AN EXPLORATORY STUDY OF THE ADOPTION OF MOBILE TELECOMMUNICATIONS SERVICE IN ORDER TO IMPROVE MOBILE HEALTH SERVICE DEVELOPMENT

by

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B.S., University of Kansas, 1988
M.B.A., University of Kansas, 1991

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Industrial and Manufacturing Systems Engineering
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2016

Abstract

This dissertation is the result of exploring the phenomenon of the adoption of a service innovation, in particular mobile telecommunications service, with the goal of informing the design of mobile health services.

A grounded research study led to the finding that older adults may not abandon a legacy service, such as landline telecommunications service, when they adopted mobile telecommunications service. To further understand the results of the first study, a multidisciplinary literature review was undertaken and resulted in a typology of the factors of individual-level innovation adoption that can be applied by human factors professionals in the field. The three categories of factors included macro environmental, innovation-specific, and human factors.

A research analysis of a study done by a county health department provided insights into what older adults contributed to the service production process in healthcare services including which common proxies do not accurately reflect the situations of older adults.

A three-state process model of individual-level innovation adoption, which incorporated the role of a legacy system, was developed using the adoption patterns of mobile telecommunications services. In this model, individuals move from a state of using a legacy system to adopting a innovative system while still using the legacy system. After a period of time, the individual moves from the state of dual use to fully abandoning the legacy system and using only the innovative system. A compartmental mathematical model is developed to allow the model to be simulated and future service demand needs can be better predicted. Two decision-making processes were identified to be employed by individuals in the abandonment of a landline telecommunications services. Finally, recommendations for the design of mobile health services are provided.

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Approved by:

Major Professor
Malgorzata J. Rys

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Dedication

To Ken – Who makes my dreams possible

Chapter 1 - Introduction

The service sector was estimated to contribute 77.8% of the United States' gross domestic product in 2014 (U.S. Central Intelligence Agency, 2014). Service can be examined using theories originating from service science research. Many of these theories draw on industrial engineering concepts to explore both quality and efficiency in service production. An important aspect of this research is a definition of service that provides a solid intersection that allows engineers to apply their domain theories to the customer aspects of specific services such as health care. The United Service Theory defines service as the production processes wherein each customer supplies one or more input components for that customer's unit of production (Sampson, 2010). This definition is in agreement with the widely-held acceptance that service is unique in the involvement of customers in production processes by supplying and controlling the inputs of the process (Spohrer & Maglio, 2008).

When customers are added to the production process, the traditional input/output model is transformed with the customer being both a supplier and a consumer of a process (Figure 1-1). The inclusion of customer inputs creates the difference between services and non-services. It also greatly affects the processes that are used to create the output. This role of customers in the production process provides a variety of new research opportunities to human factors researchers (Freund & Spohrer, 2013).

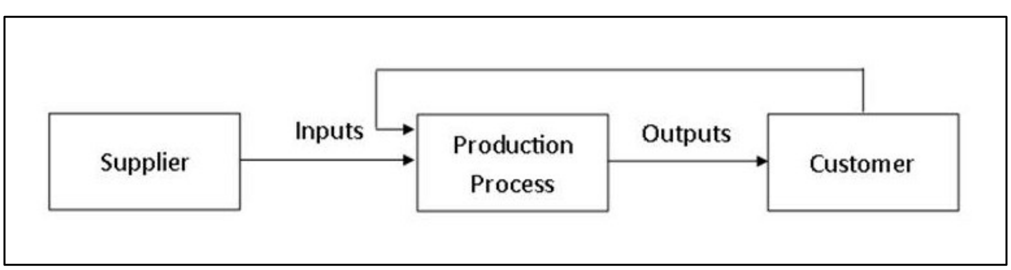

Figure 1-1 Service input/output model.

The objective of this exploratory research is to understand the adoption of mobile telecommunications services in order to inform strategies and service designs that would encourage the use and design of mobile health services (mHealth). Developments in information and communication technologies have changed the healthcare landscape and introduced new methods of healthcare delivery including electronic health (using electronic methods in patient care), connected health (using electronic methods to deliver and receive care outside of traditional healthcare settings) and mobile health (using mobile and wireless technologies in patient care). Mobile health has the potential to transform the delivery of health care especially in Third World locations and disaster zones (World Health Organization [WHO], 2011).

No standard definition of mHealth exists. The World Health Organization (2011) has defined it as medical and public health practices supported by mobile devices including mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices. Mobile health capitalizes on the functions and capabilities of mobile phones especially the functions available with smartphone technologies. In the world view, mHealth offers the potential that anyone with access to mobile phone (either cellular or satellite) can have access to medical care. In the United States, mHealth has the potential to provide better healthcare options for those who are unable to access a medical office either because of remote locations or physical limitations. Current mHealth monitoring systems track glucose and medication ingestion.

As the Baby Boomers age, the United States expects to see the population of those age 65 and older to almost double from 40.3 million in 2010 to 79.7 million in 2040 (Administration of Aging, 2013). One strategy to deal with the aging of the baby boomers is to create systems that allow older adults to live independently and safely in their own homes as long as possible. Mobile health systems that monitor conditions that may develop into future health emergencies can aid in allowing older adults to age in place. Other internet of things systems are being developed to assist with other activities of daily life. All of these systems require optional adoption.

Mobile health systems rely on mobile telecommunications systems as a platform. This research explored the adoption of mobile telecommunication service to find behavior that might inform the design and adoption of consumer mHealth services.

Established adoption process theories did not adequately explain the behavior found using naturalistic observation techniques in the field. A strong interaction between the legacy system of landline telecommunications service and the innovative system of mobile telecommunications service existed. In interviews with older adults, the benefit of mobile telecommunications service or the ability to make and take phone calls without the constraint of a fixed location drove the adoption decision (Chapter 2).

In order to understand the adoption behavior that was taking place in natural settings, a review of recent literature was conducted. This review moved beyond the extensions of established innovation adoption theory. Instead of employing only one disciplinary lens and focusing on the older population, a multidisciplinary scope that included all populations was defined. A typology of innovation adoption factors and grounding theories was organized. This typology can be used by human factors researchers addressing new service design and user experience issues (Chapter 3).

The co-production contributions of older adults in a healthcare system were analyzed. Metrics regularly used to reflect the general population did not adequately describe or measure the lifestyles or abilities of older adults (Chapter 4).

A theoretical adoption model that accurately describes the service innovation adoption process is presented. This model can more precisely match demand and production levels. The knowledge gained through this research can be applied to develop decision support systems such as training programs and instructional aids. This model describes the phenomenon what was found in the field (Chapter 5).

A mathematical model was built based on the author's theoretical model. The mathematical model was based on the principles of SIR models from epidemiology. This mathematical model can provide forecasts of long-term service system demand and production levels when dealing with a substitutable service innovation. This model can be used to simulate demand and production scenarios for both innovative and legacy systems (Chapter 6).

Once a more adequate model of service innovation adoption was developed, the research turned to the exploration of the naturalistic decision-making process of abandoning a legacy system. Individuals were found to use two different decision-making models when faced with the decision to abandon landline telecommunications service systems. This explains the behavior of the 'Wireless Mostly' group who received all or mostly all calls on wireless phones but still had landline phones (Chapter 7).

This research was then applied to the design of patient monitoring systems especially those designed for older adults who are aging in place (Chapter 8).

Chapter 2 - Exploring the Adoption of Telecommunications Service by Older Adults

Abstract

This paper was presented at the 60th Annual Meeting of Human Factors and Ergonomics Society in Washington, DC on September 20, 2016 and published in the *Proceedings of the Human Factors and Ergonomics Society 2016 Annual Meeting.*

With the expected growth of the population of Americans over the age of 65, service scientists and designers are developing systems including internet of things systems to assist older adults in remaining independent. Yet little is known about how older adults adopt new services. In this grounded research, the authors explored the adoption of telecommunication services including landlines and mobile services by older adults. This early research suggests that access to other systems, population density and fit with the norms of a social network may be promising factors in future research in telecommunication service adoption. This study addresses the gap that current innovation adoption theory has not adequately explained adoption of service innovations by older adults. Future research opportunities exist for human factors researchers in the area of service adoption by older adults.

Introduction

The number of Americans over the age of 65 is expected to grow from 40.3 million in 2010 to 79.8 million by 2040 (U.S. Census Bureau, 2014). The care of this aging group is of great concern to policy makers for it will require great resources including economic, human, social, technological and physical assets. As a result of this future need, engineers, policy makers, healthcare providers and others are working at creating solutions. Service scientists are no different. Service scientists study, manage and model service systems such as healthcare, telecommunications, and internet of things systems (Maglio, Srivivasan, Kreulen & Spohrer, 2006).

Within the human factors community the study of service systems is still quite young with a small theoretical body of knowledge. Using the lens of service science, the authors explored the nature of service innovation adoption by older adults. This knowledge is helpful in developing service systems used by older adults. When the authors found in a past project that the models of technology and innovation adoption were not easily generalizable to older adults adopting services, a field study was undertaken to explore how and why older adults adopted a telecommunications service innovation. The results of that field study are discussed in this paper. This paper opens with a brief explanation of service science, followed by the details of the study's methods. The results and a discussion of the importance of this research close this paper. Future research is suggested especially in light of the care needs of older adults and technological innovations such as internet of things devices.

Until recently little was understood about services. Adam Smith's definition that a 'service' is not manufactured or agricultural doesn't describe what service is, but focuses on what it is not (Spohrer, Vargo, Caswell & Maglio, 2009). As the United States economy and employment continues to be driven by services, the need to understand the dynamics of services takes on new importance, especially to the computer and information technology firms who work in this field. New typologies and definitions are emerging.

The definition that a service is the application of competences (knowledge and skills) through deeds, processes, and performances for the benefit of another is accepted by many in the research community (Vargo & Lusch, 2004). One premise of service science is co-production where the consumer is always involved in the production of the service (Vargo & Lusch, 2004). Whereas a physical product is traditionally created on a factory production line, the value of a service is created in a service system – a configuration of people, technologies and other resources that interact with other service systems to create mutual value (Spohrer et al., 2009). When services are created in open systems, general systems theories apply to service productions (von Bertalanffy, 1969). The research of human factors professionals fits comfortably within service science. Service design requires sufficient knowledge of the capabilities and limitations of the human beings involved in the co-creation of a service (Freund & Spohrer, 2013).

The aging of the population and the development of internet of things technologies were two conditions that encouraged this study. The grounded research resulted after a previous study on telecommunications service adoption by older adults deviated from expected theory. The author then went to the field to look at other drivers of adoption. Medical technologies can connect patients' homes to healthcare providers via the internet. These technologies are only viable if older adults adopt the technology.

An older adult's decision to adopt a technology or technology-enabled service often encompasses more factors than the Technology Acceptance Model's factors of ease of use and usability factors (Davis, 1989). Lee and Coughlin (2015) identified ten factors as determinants of older adults' adoption of technology including value, usability, affordability, accessibility, technical support, social support, emotion, independence, experience and confidence.

Lee and Coughlin (2015) utilized a literature review format to determine the factors of older adults' adoption. The authors of this paper chose to use a grounded research approach to determine how and why older adults adopt service innovations. By interviewing older adults about their behavior in a telecommunications service system, the authors discovered behavior that can benefit human factors and service researchers. The goal of this paper is to share those results and hopefully start a conversation concerning the design and acceptance of technology-enhanced services catering to older adults.

Method

This project was exploratory, grounded research to inform future research in the design and adoption of service systems. The authors conducted 17 semi-structured interviews with older adults regarding the use of telecommunication systems. The seven questions in this study were structured as a task analysis using critical decision method with probing into the process of adoption and the dual use of legacy systems. The practice of task analysis was discontinued early when the use of a smart phone to record the sessions distracted the older adult participants, who wanted to have a demonstration of the smart phone's functions. Handwritten notes were taken on each interview. Questions focused on reasons to adopt, use and abandon landline and mobile telecommunication services, years using the services and how participants used the services (Appendix A). The interviews ranged in length of 15 to 45 minutes. The authors strived to have a mix of participants from rural, suburban and urban locations that had different service providers. Three geographical areas were targeted: suburban Kansas City; the rural, small town of Atchison, Kansas and residents who lived within a five-mile radius of downtown Denver. The snowball method of sampling was used. The participants had connections to either the University of Kansas Landon Center for Aging, the Riverside, Missouri Community Center and the Atchison County, Kansas Project Concern. This diverse sample allowed the researchers to include geographic location as a variable. Interview participants were required to live independently and be over 65.

The authors chose to study telecommunications service in part because of the great many innovations to the service in the past 30 years. The study's participants had all used a landline phone service at one time in adult life and many had grown up with telephone services. All the participants could tell stories from their childhood regarding either party lines or sharing the phone with family members. For clarification purposes, participating in a telecommunication service extends beyond the use of a particular technological device such as a corded, wireless or smart phone. The authors were not interested in the devices such as smart phones or rotary dial phones. Instead a participant in the telecommunication service system uses the network infrastructure over a period of time. A quick way to test if a participant used a telecommunication system was possession of a telephone number that linked to the specific participant. In this research, the subject was not smart phones and how people used that technology. Instead the author was interested in the service that network providers such as AT&T or Verizon provided to the participants. The descriptive statistics are found in Table 2-1.

Table 2-1 Descriptive statistics according to telecommunications service

	Landline	Mobile	Both	Total
Total	4 (23.5%)	7 (41.2)	6 (35.3)	17 (100%)
Average age (yrs.)	73.5	75.4	79.5	76.1
Males	1 (14.3%)	2(28.6%)	4(57.1%)	7 (100%)
Females	3(30%)	5(50%)	2 (20%)	10 (100%)
Rural	1(14.3%)	5(71.4%)	1(14.3%)	7 (100%)
Suburban	1(14.3%)	1(14.3%)	5(71.4%)	7(100%)
Urban	2(66.7%)	1(33.3%)	0	3(100%)

Results

The participants fell into three groups based on service system: landline, mobile, and both landline and mobile. Landline users relied on landlines for their telecommunications needs. This group was split with 2 being urban, 1 suburban and 1 rural. One reported previously having a mobile phone for a job but discontinued usage upon retirement. Members in this group voiced no desire to have a mobile phone and denied that cost was a factor in not adopting a mobile phone. All members of this group used answering machines to handle missed calls and had extensive social networks that they saw regularly. Telephone communications service was used mainly for matters such as setting up appointments and dealing with medical offices. This group didn't rely on the phone for social conversations. Instead they had regular face-to-face encounters with those in their social networks. The respondents were not concerned about using the phone for safety needs such as when a car broke down. They felt confident they could borrow a phone from someone, even a stranger, nearby. They reported that their children were annoyed by the lack of a mobile phone. One participant thought her child had a greater desire to have constant access to the parent rather than a great concern about safety.

…She (my daughter) wants to talk when she has time or needs me to babysit. Believe me, if my car broke down, she would not be happy if I called her for a ride.

Patricia, 66

Phone numbers were important to this group. Most had the same phone number for over twenty years and it was part of their identity. One even pointed out her area code, which to her symbolized that she lived in a particular part of the city and had lived there a long time. Her area code rooted her to that community, not the nomadic life of a mobile phone user.

The group that only used mobile phone services included seven participants (2 males, 5 females) with an average age of 75. Five members of this group (71%) lived in a rural community. The majority of this group (5 participants) used flip phones. Convenience and safety were the most cited reason to have a mobile phone. One reported the mobile phone was primarily her medical alert system. She carried it in her walker and made sure it was always charged. Only the two participants owning smart phones reported texting. All the members of this group had a landline when they got mobile phone service, but discontinued the usage after a period of over one year. This group exhibited price sensitivity and talked about their minutes and how they monitored them.

…my doctor's office texts me to remind me of appointments. I told them to stop. Don't they know it costs me?

Dan, 76

This group reported that they discontinued landline usage due to overlapping services with the mobile service. The mobile phone satisfies the needs that the landline handled for this group.

The final group (n=6) used both mobile services and landline services. To this group, the mobile phone provided convenience and safety when they were away for the house. Five members of the group were from a suburban area. The mobile phone and the landline had different functions. Often the landline was used for daily communication while the mobile phone provided a link to help if needed. The five suburban members of this group kept landlines because the reported cost of $5 was minimal and part of their cable television service. The rural member of the group reported that her mobile phone is part of her daughter's phone plan. She relies mainly on her landline.

Discussion

In this exploratory study of older adults' adoption of a telecommunication innovation, namely a mobile phone service, three points stand out: geographic density, dependent and related service systems, and fit with other systems. Telephone services connect older adults to their social networks and other service networks such as healthcare, driver assistance in case of automobile troubles, and supply chains such as pharmacies or family members who might deliver food or supplies.

Geographic density played a role in telecommunications service. The access to help in emergencies and with everyday activities was important to rural residents. In the rural communities, assistance must be sought out by those needing aid. Most rural residents had mobile telecommunications systems. They didn't necessarily use the advanced features of the phone or internet access. They needed the security that they could get help if stranded on a lightly traveled road. Urban residents felt they could always borrow mobile service if needed. They expected people to be close at hand to help. Borrowing services has rarely been discussed in service literature regarding older adults. Only one rural resident reported borrowing telecommunications services by being a member of her daughter's plan. Younger groups regularly share services. Many college students use their parents' password to get access to HBO or Netflix programming (Spangler, 2015). The authors had seen similar behavior in the past. People reported allowing older adult neighbors access to their Wi-Fi network by sharing passwords. Further research in this area may offer service designers the option of service sharing to limit the financial and cognitive stress of dealing with system infrastructure issues.

