3.4 Diffusion of Innovations

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Turning an innovative idea into a new product or process and into a successful business venture requires getting others to adopt and use your innovation. Similarly, turning ideas into reality and getting them to market in time often requires adopting the latest in development and manufacturing technologies. These challenges are two perspectives of the same underlying process, the **diffusion of innovations**, and are central to engineering work.

Diffusion of innovations describes how new technologies spread through a population of potential adopters. On the one hand, it describes the process of getting new ideas adopted and, on the other, the process of adopting new ideas. A great deal of research has investigated how innovations diffuse in fields such as agriculture, healthcare, education, business, and manufacturing. The primary focus of diffusion research is the innovation. An innovation can be an object, a practice, or an idea that is perceived as new by those who might adopt it. Innovations present the potential adopter with a new alternative for solving

a problem, but also present more uncertainty about whether that alternative is better or worse than the old way of doing things. The primary objectives of diffusion research are to understand and predict the rate of diffusion of an innovation and the pattern of that diffusion.

Innovations do not always spread in a straightforward way. For instance, the best ideas are not always readily and quickly adopted. The British Navy first learned in 1601 that scurvy, a disease that killed more sailors than warfare, accidents, and all other types of death, could be avoided. The solution was simple (incorporating citrus fruits in a sailor's diet) and the benefits were clear (scurvy onboard was eradicated), yet the British Navy did not adopt this innovation until 1795, almost 200 years later! The best ideas are not always the ones to achieve widespread adoption. The story of the QWERTY keyboard provides the example here. The QWERTY keyboard, the current pattern of letters on a typewriter keyboard, was created in 1867. The design was a conscious effort to slow a typist's keystrokes and came from the need, in the early days of the typewriter, to avoid jamming the relatively delicate machines. As machine designs evolved, this problem diminished and competing keyboard designs as early as 1888 achieved higher typing speeds (these alternatives peaked in 1932 with August Dvorak's now-famous alternative). Yet, despite clearly more efficient alternatives, the QWERTY design holds out to this day.

These examples show that diffusion of innovations is a complicated process and that it is difficult to predict what innovations will gain widespread acceptance or when. Yet recent research has gained considerable insights into the factors that influence the rate and pattern of diffusion. This section presents the findings of this current research, drawing especially from the integrating work of Everett Rogers [1995] within a framework of the three predominant research trajectories:

1. Characteristics of the innovation
2. Characteristics of the adopters
3. Characteristics of the social environment

This section then presents several important limitations of the existing diffusion research, providing insights into the strengths and weaknesses of the current understanding of how innovations diffuse.

Characteristics of the Innovation

Much of the early attention in diffusion research went to understanding and explaining the differences among adopters and differences in the environment in which the innovation was diffusing. More recently, attention has focused on the impact that characteristics of the innovation itself can have on the subsequent rate and pattern of diffusion [Rogers, 1995]. Research has centered around five main perceived attributes of innovations: relative advantage, compatibility, complexity, trialability, and observability. These characteristics are not purely objective measures but also represent the *perceptions* held by potential adopters about an innovation.

- **Relative advantage** represents the perceived superiority of an innovation over the current practice or solution it would replace. This advantage can take the form of economic benefits to the adopter, but also benefits in social prestige, convenience, and satisfaction. Innovations may also have advantages that cannot be compared to the existing solutions, meaning they offer advantages that were not previously possible or even expected.
- **Compatibility** represents the perceived fit of an innovation with a potential adopter's existing values, experiences, and practices. The more compatible an innovation is with a cultural values surrounding the new technology and with the preexisting skills that can be transferred from the current technology, the more rapid and widespread its diffusion.
- **Complexity** describes the extent to which an innovation is perceived to be difficult to understand or use. The higher the degree of perceived complexity, the slower the rate of adoption.
- **Trialability** represents the extent to which a potential adopter can experiment with the innovation before adopting it. The greater the trialability, the higher the rate of adoption.

- **Observability** represents the extent to which the adoption and benefits of an innovation are visible to others within the population of potential adopters. The greater the visibility, the higher the rate of adoption by those that follow.

Characteristics of the Adopters

Three central characteristics of potential adopters play a large role in the diffusion of innovations. First, the rate at which a population adopts an innovation often follows a typical pattern, known as the **S-shaped curve of adoption**. Second, individual adopters can be categorized based on their **innovativeness**, or willingness to adopt new innovations. Third, individual adopters follow an **innovation-decision process** when deciding to adopt a new technology.

