

## **CHAPTER I**

### **INTRODUCTION AND LITERATURE REVIEW**

The National Science Foundation (NSF) recently proposed that Congress provide federal funding for the development of a National Ecological Observatories Network (NEON), which first equips ecological reserves throughout the country with computerized instrumentation (e.g., remote sensors) and then networks the reserves together (Dalton, 2000). This broadband telecommunications network would allow for simultaneous transmission of signals (e.g., voice, data, video). In turn, both local and national ecologists can easily share field data collections with one another and also communicate their findings via observatory museums with targeted publics such as students, the general public, government agencies, and policymakers. Although the current Fiscal Budget of the United States (United States Government Printing Office, 2003) allocates funding for the creation of two NEON sites, this project needs additional support in order to accomplish the established goals.

Simultaneously, the NSF funds a similar collaborative effort: the U.S. Long-Term Ecological Reserve (LTER) Network. The LTER network concentrates primarily upon synthesizing and comparing field research findings between ecological reserves throughout the country. The NEON project plans to build upon LTER objectives and provide additional technological infrastructure for both research and education applications, particularly concentrating on information sharing tools.

Efforts such as NEON, which seek to bridge the gap between the scientific community, the general public, and policymakers, are not exactly novel; European science shops have existed for several decades. These science shops, which were originated by the Dutch, allow scientists at research institutions to match their studies with particular public groups (e.g., environmental organizations, retirement communities) so that the broader community benefits from academic research findings (Farkas, 1999). This information sharing allows scientific innovations to be redirected from the often elite research institutions

to the common members of society and therefore provide a better appreciation of science to not only the scientists themselves, but also the general public.

Scholars such as Valente and Rogers (1995), as well as Dearing, Meyer, and Kazmierczak (1994), frequently discuss social change and policy research in relation to technology and scientific innovations. However, a review of more than 100 diffusion studies reveals that a quantitative study regarding the impact of technology upon ecological field research and education is nonexistent. Many researchers focus their efforts on technology implementation, its use, and adoption among individuals and organizations (Papa, 1990; Rubinyi, 1989). These studies, however, do not include specific insight into communication methods among and between ecologists, students in the field of environmental science, applicable landowners, government agencies, policymakers, and the general public.

Although science communication and environmental journalism is evolving into a mature profession, a wide gap between science and the general public still exists (Valenti, 1999). Further, social science research that examines field science methods in general is typically qualitative—though Noble and Coughlin (1997) presented both quantitative and qualitative results from their study which surveyed Canadian academic chemists and their experience with technology compared with their use of academic journals. Similarly, social science research that assesses the current methods of communication among ecological field researchers, their perceived attitudes toward technology, and the impact of broadband connectivity upon communication methods and ecological field research provides the broader community with a better understanding of how the NSF-funded NEON project might positively impact environmental issues faced by the United States.

Scholars such as Gill, Crosby, and Taylor (1986) found that ecological concern indirectly impacts behavior. Therefore, if policymakers can better understand environmental issues and their implications upon society, perhaps future legislation (resultant from behavior) will reflect such attitudes (concerns). Further, social science research conducted in

studies such as these also provide technologists with information on how to create computer networks that are most compatible with the needs of field scientists.

This thesis project specifically focuses on the diffusion of broadband connectivity within the 4500-acre Santa Margarita Ecological Reserve (SMER), which is located in southern California (San Diego and Riverside counties). By establishing the SMER as a prototype reserve that might participate in a project such as NEON, this thesis project includes both critical and analytical research objectives.

### **Critical and Analytical Research**

The thesis first presents a propositional diffusion model (see Figure 1), which includes four sub-models: (a) social system, (b) innovation development, (c) innovation implementation and use, and (d) consequences. Based upon Rogers' (1995) diffusion of innovations theoretical framework, this critical portion of the thesis suggests ways in which a propositional diffusion model might provide a rationale for future studies regarding longitudinal impacts of broadband connectivity upon the communication methods used by ecological field researchers and ecological field research in general.

Focusing on the innovation development and implementation stages of diffusion, the analytical portion of the thesis operationalizes the innovation development as well as the innovation implementation and use sub-models. Specifically, the analytical portion of the thesis closely examines perceived attributes, diffusion communication, and innovation adoption among SMER field scientists, who have recently received broadband connectivity via the NSF-funded High Performance Wireless Research and Education Network (HPWREN).

Following this (a) literature review and explication of a propositional diffusion model, the thesis encompasses (b) methods used to operationalize the innovation development and implementation sub-models, (c) results of the operationalization, and (d) discussion.