Bundling the landline service with either internet service or cable television service was credited by suburban participants as a reason to keep their landline service. In the rural community where the landline service provider was different from the mobile service provider, the participants were more likely to discontinue using landlines due to the cost. Rural residents viewed the services as interchangeable. Dependent and related service systems can affect the adoption of a service innovation. When studying older adults' service system adoption, any other related systems need to be reviewed. Some services require other service systems such as social networking site Facebook requires the participant to have access to the internet through a network provider. Older adults facing a health issue must deal with both the healthcare service system and the Medicare service system.

Finally the fit between the innovation and the older adult's current system usage must be considered. Using a social network example, if an older adult communicates regularly with his friends at a coffee shop or church, a cell phone might not fit the social network norms. Older adults don't require technology to facilitate the communication. A telephone simply eliminates the need of face-to-face interaction for communication. But some people prefer face-to-face communication for certain relationships. As the research demonstrated, people may reject a service innovation if they are satisfied with their current system or the switching costs are too high. Switching costs not only include financial costs but also the cognitive cost of learning a new system. To the participants who had only a landline service and an answering machine, the convenience of being able to use telecommunication service outside of the home did not enhance their satisfaction with their social encounters. This group reported using the phone primarily for arranging appointments and transacting business, but not for social activities. The two who had grandchildren out of the state reported using Skype on tablets. Their preferred communication method with family and friends was face-to-face encounters.

If I want to talk to someone, I go see them. It gets me out.

Ted, 80

While a telecommunication service system may not enhance their social interactions, transportation systems that make the face-to-face encounters possible might have a great effect on social interactions.

Future Research

Many research opportunities exist in service innovation adoption by older adults. Older adults are regular users of services. The subject of service borrowing by older adults was previously mentioned. Another area is service system interaction and fit. Does the complexity of an embedded service system stop an older adult from adopting a dependent system? How many older adults avoid tablets because they lack the Wi-Fi service?

As people age, many services that people perform for themselves such as yard maintenance and housework must be outsourced. One area can explore how older adults balance a service such as mobile telephone service with the physical act of going out to see a friend. Are older adults willing to substitute a phone conversation for a face-to-face conversation (personal visit)? Face-to-face conversations (personal visits) would require the older adults to be more physically active and therefore affect the quality of life. Does this substitution affect quality of life?

Often service design changes without much thought of the customer. Offices change forms, software requires updates, and procedures change. How do older adults adapt to changes in service systems? Do they remain in the system or drop out?

Since services are a co-production between the provider and user, a degree of trust is required. Trust issues, especially regarding data collection and data-driven decision making, can easily affect service usage and therefore, trust needs to be built into the system. But where and how do designers reassure users that the data is safe.

The Americans with Disability Act of 1990 highlighted the physical and cognitive barriers that exist in many services. But what barriers still exist? Some companies are trying to remove barriers to service access. AMC movie theaters and the Autism Society offer a sensory friendly film series where the lights are kept on, the sound is lowered and the viewers are allowed to sing, dance and move about.

At this time service designers are facing the pressing need of aging Baby Boomers. The question for service designers is still how to build service systems that people will use.

Conclusion

The process of adoption of a service innovation appears to be different from that of product innovation adoption. Since service is a co-production between the consumer and the producer, service designers need to understand both the capabilities and limitations of the consumers to operate technology and the current systems that are available. In the case of older adults, technology such as a smart phone was not reason enough to discontinue a landline telecommunication system. It is important to consider the other systems a person can access such as a family member's mobile phone plan. Many service systems require, compliment or embed with another service system. Lack of service innovation adoption may be due to problems with other related service systems. Finally service innovation adoption requires the proper fit between the innovation and the current system usage. Since most services can be internally sourced through self-service, fitting the service innovation and the current system appears to be important to the adoption. This study was done because the authors couldn't explain service innovation adoption by older adults. This field work gives researchers a starting point to explore how people, older adults in this case, interact with service systems.

Limitations

This study was exploratory and designed to inform future research. The sample size of 17 was small. The goal of this research was to explore possible factors of service adoption by older adults. Due to the small sample size, conclusions on how older adults adopt services can not be drawn from this research. While the sample size was small, a diverse sample was achieved by finding participants from urban, suburban and rural communities that had different service options.

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Chapter 3 - Typology Development of Individual-level Innovation Adoption Determinants for Human Factors Professionals

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Introduction

A considerable body of multidisciplinary research exists for individual-level innovation adoption, but the extensive research volume hinders research utilization. As a result, innovation theory is often neglected in the human factors field. With the growth of data-based services and Internet of Things (IoT) technology, more customers will be submitting data through devices connected to the Internet, and human factors professionals will be expected to provide aids and accommodations that encourage customers and employees to use new technology such as a mobile-medical or wearable devices. However, two traditionally used models, Diffusion of Innovation (DoI) model (Rogers, 2003) and the Technology Acceptance Model (TAM) (Davis, 1989), do not always sufficiently explain the complex decision of innovation adoption. Therefore, the authors explored the literature pertaining to individual-level innovation adoption and discovered that, although the large amount of research spans numerous disciplines, it is not organized for application by human factors professionals. The authors reviewed recent literature to find a sample of theories that researchers have applied when exploring individual-level innovation adoption. From this sample, a framework was developed that allows human factors professionals to categorize determinants. Although this review is not exhaustive, it provides theories that ground recent research and gives human factors professionals a resource when working with individual-level innovation adoption.

Human factors professionals do not regularly encounter individual-level innovation adoption; corporate management often considers it the domain of marketing professionals. However, human factors training can be applied to individual-level innovation adoption. System design often depends on the utilization of other technologies, such as televisions and electric grids. For example, banks that promote online banking and bill payment assume that customers are familiar with the Internet and Internet-accessible devices, and medical offices that use text appointment reminders assume that patients use mobile phones. If medical professionals expect patients with diabetes to take glucose readings using an attachment on a smartphone and upload the results via the Internet, then the medical device developers must understand patients' usage and reactions to the smartphone. In this scenario, smartphones are not the product of computer companies; they are service tools used to transmit medical information from remote locations.

The design and development of IoT services requires human factors professionals to understand technology and innovation adoption. Individual-level innovation adoption research encompasses a variety of disciplines and research methods. Discipline-specific theories commonly provide theoretical grounding for studies. With the exception of grounded research, only single dimensions of an adopter, such as the economic aspect, the cognitive aspect, or the social aspect, are considered, and the interactions between these dimensions are seldom tested.

The field of innovation adoption contains an extensive amount of research, but lack of organization of the research prevents easy access for human factors professionals. This literature review and the resulting framework attempt to fill this gap. In this paper, innovation and individual-level innovation adoption are defined. The DoI model and the TAM are briefly discussed, and the method of this multidisciplinary literature review is explained. A framework to categorize the theories that explain innovation adoption is also provided. A description of study applications concludes this paper.

Innovation Definitions

Innovation is often written about but rarely defined. A Google search of the word *innovation* yielded over 350,000,000 results. The word is derived from the Latin word *novus* meaning new. Economist Joseph Schumpeter added an economic dimension to the term by defining innovation as the engine of economic growth (Medearis, 2009). To Schumpeter, an innovation is the application or adoption of an invention by a firm (Godin, 2008). He identified specific forms of innovation, including the introduction of new products, development of new methods of production, opening of new markets, control of a new source or supply of materials, and implementation of a new form of a business organization (Medearis, 2009). Management researcher Peter Drucker extended the meaning of innovation to include the business function that transforms inventions, such as research and development activities (Drucker, 1998). These definition extensions allowed the study of innovation to encompass numerous disciplines and enlarged the innovation studies research domain.

This paper uses the definition of innovation provided by Everett Rogers in his book *Diffusion of Innovations*, which popularized the study of innovation. According to Rogers (2003), "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p12). Therefore, in this paper, newness of an innovation is not measured by time on the market or widespread adoption by the general population; instead, newness reflects a difference between the innovation and an established idea, practice, or object that is used by the individual. Rogers' work as a sociologist influenced his research to focus on the diffusion of an innovation between and within communities, including how new ideas, products, and processes spread and gain acceptance by a group.

By widening the definition of innovation to newness to the adopter instead of the traditional measurement of time on the market, the scope of innovation classification broadens to include an increased variety of research, allowing diverse entities to adopt an innovation. However, the focus of this paper is on optional innovation adoption by an individual, not an organization, group, institution, or society. Optional innovation decisions, or decisions made independently and free from coercion, are most common in market adoptions. Decision makers can be influenced by community norms and social environment, but they are not forced to make a specific decision (Rogers, 2003).

Innovation Adoption Decision-Making Theories

Two theories of individual-level innovation adoption, the DoI model and the TAM, have driven a majority of the significant research for human factors professionals. The DoI model, which was derived from sociology and grounded research, explains the decision-making process required when a new idea, process, or tool is adopted (Rogers, 2003). The TAM was developed to increase organizations' understanding of why people accept or reject computers (Davis, Bagozzi, & Warshaw, 1989; Davis, 1989). Both models have been tested frequently and contain numerous extensions. However, DoI is a decision-process model, and TAM is a variance model that focuses on factors of acceptance. According to Davis, Bagozzi & Warshaw (1989), TAM was originally designed to provide a tool for evaluating computer systems and helping management design interventions to reduce the "problem of underutilized computer technology" (p982). Because both models have been widely used in innovation research and can be applied by human factors professionals, both are briefly discussed in this paper.

Diffusion of Innovations Model

Agricultural sociologist Everett M. Rogers popularized the study of innovation and the subsequent DoI model in his book *Diffusion of Innovations*. Rogers' original work was based on grounded research that investigated farmers who adopted new farming methods (Rogers, 2003). The DoI model includes both the adoption and diffusion of innovations within and between communities and individuals. The generalizability of the DoI is the reason for its research popularity. A Google Scholar search reported over 69,000 cites of this book.

An individual's decision to optionally adopt an innovation is only a portion of the DoI model, however. Rogers (2003) proposed that individuals typically use a five-stage innovation-decision process that is affected by prior conditions. Each stage is affected by unique factors. Those factors are either characteristics of the decision maker or characteristics of the innovation. Communication channels affect all stages of the process (Table 3-1).

Table 3-1 Stages and factors of innovation-decision process

Process Stage	Factors
Prior Conditions	Previous practice Felt needs/problems Innovativeness Norms of the social systems
Knowledge	Characteristics of the decision-making unit: socioeconomic characteristics, personality variables, communication behavior Communication channels
Persuasion	Perceived characteristics of the innovation: relative advantage, compatibility, complexity, trialability, observability Communication Channels
Decision	Communication Channels
Implementation	Communication Channels
Confirmation	Communication Channels

Rogers (2003) acknowledged that the stages are difficult to study and are usually investigated using qualitative research. A majority of research in innovation adoption decision making has focused on the factors or the innovation at a particular time. Since the DoI is a descriptive model, researchers have used discipline-specific theories to fill in explanatory gaps in the model.

Technology Acceptance Model

The TAM applies a discipline-specific theory to fill in an explanatory gap found in DoI (Davis, 1989). Davis (1989) focused on the effect of innovation characteristics on the adoption of a computer system in a corporate setting. TAM is theoretically grounded in social psychology's theory of reasoned action, in which behavior occurs when behavioral intent is present (Ajzen & Fishbein, 1980). Various determinants have been explored to determine behavioral intent to adopt an innovation (Davis, 1989). TAM explores two determinants of the intent to adopt atechnology in a forced adoption situation: perceived usefulness of the innovation and perceived ease of use of the innovation. Perceived usefulness refers to the utility of the innovation, and perceived ease of use refers to the effort required to use the innovation (Venkatesh, Morris, Davis, & Davis, 2003b). TAM's dependent variable is behavioral intention and not innovation usage. This dependent variable is discussed further in the Methods section. Researchers have extended TAM by adding determinants. For human factors professionals, TAM's contribution to individual-level adoption may be summarized by the following: people adopt tools that are perceived as useful and that are perceived as easy to use.

Using these two models and other models specific to particular disciplines, researchers from sociology, marketing, information studies, technology studies, management, psychology, and economics have explored individual-level innovation adoption. Unfortunately for human factors researchers, this research is scattered among journals in a range of fields.

Methods

Mature research fields such as innovation adoption offer the unique problem of excessive research for applied scientists. This overwhelming volume of research on all forms of innovation creates complications when determining useful research in applied situations. The scope of this paper includes individual-level adoption with regard to the focus innovation, and the dependent variable of interest is observable usage/adoption, thereby considerably reducing the body of research. Intention to adopt, a theoretically acceptable construct in psychology models, is typically used as the dependent variable in studies using TAM. Behavioral intention may be a necessary condition for adoption but it is not sufficient. Using behavioral intention constructs as a proxy for adoption does not take into account the many factors such as social support that can be barriers to adoption in an optional adoption decision. Many of these factors can be controlled in a forced adoption situation such as when management installs a new computer system. With the continued development of IoT, sensors, and big data, actual usage of an innovation can be observed. Barriers to adoption that can possible affect innovation usage are not consistently reflected in intent constructs. The dependent variable of innovation usage reflects the complex determinants and interactions that affect the optional individual-level adoption decision.

For example, Christou, Eliophotou-Menon & Philippou (2004) found that when teachers were asked about the adoption of a new math curriculum, teaching experience was a factor in determining adoption. Novice teachers were more concerned with the effect on daily tasks and time management concerns regarding the adoption process, whereas experienced teachers were concerned with the consequences of adoption on student-learning outcomes and were more involved and active in the adoption process. Researchers found that if supportive training was absent throughout the adoption process, novice teachers were less likely to understand innovation benefits for student outcomes or adopt the new curriculum. This insight would have been lost in a TAM study since the problems of time and task management appeared in the actual usage phase of the study, and TAM does not always measure actual usage. Novice teachers may have intended to adopt the curriculum, but they hadn't accounted for the time or task constraint.

Twenty-nine fields of research were searched for literature in this study, as listed in Table 3-2. Journals from medicine and the sciences were not searched.

Table 3-2 Journal sub-disciplines and number of journals searched

Sub-Discipline	Number of Journals Searched
Aging	8
Applied Psychology	46
Demography	19
Experimental and Cognitive Psychology	30
Finance	50
Geriatrics and Gerontology	28
Gerontology	10
History and Philosophy of Science	33
Human-Computer Interaction	25
Human Factors and Ergonomics	7
Information Systems	62
Information Systems and Management	18
Management Information Systems	16
Management of Technology and Innovation	37
Marketing	38
Management Science and Operations	28
Media Technology	35
Organizational Behavior and Human Resource Management	38
Philosophy	103
Political Science and International Relations	94
Psychology (miscellaneous)	55
Public Administration	26
Social Psychology	53
Social Sciences (miscellaneous)	100
Sociology and Political Science	225
Software	110
Strategy and Management	80
Transportation	16
Urban Studies	27
Total Journals	**1,417**
Minus Duplicates	**400**
Journal Search Space	**1,017**
Inaccessible	**101**
Total Journals Searched	**916**

In order to control the research quality, the search was limited to specific journals rather than keywords. Because the search was multidisciplinary, individual journals were chosen using the SCImago literature rankings from 2013. SCImago Journal Rank (SJR), which uses the SCOPUS database, measures the number of citations received by a journal and the prestige of the citing journal (WWW.journalmetric.com/sjr.php). The top fourth of the highest ranked journals in each discipline were searched, thereby creating a weighted average depending on the total number of journals in the field. The resulting list included 1,017 journals after duplicate journals between categories were removed. From this list, 101 journals were not readily accessible using available databases.

Each journal was initially searched using the keyword *innovation*. If that search resulted in more than 25 articles, the word *adoption* narrowed the search. If less than 25 articles were revealed in the search, the abstracts were scanned to determine if the article covered individual-level adoption. Due to the breadth of the journal disciplines, the use of the word *adoption* was not commonly used in many journals. If articles continued to be identified after adding the keyword *adoption*, they were scanned for individual-level adoption. The journal *Organizational Science* had 166 articles with the key word *innovation* and 48 articles with the keyword *adoption*, none of which related to individual-level adoption. As expected, all the articles included organization-level adoption. The search included journals from January 2000 to March 2015. The search resulted in 98 articles from nine disciplines (Table 3-3). Eight studies were grounded research and are discussed in a following section. The remainder of the articles included six theoretical articles, three literature reviews, one meta analysis, and 80 empirical articles. The empirical articles were reviewed to determine the theoretical foundations used.

Table 3-3 Broad disciplines of reviewed articles

Discipline	Number of Articles Reviewed
Agricultural	5
Economic	6
Education	5
Human-Factors/Human-Computer Interaction	9
Information Studies	17
Management	9
Marketing	27
Psychology	4
Sociology	16
Total	**98**

Results

The empirical articles were reviewed for theories researchers used to ground their studies. Once the theories were listed, a framework emerged that categorized the theories into three applicable categories for human factors researchers. The theories focused on characteristics specific to the adopter, the adopter's social network, and environmental factors.