S-Shaped Curve of Adoption

Individuals in a population do not all adopt a new technology at the same time nor do they adopt at a constant rate. Instead, diffusion studies have found a pattern that follows an S-shaped curve of cumulative adoptions, shown in Fig. 3.6. This adoption curve begins slowly but soon the rate of adoptions increases as more individuals in each successive time period make the decision to adopt. Ultimately, the rate declines again as fewer individuals in the population are left to adopt the innovation. There is variation in the slope of the curve, some innovations are adopted rapidly while others take longer, and in the length of the "tails" of the curve. While this curve decribes the diffusion rates of many innovations, there are circumstances under which it is not appropriate, for instance, when an innovation is difficult to communicate and the number of existing adopters does not affect a potential adopter's awareness or opinions of an innovation.

Adopter Categories

Because all individuals in a population do not adopt at the same time, diffusion researchers have characterized adopters by the degree to which they are more or less likely to adopt an innovation relative

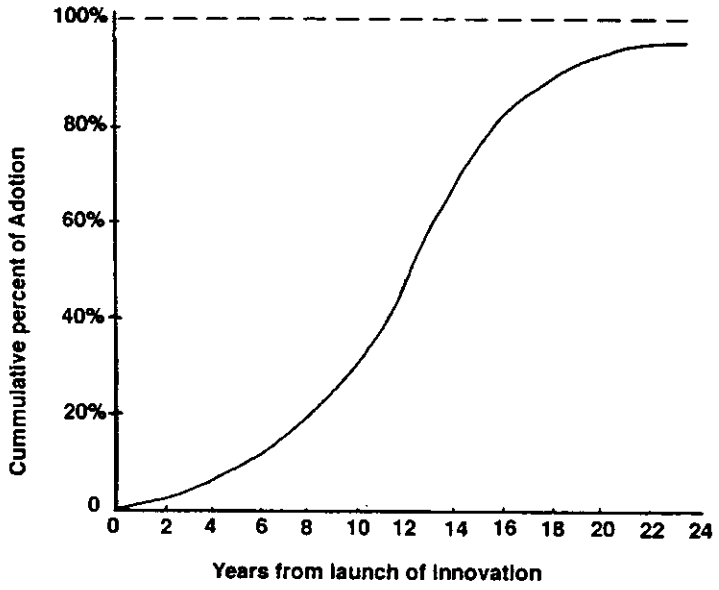

FIGURE 3.6 The S-shaped curve of cumulative adoption demonstrated by number of new adopters each year of hybrid corn seed in two Iowa communities. (*Source:* based on Ryan and Gross, 1943) in Rogers, E. M. [1995]. *Diffusion of Innovations*, 4th ed., Free Press, New York.

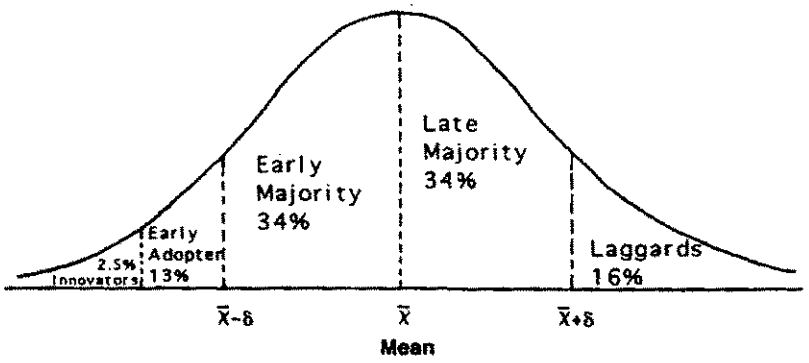

FIGURE 3.7 Adopter categories on the basis of innovativeness. (*Source:* Rogers, E. M. 1995. *Diffusion of Innovations*, 4th ed., Free Press, New York.

to others in the population, their **innovativeness** [Rogers, 1995]. When the cumulative adoption curve follows an S-shaped pattern, the distribution curve of adopters over time follows a normal distribution, as shown in Fig. 3.7. Diffusion research divides this curve into five categories of adopters and has found each category to have distinctive traits.