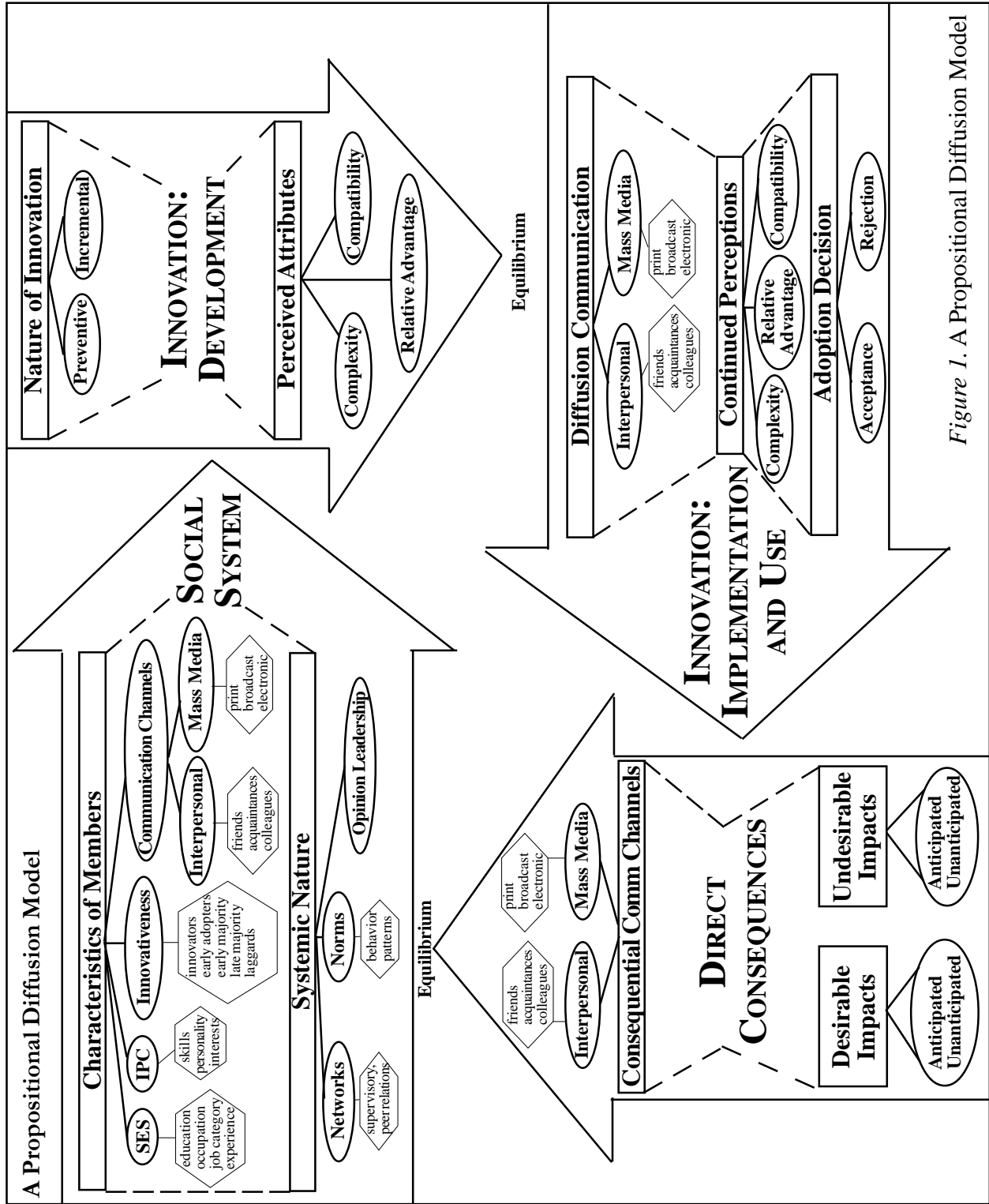


Figure 1. A Propositional Diffusion Model

## **Development of a Propositional Diffusion Model Based Upon Related Literature**

Rogers (1995) explained the *diffusion of innovations* as a ubiquitous human process whereby ideas, processes, and technologies are spread throughout a social system. He further defined diffusion of innovations as a process involving four elements: (a) one or more social systems, (b) an innovation, (c) one or more communication channels, and (d) time. Universal among diffusion of innovations research related specifically to communication, these elements appear within all diffusion studies—no matter the discipline.

Diffusion of innovation studies specific to communication research now represent approximately 12% of the nearly 4000 total diffusion publications (Rogers, 1995). However, few theoretical models exist that visually represent conceptual and measurement components found in many of these studies. Furthermore, a literature review of more than 100 journal articles revealed that comprehensive models combining concepts from diffusion theory and related theories (e.g., social impact assessment theory) are virtually nonexistent.

### **Propositional Diffusion Model: Social System Sub-Model**

The proposed theoretical model begins with the social system sub-model (see Figure 2), which consists of individuals, informal groups of individuals, entire organizations, or subsystems (Rice & Anderson, 1994; Rogers, 1995; Valente, 1996). More specifically, the proposed model conceptualizes the social system as comprising of two primary segments: (a) characteristics of members and (b) systemic nature. Both of these facets (networks and norms) encompass a realm of considerations that are absent from most diffusion scholarship, yet scholars should examine them in order to truly understand the vast range of social system characteristics that influence innovation diffusion (Miller & Garnsey, 2000).

#### **Characteristics of Members**

The characteristics of a social system's membership are complex, consisting of many facets. The proposed model emphasizes four components: (a) socioeconomic status (SES), (b) interpersonal competence (IPC), (c) innovativeness, and (d) communication channels. These components each play an important role in determining the characteristics of social

system members, and scholars measure these facets using quantitative methods such as surveys or qualitative methods such as natural observation.

**Socioeconomic status (SES) and interpersonal competence (IPC).** Specific measurements for summarizing SES and IPC include comparing and analyzing education level (Hindman, 2000; LaRose, 1989; Leung & Wei, 2000; Miller, 2001; Papa, 1990), occupation and income (Hindman, 2000; LaRose, 1989; Leung & Wei, 2000), job category (Noble & Coughlin, 1997; Rice & Manross, 1987), experience and skills (Bubas, Klicek, Hutinski, 2001; Spitzberg & Cupach, in press), activities and interests (Leung, 1998), and psychological traits such as intelligence, motivation, personality, attitude, and culture (Dickson, 2000; Maitland, 1998; Midgley & Dowling, 1978; Morreale, Spitzberg, & Barge, 2001; Rice & Manross, 1987; Sitkin, Sutcliffe, & Barrios-Choplin, 1992). Built upon prior interpersonal communication research (Duran & Spitzberg, 1995; Spitzberg, 1991), tools like the Computer-Mediated Competence (CMC) Scale (Spitzberg, 1997) provide a mechanism for quantitatively measuring the characteristics of social system members via survey methodology. Specifically, the CMC scale measures coordination, expressiveness,

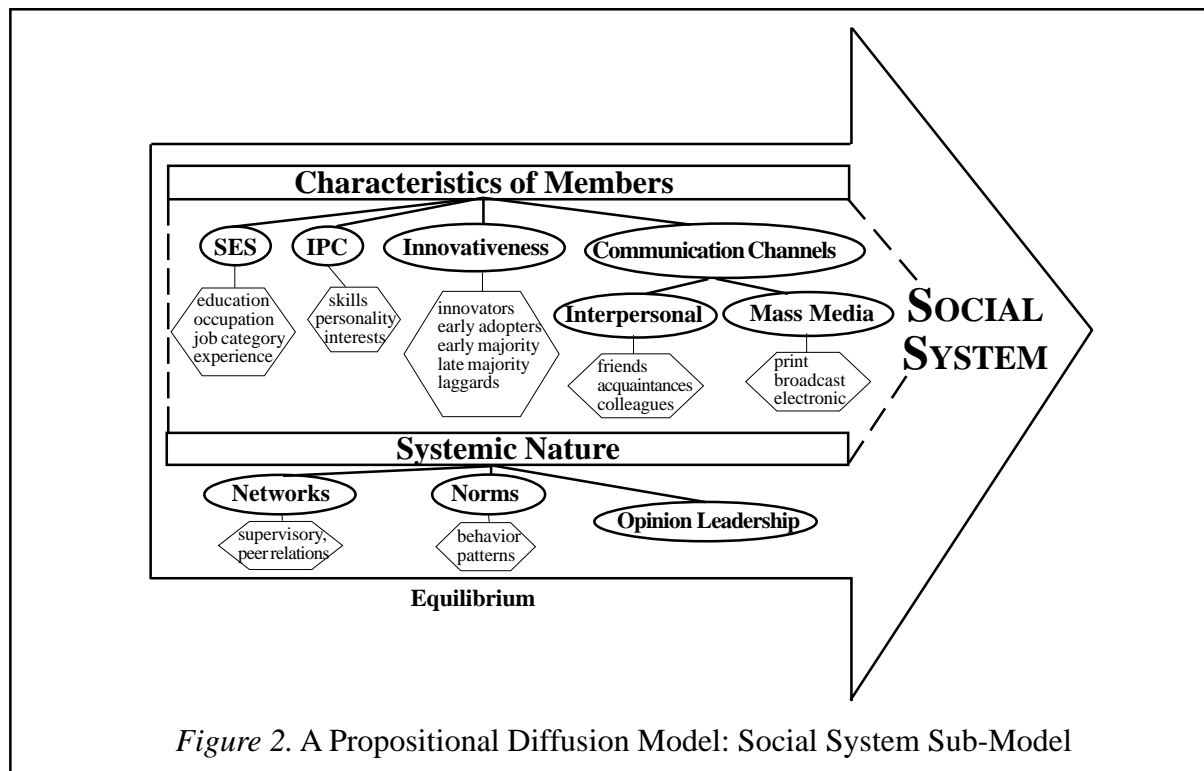


Figure 2. A Propositional Diffusion Model: Social System Sub-Model

attentiveness, composure, efficacy, general usage (of innovation), motivation, knowledge, contextual factors, message factors, media factors, co-orientation, productivity, satisfaction, appropriateness, and effectiveness.