Grounded Research

Grounded research provides insight into the complexity of the innovation adoption decision-making process. Determinants of the decision-making process often vary, and interaction in the form of trade-offs occurs. In a study of Colombian farmers, the decision to adopt an innovation was dependent on the number of family members who could work, which was dependent on available jobs in nearby towns (economic and geography factors) (Álvarez, 2010). Owning a bicycle affected an innovation adoption of seeds in Zambia because bicycle ownership increased information transfer (social network factors) and demonstrated the availability of economic resources (resource allocation) (Langyintuo & Mungoma, 2008). Individuals with prior knowledge of food labels (past knowledge and schema development) were more likely to adopt ecolabels for fish products (Thøgersen, Haugaard, & Olesen, 2010). Unlike the empirical studies, grounded research revealed that each decision is based on distinct criteria for individuals, the innovation and the environment.

Model of Innovation Adoption Determinants

Based on the grounded research, DoI, TAM, and theories used by empirical researchers in this review, individual-level innovation adoption was shown to be a function of three categories of determinants: the human factors of the adopter, the macro environmental factors and innovation factors (Figure 3-1). Determinants that are categorized as macro environmental are major external factors and can't be controlled by the adopter. These include market conditions, governmental policy, social conditions or natural resources and can encourage groups of potential adopters to accept or reject an innovation. Shklovaksi, Burke, Kiesler & Kraut (2010) drew on the domestication of technology theory when exploring the effect of Hurricane Katrina, a natural disaster, on mobile phone adoption by New Orleans musicians whose social networks were disrupted. Economic utility models grounded a study of Ethiopian farmers who were more likely to adopt a seed innovation when the government provided experts to provide advice to the farmers (Feleke & Zegeye, 2006). Framing the adoption of electric motorcycles in Vietnam as an economic choice decision, researchers found sales tax incentives were a significant determinant of adoption, but only for drivers who traveled within the mileage range of a battery charge (Jones, Cherry, Vu, & Nguyen, 2013). These three examples highlight the role of determinants that are external to the individual.

The second category of determinants, focus on the unique characteristics of the innovation itself. TAM recognized two of these characteristics: perceived usefulness and perceived ease of use. DoI also highlighted characteristics, as listed in Figure 3-1. These determinants include product features. In the above study on Vietnamese motorcycle riders, the riders who rejected the electric motorcycles did so because the motorcycle did not have the functionality of a longer battery charges. Tax incentives did not overcome the electric motorcycle's lack of functionality for the non-adopters. This highlights that the determinants important to adopters are not necessarily the same determinant significant to non-adopters.

The third category of determinants, human factors of the adopter, are characteristics of the individual adopting the innovation and are the most relevant to human factors professionals. Human factors cover, but are not limited to, physical, mental, cognitive, economic and cultural dimensions. The human factors are divided into three subcategories: personal factors, social connections and micro environmental factors. The theories used to ground the research exploring these factors are included.

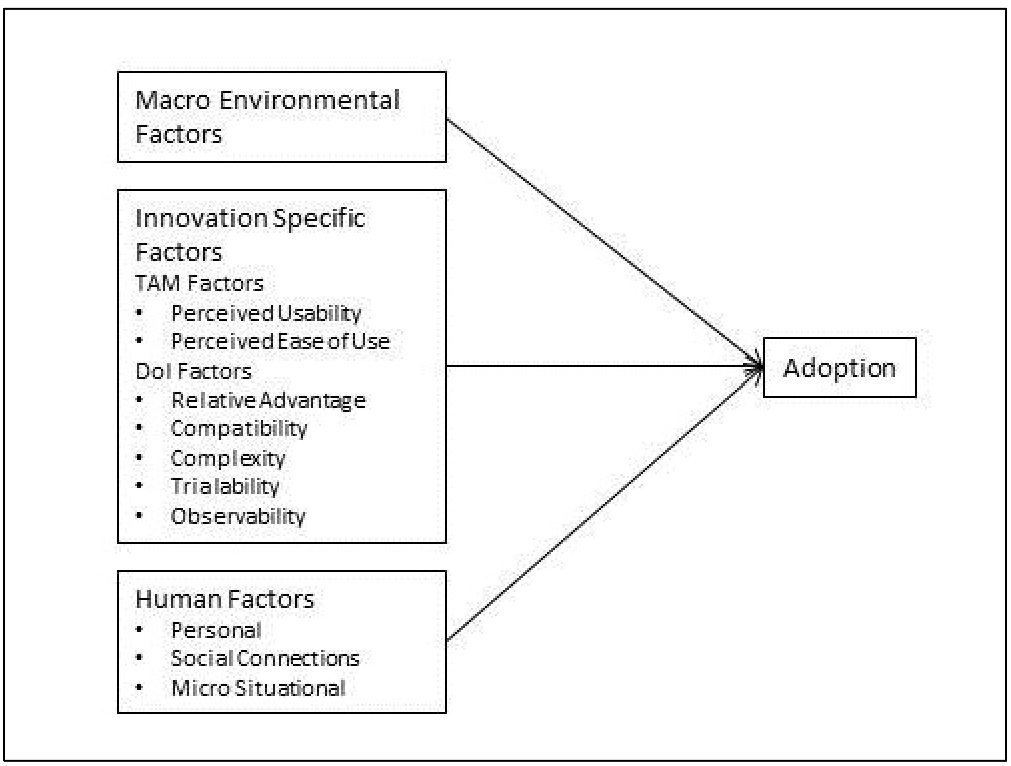

Figure 3-1 Factors of individual-level innovation adoption

Personal Factors

Characteristics specific to individual adopters are often used to explain innovation adoption. These characteristics are distinctive to an individual and do not necessarily vary over time. The studied characteristics varied widely depending on the discipline of the researcher (Table 3-4). Theoretical groundings included theories of psychological processes or characteristics of the individual.

Table 3-4 Theories used to ground personal factors research

Individual Factors	Theoretical Grounding
Age	Age-Biased Work Practices (Aubert, Caroli, & Roger, 2006)
	Human Capital Theory (Becker, 1964)
Behavioral Heuristics	Prospect Theory (Kahneman & Tversky, 1979)
	Optimistic Bias Theory (Weinstein, 1980)
	Bounded Rationality (March & Simon, 1958; Simon, 1955)
Cognitive Processing	Three-Stage Processing Model of Memory (Atkinson & Shiffrin, 1968; Winn 2004)
	Structured Imagination (Ward, 1994)
	Structured Mapping (Gentner, 1983)
	Analogical Mapping (Holyoak & Thagard, 1989)
	Sense-Making (Prasad, 1993)
	Frustration Theory (Amsel, 1992)
	Attribution Theory (Weiner, 1985)
	Cognitive Limits (MacGregor, 1987)
	Ill-defined Problem Solving (Schunn, Mcgregor, & Saner, 2005)
	Schema Theory (Mandler & DeForest, 1979)
National Culture	National Character (Clark, 1990)
	Cultural Dimensions Theory (Hofstede, 1983)
	Users and Gratifications Theory (Lichtenstein & Rosenfeld, 1984)
Occupational Identity	Professional Identity (Freidson, 1984)
	Technology and Occupational Identity (Ashcraft, 2013)
Personality Traits	Innovativeness Personality Trait (Hirschman, 1980)
	Consumer Innovativeness (Parasuraman, 2000)
	Global Innovativeness (Kirton, 1976)

Information and communication technologies allow researchers an innovation to test. In innovation variance research two groups, those who adopt an innovation and those who reject an innovation, are compared. Psychology theories ground research such as Gounaris & Koritos (2012) that found cognitive strain resulting from information overload had a negative effect on the probability of adoption of internet banking. The three-stage processing model of memory has been used to research adoption. Kim (2009) found when old and new technologies, specific computer software packages, are similar, the existing schema and script used for the old technology are likely to be evoked for the new technology, therefore encouraging adoption of innovations that are similar to existing products or technology. Using the paradigm of knowledge transfer, researchers found experts with entrenched knowledge structures struggle to understand the benefits disruptive innovations when compared with novices (Moreau, Lehmann, & Markman, 2001). Once an innovation has been adopted, experienced users attribute any failures of the adopted technology to the situation and not to the technology (Vishwanath & LaVail, 2013). These examples highlight the role of cognitive processing in the innovation adoption decision.

One stream of research suggests innovation adoption behavior is a manifestation of the innovative cognitive style, a personality trait (Im, Mason, & Houston, 2007; Jin, 2013; Koenigstorfer & Groeppel-Klein, 2012; Lam, Chiang, & Parasuraman, 2008; van Rijnsoever & Donders, 2009). Innovative consumers seek out interactions and situations where consumers learn about new products and are therefore, more likely to adopt the new products (Hirschman, 1980). In the literature reviewed, researchers applied discipline specific theories such as social learning, schema theory or technology optimism to explain the difference between those with and without the innovativeness personality trait. National culture did not affect how adopters related to technologies that are the closest to self-identity such as e-mails, home phones, mobile phones and home addresses (Vishwanath & Chen, 2008). Adoptions of innovations that violate cultural norms and traditions were rejected (Rogers, 2003).

Individuals' perceptions of their work identity have been shown to affect innovation adoption. Korica and Molloy (2010) found that junior surgeons were more likely than established surgeons to adopt a new technology or technique in order to establish credentials and achieve acceptance in the surgeon community. Librarians' acceptance of Internet search technology was founded to be negatively affected by the job identification. Early in Internet diffusion, librarians were slow to teach or encourage library patrons to use search engines because the technology did similar tasks as the librarians (Nelson & Irwin, 2014).

Social Connections

Adopter's social connections and sources of outside information including the media have influenced the decision to adopt an innovation (Rogers, 2003). The literature that was reviewed included research exploring these relationships. Network theories from sociology and corresponding mathematical network models have influenced innovation research (Granovetter, 1973). In a study of bribery in radio, external influences such as media and record company promotions positively affected the number of times a new song, which was modeled as an innovation, was played (Rossman, Chiu, & Mol, 2008). The structure of an adopter's social network determines how an adopter gets new information from social contacts. Structural holes, a social contact that links two groups in social network, and weak leaks, a contact that has seldom interaction with the adopter but links the adopter to new information, provide new and unusual information to the adopter. Individuals were more likely to adopt a new mobile gift service when the service was introduced by a contact that filled a structural hole (Kim & Park, 2011). Social hubs, people who have a large number of people with whom they are connected, adopted the use of a social networking web site sooner than non-hubs because social hubs were exposed to the innovation earlier than non-hubs (Goldenberg, Han, Lehmann, & Hong, 2009). Of those who had already adopted an Internet social networking site, people who had many friends had less influence on a friend's potential adoption than those who had few friends (Katona, Zubcsek, & Sarvary, 2011). When several technologies compete for adoption, strong ties in a network were shown to be a key determinant of technology adoptions (Suarez, 2005).

Adopters are more likely to adopt innovations that provide a high benefit to the community but a low benefit to the individual such as green farming techniques than innovations with a low community benefit but a high individual benefit (Deffuant, 2005). Soule (1999) explored the ineffective protest method of shantytowns on college campuses in the 1980s and found that individuals may adopt inefficient innovations in the presence of imperfect information and when the innovation correlates to the existing belief system and experiences of the potential adopter. The role of meaning that communities attach to an innovation was shown to hinder adoption (Fox, 2011). Theories used to ground the studies on the effect of social factors on adoption are listed in Table 3-5.

Table 3-5 Theories used to ground social connection research

Social Connection Factors	Theoretical Grounding
Collaboration	Activity Theory (Kaptelinin & Nardi, 2006)
Family and Social Structure	Socialization (Putney & Bengtson, 2002) Kinwork (Di Leonardo, 1987) Social Inequality (Zappala, 2000) Domestication of Technology (Silverstone & Haddon, 1996) Functional Equivalence (Postman, 1985)
Network Effects	Network Theory (Coleman, 1988)
Network Hubs	Interpersonal Network Hubs (Brown & Reingen, 1987)
Network Ties	Social Network Ties (Ahuja, 2000)
Social Learning	Social Learning (Bikhchandani, Hirshleifer, & Welch, 1998) Situated Learning (J. Lave & Wenger, 1991)
Social Prompts, Meanings, and Values	Conformity Theory (Lascu & Zinkhan, 1999) Source Attractiveness(McGuire, 1969) Threshold Model (M. Granovetter, 1978) Cognitive Agent (Conte, 1999; Ferber, 1999; Müller, 1996) Domestication of Technology (Silverstone, Hirsch, & Morley, 1992) Symbolic Adoption (Klonglan & Coward, 1970)

Micro Situational Factors

Micro situational factors are factors that are specific to the adopter at that particular point in time such as income level, task behavior, past experience or local of residence. These are affected by temporal elements. For example, utility is a variable in which an individual may reject an innovation today because a need does not exist, but a need may develop at another time. The theoretical groundings of the micro environmental factors found in the review are listed in Table 3-6.

Utility of an innovation often encourages adoption. Kim (2011) explored the hypothesis that utility of an Internet service increases as more users adopt Internet service. When a technology includes features that may not serve the adopter's immediate needs, additional features may encourage initial purchase, but those additional features can damage satisfaction, resulting in feature fatigue (Thompson, Hamilton, & Rust, 2005). Utility includes psychological and social needs. Pai & Arnott (2013) found users of an Internet social network site reported adopted the service to satisfy needs of belonging, hedonism, self-esteem, and reciprocity.

The role of task in the adoption decision is similar to the role of utility. The Task-Technology Fit model from information technology explains that technology is more readily adopted when it matches the tasks to be performed (Goodhue & Thompson, 1995). One study showed adoption of e-books by academics was dependent on the user's perception of e-books performance (D'Ambra, Wilson, & Akter, 2013). Adopters' concerns over future problems with an innovation have been studied using a discipline-specific, concerns-based adoption model that is often used to study education innovations (Hall & Hord, 2006; Christou, Eliophotou-Menon, & Philippou, 2004; Tunks & Weller, 2009). Another study showed that concerns regarding cybersecurity discouraged adoption of services that require a high level of interaction between the provider and customer via the Internet (Wünderlich, Wangenheim, & Bitner, 2013).

Table 3-6 Theories used to ground micro environmental factors

Situational Factors	Theoretical Grounding
Attitude Toward an Innovation	Concerns-based Adoption Model (Hall & Hord, 2006) Determinants of Employee Behavior (Vroom, 1964) Offset Hypothesis (L. B. Lave & Weber, 1970)
Communication	Temporal Distance Theory (Trope & Liberman, 2003; Wright & Weitz, 1977) Two-Step Flow Model of Communication (Katz & Lazarsfeld, 1955; Katz, 1957) Media Richness Model (Daft & Lengel, 1986)
Economic Substitutes	Economic Principle on the Substitution of Labor and Machinery Random Utility Theory and Discrete Choice
Geography	Social Capital (Portes, 2000)
Resource Efficiency, Allocation, and Optimization	Resource Matching Theory (Anand & Sternthal, 1990) Social Planning and Operational Optimization Models (Messner & Strubegger, 1994) ROI for Knowledge (Ratchford, 2001)
Risk, Ambiguity, Uncertainty, and Regret	Risk Aversion (Pratt, 1964) Ambiguity Aversion (Ellsberg, 1961) Coping Model of User Adaptation (Beaudry & Pinsonneault, 2005) New Product Uncertainties (Hoeffler, 2003) Anticipated Regret (Janis & Mann, 1977) Consumer Resistance to Innovation (Ram, 1987; Ram & Sheth, 1989) Expectations Disconfirmation Theory (Oliver, 1980)
Task	Task-Technology Fit Model (Goodhue & Thompson, 1995) Activity Theory (Kaptelinin & Nardi, 2006)
Utility of an Innovation	Productivity of Technology Adoption (Glass, 1999) Uses and Gratifications Theory (Katz, Blumler, & Gurevitch, 1973) Discrete Choice Model (McFadden & Zarembka, 1974) Innovation Utility (Davis et al., 1989) Automation Tolerance (Crosby, Evans, & Cowles, 1990) Lancaster Model of Additive Utility Function Applied to Product Attributes (Lancaster, 1971)
Time Investment	Deferral Option Theory (Dos Santos, 1991)

Decision science has contributed theories on risk (Pratt, 1964), ambiguity aversion (Ellsberg, 1961), regret (Janis & Mann, 1977), and expectations (Oliver, 1980). Farmers were more likely to quickly adopt a genetically-modified crop if it reduced the ambiguity of pest damage than a genetically-modified crop that did not (Barham, Chavas, Fitz, Salas, & Schechter, 2014). Shih & Schau (2001) founded that people were less likely to adopt an innovation when they anticipated an upgraded version of the original innovation will soon be available. A common situation would be a person not adopting a mobile phone version 2 because version 3 will be on the market in a year. This may also be a reason to avoid a cognitive investment of learning a technology because another technology will soon be available or also sticking to a known technology to avoid the threat of expected constant upgrades. The slow adoption rate of Microsoft's Windows 10 operating system was due to the deeply-entrenched usage of Windows 7 (Newman, 2015).