- **Innovators** typically make up the most innovative 2.5% of the population. They have been decribed as rash, risky, and daring. An ability to work with complex and often underdeveloped technology as well as substantial financial resources help them absorb the uncertainties and potential losses from innovations. Innovators are not usually opinion leaders when it comes to new innovations; their skills and risk-taking behavior often set them apart from the rest of the social system, but they often play a large role in importing innovations from outside and adapting them for broader adoption [see Von Hippel, 1988].
- **Early adopters** are more integrated with the existing social system than innovators, and often have the greatest degree of opinion leadership, providing other potential adopters with information and advice about a new technology. Change efforts surrounding new innovations often target this population first as they represent the successful, discrete, and objective adopters that hold the respect of the larger social system.
- **The early majority** adopts just ahead of the average of the population. They have much interaction within the social system but are not often opinion leaders; instead they typically undertake deliberate and, at times, lengthy decision making [Rogers, 1995]. Because of their size and connectedness with the rest of the social system, they link the early adopters with the bulk of the population, and their adoption signals the phase of rapid diffusion through the population.
- **The late majority** is described as adopting innovations because of economic necessity and pressure from peers. While they make up as large a portion of the overall population as the early majority, they tend to have fewer resources and be more skeptical, requiring more evidence of the value of an innovation before adopting it.
- **Laggards** are the last in a social system to adopt a new innovation. They tend to be relatively isolated from the rest of the social system, have little or no opinion leadership, and focus on past experiences and traditions. They are the most cautious when it comes to risking their limited resources on a new technology.

A number of generalizations have emerged from diffusions studies to differentiate between earlier and later adopters in a social system. In terms of socioeconomic characteristics, there tends to be no age difference between early and late adopters, but earlier adopters are more likely to have more years of formal education, to be more literate, and to have higher social status. In terms of personality traits,

earlier adopters tend to have greater empathy, to be less dogmatic, to be more able to deal with abstractions and uncertainty, to have greater intelligence and rationality, and to have more favorable attitudes toward science. In terms of communication behavior, earlier adopters tend to have more social participation, to be more connected through interpersonal networks in their social system, to have traveled more widely and be aware of matters outside of their local system (to be more cosmopolite), and to have greater interaction with communication channels that provide information about possible innovations.

The Innovation Decision

The innovation decision process describes how an individual moves from knowledge of an innovation to adoption; research has focused on five stages [Rogers, 1995]:

- During the **knowledge** stage, an individual gains awareness of an innovation and some understanding of how it functions. This awareness is an interactive process; the existence of an innovation must be communicated to a population, but the potential adopters choose where to focus their attention and whether to value the problems the innovation is promising to solve.
- In the **persuasion** stage, a potential adopter attempts to gather more information and forms a positive or negative opinion about an innovation.
- The **decision** stage refers to the activities an individual adopter engages in that lead to a decision to adopt or reject an innovation. This includes experimentation on a limited basis, "trial-by-others" in which the experiences of other adopters are studied, and the decision to wait.
- The **implementation** stage describes when an adopter puts the innovation into use. During this phase much of the uncertainty surrounding the innovation is resolved, and the consequences, intended and otherwise, become apparent.
- The **confirmation** stage occurs when an adopter considers the consequences of adoption and may or may not continue with its use. In some cases the confirmation stage may never occur, as individuals neglect or avoid seeking information about an innovation's consequences.

Diffusion research suggests these stages exist in the innovation decision process. However, most social processes contain exceptions to the linearity implied by the stage models that attempt to describe them (e.g., stage C does not necessarily follow stages A and B) [Wolfe, 1994; Weick, 1979], and innovation decision models are no different. Individuals often form opinions before adequate awareness of an innovation, they often make decisions and then gather supporting evidence, and they often confirm (or reject) an innovation before completing its implementation. Stage models such as the innovation-decision model help to outline a general process but cannot adequately reflect all of its complexities.

Characteristics of the Environment

Potential adopters learn about, adopt, and implement new technologies within a larger social and technological environment. The characteristics of this environment have as much impact on the nature of the diffusion process as do the characteristics of the innovation itself or the adopters. Two aspects of the environment, the communication channels through which information about new innovations spreads and the social system within which potential adopters make their decisions, are discussed in this section.

Communication Channels

Communication channels refer to the means by which information about an innovation reaches the population of potential adopters. There are two primary distinctions between communication channels: mass media vs. interpersonal channels and cosmopolite vs. localite channels. The differences between these channels are best understood in terms of their effects at different stages of the innovation decision.