**Innovativeness.** Rogers (1995) described innovativeness as how quickly (or slowly) a social system member adopts an innovation—in comparison with other members. Rogers classified innovativeness using five adopter categories: (a) innovators, (b) early adopters, (c) early majority, (d) late majority, and (e) laggards. The *innovators* of a social system actively seek information about new ideas, practices, or objects. Typically, innovators have widespread interpersonal communication channels, often reaching beyond their locale, and they frequently seek out mass media channels. While the innovators often do not integrate themselves within the local social system, the *early adopters* are local and serve as role models and primary interpersonal communication channels for potential adopters. Similar to the early adopters, the *early majority* merely lacks the leadership roles frequently found within the early adopter category. Though the innovators, early adopters, and early majority typically use both interpersonal and mass media communication channels, the *late majority* primarily relies upon interpersonal channels for information regarding innovations and seldom uses media channels; this category of adopters accepts innovations just after the average potential adopter. Rogers explained the last category of adopters to accept an innovation as *laggards*; they are usually isolated from both interpersonal and mass communication channels. If laggards adopt at all, they tend to adopt innovations that others have already abandoned.

Adopter categories help diffusion scholars better determine the relative time in which users adopt an innovation (Rogers, 1995). That is, studies typically reveal that as individuals adopt an innovation over time, relative speed of innovation diffusion is plotted on a collective frequency basis; the resulting distribution is an S-shaped curve, which typically represents few innovators at the beginning of the period and multiple late majority toward the end. As an innovation completes its diffusion into the social system, the curve also reaches its completion (Rogers, 1995).

While adopter categories allow researchers to better understand innovativeness and the extent to which a potential adopter appropriates an innovation relatively earlier or later, they also provide a relatively clear-cut classification mechanism for individuals within a social system. Past studies using adopter categories include Hurt, Joseph, and Cook (1977), who asked study participants Likert-scale survey questions regarding their willingness to (a) try out new ideas, (b) seek new ways to do things, and (c) trust new inventions. Meanwhile, Valente (1996) suggested a threshold model for determining adopter categories and places particular emphasis upon an individual's behavior as related to others in the social system; he measured thresholds via comparison and analysis of data regarding time-of-adoption and social network ties. Adopter categories can be further determined by comparing individual interpersonal communication channels with network relationships, which are usually measured by determining the individuals within the social system who influence one another—such as supervisors, peers, friends, and family (Rice & Anderson, 1994).

While Rogers' (1995) concept of adopter categories subsumed social indicators (e.g., education and income), researchers such as Hindman (2000) and Miller (2001) placed greater importance upon social indicators than communication channels when examining the adoption of technological innovations. Cultural, political, and religious appropriateness values are also valid considerations within diffusion research—particularly when the innovation may expose the social system to controversial materials, as in the case of the Internet. For example, Unesco (1986) reported that popularization of television greatly varies between Indonesian villages—with the differences primarily reflective of individual villages' political, cultural, and religious norms.

**Communication channels.** While mass media channels allow social system members to learn quickly and efficiently about the existence of an innovation, interpersonal communication serves as the channel by which most individuals are motivated to accept or reject innovations (Rogers, 1995). As a matter of fact, diversity in interpersonal communication style is one of the most common concerns among diffusion of innovations

researchers (e.g., Auwal & Singhal, 1992; Valente & Saba, 1998). Therefore, measuring interpersonal communication channels of individuals within a social system seems crucial to better understanding the overall diffusion process. Examples of diffusion scholars who have published studies measuring interpersonal components include Singhal, Rogers, and Mahajan (1999) as well as Valente and Saba (1998). Both of these studies used survey methods to examine how often and to what extent respondents talk with others about the innovation at hand. Additional studies consider these same components and specifically use the data for predicting innovation impact. For instance, Rice and Shook (1990) found that the extent of communication by an individual with others adopting an innovation is the best indicator of several effects after adoption.

On the other hand, if prospective innovation adopters lack an interpersonal communication channel with current innovation users, they often rely solely upon mass media messages for information related to innovations (Valente & Saba, 1998). To best measure mass media consumption, scholars like Leung (1998) and Valente (1993) surveyed individuals regarding their use of newspapers, magazines, academic journals, television, radio, Internet, and other applicable mediums. Additional measures include paid media subscriptions versus free media (Atkin & Jeffres, 1998) and communication requirements such as the need to receive information, to generate concepts, to learn new things, to make decisions, and to solve problems (Flanagin & Metzger, 2001).

Several of the aforementioned diffusion scholars have studied aspects of both SES and innovativeness (Dearing et al., 1996; Rice & Shook, 1990; Valente & Rogers, 1995) as well as communication channels and innovativeness (Auwal & Singhal, 1992; Hays, 1996; Rice & Shook, 1990; Valente, 1996). For example, Valente (1996) found that mass media consumption, as part of an external influence measure, is positively related to innovativeness and personal networks. Meanwhile, Auwal and Singhal (1992) explained the formation of interpersonal communication channels, the establishment of social networks, and their importance during an innovation diffusion process among a poverty-stricken population.

Further, Rice and Shook (1990) discovered that individuals with complex, non-routine positions are more likely to use complicated communications systems than those individuals with simple, routine positions. Although few researchers have studied the direct relationships between SES, communication channels, and innovativeness levels, current research indicates that combining measures of SES and communication channels can even more accurately predict innovativeness levels.

**P1: As socioeconomic status (SES) and communication channels increase, innovativeness levels increase.**

Considering an innovator as the highest level of innovativeness and a laggard as the lowest level of innovativeness, this proposition suggests that socioeconomic status coupled with communication channels predict an individual's innovativeness (Rogers, 1995). That is, innovators and early adopters tend to be well-educated individuals who read the newspaper on a regular basis, watch television, have Internet access, and have many friends, acquaintances, and colleagues. Meanwhile, late majority and laggards are more likely to be poorly-educated individuals who do not read the newspaper, watch TV, or have Internet access. Similarly, late majority and laggards typically have few friends, acquaintances, and colleagues. Scholars like Hindman (2000) also discussed the strong role that income plays upon the ability for an individual or social system to participate in certain innovations—particularly those involving technology and its multiple uses. Specifically, Hindman found a positive relationship between the uses of information technology and social indicators such as income.

Likewise, interpersonal competence (IPC), interpersonal communication channels and the systemic nature of opinion leadership also appear to exhibit positive relationships with one another (Rice, 1987; Rice, 1991; Valente & Davis, 1999). An explication of the proposition model's components related to systemic nature facilitates a better understanding of this concept.