The decision to adopt an innovation is often based on trade-off balances between the benefits and costs of adoption. Costs include the time to learn the technology and return of the investment when learning a new technology (Yang & Ching, 2014). Ma & Chen (2015), the only simulation found in the literature, used operational optimization models (Messner & Strubegger, 1994) to model trade-offs between infrastructure initial investment cost, learning potential, and innovation efficiency.

How potential adopters learn about an innovation determined the probability of innovation adoption. Lee, Lee & Schumann (2002) investigated how and where individuals learned about automatic teller machines and the process of machine adoption. Non-adopters were less likely to receive information about an innovation. Negative reviews of an innovation were shown to more strongly discourage innovation adoption than positive word-of-mouth communications encouraged adoption (Nam, Manchanda, & Chintagunta, 2010).

Application

This project emerged because field results related to the adoption of services requiring mobile devices were not explained by traditionally applied models based on DoI and TAM. Innovation theory can be used in the design of services, as demonstrated by digital payments. Because customers are typically comfortable using cash, a credit/debit card, or a check as payment at the corner store, an engineer must design digital payments services to encourage customer comfort when using a smartphone as a payment device. Some users may readily adopt the technology, but other users may not be as comfortable adopting this innovation. Can security concerns be minimized by providing support to learn the system? Will an economic incentive drive adoption? Can further training by bank personnel help ease concerns about the service? Human factors professionals can address these and other innovation adoption questions. By developing a framework for determinants of innovation (i.e., macro-situational, adopter, and innovation), human factors professionals can systematically analyze innovation adoption situations.

This review and resulting typology can be applied when determining variables to explore in big data models. Since the research on individual-level adoption spans many disciplines, determination of factors to include in big data models has been challenging. This research provides a framework for mathematical modelers to use when designing prediction models of adoption for individual innovations.

Conclusion

Innovation adoption, the use of a new idea, product, process or tool, fits in the domain of human factors. But the research covers numerous fields and has not been organized in a manner to encourage access to human factors professionals. This literature review addresses this gap. By focusing on the theoretical groundings of the various studies, the authors were able to create a framework for human factors professionals dealing with individual-level innovation adoption issues.

The primary purpose of this research was to sample multidisciplinary literature from the vast body of individual-level innovation adoption research. Theories that grounded the research were noted from each article. Using a sample of 98 articles from 2000 to 2015 and the DoI model and the TAM, a typology of determinants of adoption was developed. For the benefit of human factors professionals, the adopter determinant that addressed human factors were thoroughly explored. Human Factors included the categories of personal factors, social connections, and micro situational factors.

With the development of IoT technology and the growth of services such as fitness and remote medical monitoring, this review and typology will help human factors professionals apply the rich and varied research tradition of individual-level innovation adoption.

Limitations

Each academic discipline has unique research standards and methods. As result, comparing research across disciplines is difficult due to the wide range of research methods. This typology doesn’t attempt to judge the significance of the factors presented. Instead the authors’ goal was to provide a listing of possible factors of individual-level innovation adoption that human factors professionals can apply in their work. This work doesn't attempt to comment on the validity of any theory currently used in innovation research.

Chapter 4 - Determining What Seniors Contribution to the Co-Production of Healthcare Services

The paper was presented at the 2015 Industrial and Systems Engineering Research Conference in 2015 in Nashville, TN. It was published in the *Proceedings of the 2015 Industrial and Systems Engineering Research Conference*, S. Cetinkay a and J.K. Ryan, eds.

Abstract

The number of Americans over the age of 65 is expected to almost double over the next 30 years. In order to deal with this increase and gain efficiency, healthcare providers will be required to develop new services and update current services. Service science theory defines services as a co-production between the provider and the consumer. In order to develop efficient systems, healthcare engineers and designers need to understand what the consumer is contributing to the service production. This is important in healthcare services where better outcomes have been found when patients participate effectively with their doctor. Using a survey of 160 older Kansans who live independently, the authors found the participants perceived their doctor's office as the best place for their healthcare needs, were comfortable interacting with and interrupting their doctors, and were comfortable using memory assistance strategies such as note taking or bringing someone for cognitive assistance. This survey was originally designed to test the efficiency of a county public health program and has a balanced mix of poverty, age and education levels. This research will be used to understand and build more efficient healthcare services in Kansas, which could be also adopted by other states.

Keywords: service engineering, human factors, aging, healthcare systems

Introduction

In the coming few years, the United States is facing the aging of the baby boomers and numerous service systems will be affected by this demographic shift. Health care is one system that will be greatly stressed in its current state by the large number of customers with the new healthcare needs and expectations. But health care is not alone. Financial services, technology services including internet and mobile phone providers, transportation services and numerous personal services are going to have to adjust for the aging baby boomers' changing needs. But little is known on how older adults interact with a service system especially when the system requires cognitive capabilities on the part of the older adult. In this paper the authors address the difficult question of customer-provided cognitive inputs of older adults in service systems.

Using a data set that tested health literacy in 160 respondents between the ages of 60-96, we applied grounded theory practice to explore issues about the needs of this aging population that should to be considered in future service modeling and design. This is important as engineers build more efficient and effective service systems that combine people and technology.

The data is drawn from the healthcare field. Older adults have much different expectations from healthcare systems than when they were younger. This shift in system expectations on the part of the customer is occurring at time when healthcare costs and payment systems are also changing. As a result policy leaders, healthcare professionals and customers are all looking for opportunities to create both efficiency and improved quality of service.

In this paper, the authors first address the demographic shift as the baby boomers age. The role of health literacy as a cognitive input of a healthcare system is explained. While health literacy was measured in the data set, this discussion can be generalized to a number of fields that require cognitive capabilities such as financial literacy or technology literacy. The theory of service production provides a model of the role customers play in the service processes. Using data from a specific study in health literacy, an understanding of what older adults are supplying to the production process can be determined. This discussion can help develop future research regarding both older adults and service design and engineering.

The Aging of America's Baby Boomers and the Effect on Healthcare

The United States' population, along with the rest of the world's, is aging at an unprecedented numbers. The U.S. Census Bureau reported that in 2010 40.3 million Americans were aged 65 and older and made up 13 percent of the total population (U.S. Census Bureau, 2014). By 2040, this segment of the population, fueled by the aging of the Baby Boomers, is expected to grow to 79.7 million or 21 percent of the total population (Administration on Aging, 2013). That demographic shift has important implications to the social, economic, political and health policies of the United States.

While the older population is expanding in part due to the aging of the Baby Boomers, the generation born between 1946 and 1964, improvements in health care have led to increased life expectancies and economic development has led to lower fertility rates (U.S. Census Bureau, 2014). The decrease in fertility rates creates a change in the age structure of the United States population. Fewer young people are available to support and care for a large number of older adults. The dependency ratio estimates the stress that non-working members of society put on the working members. In 2010, each older person was supported by four and a half working-age people. In 2030, each older person is expected to be supported by fewer than three people of working age (U.S. Census Bureau, 2014).

Health care for this growing, older population creates many challenges for the U.S. society. Median annual out-of-pocket healthcare expenses for adults aged 65 and over are projected to more than double in constant dollars between 2010 and 2040. Long-term care, which is often provided by nursing homes, is required for people who have prolonged physical illness, disability or severe cognitive impairment that hinders daily function. This care is costly with the yearly average cost of $83,585 in 2010 (U.S. Census Bureau, 2014). Alternatives to nursing home care include assisted living facilities with an annual average cost of $39,516 (U.S. Census Bureau, 2014).

Health Literacy

The healthcare system, especially for older adults who face more complex, complicated or chronic conditions, provides an individualized, customized service. But the quality of that service depends heavily on the older adult's cognitive abilities regarding healthcare information. Health literacy is defined as the capacity to find, understand and use basic health information and services needed to make appropriate health decisions (U.S. Department of Health and Human Services, 2000). Health literacy can be used as a measurement of what patients input into a healthcare service process.

Healthcare activities that require moderate to high health literacy include but are not limited to patient-physician communication, drug labeling and medical instructions, health information presentation such as webpages and publications, informed consent, medical and insurance forms and providing patient history (U.S. Department of Health and Human Services, 2000). Health literacy requires a range of abilities beyond basic literacy (U.S. Department of Health and Human Services, 2000). The cognitive tasks that are required in health literacy are shown in Figure 4-1. Recent literature has focused not only on individual's health literacy but also the health literacy-related demands of health care systems (Baker, 2006; IOM, 2012). This has also led to the recognition that system requirements need to fit the abilities of the patients (IOM, 2012; Rudd, 2010).

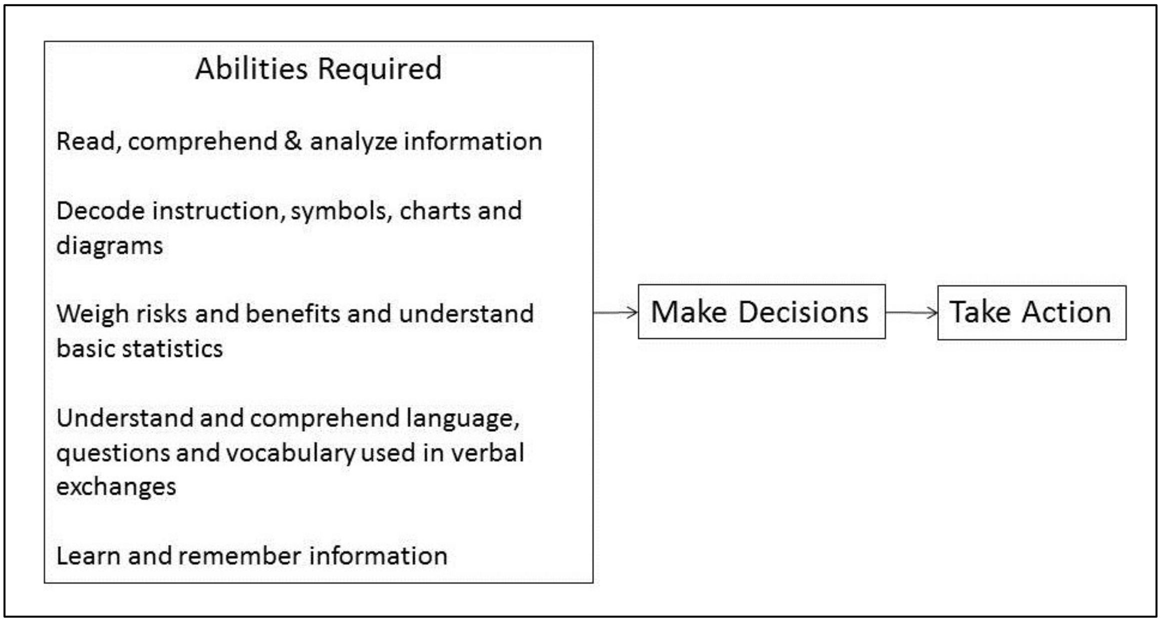

Figure 4-1 Cognitive tasks required for health literacy

The problem of dealing with health literacy is more acute when dealing with older adults. Aging affects the cognitive and physical abilities such as hearing and sight differently for each patient. Therefore, health literacy of older adults may be a dynamic capability. There would then be variation between patients and variations of health literacy within patients over time. These physical and mental changes often coincide with the patient's increased use of healthcare services.

While health literacy may be an unusual input into a service system to traditional systems designers, the results of low health literacy were estimated in a 2009 study to be between $143 and $7,798 per patient with low health literacy compared with patients with adequate health literacy (Eichler, Wieser & Brugger, 2009). Before looking closely at what level of health literacy older adults feel that they are inputting into the healthcare service, a model of service production is needed to explain the role of health literacy.

Service Science Theory

Services can be examined using theories originating from service science research. Many of these theories use industrial engineering concepts to explore both quality and efficiency in services. An important aspect of this research is a definition of services that provide the solid intersection that allows engineers to apply their domain theories to customer aspects of services such as health care. The Unified Service Theory defines services as production processes wherein each customer supplies one or more input components for that customer's unit of production (Sampson, 2010). This definition is in agreement with the widely- held acceptance that the services are unique in the involvement of customers in production processes by supplying and controlling the inputs of the process (Spohrer & Maglio, 2008).

When customers are added to the production process what was a traditional input/output model is transformed with the customer being both a supplier and a consumer of a process (Sampson, 2010). The inclusion of customer inputs creates the difference between services and non-services. It also greatly affects the processes that are used to create the output (Figure 4-2).

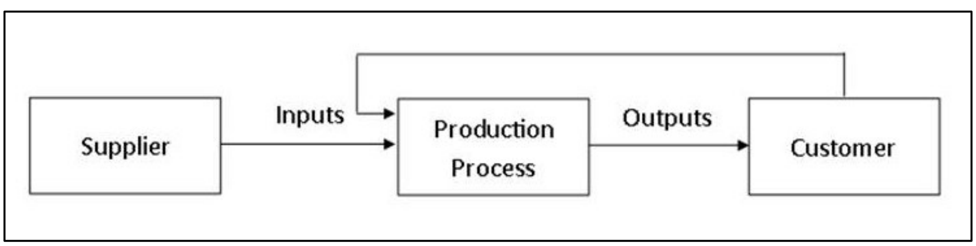

Figure 4-2 Service I/O model

These customer inputs include customer-self inputs, tangible belongings and customer-provided information (Lovelock, 1992). Customer-self inputs require the physical presence of the customer, which can be further separated into either bodily or cognitive inputs (Lovelock, 1992). The inputs of tangible belongings are physical objects that can be transformed in the production process such as repairing a car or cleaning a house. The last type of inputs is information inputs where information provided by the customer is transformed into another output (Sampson & Froehle, 2006). This includes big data services where raw data from the customers is analyzed into meaningful conclusions.

The type of input (customer-self, tangible belongings, information inputs) dictates the customer contact with the production process. According to customer contact theory, the service production system is greatly affected by the amount of customer interaction (Chase & Tansik, 1983). Customer contact is defined as the percentage of time a customer is in the system relative to the total service time (Chase & Tansik, 1983). Customer contact theory suggests that the less direct contact the customer has with the service system, the greater the potential of the system to operate at peak efficiency (Chase, 1981). If a system has a high level of customer contact, it has less potential to achieve high levels of efficiency.

Customer contact drives efficiency in a service process because customer inputs impact the production process by introducing variability, which is referred to as customer intensity (Sampson, 2010). This is the rationale behind the service operations strategy of reducing costs by reducing customer intensity. To truly understand the service process, the engineers designing service systems need to understand the sources of customer variation and the contact a customer has with a system.

Designers of healthcare services have the possibility of dealing with a high degree of customer intensity along with highly variable levels of health literacy, an important customer input. The time spent in face-to-face discussion with a doctor demand a high degree of system resources – namely the doctor's time. This situation has led healthcare providers and public health departments to address the issue of health literacy within older adult populations. It is hoped that patients can contribute more effectively if they have adequate health literacy and therefore the system will be more efficient.

Method

The data originated from a study to improve health literacy in adults over the age of 60. The study was done by the Johnson County, Kansas Department of Health and Environment during the spring and summer of 2014. The study was funded by a grant from the Health Care Foundation of Greater Kansas City. One of the project's goals was to find a best-practice approach to increase older adults' skills in working with healthcare providers. It was this goal that interested the authors since it pertained to the skills that older adults use in the production of a healthcare service.

The study used the book What to do for Senior Health. Participants were divided into two groups. One group received the book and training on health literacy; the other group received only the book. A pre-treatment evaluation was done before book distribution. A month after the distribution of the book and possible training, a post-treatment evaluation was completed to measure any increase in health literacy. The study found that the participants had a high level of health literacy.

For this study's purposes, the data was analyzed after the original study had been completed. The authors also analyzed only the pre-evaluation results. This was chosen since it was the most naturalistic setting. The authors only had access to the variables that the Johnson County researchers collected. The authors also had no input into the research design.

This data set that was provided had 160 respondents and it would have been difficult and expensive to replicate for the purposes of studying what older adults contribute to service systems.

Participants

The respondents were residents of metropolitan Kansas City area including Johnson and Wyandotte counties in Kansas and Jackson and Cass counties in Missouri. Participants were recruited from senior centers, senior apartments, subsidized housing, the Landon Center on Aging, churches and branch library locations. The participants were given a gift card for their participation.

Two hundred four adults aged 59-96 participated in the original study. After removing missing data, 160 respondents aged 60-96 were analyzed. This data did not include subjects who reported cognitive decline. None of the 160 respondents lived in a facility such as assistant living. 48.1% (n=77) reported living in poverty as defined by the definition of the Federal Poverty Limit which was $11,670 in income for a single member household. From the data it could not be determined if these respondents had savings. The majority of respondents (65.63%, n=105) reported having attained at least some college. The gender of the respondents was not included in the data set provided.

Results

The authors focused on seven questions from the survey that highlighted the respondents self-reporting behaviors regarding health literacy. The remaining questions were true/false questions that addressed general health knowledge. For example question number 6 asked if "Most falls that seniors have take place at home." Since in this paper a grounded theory lens was applied, the authors looked mainly at frequencies of the answers given before a treatment was applied. This reflected what the respondents felt were inputs into their service system.