- **Mass media vs. interpersonal channels.** Mass media channels move information across a mass medium such as television, radio, or newspapers and typically involve one-way communication of information from a single or few sources to a large audience. Interpersonal channels are

face-to-face exchanges of information between individuals. Mass media is more effective at quickly spreading knowledge of an innovation to a large audience; interpersonal channels are more effective at providing and clarifying the detailed information that will affect the persuasion of individual adopters.

- **Cosmopolite vs. localite channels.** Cosmopolite channels link potential adopters to others outside of the social system of interest. Localite channels, in contrast, represent communication between individuals within the social system. Cosmopolite channels bring new information into a social system and may be more influential in the early stages of the diffusion process, when new technologies are introduced into a population [see Attewell, 1992]. Cosmopolite channels are more valued at the knowledge stage of the innovation decision, while localite channels offer more value during the persuasion stage.

Social System

The social system within which innovations diffuse contains more than just the communication channels linking information and potential adopters. The social structure, norms and values, opinion leaders and change agents, decision environments, and consequences also influence how innovations diffuse.

- The **social structure**, or diffusion network, describes how individuals are connected to one another within a given social system. The more densely connected individuals are with one another, the more likely innovations will diffuse rapidly. The more connected some individuals are with outside sources of information, the more likely they will act as early adopters, importing new technologies into the social system.
- A social system's prevailing **norms and values** have profound effects on the rate and pattern of diffusion. Accepted behavior patterns within a society may inhibit, if not openly persecute, adopters of a new technology. The taboo nature of many subjects may prevent communication of a potential innovation to those who would adopt it. However, not all norms and values run contrary to innovation. A pro-innovation bias in, for example, fashion and business management often encourages adoption of innovations before their benefits are completely understood [see Abrahamson, 1991].
- **Opinion leaders**, as described earlier, are those members of a social system that other potential adopters respect and seek out when making their own adoption decision. **Change agents** represent outside interests that have interest in the diffusion of an innovation within a particular social system. Change agents often play an important role in introducing a new technology into the social system, while opinion leaders influence the rate at which that technology is adopted.
- Social systems will often have different **decision environments**, depending on the political stucture of the system under study. These decision environments vary according to whether the individual decision to adopt an innovation is optional, collective (consensus), authority based, or contingent. Optional means that each individual within the population makes his own choice to adopt or reject an innovation; collective means that the adoption decision is made as a group; authority based means that adoption decisions are made for the group by one or a few. Contingent refers to some combination of the former as, for example, when the individual adoption decision is optional only after an authority has approved of that option.
- The **consequences of an innovation** are not always clear before adoption and implementation, but must be considered for their implications to subsequent adoptions and for sustained use of the innovation within a social system. Consequences have been described in such terms as desirable vs. undesirable, direct vs. indirect, and anticipated vs. unanticipated.

Limitations of the Diffusion Model

The quantity and rigor of research in diffusion of innovations can be misleading. Any theoretical model of social processes oversimplifies a complex reality, and it is important to consider several of the under-

lying assumptions of diffusion research that limit the general applicability of its findings. This section discusses three related assumptions: that the primary focus of diffusion research, the innovation, remains unchanged; that the process of adoption is distinct from the process of invention; and that the adoption of one innovation is independent of the adoption of others.

- **The evolution of innovations.** The current diffusion research model and methodology originated in the field of rural sociology with the Ryan and Gross [1943] study of hybrid corn seed adoption but soon spread to a wide variety of fields, including education, anthropology, public health, marketing, geography, and communications. The methodology focused on measuring the rates and patterns of adoption of an innovation within a well-defined population. To do this, the research assumes that an innovation remains unchanged as it diffuses through a population. This is a more viable assumption for hybrid corn seeds than for computers; often early adopters play an active role in transforming a new technology to meet the needs of the market [Von Hippel, 1988]. Many modern innovations evolve more rapidly than they diffuse. For example, the personal computer has undergone significant changes and has yet to saturate the market of potential adopters. This evolution of innovations during the diffusion process makes it more difficult to compare the adoption decisions of the individuals of the population.
- **Invention and innovation adoption.** Diffusion research focuses on the adoption of innovations subsequent to their invention and development. Recent studies, however, suggest that the invention process itself involves significant amounts of adoption of component innovations, which are then combined to form larger systems as new products or processes [Hargadon and Sutton, 1997; Basalla, 1988]. When an innovation is combined with other technologies, new uses may emerge that greatly extend the population of potential adopters. This occurred, for example, during the diffusion of the microprocessor. First used in computers, this technology has now been incorporated as an innovative component in such products as automobile engines, toys, and medical devices. As innovations evolve through the diffusion process and are combined with other components, the population of potential adopters may change dramatically.
- **The interdependence of innovations.** The rate of adoption of a particular innovation is often dependent on the adoption of other innovations, forming what Rogers [1995] describes as "technology clusters". Synergies emerge, for instance, between innovations and create positive feedback loops in their adoption. The steam engine (as pump) increased the productivity of coal mines which, in turn, helped increase steel production through lower costs and higher quality inputs. Better and cheaper steel led to better steam engines and to railroads. Steam-driven trains led to a greater demand for coal, steel, and better steam engines. A similar feedback loop has emerged between computers, microprocessor designs, and the Internet, as computers both enable and drive the demand for more complex microprocessors and the Internet creates broad uses for the computer and more demands on the microprocessor.