## **Systemic Nature**

To obtain a clear understanding of a social system, research must include not only an examination of the characteristics of its members (i.e., SES, IPC, innovativeness, and communication channels), but also the nature of the system (i.e., networks, norms, and opinion leadership). The combination of these three systemic nature components leads to the innovation development.

**Networks.** Closely related to measuring individuals' interpersonal communication channels, networks concern the interpersonal relationships within the overall social system and how well individuals are integrated into their system (Rogers, 1995). The proposed model focuses on relationships between supervisors, supervisors and employees, and peers. For instance, data collected via surveys to obtain SES and communication channels can represent how particular individuals are affiliated with others (e.g., supervisory relationships, friendships, relatives).

**Norms.** Rogers (1995) defined the norms of a system as the established behavior patterns of its members. The size and diversity of the social system comprise these patterns (Maitland, 1998; Papa, 1990), which survey methods often measure. Additional factors include task characteristics (Kraut, Rice, Cool, & Fish, 1998), such as the analysis of personnel management tasks, document tasks, and task analyzability, which survey methodologies can also assess.

**Opinion Leadership.** The amount of influence an individual has upon the attitudes and behaviors of others is known as *opinion leadership* and is typically measured by assessing individuals' external communication channels, their accessibility, their socioeconomic status, and their innovativeness (Rogers, 1995). Opinion leadership studies constitute research that typically examines interpersonal communication channel components of opinion leaders (Dearing et al., 1996; Rice, 1991). Scales such as the polymorphic opinion leadership test (Witteman & Andersen, 1976) allow researchers to quantitatively measure the constructs of opinion leadership via twelve Likert-scale survey items; these questions focus on how

often individuals volunteer their opinions or offer advice to others and how often others ask these same individuals to give their opinions or advice.

Valente (1996) measured opinion leadership in a similar manner by examining influences of interpersonal, mass media, and mixed media (e.g., computer-mediated communication) to determine opinion leaders. In contrast, Leung (1998) and Midgley and Dowling (1978) investigated how communication channels can influence opinion leadership by comparing and analyzing individuals' communication channel data from individuals and summing for representation of an entire social system.

**P2: As interpersonal competence (IPC) and interpersonal communication channels increase, opinion leadership increases.**

As mentioned earlier, interpersonal competence coupled with interpersonal communication channels seem to be predictive of opinion leadership (Rice, 1987; Rice, 1991; Rogers, 1995; Valente & Davis, 1999). That is, typical opinion leaders appear to exhibit traits of positive personalities, have an appreciation for cultural diversity, and maintain multiple interpersonal channels. Additionally, Andersen and Singleton (1978) found that opinion leaders have many positive attributes such as high media contact and low communication apprehension. As such, opinion leaders are usually individuals who bind their peers and often bridge the gap between status groups within a social system (Burt, 1999).

Papa (1990), Rice (1987, 1991) and Rice and Anderson (1994) also examined relationships between norms, networks, and innovation adoption; they discover significant positive relationships between norms and innovation adoption, as well as relationships between networks and innovation adoption. The conceptual model proposes an examination of relationships between networks and norms, as a combination of the two measures provide additional insight into the overall innovation diffusion process.

**P3: As the breadth of norms increases, positive networks decrease.**

*Positive networks* encompass positive relationships among supervisors and peers, as well as positive relationships between supervisors and employees. Because networks and

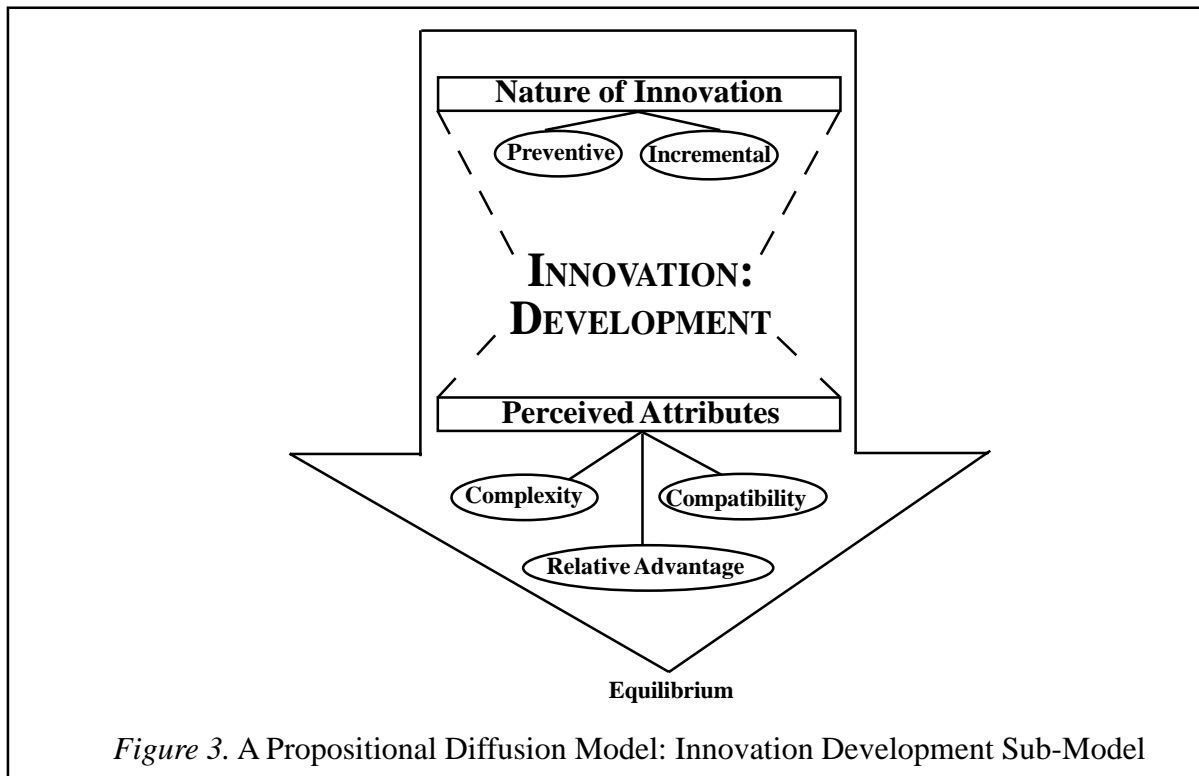
norms are predictive of relationships between innovation diffusion and adoption patterns (Papa, 1990; Rice, 1987, 1991; Rice & Anderson, 1994), these networks and norms affect communication within social systems. Therefore, the expansion of the size, diversity, and behavior patterns of a social system will lead to decreased positive relationships between the networks of a system—whether communication occurs via CMC or more traditional channels (e.g., face-to-face, telephone, etc). Although one might assume that CMC greatly impacts system norms, Postmes, Spears, and Lea (2000) found that even though CMC “alters ‘normal’ interactions, it still provides a vehicle for normative social regulation” (p. 367). However, Postmes et al. also mention that norms are restricted to the environment of the particular social system at hand. This leads one to believe that certain aspects of systemic networks and norms have a negative correlation with one another.