No matter what the question, this group reported they were providing the positive inputs necessary for the production of a successful service encounter (Table 4-1). The majority

(88.75%) of respondents agreed or strongly agreed that they were comfortable filling out forms at the doctor's office. Over 90% of the respondents reported agreeing or strongly agreeing that they were comfortable following doctor's instructions (92.5%); that they were comfortable writing a list of questions or concerns prior to a doctor's visit (90.625%); and that they were comfortable interrupting the doctor if they didn't understand what the doctor was telling them (95%). The majority of respondents also agreed with general health literacy statements including the doctor's office is the best place for most of their healthcare needs (72.5%); that patients should bring someone else to appointments to help when patients have trouble understanding the doctor (95%); and the activities that make up a checkup (94.38%).

Table 4-1 Health literacy questions

Question	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am comfortable filling out forms at my doctor's office.	4 (2.50%)	5 (3.13%)	9 (5.63%)	80 (50.00%)	62 (38.75%)
I am comfortable following my doctor's instructions.	2 (1.25%)	1 (0.63%)	9 (5.63%)	83 (51.88%)	65 (40.63%)
I am comfortable writing a list of questions or concerns prior to my doctor visit.	2 (1.25%)	2 (1.25%)	11 (6.88%)	65 (40.63%)	80 (50.00%)
I am comfortable interrupting my doctor if I do not understand what he or she is telling me.	3 (1.88%)	2 (1.25%)	3 (1.88%)	69 (43.13%)	83 (51.88%)
	True			False	
Your doctor's office is the best place for most of your healthcare needs.	116 (72.50%)			44 (27.40%)	
If you find it hard to understand your doctor, you should bring someone with you to help.	152 (95.00%)			8 (5.00%)	
There are four parts to a checkup with your doctor: (1) health and family history, (2) body measurement, (3) tests and (4) advice.	151 (94.38%)			9 (5.63%)	

Discussion

The research question focuses on exploring the cognitive inputs older adults were contributing to a service system with the goal of building better models and designing service systems for older adults. While the data set focused on measuring health literacy, when viewed using the lens of service science, health literacy can be considered a customer input. The health care system is designed for a customer with a specific level of health literacy even if it is not formally acknowledged. The data showed the respondents had a high level of health literacy. There were no statistically significant differences in answers between the different treatment groups.

In the data set, the majority of the respondents self-reported that they behaved in a way that would create a successful service production. The authors were not concerned whether the respondents truly did have the cognitive skills they reported. That would require a different research design. The authors are concerned that the respondents believe that they contributed the inputs necessary for service production. In a service process, it is hard to measure the quality of customer inputs. If different subjective measurements of customer inputs are used by the producer and the customer, it is hard to determine whether an input is useful or not. Customer-provided information inputs that are often used in healthcare services are subject of great variability due to varying communication levels or the moods of the customer and the producer (Sampson & Froehle, 2006).

Age can affect the cognitive abilities of customers and therefore the inputs that a service production may require. Aging can improve some decision-making skills such as those requiring experience. These include tasks that an older adult might have done repeatedly for a long time such as cooking. Some decision-making skills like problem solving decline with age (de Bruin, Parker & Fischhoff, 2012). Therefore, it is important that customers have strong information regarding the input requirement standards of a system. It is also required that the customers understand those requirements and can adequately measure their inputs.

Proposition 1: Older adult customers who are unaware of the specific cognitive inputs required by a service system may assume they are providing what is necessary and therefore, be unhappy with the final service outcome.

Cognitive Measurements

Often education level is used by designers and modelers as a measure of cognitive ability. This is often done due to the correlation between cognitive ability and education level. As people age, cognitive abilities such as memory attention, spatial cognition and language comprehension change. But education does not slow down cognitive decline (Zahodne, Glymour, Sparks, Bontempo, Dixon, MacDonald & Manly, 2011). Individual cognitive functions are affected differently by age. Semantic memory doesn't decline heavily with age but working memory does decline with age (Fisk, Rogers, Charness, Czaja & Sharit). College education levels do not measure the cognitive requirements such as working memory needed for a specific service system. An example of this would be if a medical service provider asked if a patient took medication that day. Therefore, a college education is not a good measure of the cognitive function required for that task.

Proposition 2: In service systems, cognitive ability requirements for older adults should not be described using education levels. Instead cognitive abilities should focus on requirements of the task at hand.

Cognition function is dependent on other physical sensory systems that may decline over time such as touch, sight and hearing. Hearing and vision have both been found to decline with age (Fisk et al, 2009). Since sensory systems provide the needed inputs for cognition, it is vital to recognize if sensory decline is responsible for what is believed to be a cognition failure. Therefore sensory system declines may be confused with cognitive declines. Sensory declines can often be dealt with by using environmental adjustments such as increased lighting, increased contrast, hearing aids, etc. Designers of service systems must be attuned to the demands of the sensory systems of older adults (Fisk et al., 2009). A service customer can't be expected to understand written instructions if the font is too small to read.

Proposition 2b: In service systems, sensory requirements should be teased away from cognitive ability requirements when considering older adults system inputs.

Resource measurements

As found in the data, income as a variable is very different among older adults. The results from our data set show how complex older adults can be. Often poverty is correlated with education level. In the sample 27.50% who reported living in poverty also reported some college compared with 20.63% who reported living in poverty and not attending college (Table 4- 2).

Table 4-2 Poverty and education frequencies

Table 2: Poverty and education frequencies

	No college	Some college
Poverty	20.63%	27.50%
Not Poverty	13.75%	38.13%

Income is often used as a proxy variable to measure available resources. Retired people have more complicated financial situations than working members of the community. Retired people may have income from pensions, investment, savings, social security and other resources. It is also unknown what their expenses may be in regard to their fixed income. Price sensitivity may vary greatly and may be unknown. It is also unknown who is paying for services whether it is the customer, family members, Medicare and insurance providers. This affects customer inputs regarding any supporting infrastructure that may be required to produce the service such as internet connectivity and medical devices.

Proposition 3: When determining resources required for customer inputs, income is not a reliable measurement of financial resources of older adults.

Conclusion

As the U.S. population ages, service systems will need to adjust to the changing needs and abilities of the older adults. Further research is needed into the inputs that older adults supply to service systems. These need to be outlined in terms of the cognitive and physical abilities of the customers. Once it is determined exactly what inputs are required in service production, then service designers can explore possible substitutes between human capabilities and technology capabilities.

Acknowledgements

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Chapter 5 - Cutting the Cord: A Process Model of Individual-Level Service Innovation Adoption

An abstract for this paper has been submitted to the 2017 Industrial and Systems Engineering Research Conference in Pittsburgh.

Introduction

Theories developed using goods-dominant logic (Vargo & Lusch, 2004) may not adequately explain specific phenomenon occurring in human-centered service systems. Assumptions based on individual-level innovation adoption theory did not hold in the authors' human factors engineering field work exploring ways to design easily-adoptable mobile health service systems. According to the Pew Research Center (2014), 77 percent of American adults 65-years-old and older had adopted mobile telecommunications service. Based on this and similar reports of wide-spread adoption, using mobile telecommunications service as a platform for a mobile health service system seemed a reasonable assumption. Early in the exploratory research, individuals were asked how they adopted and used mobile telecommunications service systems. The answers did not fit the traditional two-state individual-level innovation adoption model (Figure 5-1). The authors found that users toggled between a legacy system (landline telecommunications service) and an innovative system (mobile telecommunications service) thus complicating any designs. Failing to factor in the continued use of landlines by mobile phone users caused the authors to overestimate the co-production levels of older adults. To improve mobile health designs, the authors needed to understand how people, no matter the age, were interacting within telecommunications service systems. Designers and developers of Internet of Things (IoT) service systems require an understanding of the consumers' use of mobile telecommunications service in order to determine co-production specifications. A more accurate model is needed to describe the process of optional, individual-level service system adoption needed.

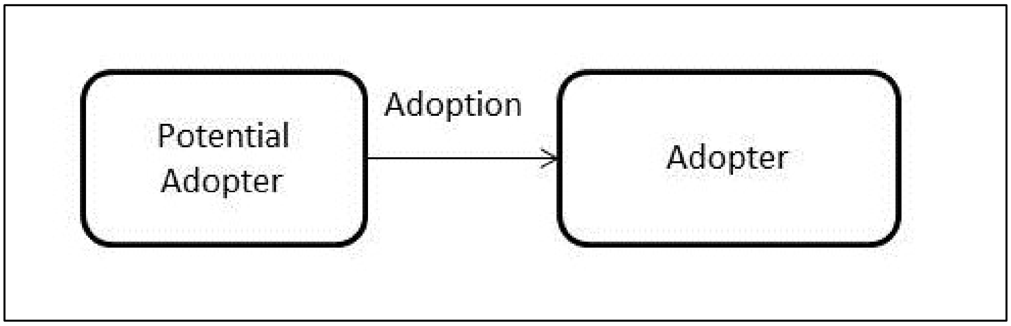


Figure 5-1 Two-state model of the individual-level innovation adoption process.

Innovation scholar Ronald Burt pointed out that innovation adoption is about both accepting the new and detaching from the old (Burt, 2000). In the case of adoption of mobile telecommunications service, Americans adopted the mobile phone service but were slow to abandon the legacy service system of landline telecommunications. In 2015, the United States Centers for Disease Control and Prevention (CDC) estimated that 41.2 percent of U.S. households had both landline and mobile telecommunications service (Blumberg & Luke, 2016).

Mobile telecommunications service adoption and the resulting abandonment of landline systems had caused problems for the CDC. Since 1957 it has collected data using personal interviews as part of the National Health Interview Survey (NHIS). The interviews, which are conducted continuously throughout the year, collect data on health status, health-related behaviors, health care utilization and telephone usage. The adoption of mobile telephones concerned statisticians and pollsters who conducted random-digit-dial telephone surveys that rely on landline service. For years the NHIS had dealt with the potential of under-coverage of adults without phone service. As Americans started abandoning landline telecommunications service and relying solely on mobile service, the CDC grew concerned about new threats of bias. Beginning in 2003 the NHIS included questions regarding mobile telecommunications service.

As a result, the CDC's NHIS provides the most up-to-date estimates available from the federal government concerning mobile telecommunications usage (Blumberg & Luke, 2007).

To better describe the service innovation adoption behavior that was found in the field, a three-state process model of optional, individual-level adoption of an innovative service system is presented. The case of mobile telecommunications service adoption is used to test this model.

Optional, Individual-level Innovation Adoption Models of Service Systems

The subject of service innovation has been popular in research. Recent research on innovation creation included work in professional services (Breidbach, Smith & Callagher, 2013; Kallio & Lappalainen, 2014); health care (Krishnan, Maki, Castillo, & Guss, 2015; Thune & Mina, 2016; Wallin, Harjumaa, Pussinen & Isomursu, 2015); innovation design and development (Andreassen, Kristensson, Lervik-Olsen, Parasuraman, McColl-Kennedy, Edvardsson & Colurcio, 2016; Lusch & Nambisan, 2015; Sawatani & Fujigaki, 2014;) and the role of co-creation in the innovation process (Lessard, 2015; Wetter-Edman, Sangiorgi, Edvardsson, Holmlid, Grönroos & Mattelmäki, 2014). Few researchers using the service science lens have focused on service adoption by consumers. In the research that has been done, factors including enjoyment (Koenig-Lewis, Marquet, Palmer & Zhao, 2015), convenience (Collier & Kimes, 2013), and relevance (Malhotra & Malhotra, 2009) have been found to effect the decision to adopt service innovations. Ordanini, Parasuraman & Rubera (2014) determined that a combination of attributes, rather than single attributes, drives new service adoption. No research using service-dominant logic was found that explored the process of optional, individual-level innovation adoption of a service innovation.

Innovation adoption and diffusion theory

Innovation adoption research explores how an individual accepts and uses a new idea, practice or object (Roger, 2003). Innovation diffusion, the spread of a new idea, practice or object through a community, works at a higher level of analysis than adoption research. In applied work, diffusion research examines the spread of the knowledge and use of an innovation through a specific population over a time period (Rogers, 2003). Product and service designers apply both adoption and diffusion research to build new products or services that are easily accepted and used by consumers.

Theories explaining optional, individual-level innovation adoption reflect a variety of disciplinary research streams including sociology, behavioral economics, management of information studies and marketing. Theories used in variance research divides individuals into two categories: adopters and non-adopters (Davis, 1989; Venkatesh, Morris, Davis & Davis, 2003; Rogers, 2003). The two groups are compared based on who adopts, what is being adopted, where the adopter fits in the social network, when individuals adopt and why individuals adopt. Process research in innovation adoption explores the decision-making process (Rogers, 2003) or the process of incorporating technology into daily life (Silverstone & Haddon, 1996; Silverstone, Hirsch & Morley, 1992).

Diffusion models can provide some insight into the adoption process. The Bass (1969) growth model of diffusion considers the effect of external information sources on the rate of moving from ‘Potential adopter’ to ‘Adopter’. The Bass model is widely used to predict new product sales (Sterman, 2000).

These traditional theories are based on a simple model of an adopter’s behavior. In a population of potential adopters at time zero, an individual starts at the state of ‘Potential adopter' then as time progresses individuals move to the state of 'Adopter' or remain at the 'Potential adopter' state (Figure 5-1). This two-state model is central to innovation research and modeling. For an in-depth description of modeling the innovation adoption process, see Chapter 9 of Sterman (2000).

Compartment Systems Models

The two-state 'Potential adopter/Adopter' model is a basic compartment system model. These models are useful when a system can be divided into separate subsystems or compartments where the units of analysis flow or transition between compartments and/or the outside environment (Godfrey, 1983). Originally scientists used these models to describe the diffusion of salts between two containers of liquids. The mathematical principles that describe the movement between compartments are based on first-order differential equations (Sterman, 2000). The system can be modeled as either a closed system without movement from the outside environment or an open system, which includes births and deaths.

Social scientists realized the value of compartmental system models and employed them to describe the spread of a variety of phenomena through a population including revolutions (Lang & De Sterch, 2014), infection (Kermack & McKendrick, 1927) or new products (Bass, 1969). A benefit of using compartmental systems model in innovation adoption is that it connects the individual-level process of adoption with a population-level description of the diffusion of an innovation (Kretzschmar & Wallinga, 2010).

In innovation models the compartments are defined by the possible states of adoption of the individual. Two-compartment models are binary models with compartments defined by an individual's adoption or non-adoption. These models often reflect goods-dominant logic since the metric used to measure adoption is sales and market penetration of an innovation. Little knowledge is gained on how the consumer is using this service to co-create value.

The compartments can be compared based on the fraction of the compartment's population over the total system population. The rate of transfer describes the movement between the compartments. In the simplest models, the rates are constant over time although this is not necessary (Kretzchmar & Wallinga, 2010). Three characteristics that are necessary for compartments are homogeneity, definition and being well-mixed (Godfrey, 1983).

The two-compartment model for innovation diffusion is uniquely S-shaped (Figure 5-2) (Sterman, 2000). Often in innovation diffusion, only one curve, the growth curve, is presented. S-shaped diffusion curves are specific to the innovation (Rogers, 2003; Ryan & Gross, 1943; Tarde, 1969). The growth curve represents the population changes in the 'Adopter'. The second curve represents the change in the 'Non-Adopter' population and mirrors the growth curve. Often this curve is not included on the diffusion graph. This graphical description only applies to innovations that have successfully diffused through a population. Unsuccessful innovations are seldom researched (Rogers, 2003). Some innovation adoption processes are better described with a more complex model. Sterman (2000) extended the two-compartment model and suggested that a three-compartment model described the diffusion of a fad or a fashion (Figure 5-3). Three-compartment models have been used in epidemiology to explain the spread of a disease. The Susceptible-Infected-Recovered (SIR) model categorizes individuals of a population as susceptible to infection, infected or recovered (Kermack & McKendrick, 1927; Kretzschmar & Wallinga, 2010). The SIR model was not designed as a forecast model but is better suited to measure the effect of interventions, such as vaccinations, that potentially change the rates of infection and recovery (Kretzchmar & Wallinga, 2010).

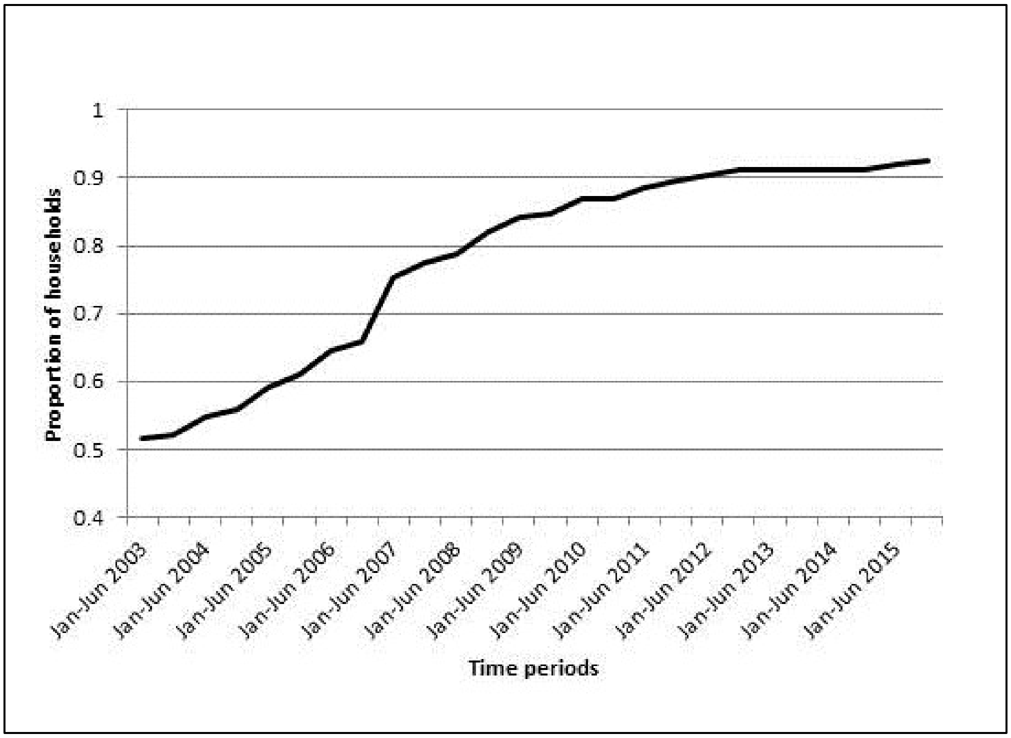


Figure 5-2 Proportion of U.S. households with mobile telecommunications service 2003-2015.

