gives an idea of the different ways in which such engineered networks can be configured to help with the innovation process. Innovation networks are more than just ways of assembling and deploying knowledge in a complex world; they can also have what are termed as "emergent properties" — the potential for the whole to be greater than the sum of its parts. Being in an effective innovation network can deliver a wide range of benefits beyond the collective knowledge efficiency mentioned above. These include gaining access to different and complementary knowledge sets, reducing risks by sharing them, accessing new markets and technologies, and pooling complementary skills and assets.

Research suggests that the challenge facing firms in building new networks can be broken down into two separate activities: identifying the relevant new partners, and learning how to work with them. It is a little like the recipe for effective team-working (forming, storming, norming and performing), except that here it is a three-stage process: finding, forming and performing (Birkinshaw *et al.*, 2007). Finding refers essentially to the breadth of search that is conducted. Finding is enabled by the scope and diversity of current operations as well as by the capacity to move beyond the dominant models in the industry,

Table 1.2. Types of innovation networks.

Network type	Examples
Entrepreneur-based	Bringing different complementary resources together to help take an opportunity forward. Often a combination of formal and informal networks. Depends a lot on the entrepreneur's energy and enthusiasm in getting people interested to join — and stay in — the network.
Internal project teams	Formal and informal networks of knowledge and key skills which can be brought together to help enable some opportunity to be taken forward. Essentially like entrepreneur networks, but on the inside of established organizations. May run into difficulties because of having to cross internal organizational boundaries.
Communities of practice	Networks which can involve players inside and across different organizations — what binds them together is a shared concern with a particular aspect or area of knowledge.
Spatial clusters	Networks which form because of the players being close to each other, for example, in the same geographical region. Silicon Valley is a good example of a cluster which thrives on proximity — knowledge flows amongst and across the members of the network, but is hugely helped by the geographical closeness and the ability of key players to meet and talk.
Sectoral networks	Networks which bring different players together because they share a common sector — and often have the purpose of shared innovation to preserve competitiveness. Often organized by sector or business associations on behalf of their members. Shared concern to adopt and develop innovative good practice across a sector or product market grouping, for example, the SMMT Industry Forum or LOGIC (Leading Oil and Gas Industry Competitiveness), a gas and oil industry forum.

(*Continued*)

Table 1.2. (*Continued*)

Network type	Examples
New product or process development consortium	Sharing knowledge and perspectives to create and market a new product or process concept, for example, the Symbian consortium (Sony, Ericsson, Motorola and others) working towards developing a new operating system for mobile phones and PDAs.
Sectoral forum	Working together across a sector to improve competitiveness through product, process and service innovation.
New technology development consortium	Sharing and learning around newly emerging technologies, for example, the pioneering semiconductor research programs in the US and Japan.
Emerging standards	Exploring and establishing standards around innovative technologies, for example, the Moving Picture Experts Group (MPEG) working on audio and video compression standards.
Supply-chain learning	Developing and sharing innovative good practice and possibly shared product development across a value chain, for example, the SCRIA initiative in aerospace.

Source: Tidd and Bessant (2009).

but is hindered by a combination of geographical, technological and institutional barriers (see Table 1.3). Forming refers to the attitude of prospective partners. How likely is a link-up and what are the advantages or barriers? Finally, performing refers to how to make the network function.

Operating an innovation network depends heavily on the type of network and the purposes it is set up to achieve. Challenges include keeping the network up to date and engaged, building trust and reciprocity, positioning oneself within the network and decoupling from

Table 1.3. Barriers to new network formation.

Primary objective	Type of barrier	Description
Finding prospective partners	Geographical	Discontinuities often emerge in unexpected corners of the world. Geographical and cultural distance makes complex opportunities more difficult to assess, and as a result they typically get discounted.
	Technological	Discontinuous opportunities often emerge at the intersection of two technological domains.
	Institutional	Institutional barriers often arise because of the different objectives or origins of two groups, such as those dividing the public sector from the private sector.
Forming relationships with prospective partners	Ideological	Many potential partners do not share the values and norms of the focal firm, which can blind it from seeing the threats or opportunities that might arise at the interfaces between the two world views.
	Demographic	Barriers to building effective networks can arise from the different values and needs of different demographic groups.
	Ethnic	Ethnic barriers arise from deep-rooted cultural differences between countries or regions of the world.

Source: Based on Birkinshaw *et al.* (2007).

existing networks. For example, there is a big difference between the demands for an innovation network working at the frontier where issues of intellectual property management and risk are critical, and one where there is an established innovation agenda (as might be the case in using supply chains to enhance product and process innovation).