### **Propositional Diffusion Model: Innovation Development Sub-Model**

Development of innovations largely depends upon the components that comprise the social system’s nature and characteristics of its members. The proposed model suggests two primary components within the social system (i.e., characteristics of members and systemic nature). In turn, these components greatly influence innovation development facets illustrated in Figure 3: (a) the nature of innovations (i.e., preventive or incremental) and (b) perceived attributes.

#### **Nature of Innovation: Preventive or Incremental**

Rogers (1995) defined a *preventive innovation* as a new idea, practice, or concept that seeks to prevent unwanted long-term future activity; for instance, a smoking cessation program represents a preventive innovation—preventing the social system members from future health problems. Observing the prevented events is the primary challenge when studying the diffusion of preventive innovations; therefore, most diffusion studies focus on incremental innovations. An *incremental innovation* is considered non-preventive, as these innovations provide desired outcomes in the near future. Because the diffusion of innovations that produce short-term impact are easier to examine, they are studied much more frequently (Rogers, 1995).



### **Perceived Attributes**

According to Rogers (1995), all innovations have specific traits that allow for prediction regarding the adoption rate (i.e., the time it takes for an individual to accept an innovation). Rogers specifically discussed five innovation characteristics: (a) relative advantage, (b) compatibility, (c) complexity, (d) trialability, and (e) observability. First, *relative advantage* refers to the degree that an innovation appears to be better than its preceding idea, practice, or object. Relative advantage is typically expressed as the degree to which an innovation benefits, profits, or generates prestige for the individual or the overall social system. While the benefits of an innovation may outweigh its costs for one social system, this may not be the case for other social systems; for example, some individuals place more value on financial profitability while others may consider other attributes, such as overall societal benefit, more important.

Similarly, *compatibility* is the innovation's level of consistency with previous experiences, existing ideals, and potential adopters' needs (Rogers, 1995). Compatibility encompasses the degree to which an innovation fits with the culture of a social system; for

instance, an innovation developed for one culture may not necessarily be compatible with another the belief system and needs of another culture. Meanwhile, *complexity* is how difficult or easy an innovation appears to an individual (Rogers, 1995). While some innovations are easy to understand at first glimpse, others are more complicated and require thorough explanation.

Finally, *trialability* refers to the degree that an individual can test an innovation within a limited basis while *observability* is the visibility level of the innovation—how much or little others observe the results of an innovation (Rogers, 1995). Related to compatibility, trialability involves individuals actually trying out an innovation to better understand if and how it will work for their particular social systems. Likewise, observability allows an individual to see how an innovation works out for others and hear about the experiences of an innovation from others. Though trialability and observability are important attributes, the proposed model specifically focuses on relative advantage, compatibility, and complexity measures.

Specifically, the diffusion of innovations theory indicates that social systems develop both preventive and incremental innovations when members exhibit high relative advantage and compatibility coupled with low complexity toward discussed innovations (Rogers, 1995).

Individuals in social systems are more likely to develop innovations, both preventive and incremental, if they perceive the innovation to have a high level of relative advantage and compatibility and a low level of complexity (Rogers, 1995). On the other hand, members of a social system might develop incremental innovations if they perceive the innovation to have a fair level of relative advantage and compatibility while individuals might develop preventive innovations only if there is a high level of relative advantage and compatibility. In other words, members of a social system are less likely to develop innovations if incentives are not prominent, complexity is high, and there is little relative advantage and compatibility; whereas, members are more apt to develop an innovation if incentives are prominent, complexity is low, and perceived relative advantage and compatibility is high. For example, Leung and Wei (2000) found that cellular telephones have a high level of compatibility and relative

advantage among individuals, particularly business persons, in need of immediate access to mobile communication. Although this finding is no surprise, their research also indicated that cell phones provide certain individuals with emotional gratifications, as the technology is a mechanism for immediate communication with distant family members and friends; this fits the profile of high relative advantage and compatibility as well. Meanwhile, cell phones typically have low complexity; therefore, cell phones provide an innovation that has been cleverly developed for a society that is becoming more mobile and technologically advanced, yet still needs a method to communicate with family, friends, acquaintances, and colleagues. Hence, Leung and Wei found high levels of relative advantage and compatibility among cell phone adopters. One can conclude, therefore, that perceived attributes during the innovation development phase greatly impact the communication channels during an innovation's implementation and use.

**P4: As the degree of perceived relative advantage increases, the degree of favorable diffusion communication increases.**

**P5: As the degree of perceived compatibility increases, the degree of favorable diffusion communication increases.**

**P6: As the degree of perceived complexity increases, the degree of favorable diffusion communication decreases.**

### **Equilibrium Period**

Another proposed concept related to innovation development involves the equilibrium period between the development phase and innovation implementation and use. Rogers (1995) defines equilibrium as the period of time that it takes for a social system to adjust to a new innovation. The proposed model suggests that members experience an equilibrium state before they implement and use an innovation; further, the model suggests that the equilibrium period length further impacts the diffusion communication.

**P7: As the period of equilibrium between innovation development and implementation decreases, the breadth of diffusion communication increases.**

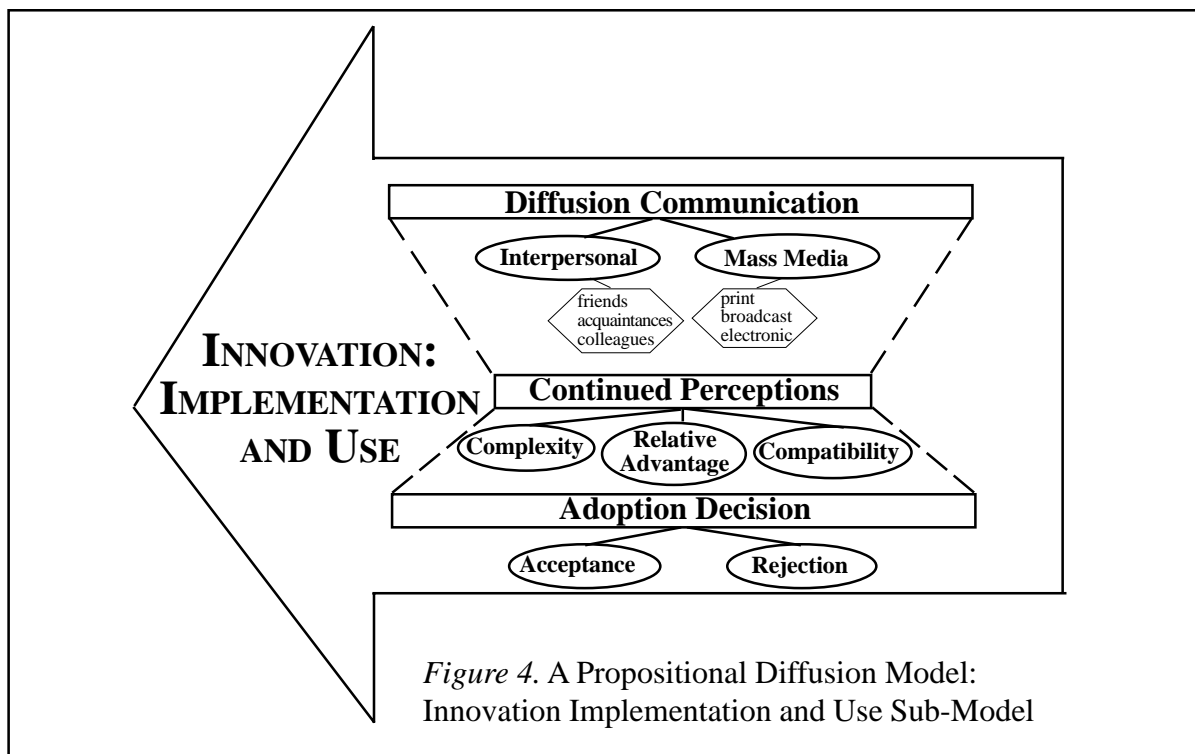
Time is one of the primary components of diffusion research (Rogers, 1995), and many diffusion studies (e.g., Cancino, Galvez, Roth, & Conneschky, 2001; Gurien & Beebe, 1999; Rice & Steinfield, 1994) include specific measures related to both purpose and time of innovation use. Though these studies do not consistently compare communication channels with time and use of innovation, it appears that brief equilibrium periods result in more widespread diffusion communication. Consequently, innovation implementation and use also depend upon continued perceptions, which eventually result in an adoption decision.