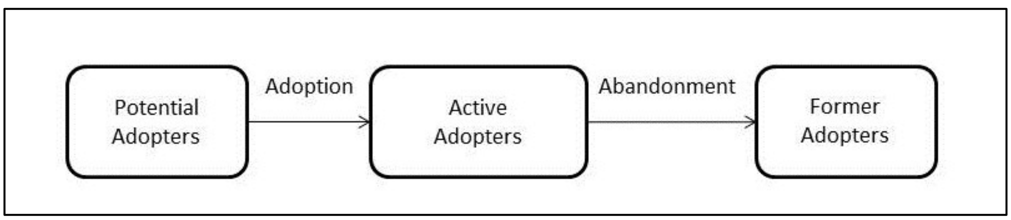


Figure 5-3 Three-compartment model of adoption and abandonment of a fad

Innovative Service Systems and the Effect of Legacy Systems

When service is modeled as a system (Maglio, Vargo, Caswell & Spohrer, 2009; Maglio & Spohrer, 2008), the adoption process addresses how a potential adopter enters a system. When an innovation is introduced that can replace a current service offering, the individual doesn't necessarily need to abandon the original service or legacy system in order to adopt the innovative service system. If willing to pay, an individual can often rely on both service systems – an innovative system and a legacy system. Adopters of roof solar panels, a self-serve system, are not necessarily giving up the security of the power grid. College students can take both an online class and an on-campus class. Unless forced by government or market players, individuals can satisfy their needs by participating in any number of similar and/or substitutable service systems.

The Diffusion of Innovation theory noted that ‘previous practice’ can affect the decision process of adoption (Rogers, 2003). Beyond suggesting it as a factor in the decision, the authors found no process research concerning the interaction of a legacy system and an innovation system in optional, individual-level innovation adoption literature. Legacy systems have been addressed in information science research but on the organizational level. Individuals within organizations are seldom given a choice to adopt an innovation. The popular press has reported on the optional adoption of particular software that replaces legacy software such as Microsoft’s attempt to get Windows 7 and 8 users to adopt Windows 10 (Chacos, 2016; Greene, 2016). Legacy systems may be overlooked due to pro-innovation bias that focuses on the new and ignores the old. This bias implies that an innovation should be diffused and adopted by all members of the community and it would be irrational not to adopt (Rogers, 2003).

Through interviews in the field the authors found that legacy systems played a role in the adoption of service innovations (Grego-Nagel & Rys, 2016). Instead of discovering that a legacy system was a factor in the decision to adopt a service innovation, which is a traditional focus of innovation studies, the authors found that legacy systems are part of the process of adoption. Adopters use an innovative system in some situations and a legacy system at other times before fully abandoning the legacy system. Therefore a three-stage process that allows for this behavior is being proposed.

Instead of limiting individuals to the two-compartments of 'Potential-adopter' and 'Adopter' states, three classifications can be used to describe the service system individuals were using. The beginning state is 'Legacy system only' where the individual only relies on the legacy system. At time 0 the 'Legacy system only' is where all individuals who use the legacy service system reside. Once an innovative system is introduced, individuals can reside in three possible states.

1) 'Legacy system only' – an individual only uses the legacy system and doesn't adopt the innovative system.

2) 'Legacy system & innovative system' – an individual uses both the legacy system and the innovative system.

3) 'Innovative system only' – an individual fully adopts the innovative system and abandons the legacy system completely.

During any given time period, individuals can transition between the states or remain in the current state. Individuals can choose not to adopt and can reside in any state indefinitely. Numerous paths are possible (Figure 5-4) but exploratory field research lead to the following formal hypothesis regarding the process individuals take when adopting a service innovation:

H1: When given a choice, an individual using a legacy service system at the time of the introduction of an innovative service system will transition to a period of being able to utilize both a legacy system and an innovative system before fully abandoning the legacy system and completely adopting the innovative system (Figure 5-5).

This hypothesis is tested using the case of the adoption of mobile telecommunications service in the United States that draws on historical data from the CDC and a survey the authors administered.

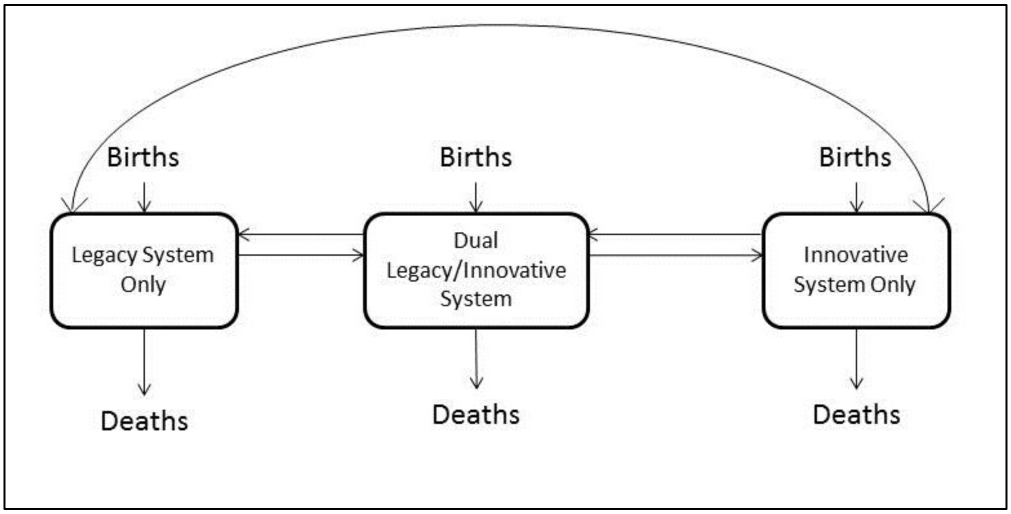


Figure 5-4 Possible transitions in three-state model of service innovation adoption.

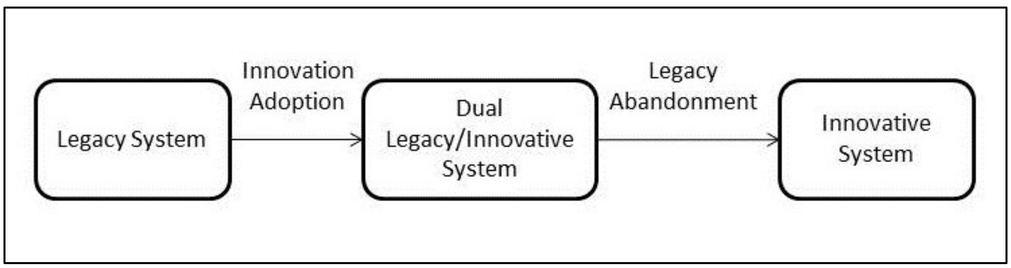


Figure 5-5 Expected transitions behavior in three-state model of service innovation adoption.

Mobile Telecommunications Service Adoption in the U.S.

Motorola introduced the first consumer mobile phone in 1984 (History of Motorola, n.d). Since then mobile telecommunications service has been accessible to the general population and has steadily gained acceptance. Now the service is ubiquitous in American culture. Along with adopting mobile telecommunications service, Americans have been abandoning landline services.

The federal agency that tracks telephone system usage is the Center for Disease Control. The data is collected through the National Health Interview Survey. The survey is designed to have a representative sample of the U.S. population. Twice a year the CDC releases data on the usage of telecommunications services. Between 2003 and 2015 the number of households surveyed per time period ranged from 16,524 to 22,438 with an average of 18,239 households. The large sample sizes control for random variation that may be present between and within groups. The data covers the periods between January-June and July-December (Blumberg & Luke, 2007).

The CDC classifies households in one of six categories based on telecommunications service use: 'Landline service only', 'Landline & wireless service', 'Wireless service only', 'Landline service with unknown wireless service', 'No landline service with unknown wireless service', and 'No telephone service'. The proportion of households in each category and total number of households surveyed are reported by the CDC. The majority of Americans fall into three categories (Figure 5-6).

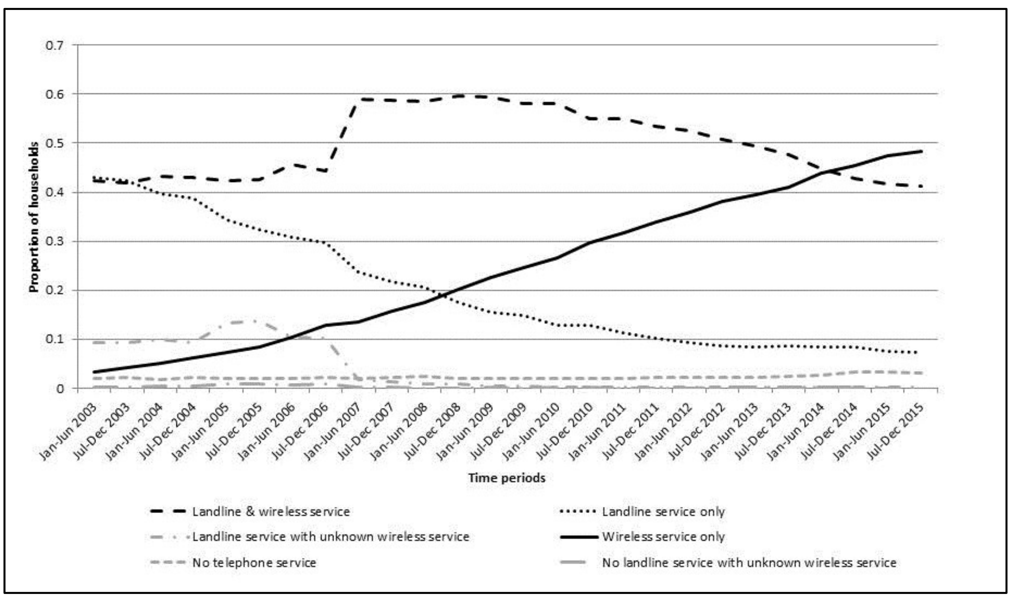


Figure 5-6 Proportion of U.S. households with various telecommunications services, 2003-2015.

In 2007, the questions regarding telecommunications service were changed to improve data collection. As a result fewer households reported a mobile telecommunications status of 'unknown' (Blumberg & Luke, 2007). During the period July-December 2006, 10.2 percent of households reported having an unknown mobile telephone status. As a result of the questionnaire's changes, that percentage dropped to 1.7 percent for the next reporting period. A corresponding increase occurred for the category of 'Landline & wireless service' (Figure 5- 6).

Using the CDC's classification structure, three compartments based on telecommunication systems usage can be constructed. Households with unknown wireless status were treated as missing data and were therefore removed. Since our population of interest is consumers of telecommunications services, the group classified as 'No telephone service' is removed from the model. Between 2003 and 2015, this group ranged from 1.8 percent to 3.4 percent of the U.S. population. After those categories were removed, the proportions for the three remaining categories ('Landline service only', 'Landline & wireless service', 'Wireless service only') are recalculated (Figure 5-7). These three groups make up the system's compartments in an adoption model.

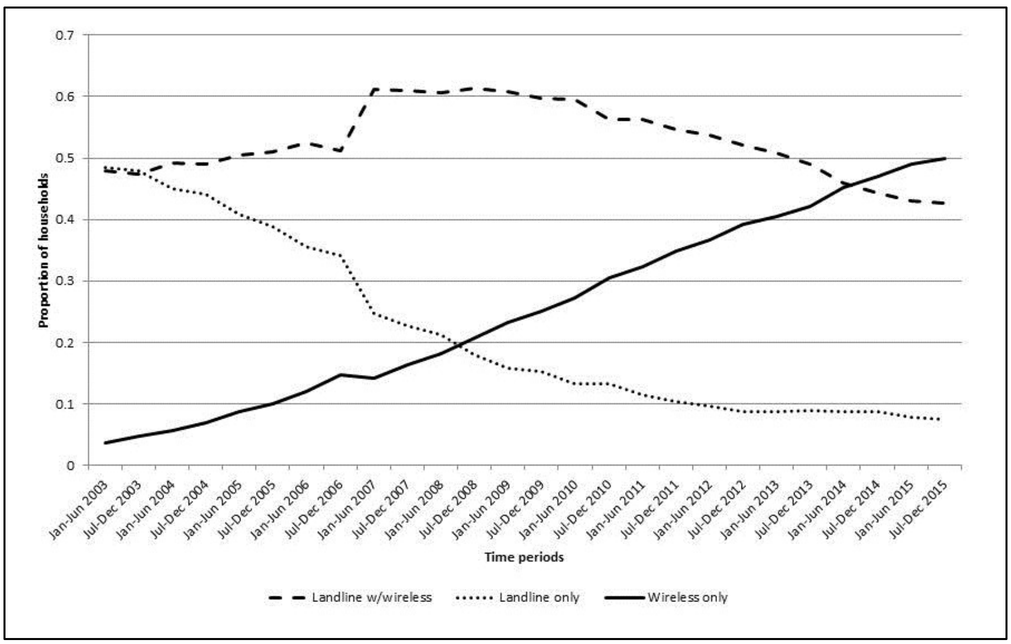


Figure 5-7 Adjusted proportions of U.S. households with various telecommunications services, 2003-2015.

Unfortunately the CDC did not begin collecting this data until 2003, 18 years after consumers started adopting mobile telecommunications service. Therefore, data from the early period of diffusion is missing. Fortunately the data available covers important points in the adoption process. Between December 2003 and June 2004, the proportion of households with ‘Landline & wireless’ service exceeded the proportion of households with ‘Landline only’ service. The proportion of households with ‘Landline & wireless’ service peaked at 61.3 percent in the July-December 2008 period. Between June and December of 2008, the proportions of households with ‘Wireless only’ service exceeded the proportion of households with ‘Landline only’ service. By mid-2014 the proportion of households with ‘Wireless only’ service had overtaken the proportion of households with ‘Landline and wireless’ service. During the 13 years that are covered, the percentage of households that had abandoned landline service completely for ‘Wireless only’ service grew from 3.6 percent in 2003 to 49.9 percent in 2014 (Figure 5-6). While the data from the beginning of the adoption period is missing, the data available covers a pivotal point in the adoption cycle: when usage of the innovation surpasses that of the legacy system.

The graph of each compartment’s proportion over time (Figure 5-7) resembles the behavior of a three-compartment system. The proportion of households that strictly used landline telecommunications service decreased over the years. Households that used both landline and mobile systems first increased, reached a peak at 61 percent, and then decreased steadily through 2015. Finally the number of households that relied strictly on mobile services steadily increased between 2003 and 2015. The CDC data never specified the path households took to get to each compartment. The CDC’s work provides definition for the compartments and evidence that the U.S. population fit into the various compartments.

A mathematical proof does not seem reasonable because births to the system can not be estimated. Without a knowledge of births, the proportion of individuals in the ‘Wireless only’ compartment that originated by 'Landline & Wireless' compartment may be overstated. Due to this weakness, a non-statistical survey that used the CDC's classification method was administered to determine the transition path people took to get to each compartment.

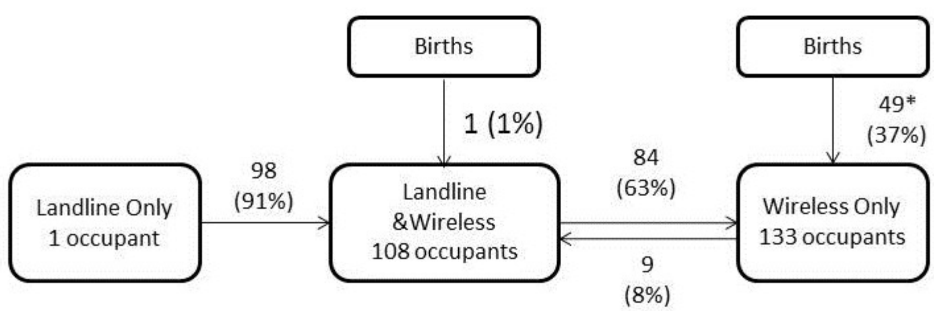
A multiple-choice survey addressing an individual's adoption and abandonment of telecommunications services was created. The survey can be found in Appendix C. Using the snowball method, a link to the online questionnaire was distributed through email and Facebook requests to participate and to share the survey with friends and colleagues. The questionnaire was formatted for both online and smartphone applications using Qualtrics. The 242 participants in this survey included 63 males and 179 females. The descriptive statistics are included in Table 5-1. The survey measured the path the occupants took to arrive at the three compartments. It was distributed in the spring of 2016. Originally 253 individuals had responded, but eleven had never paid for their own service. They were included on someone's, such as a parent's, phone plan. By not purchasing their own service, they had not optionally adopted a telecommunications service, thus disqualifying them from this study.