Current diffusion research models have difficulty quantifying the evolution, adoption through invention, and interdependence of innovations. As a result, the impacts of such phenomenon have not been adequately studied and are less understood. Diffusion researchers must account for these overlooked complexities, and engineers and managers adopting or marketing innovations must also be aware of them, for their implications on the rate and pattern of diffusion are undeniable.

Summary

This section has described the research on diffusion of innovations. Diffusion research studies the process by which new innovations spread through a population of potential adopters. Its focus is on the innovation itself, and its objective is to understand and predict the rate and pattern of diffusion across the population. The section described the influence of three major aspects of the diffusion process: the characteristics of the innovation, the characteristics of the adopter and the adoption decision, and the characteristics of the environment surrounding the population of potential adopters.

The characteristics of an innovation that influence the rate of its adoption through a population include **relative advantage, compatibility, complexity, trialibility,** and **observability**. Adopter characteristics explain the **S-shaped curve of cumulative adoption** by separating individual adopters into categories distinguishing between **innovators, early adopters, early majority, late majority,** and **laggards**. Adoption involves an **innovation-decision process** characterized by five stages: **knowledge, persuasion, decision, implementation,** and **confirmation**. Environmental characteristics that influence the diffusion process include the **communication channels** along which information concerning an innovation spreads and the **social system** surrounding the population. These channels differ from **mass media** to **interpersonal** and from **cosmopolite** to **localite**. The social system influences adoption through its **social (or network) structure**, its **norms and values, opinion leaders and change agents, decision environment**, and the **consequences** of the innovation. Three limitations of the current diffusion model are noted: that innovations continue to evolve throughout the diffusion process, that invention and adoption are often indistinguishable, and that innovations often depend on (or drive) the adoption of other innovations.

Defining Terms

Communication channels: The means by which information concerning a new technology is spread through the population, for example, through mass media or interpersonal channels.

Diffusion of innovations: The term describing the process by which new technologies spread through a population of potential adopters.

Innovativeness: The likelihoood that an individual will adopt a new technology relative to other potential adopters in the population.

References

Abrahamson, E. Managerial fads and fashions, *Acad. Mgt. Rev.*, 16(3): 1991.

Attewell, P. Technology diffusion and organizational learning: the case of business computing, *Organ. Sci.*, 3(1), 1992.

Basalla, G. *The Evolution of Technology*, Cambridge University Press, New York, 1988.

Hargadon, A. B. and Sutton, R. I. Technology brokering and innovation in a product development firm, *Admin. Sci. Q.* 1997.

Rogers, E. M. *Diffusion of Innovations*, 4th ed., Free Press, New York, 1995.

Ryan, B. and Gross, N. C. The diffusion of hybrid corn seed in two Iowa communities, *Rural Sociol.*, 8: 15–24, 1943.

Von Hippel, E. *The Sources of Innovation*, Oxford University Press, New York, 1988.

Weick, K. E. *The Social Psychology of Organizing*, Addison-Wesley, Reading, MA, 1979.

Wolfe, R. A. Organizational innovation: review, critique, and suggested research directions, *J. Mgt. Stud.*, 31(3), 1994.

Further Information

An in-depth review of the research in the diffusion of innovations can be found in *Diffusion of Innovations*, 4th edition, by Everett Rogers. Rogers' research and earlier editions of this book set the direction for much of the current work in this field.

3.5 Knowledge Management

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Knowledge management is a process for helping an organization continuously build its capabilities to maintain and improve organizational performance. Knowledge management supports an organization being a learning organization or "an organization skilled at creating, acquiring, and transferring