### **Propositional Diffusion Model: Innovation Implementation and Use Sub-Model**

The proposed model suggests three components within the innovation implementation and use sub-model: (a) diffusion communication, (b) continued perceptions, and (c) adoption decision (see Figure 4).

#### **Diffusion Communication**

Diffusion communication refers to the interpersonal and mass media communication channels that occur during the implementation and use of an innovation. Measures that



examine diffusion communication include changes that occur between initial communication channels of an individual and those used during the implementation of an innovation. For instance, an individual might initially rely upon interpersonal communication channels; however, as implementation and use of an innovation begins, the individual may also be exposed to mass media channels—perhaps even as a result of the innovation itself as in the research presented by Unesco (1986).

**P8: As communication channels of a social system’s members increase in breadth, diffusion communication increases.**

While Flanagin and Metzger (2001), Rice (1987, 1991), and Valente (1993) examined both interpersonal and mass media communication channels during innovation diffusion, the proposed model suggests a specific examination of the relationship between initial communication channels of a social system and communication channels during innovation implementation and use. Experiments that involve pre-tests and post-tests—specifically analyzing change patterns within communication channels—operationalize this proposition.

Similarly, the model also suggests a proposition related to innovation adoption, social system nature, and member characteristics. While Kraut, Rice, Cool, and Fish (1998), Rice and Anderson (1994), and Rice, Grant, Schmitz, and Torobin (1990) studied networks and adoption, Durrington, Repman, and Valente (2000) and Flanagin and Metzger (2001) examined both interpersonal communication channels and adoption. Further research by Aydin and Rice (1992) included measures of networks, interpersonal communication channels, and innovation adoption. This literature suggests significant relationships among innovation adoption, social system nature, and member characteristics.

**P9: Positive, dense networks and broad interpersonal communication channels are positively related to the acceptance of preventive innovations.**

Preventive innovations are typically difficult to diffuse within most social systems (Rogers, 1995). However, it appears that positive, dense networks (e.g., strong supervisory

and peer relations), along with broad interpersonal communication channels (e.g., multiple, diverse number of friends, acquaintances, and colleagues), result in an increased possibility for the acceptance of preventive innovations.

Accordingly, relationships also exist between communication channels and perceived relative advantage, compatibility, and complexity. Papa, Singhal, Law, Pant, Sood, Rogers, and Shefner-Rogers (2000) found that mass media communication, specifically entertainment education (e.g., television shows), has a direct influence upon the thoughts and behaviors exerted by the audience as well as interpersonal communication that takes place between those individuals. Aydin and Rice (1992), Rice, Grant, Schmitz, and Torobin (1990), and Valente and Saba (1998) further examined measures related to both communication channels and perceived attributes. Though their findings support the following propositions, they are unique in that the communication channels are measured specifically during innovation implementation, whereas the aforementioned diffusion studies are not specific with regard to the timing of their measures (e.g., initial communication channels versus diffusion communication channels).

**P10: As the breadth of positive diffusion communication channels increases, the degree of perceived complexity decreases.**

**P11: As the breadth of positive diffusion communication channels increases, the degree of perceived relative advantage increases.**

**P12: As the breadth of positive diffusion communication channels increases, the degree of perceived compatibility increases.**

That is, perceived complexity decreases as more social system members speak positively during innovation implementation—coupled with an increase in “pro-innovation” mass media exposure. Likewise, perceived relative advantage and compatibility appears to increase as positive diffusion communication channels increase. In short, effective positive communication results in greater relative advantage and compatibility as well as lower complexity; this leads to higher adoption rates (Rogers, 1995; Singh & Sahay, 1972).

### **Continued Perceptions**

Just as communication channels evolve during the innovation diffusion process, so do perceptions related to relative advantage, compatibility, and complexity. That is, perceived attributes that are formed during innovation development evolve into continued perceptions during innovation implementation and use. Specifically, perceived attributes, such as relative advantage and compatibility, usually change as a social system implements and uses an innovation. If these perceptions of relative advantage and compatibility become more positive than negative, an individual is more likely to adopt an innovation (Valente, 1986).

### **Adoption Decision**

The proposed model suggests that diffusion communication coupled with continued perceptions eventually leads to the adoption decision: an individual either adopts or rejects the innovation. Even though an individual does not immediately adopt some innovations, reinvention (i.e., degree to which the social system changes an innovation to better suit its needs) often provides an opportunity for the social system to adopt an initially rejected innovation (Rogers, 1995).

As propositions four, five, and six indicate the importance of perceived attributes during innovation development, the proposed model suggests that perceptions continue to affect innovation diffusion during implementation and use of innovations; this is especially influential during the adoption decision phase.

**P13: As continued relative advantage increases, acceptance rates increase.**

**P14: As continued compatibility increases, acceptance rates increase.**

**P15: As continued perceived complexity increases, rejection rates increase.**

That is, social system members continue to accept innovations as continued relative advantage and compatibility increase; meanwhile, members appear to reject innovations as perceived complexity increases. Scholars such as Dearing and Meyer (1994), Rice and Anderson (1994), and Rubinyi (1989) examined perceptions such as relative advantage and compatibility as well as adoption rates; studies such as these usually find that adoption rates increase as relative advantage and compatibility increase among a social system.

### **Propositional Diffusion Model: Direct Consequences Sub-Model**

Even though innovations are instituted to directly benefit social systems, there are normally undesirable effects, both anticipated and unanticipated, that also come with the innovations' advantages. The proposed direct consequences sub-model (see Figure 5) illustrates the impacts of innovations—especially upon communication channels.