Table 5-1 Select demographics for each telephone service.

	Telephone Service					
Age	Landline Only		Landline & Wireless		Wireless Only	
	Males	Females	Males	Females	Males	Females
18-24 years	0	0	0	1	2	8
25-34 years	0	0	1	5	8	25
35-44 years	0	0	1	8	5	19
45-54 years	0	0	12	31	8	24
55-64 years	0	0	7	21	8	15
65-74 years	0	0	4	13	4	5
75 years and older	1	0	2	2	0	2
Total (N=242)	1	0	27	81	35	98

Of the 242 participants, 183 reported that the landline telecommunications service was the first service they purchased. This designation classified them as potential adopters of the innovation- mobile telecommunications service. At the time of the survey, 53 percent of the potential adopters had adopted wireless service while keeping landline service and 46 percent had abandoned landline service after purchasing both landline and wireless service for over a year. No one reported immediately (within one year) abandoning landline service after adopting mobile service. Of our sample of potential adopters, 100 percent who abandoned landline service followed the path described in the hypothesis.

The survey also confirmed that births make up a substantial proportion (37%) of the population in the 'Wireless only' compartment (Figure 5-8). This subgroup skews young with 80% being under the age of 35. This is not unexpected. Younger adults grew up with mobile phones, which is the dominant technology of the time.



*Age distribution for 'Wireless only' births :

Age	Count (%)
18-24	10 (21%)
25-34	29 (59%)
35-44	8 (16%)
45-54	2 (4%)

Figure 5-8 Transition paths to the individual compartments as determined by survey results.

Of the group that transitioned from ‘Landline & Wireless’ to ‘Wireless Only’, 66 percent had a landline for over 15 years before giving up the landline. Six percent reported having a landline for between 1 and 5 years. Of the group transitioning from ‘Landline Only’ to ‘Landline & Wireless’, 99 percent had a landline for more than 15 years. Nine respondents went from ‘Wireless Only’ to ‘Landline & Wireless’. The one birth into the ‘Landline & Wireless’ compartment resulted from a bundled service package from an internet provider.

Discussion

This paper’s contributions to the area of service science include a descriptive model of optional, individual-level adoption of a service innovation. Understanding how individuals adopt service innovations is necessary for service designers. To this group, optional, individual-level innovation adoption is the process used to get individuals, who have a choice, to participate in a service system. The traditional two-state model of innovation adoption does not address that an individual might use a legacy service system.

The two-state process model where individuals move from ‘Potential adopter’ to ‘Adopter’ reflects a goods-dominant logic that is concerned with the acceptance of the innovation and not the process of value co-creation by the consumer. The traditional metric used to measure adoption is sales and market saturation. A subscription to mobile telecommunications services is a metric that classifies the service as a good to be sold, not a system of value co-creation. Purchase of a service or product doesn’t equate usage. Adoption is defined as the acceptance and usage of a new idea, practice or object (Rogers, 2003).

The three-compartment model provides a better description of adoption behavior as demonstrated when the graphs of the two-compartment (Figure 5-1) and three-compartment model (Figure 5-5) are compared. The graph of the three-compartment model reflects that users participate in both a legacy system and innovative system.

This research originated when the behavior surrounding embedded and platform systems was not explained using the traditional two-state model. Further research is needed to explore the effect of legacy systems on optional, service innovation adoption. Designers of human-centered service systems need to understand the human behavior in their own service system and the behavior in the embedded and platform systems they incorporate. This is analogous to product designers needing to understand material science. Further research is needed to understand the relationship between service innovation and the underlying platform and embedded services systems.

The three-state adoption model of service adoption describes the situations that are facing a number of legacy service industries. Some legacy service systems that are currently affected by innovations include utilities (solar panels), telecommunications (mobile service), healthcare (telemedicine), transportation (ride sharing services) and education services (online education).

The business models of some services may be threatened by the adoption behavior. These services are dependent on large-scale usage to justify the investment in the system's infrastructure. When individuals abandon a legacy service system, the return on investment from the continued operation of the infrastructure falls.

The current situation facing utility companies in the United States provides an example of the effects caused by a service innovation. In distributed solar photovoltaic generation, individuals who adopt solar panels are moving to a self-service system by generating their own power. These adopters still participate in the legacy system that utility companies provide. They sell any excess power to the utilities and purchase power from utilities when needed. Therefore, the power generation shifts from a small number of large, expensive power plants to a large number of small individual providers (Edison Electric Institute, 2013). As more users adopt solar panels and demand less of utility-generated power, distributed solar generation may disrupt the utility industry to the point that the phrase 'utility death spiral' has been used to describe the situation (Edison Electric Institute, 2013; Fairley, 2013; LaMonica, 2014). A Lawrence Berkeley National Laboratory study found if distributed solar photovoltaic adoption rose to 2.5 percent of utilities' retail sales, shareholder earnings of utility companies would be cut by 4 percent. That same report estimates that if 10 percent of power generation came from rooftop solar, shareholder earnings of utility companies would fall between five to more than 40 percent (LaMonica, 2014). The ability of consumers to generate their own power can greatly change the co-creation of value specifications in the power generation service system. Consumers, who are now also suppliers, must acquire new equipment such as smart meters and follow new building codes and regulations. Utilities, which are still regulated, have to adjust to new pricing demands with consumers who are also producers. Utilities are no longer the only power generators, but they are also power shipping companies moving power from solar panel users to other consumers. The desire of consumers to have solar power has created a new service offering in solar panel financing (The White House, 2015).

Conclusion

This research's theoretical contribution to the field of service science is a descriptive model of service innovation adoption that is specific to service science and not simply an extension of another discipline's theory to a service situation. In the proposed model, potential adopters move from the state of using strictly a legacy system upon the release of a service innovation to a state where both the legacy system and the innovative system are used or are available for potential use. After a period of time, individuals abandon the legacy system and fully adopt the innovative system. This use of both a legacy and an innovative system is unique to service systems. The business models of goods manufacturers are seldom affected if individuals continue to use a legacy product after purchasing an innovative product. Goods manufacturers achieve scale in production whereas service providers achieve scale in usage. In this case generalizing a model based on goods-dominant logic to a service situation was not adequate in describing service system behavior.

This research responds to the call that Maglio, Kwan & Spohrer (2015) made for new theories and methods that addressed problems unique to services and that industrial engineering could contribute to this new research stream. Using the case study method, the authors attempted to fill the gap in theory regarding the optional, individual-level adoption of service innovations.

Limitations

This case study covers only one service system innovation, mobile telecommunications service, and therefore, may not be generalizable to other systems. Any interventions or technological changes over the 30 years of adoption have not been addressed such as landline service being bundled with home internet service.

Some will see the use of qualitative methods as a weakness. Case study is appropriate when little is known about a phenomenon and existing theory is not adequate (Eisenhardt, 1989). A clarification may be needed on the use of a non-statistical survey. The survey measured the process people used in adoption. As a result, it was structured as an interview that could be scaled using simple questions and formatted using both an online application and mobile application. Using the internet as a medium, the number of participants in this qualitative study was high. The population of survey participants did have a high number of women. This may be a result of using the snowball method to find participants. Since the participants were asked about past events, issues regarding recall may have some effect.

Chapter 6 - A Compartmental Mathematical Model of Mobile Telecommunications Service Diffusion

An abstract based on this chapter was submitted to the 2017 Frontiers in Service Conference in New York City.

Introduction

Service operations provide unique management challenges. Balancing demand with capacity is one challenge that is more difficult in service operations that in a manufacturing situation (Olivia & Sterman, 2010). Customers provide inputs into the service process (Sampson & Froehle, 2006). Therefore processing of the service can not be completed until the demand has been presented. As a result, finished goods inventory can not act as a buffer between production and demand (Hopp & Spearman, 2008). Often the service is consumed immediately upon the demand request such as retail service. When the service is consumed immediately and no finished goods inventory is available, service providers are vulnerable to imbalances between supply and demand (Olivia & Sterman, 2010).

Since the luxury of a finished goods inventory buffer is not available to service system designers and managers, other strategies are used to balance supply and demand. Demand can be stored or managed through the use of queues, wait times and appointment schedules. A level of reserve capacity can also be built into the service system. These techniques may be adequate in absorbing short-term variations in demand (Olivia & Sterman, 2010). If demand is increasing, the response of last resort is capacity expansion (Olivia & Sterman, 2010). The authors found one article from 1957 dealing with a situation where service system demand is falling and capacity contraction is required (Due, 1957).

In long-term situations service managers and designers must determine the capacity levels that will satisfy potential demand. These decisions are made in an environment of uncertainty. Accurate forecasts of future demand can be invaluable. When the industry is dealing with an innovative service system, the information regarding future capacity needs is more fuzzy and ambiguous than in periods of stability.

Past research has focused on solutions to short-term supply and demand problems in service operations using scheduling and routing of resources (Xiouli, Hong & Shaohui, 2009), workforce planning solutions (Robbins & Harrison, 2011; Villarreal, Goldsman & Keskinocak, 2015; Li & Zhang, 2009; Goodale, Verma & Pullman, 2003; Qin, 2011; Li, Field, Tian, Pang, 2015); or the timing and arrival of demand (Gang, Wong, Song & Witt, 2006; Ng, 2007, 1999). Queue research works on the premise of timing demand to arrive when the capacity of the system is available.

One solution to better match long-term capacity to future demand is to address better forecasting (Hopp & Spearman, 2008). In long-term capacity decisions, forecasts of demand determine the system capacity and location. Accurate forecasting goes a long way in building service systems that actually have the capacity to handle demand.

In manufacturing processes, input delivery can be managed using raw materials inventories. In service processes where the consumer provides the inputs, input delivery can be synonymous with consumer demand. As in production, scheduling must be based on a realistic model of system behavior (Hopp & Spearman, 2008). In service production, it is imperative that production management have a deep understanding of the behavior of consumers in the service system. Not understanding consumer behavior in a service system is equivalent to not understanding the raw material arrival behavior in a manufacturing system.

Adoption of an innovative service marks the entrance of a consumer into a new a service system. Often an innovative service replaces an existing or legacy service system. Uber and ride sharing services are replacing taxi and shuttle services. Email replaced much of the letters the postal service once handled. During periods where a major innovation has been released, demand uncertainty for both the innovative system and the legacy system that may be abandoned is high.

When past models of consumer behavior regarding mobile telecommunications services did not hold, the authors realized that the new model had the potential to more accurately describe and simulate consumer behavior during a period of uncertainty. While this doesn't solve the problem of matching capacity supply with consumer demand in a service system, a three-compartmental model of service innovation adoption along with the mathematical component can help managers in determining future capacity needs. This model was designed using the case study of mobile telecommunications adoption in the United States.

Compartmental Systems

Innovation diffusion is the process of an innovation spreading through a population; innovation adoption is the process of an individual accepting and using something new. Adoption is the micro situation and diffusion is a macro situation. When innovation adoption is modeled as a process, diffusion can also be modeled as a compartmental system. A three-compartmental mathematical model describes the adoption process of a service innovation as described in the previous chapter. This model is demonstrated using the CDC data on mobile telecommunications service.

Compartmental systems models are useful when a system can be divided into separate subsystems or compartments where the units are able to flow or transition between compartments and/or the outside environment (Godfrey, 1983).

A three-compartment system model can be used to describe the behavior of the adoption process of mobile telecommunications service. This model is similar to the Susceptible-Infected-Recovered (SIR) model developed by Kermack and McKendrick (1927) for epidemiology. In the SIR model, members of a given population flow through three compartments based on the infection of a disease: susceptible to infection, infected, and recovered (Kretzschmar & Wallinga, 2010). Individuals who contact a disease are infectious for a time, recover and are then immune from re-contracting the disease (Sterman, 2000). Innovation diffusion can be modeled as an epidemic that spreads through a community due to the role of a positive feedback loop (Sterman, 2000).

At time 0, all members of a defined population reside in the first compartment. As individuals transition between compartments, the compartments can be compared using the population or volume in a compartment or the compartment's proportion of the total system population. Compartments have three necessary characteristics: homogeneity, definition and being well-mixed (Godrey, 1983).

The rate of transfer describes the movement between compartments. In the simplest models, the rates are constant over time although that is not necessary (Kretzschmar & Wallinga, 2010). The following first-order differential equations describe the behavior within the compartmental system (Kretzschmar & Wallinga, 2010):

$$\frac{dx}{dt} = -bx(t)y(t) \quad (1)$$

$$\frac{dy}{dt} = bx(t)y(t) - k\,y(t) \quad (2)$$

$$\frac{dz}{dt} = -k\,y(t) \quad (3)$$

Where *x(t)* is the proportion of the population in the first compartment at time *(t)*, *y(t)* is the proportion of the population in the second compartment at time *(t)*, *z(t)* is the proportion of the population in the third compartment at time *(t)*, b is the rate of transition between compartment x and compartment y and k is the rate of transition between compartment y and compartment z (Figure 6-1).

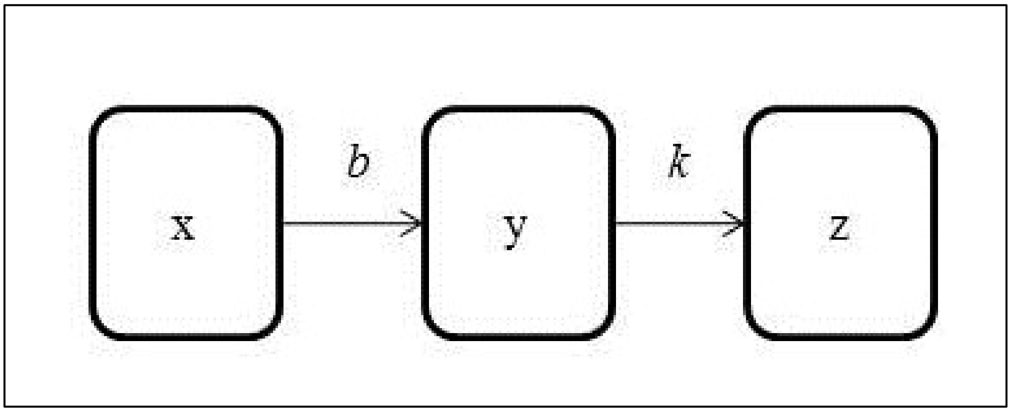


Figure 6-1 General three-compartmental system

The model has the following condition:

$$\frac{dx}{dt} + \frac{dy}{dt} + \frac{dz}{dt} = 0$$

A model of mobile telecommunications service diffusion

The diffusion of mobile telecommunications service in the U.S. can be described using a three-compartment systems model (Figure 6-2). Drawing on the labels created by the Center of Disease Control and Prevention, the three compartments include ‘Landline Only’, ‘Landline & Wireless’, and ‘Wireless Only’. The CDC sampled households within the United States satisfying the necessary compartmental condition of homogeneity. The categories designated by the CDC are well-defined and satisfies the second characteristic of definition. Finally, over 99% of U.S. households have access to a least one mobile telecommunications provider (United States Federal Communication Commission, 2008). The competitive nature of the mobile telecommunications industry allows free movement of individuals between the compartments thus satisfies the characteristic of being well-mixed. In 1984 when the first commercially available mobile phone was released, all potential adopters resided in the ‘Landline Only’ compartment.

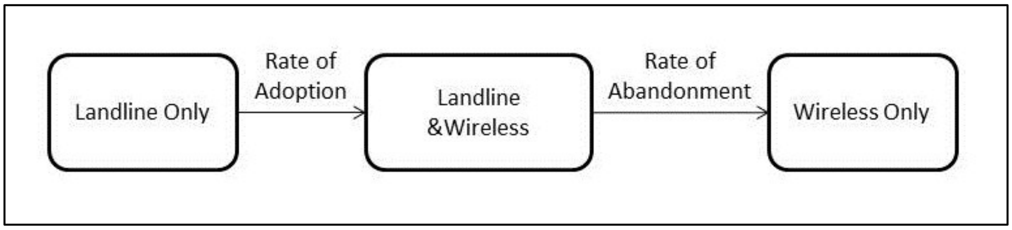


Figure 6-2 Three-compartment model of mobile telecommunications diffusion

The CDC collected data for 26 six-month time periods between 2003 and 2015. Twenty four data points are used to build the model and two were held out for model validation. A limitation of the CDC data is the inability to model for births into the system. Births affect the composition of the population of the ‘Wireless only’ compartment according to the author’s 2016 survey results. Since this is a demonstration rather than a validation model, the births and deaths are not incorporated due to data limitations.

Using SAS 9.3, linear and quadratic regression models were fit to describe changes within each of the compartments over time. The fit statistics are included in Table 6-1. All have a .05 level of significance and R-square values ranging from .8315 to .9909.