For example, LEGO's decision to develop its next-generation Mindstorms product involved using a network of lead users of the first-generation product. LEGO's experience after the first Mindstorms product had been that the enthusiastic user community was an asset, despite its approaches such as hacking into the old software and sharing this information on the Web. As described by the LEGO senior vice president, Mads Nipper, "We came to understand that this is a great way to make the product more exciting. It's a totally different business paradigm." In other cases, potential partners are easy to find but may be reluctant to engage. This might occur for ideological reasons, or because of institutional or demographic barriers. An illustration of this approach can be seen in the Danish pharmaceutical company, Novo Nordisk. Faced with long-term changes in the business environment towards greater obesity and rising healthcare costs associated with diabetes (its core market), Novo Nordisk realized that it needed to start exploring opportunities for discontinuous innovation in its products and offerings. Its "Diabetes 2020" process involved exploring radical alternative scenarios for chronic disease treatment and the roles which a player like Novo Nordisk could play. As part of the follow-up from this initiative, in 2003 the company helped set up the Oxford Health Alliance, a non-profit collaborative entity that brought together key stakeholders — medical scientists, doctors, patients and government officials — with views and perspectives which were sometimes quite widely disparate. To make it happen, Novo Nordisk made clear that its goal was nothing less than the prevention of or cure for diabetes — a goal which, if it were achieved, would potentially kill off the company's main line of business. As Lars Rebien Sørensen, CEO of Novo Nordisk, explained:

> In moving from intervention to prevention — that's challenging the business model where the pharmaceuticals industry is deriving its revenues! . . . We

Table 1.4. Challenges in managing innovation networks.

Set-up stage	**Operating stage**	**Sustaining (or closure) stage**
Issues here are around providing the momentum for bringing the network together and clearly defining its purpose. It may be crisis-triggered, e.g. perception of the urgent need to catch up via adoption of innovation. Equally, it may be driven by a shared perception of opportunity — the potential to enter new markets or exploit new technologies. Key roles here will often be played by third parties, e.g. network brokers, gatekeepers, policy agents and facilitators.	The key issues here are about trying to establish some core operating processes for which there is support and agreement. These need to deal with: • Network boundary management: how the membership of the network is defined and maintained; • Decision making: how (where, when, who) decisions get taken at the network level; • Conflict resolution: how conflicts are resolved effectively; • Information processing: how information flows among members and is managed; • Knowledge management: how knowledge is created, captured, shared and used across the network; • Motivation: how members are motivated to join/remain within the network; • Risk/benefit sharing: how the risks and rewards are allocated across members of the network; and • Coordination: how the operations of the network are integrated and coordinated.	Networks need not last forever — sometimes, they are set up to achieve a highly specific purpose (e.g. development of a new product concept) and once this has been done the network can be disbanded. In other cases, there is a case for sustaining the networking activities for as long as members see benefits. This may require periodic review and "re-targeting" to keep the motivation high. For example, CRINE, a successful development program for the offshore oil and gas industry, was launched in 1992 by key players in the industry such as BP, Shell and major contractors with support from from the UK government, with the target of cost reduction. Using a network model, it delivered extensive innovation in products/services and processes. Having met its original cost-reduction targets, the program moved to a second phase with a focus aimed more at capturing a bigger export share of the global industry through innovation.

Source: Tidd and Bessant (2009).

believe that we can focus on some major global health issue — mainly diabetes — and at the same time create business opportunities for our company. [Tidd and Bessant, 2009, p. 264]

Different types of networks have different issues to resolve, but we can identify some common challenges (Tidd and Bessant, 2009):

(1) How to manage something we do not own or control;
(2) How to see system-level effects, not narrow self-interests;
(3) How to build trust and shared risk-taking without tying the process up in contractual red tape; and
(4) How to minimize unintended consequences and spillovers.

Table 1.4 summarizes some of the key management questions associated with each stage.

1.7 Conclusions

The successful diffusion of innovations is necessary to achieve any widespread economic or social benefit. It demands much more than marketing. Research and experience have created several predictive models of the process(es) of diffusion that apply in different contexts, and we know many of the attributes of an innovation that influence adoption. Many disparate fields such as economics and sociology also provide useful insights, but alone are not sufficient to understand and manage this process. Instead, we need to integrate this knowledge to tackle some of the key common challenges, such as dealing with the inevitable risk of unintended consequences, and building coalitions and maintaining innovation networks to help to mitigate and share the risks and benefits of adoption. This suggests a strategy of experimentation and learning, in contrast to the "precautionary principle". It favors incrementalism, the step-by-step modification of objectives and resources, in light of new evidence, such that key uncertainties — technical, market and social — are revealed and reduced before any irreversible commitments are made.

Most studies are concerned only with the rate of adoption or the final proportion of a population that adopts an innovation. However, diffusion should be treated as a vector in that it has both magnitude and *direction*. The direction of the diffusion of innovations needs more attention: how and why different types of innovations are adopted (or not). This is critical for innovations which have profound social and economic implications, such as those affecting development, health and the environment.

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