According to the proposed model, the combination of desirable and undesirable, anticipated and unanticipated impacts leads to changes in communication channels, both interpersonal and mass media. Direct consequences can be measured via surveys that continue to measure, compare, and analyze (a) social system, (b) innovation development, and (c) innovation implementation and use (Majchrzak, Rice, Malhotra, King, & Ba, 2000). Specifically, Singhal and Law (1997) presented three measures for impact studies that researchers can use to obtain both quantitative and qualitative data: (a) resistance to adoption, (b) success/failure analysis, and (c) tracking the spread of innovation throughout the social system. Additional innovation consequence measures include perceived impacts (Hollifield, Donnermeyer, Wolford, & Agunga, 2000; Rice & Steinfield, 1994), task benefits (Rice & Manross, 1987) and productivity (Manross & Rice, 1986; Papa, 1990; Rubinyi, 1989).

**P16: As the density of innovation adoption increases, the breadth of direct innovation consequences increases.**

The proposed model specifically addresses issues related to the breadth of direct impacts and consequential communication channels, which refer to the communication channels that result from implementation and use of an innovation. That is, the acceptance or rejection of an innovation results in both desirable and undesirable impacts (Cancino, Galvez, Roth, & Bonneschky, 2001; Kraut, Rice, Cool, & Fish, 1998; Rogers, 1995; Rubinyi, 1989; Valente, 1993). The proposed model states that increases in acceptance or rejection of an innovation results in increases in the breadth of consequences. Consequently, if individuals neither accept nor reject an innovation, impacts are not as broad—and perhaps even non-existent. By simply learning of an innovation, an individual and an entire social system can

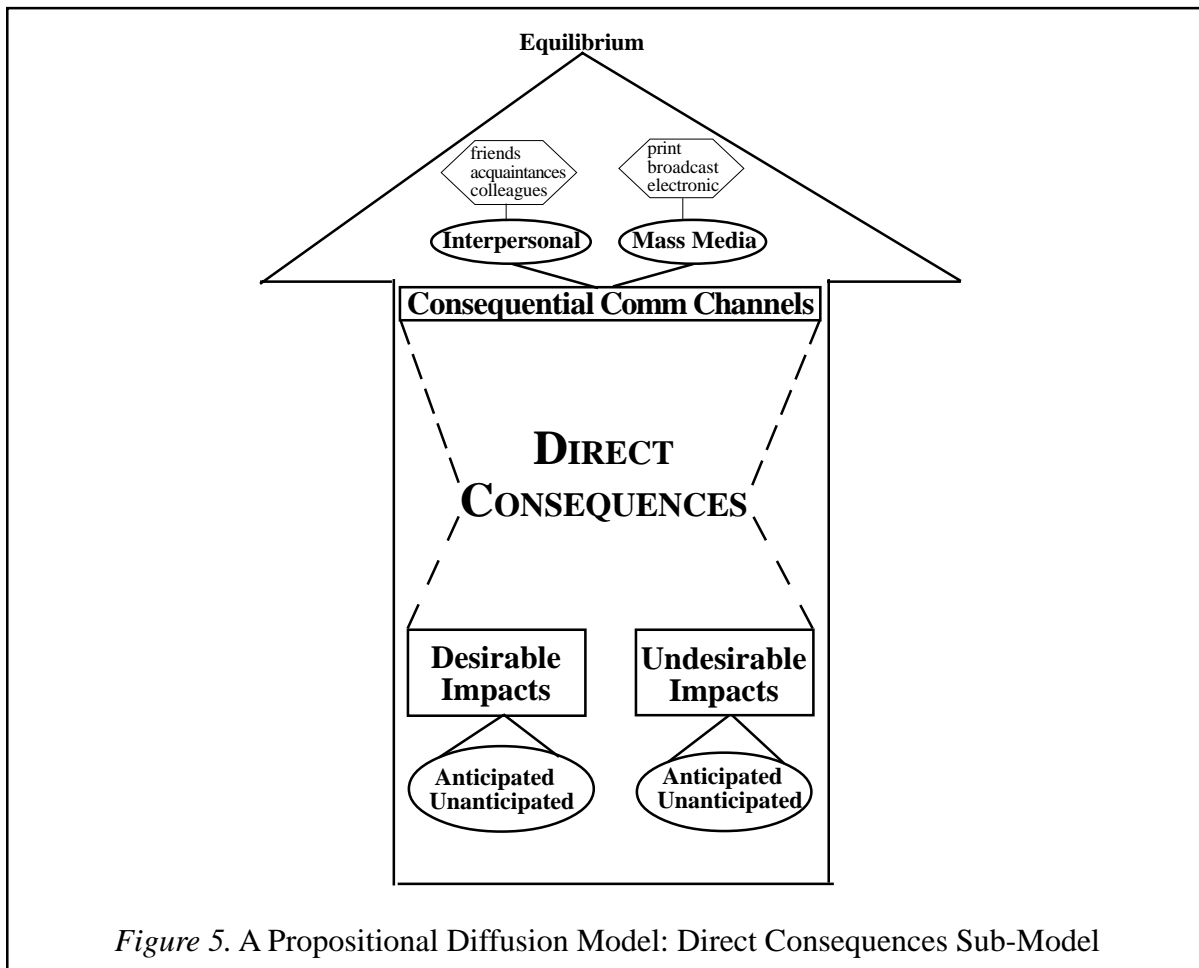
experience one or more consequences. For instance, Chilcoat and DeWine (1985) examined the use of teleconferencing among business persons and university students; they report that visual contact can negatively effect interpersonal perceptions, with regard to information dissemination during teleconferencing. However, Chilcoat and DeWine also explained that teleconferencing does not impact credibility in a negative manner; therefore, the study results indicate that mixed consequences are possible and while an innovation may result in a negative impact regarding one task, it may not impact another task at all.

**P17: The greater the impacts of an innovation, the greater the breadth of consequential communication channels.**

While scholars such as Auwal and Singhal (1992), Kraut, Rice, Cool, and Fish (1998), and Manross and Rice (1986) conducted studies measuring social impacts of innovation diffusion, the proposed model specifically examines consequential communication channels; that is, the resulting communication channels once a social system develops, implements, uses, adopts or rejects an innovation. Rogers (1995) implied that greater diffusion impacts equate to greater communication channel changes. Increased impacts result in broader consequential communication channels; in other words, the more an innovation impacts a social system, the more likely members will discuss (via both interpersonal and mass media) the innovation, its diffusion, and the consequences.

This particular area of diffusion research is somewhat deficient (Rogers, 1995), as it appears to be quite difficult to measure precisely the direct consequences of an innovation upon communication channels. However, a longitudinal study using a multi-methodological approach (i.e., surveys and interviews) might provide an efficient mechanism for operationalization.

Likewise, longitudinal studies spanning multiple generations would allow for analysis of the equilibrium period between innovation consequences and next-generation social systems. The proposed model suggests that this equilibrium shares a relationship with the communication channels of the next-generation social system. Specifically, this model



proposes that impacts of an innovation are not only experienced by the current social system; instead, generations to come also feel the impacts. That is, innovations and their impacts play a crucial role in defining both current and future social systems. For example, the impacts of technologies, such as the Internet, profoundly influence future social systems (Havick, 2000). Because the Internet effects a range of societal activities, ranging from business transactions to entertainment, the innovation can immensely impact the ways in which a social system sends and receives communication—both interpersonal and mass media.

**P18: As the period of equilibrium between direct consequences and the next-generation social system decreases, the density of next-generation social system communication channels increases.**

Before social systems continue from one generation to the next, the members typically experience another equilibrium state, as they did between innovation development

and implementation. One might compare this to the state of a society when certain cliches have adopted an innovation, but everyone else is still making their decision to adopt or reject. Once the majority of the society has either adopted or rejected the innovation, the equilibrium is again balanced and another generation forges ahead with both desirable and undesirable, anticipated and unanticipated effects of innovations.

### **Propositional Diffusion Model: Summary**

Because modern society thrives upon innovations, particularly technological advances, continued diffusion research is crucial. Although Rogers does not plan to write a fifth edition of his widely cited diffusion text, it is likely that social scientists such as Dearing, Rice, Singhal, and Valente will pave the way for future diffusion scholarship (Singhal & Law, 1997), with continued focus upon a wide array of issues ranging from healthcare and policymaking to technology and social change. Communication research in the diffusion arena not only allows scholars to better understand social implications of increased societal reliance on innovations, but also the role of communication patterns within diffusion.

In order for researchers to continue to operationalize diffusion theory concepts, it is important that scholars continue to develop and hone diffusion models, such as the proposed propositional model. However, it is not easy to test such a complex model. Hence, the author focuses current research on the innovation development and implementation sub-models.

### **Concluding Remarks and Analytical Research Overview**

While the proposed theoretical model attempts to provide guidance for research design that allows scholars to better understand four primary components of innovation diffusion: (a) social system, (b) innovation development, (c) implementation and use, and (d) direct consequences, the analytical portion of this thesis project operationalizes the innovation development and implementation sub-models (see Figures 3 and 4). Based on the literature review and proposed theoretical model, this investigation studies perceived attributes, diffusion communication, and continued perceptions during the development,

implementation, and use of the NSF-funded broadband telecommunications infrastructure , HPWREN, among field scientists at the Santa Margarita Ecological Reserve.

Because ecological field researchers are typically leading very mobile lives, the HPWREN provides them with a mechanism for not only sharing data with one another, as well as outside research communities, but also an opportunity to establish better interpersonal communication with one another and an expansion of their social system membership. On the other hand, individuals must first adopt the technology, which will not simply happen due to trust in an opinion leader as this social system is not as tightly knit as other social systems which primarily rely upon opinion leaders to assist them with decisions regarding adoption (Rogers, 1995). Instead, the ecological field researcher social system is likely to adopt only if its members are able to individually recognize the positive relative advantage and compatibility of the technology presented to them by the opinion leader. That is, the social system will not adopt simply based on an opinion leader presenting them with an innovation that the opinion leader perceives as an advantage and compatible with their research (Burt, 1999). Because the social system at hand lacks the traditional opinion leader typically found in diffusion studies, the current research does not encompass opinion leadership measures, but instead focuses upon individual interpersonal communication channels as well as mass media consumption related to the innovation.

Similar to studies conducted by Aydin and Rice (1992), Dearing and Meyer (1994), Rice, Grant, Schmitz, and Torobin (1990), and Valente and Saba (1998), the first three hypotheses of the analytical portion of this paper operationalize propositions 4, 5, 6, 10, 11, and 12. These hypotheses focus on the relationship between perceived attributes (relative advantage, compatibility, and complexity) during the innovation development stage and the diffusion communication and continued perceptions during the innovation implementation phase.

**H1: As scores within the HPWREN Relative Advantage Index (T1) increase, favorable diffusion communication channels increase.**

**H2: As scores within the HPWREN Compatibility Index increase (T1), favorable diffusion communication channels increase.**

**H3: As scores within the HPWREN Complexity Index (T1) increase, favorable diffusion communication channels decrease.**

**H4: As positive diffusion communication channels (T2) increase, the degree of perceived complexity (T2) decreases.**

**H5: As positive diffusion communication channels (T2) increase, the degree of perceived relative advantage (T2) increases.**

**H6: As positive diffusion communication channels (T2) increase, the degree of perceived compatibility (T2) increases.**

Explicitly, perceived complexity decreases as social system members speak more positively and individuals receive favorable mass media exposure between the innovation development and innovation implementation phases. Likewise, perceived relative advantage and compatibility increases as positive diffusion communication channels increase. For instance, Valente and Saba (1998) found that mass media communication channels are positively related to information awareness stages in the diffusion process while interpersonal communication channels (referred to as “personal networks” by Valente and Saba) are positively related to behavior change. That is, if a person has a broad personal network and those channels communicate positively about an innovation, the person likely perceives the relative advantage and compatibility of an innovation in a more favorable light; if interpersonal communication channels of an individual are primarily negative, the person likely perceives the innovation’s relative advantage and compatibility in a more negative light. On the other hand, “individuals who lack personal contact with many users of an innovation may turn to the mass media for information about new ideas and products” (p. 116).

Closely related to the first six hypotheses, the final three hypotheses also examine continued perceptions, however, these hypotheses focuses on relationships between attitudes and adoption by operationalizing propositions 13, 14, and 15:

**H7: Subjects who score high within the HPWREN Relative Advantage Index (T2) are more likely to use the network connectivity than those who score low.**

**H8: Subjects who score high within the HPWREN Compatibility Index (T2) are more likely to use the network connectivity than those who score low.**

**H9: Subjects who score high within the HPWREN Complexity Index (T2) are less likely to use the network connectivity than those who score low.**

As previously discussed in the innovation development sub-model section, Rogers (1995) found that positive relationships exist between relative advantage and adoption as well as compatibility and adoption. Meanwhile, Rogers illustrated a negative relationship between complexity and adoption rates. Additional diffusion studies confirm the relationships posited by Rogers. For instance, Rubinyi (1989) examined an office setting originally unfamiliar with computerized systems and their efforts to computerize all internal office functions. After one year, more than 90 percent of the groups did not have the majority of their network functions up and running. However, by the end of the two-year study, most of the groups were networking data between their own group and other groups. On the other hand, computer use in general did not have the same slow adoption rate. Rubinyi attributed the slow networking adoption rate to its complexity—compared with simply using computers, networking takes more coordination with others and more technical savvy than simply operating a single computer that is not networked to others.

Likewise, Manross and Rice (1986) found that technical savvy, or lack thereof, also played a large role in the adoption rate of an intelligent telephone in an organization. Although their study did not find a correlation between overall attitudes and usage of the phone's specific functions, Manross and Rice discovered a difference between the relationship among those users at differing organizational levels (e.g., managers versus

administrative assistants), their attitudes, and adoption decisions. Further, Kleinman (2000) found that the flexibility of CMC provided high relative advantage among women scientists and engineers who joined a 24-hour on-line forum which allowed them to share their research with peers and mentors.

In order to test these hypotheses, surveys were administered to the Santa Margarita ecological field researchers. The next chapter encompasses details regarding the methodology used to operationalize the innovation development and implementation sub-models. Specifically, the Methods chapter includes information pertaining to the (a) setting, (b) participants, (c) variables, (d) procedures for data collection, and (e) statistical analysis of the study.