Table 6-1 Regression models of household data

	Landline Only			Landline & Wireless			Wireless Only		
	t	p	B	T	p	B	t	p	B
Constant	40.74	<.0001	.57149	26.60	<.0001	.41310	-.209	.0480	-.01197
Period	-16.03	<.0001	-.04144	9.88	<.0001	.02828	49.06	<.0001	.01963
Period* Period	8.68	<.0001	.00087	-10.18	<.0001	-.00113			
	Model: R^2=.9810; F=540.61; p=<.0001;			Model: R^2=.8315; F=51.81; p=<.0001;			Model: R^2=.9909; F=2406.59; p=<.0001;		

The resulting regression equations that are derived to find the rates of adoption and abandonment are

$$\text{Landline only} = .57149 - .04144 * \text{time} + .00087 * \text{time}^2 \quad (4)$$

$$\text{Landline/Wireless} = .41310 + .02828*\text{time} - .00113*\text{time}^2 \quad (5)$$

$$\text{Wireless only}=-.01197+.01963*\text{time} \quad (6)$$

For each time period, the adoption rate and the abandonment rate are calculated by plugging the first-order derivatives of equations (4), (5) and (6) into equations (1), (2) and (3). The average rate for adoption (*b*) over the 24 periods is .149 percentage point per time period and the average rate of abandonment (*k*) over the 24 periods is .037 percentage point per time period.

Simulation of Mobile Telecommunication Diffusion

Since a common epidemiology model (SIR) is based on the same mathematical principles, SAS code designed for SIR applications was adapted to create a simulation of mobile telecommunications service diffusion (Chong & Zee, 2014). The code of the simulation can be found in Appendix D. Using the average adoption rate of .149 percentage points per six month time period and the average abandonment rate of .037 percentage points per six month time period, a simulation was run using SAS 9.3. The simulation results estimated the proportion of 'Wireless Only' users would exceed 'Landline Only' users one period sooner than the actual event. The maximum proportion of households in the 'Landline & Wireless' compartment was greater by .065 points than the simulation predicted (Figure 6-3).

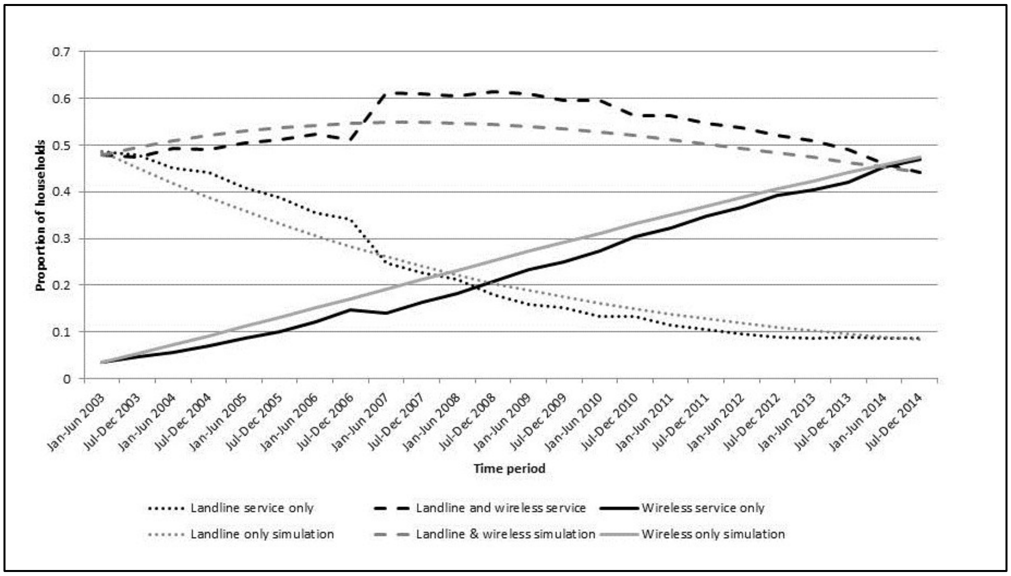


Figure 6-3 Simulated and actual values of household telecommunications service adoption, 2003-2014

To validate the model, two data points, Jan-Jun 2015 and Jul-Dec 2015, were held out of the regression models. The comparison of the simulation and the actual data for these two time periods is shown in Table 6-2. For the period Jul-Dec 2015, the 'Landline & Wireless' category was underestimated by .6 percent in the simulation while the 'Wireless Only' category was overestimated by the same percentage.

Table 6-2 Comparison between actual proportions and simulated proportions

	Adjusted CDC data	Simulation data	Difference
Jan-Jun 2015			
Landline only	.079	.079	.000
Landline & wireless	.430	.431	-.001
Wireless only	.491	.490	.001
Jul-Dec 2015			
Landline only	.074	.074	.000
Landline & wireless	.426	.420	.006
Wireless only	.500	.506	-.006

Using the average rate of adoption of .149 percentage points a period and the rate of abandonment of .037 percentage points a period, a simulation was run for a 30-year period (Figure 6-4). Under the current conditions, it is estimated that in 2032, 1.9% of American households would use a landline system only while 14% use both a landline and a mobile system. At the introduction of an innovation, the pool of potential adopters is often composed of customers using the legacy system. In telecommunications, the number of legacy system subscribers is estimated to decline from 100% in 1984 to below 2% in 2032. With so many customers leaving the system, landline operators need to decide when to cut their own cords.

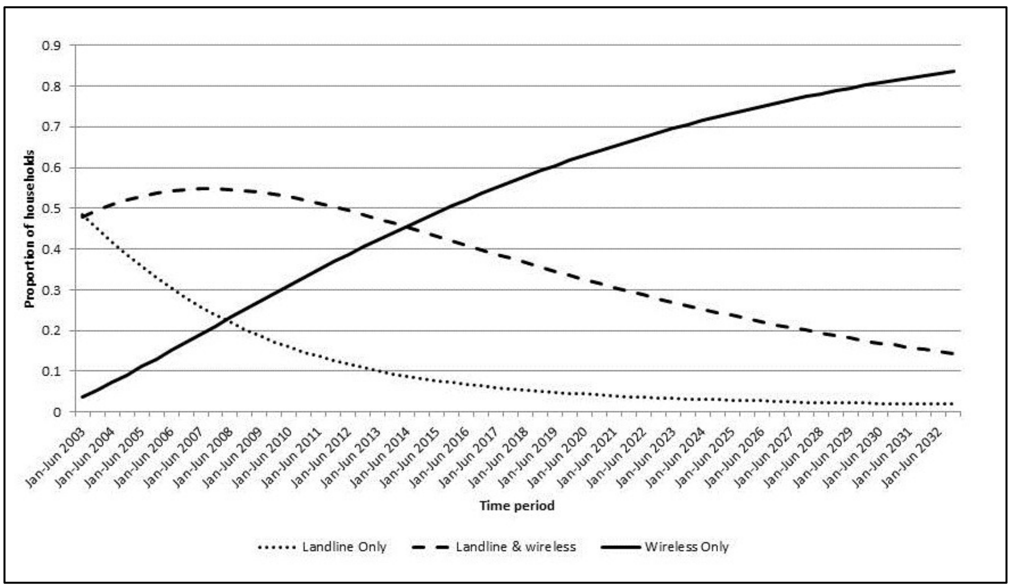


Figure 6-4 Simulation of household telecommunication usage based on CDC data, 2003-2032

While this simulation makes many assumptions, the inability to model deaths and births due to the lack of the data from the CDC is a problem. It is assumed that before 2032 a number of the landline users would have exited the system due to death and attrition.

Simulations to gage adoption behavior

The benefit of simulations is to test interventions and situations to allow for better decision making. Using the case of mobile telecommunications adoption, a number of situations are simulated to determine the effect of changes to the adoption behavior in a three-compartment model (Figure 6-2). In this section, the effect of changes to the rate of adoption, the rate of abandonment and the introduction of interventions that circumvent the traditional path of adoption are discussed.

In 2003, the mobile telecommunications network had been built out to the point that it is realistic to believe it could handle the increased traffic that might relate to any changes. A small portion (3.6%) had completely abandoned the landline system. In 2003 an estimated 48.5% of the population relied strictly on 'Landline Only' systems, 47.9% used both 'Landline & Wireless' systems and 3.6% had abandoned the landline system and resided in the 'Wireless Only' compartment. A benchmark simulation was done using the average rate of adoption of .149 and the average rate of abandonment of .037 percentage points per period. The benchmark also used the 2003 proportions of population in each compartment. In 2003 over half the population used mobile telecommunications and trust in the system had been established. Trust in an innovative system is required for the abandonment of a legacy system.

The rates of adoption and abandonment can be affected through marketing efforts including price changes, special incentives, and marketing campaigns that can encourage the population to adopt a mobile phone. Social networks can also be a powerful source in encouragement of adoption.

Simulation Situation 1: Changing the rate of adoption

The rate of adoption affects the size of the population in both the 'Landline Only' and the 'Landline & Wireless' compartments. It also affects the speed in which the compartments either fill or empty. When the rate of adoption is increased, the population of the 'Landline Only' compartment decreases quicker than at lower rates. This also leads to an increase in the population of the ‘Landline & Wireless’ compartments if the rate of abandonment does not experience a similar increase.

Two simulations were run: a baseline and one that doubled the adoption rate of from .149 percentage change per period to .298 percentage change per period. This change resulted in a decrease in the population of the ‘Landline Only’ compartment. By 2011, the estimated population in the ‘Landline Only’ compartment with the doubled adoption rate is 2% of the U.S. population compared with 14% under the original conditions (Figure 6-5). The ‘Landline Only’ population does not fall to 2% until 2027 under the original conditions. The decrease in the ‘Landline Only’ category encourages the total abandonment of the landline system as a platform system in services such as polling. The population can be contacted through the alternative mobile system.

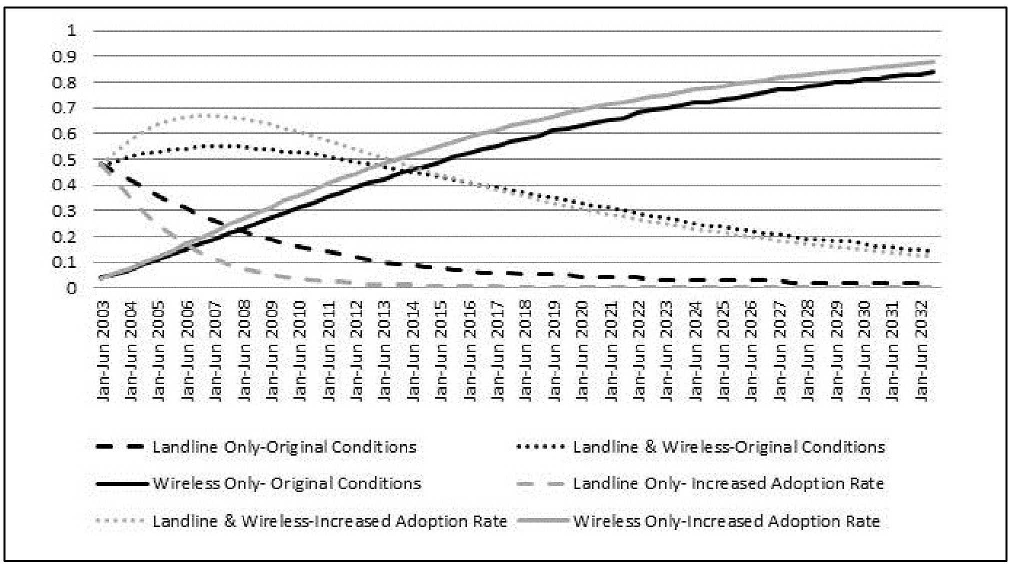


Figure 6-5 Effect on the increasing the adoption rate compared to average rates

Under the increased rate, the decreases in the ‘Landline Only’ population resulted in an increase in the ‘Landline & Wireless’ population which peaked with an estimated 67% between 2007 and 2008. This occurred at about the same time as under the original conditions. That optimal point occurred at an estimated 55% of the total population between 2006 and 2008. A decrease in the ‘Landline Only’ population didn’t translate to a large percentage change in the total population using the landline service at any time (Figure 6-6). Landline service includes both ‘Landline Only’ and ‘Landline & Wireless’ categories. In 2019 39% of the population had landline service under the original conditions compared to the 32% of the population with landline service under the increase adoption rate.

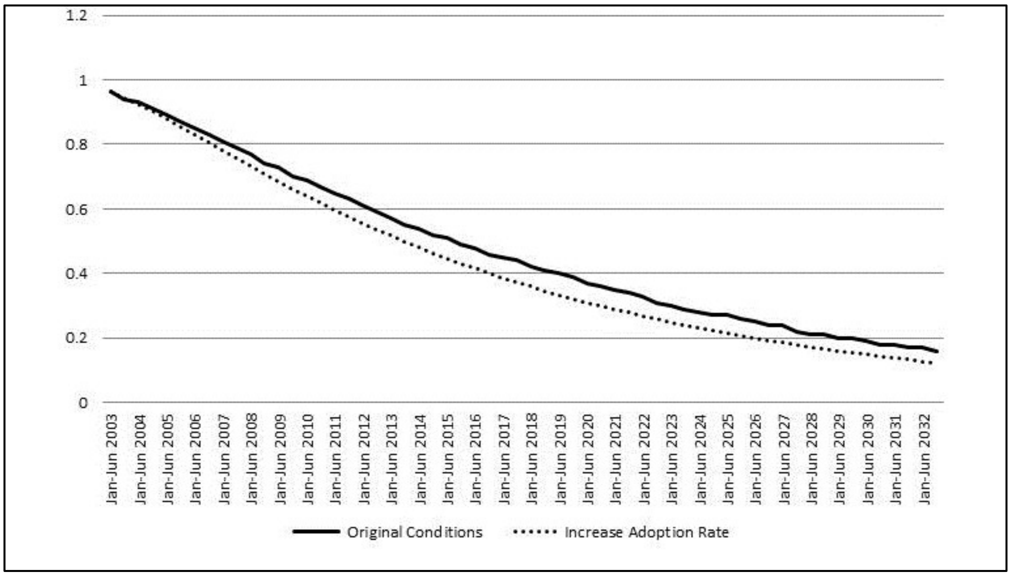


Figure 6-6 Total landline usage between average rate and increased adoption rate

Simulation Situation 2: Changing the rate of abandonment

The rate of abandonment of the landline system can also affect the compartments’ population. The abandonment rate affects the transition from the ‘Landline & Wireless’ compartment to the ‘Wireless Only’ system. Increasing the abandonment rate from .037 to .1 would result in individuals spending less time in the ‘Landline &Wireless’ category. The expected changes include a dramatic decrease in the population in the ‘Landline & Wireless’ category and an increase in the ‘Wireless Only’ population (Figure 6-7). Since the abandonment rate of .1 percentage points per period is less than the adoption rate of .149 percentage points per period, the ‘Landline & Wireless’ continues to have a population. When the abandonment rate exceeds the adoption rate, the population will pass through the 'Landline & Wireless' state without a delay.

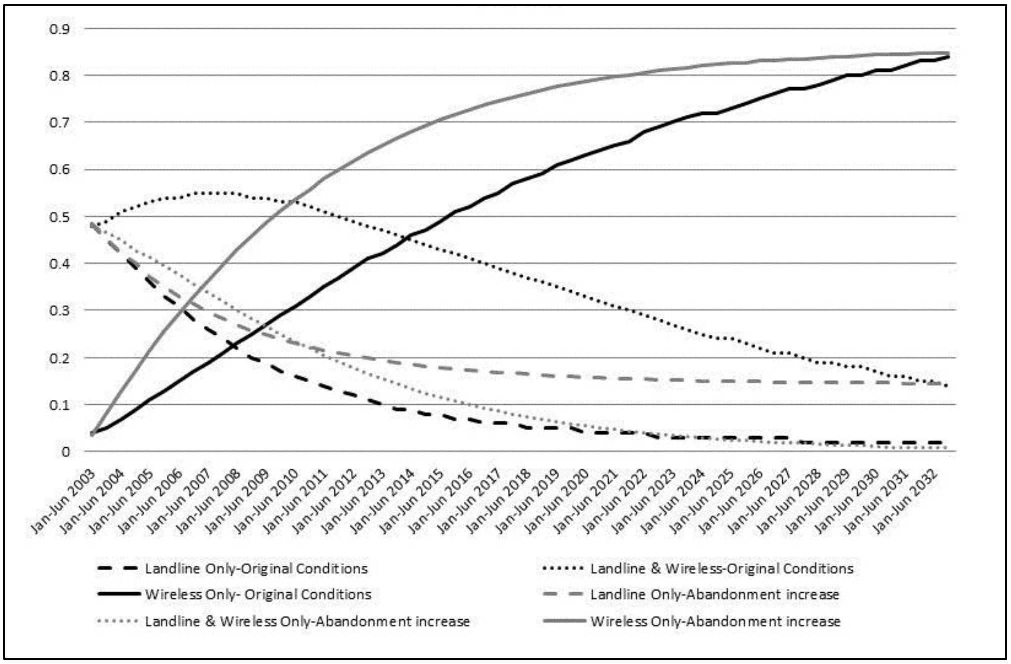


Figure 6-7 Effect of increasing the abandonment rate compared with the average rate

After 30 years, the population of the 'Wireless Only' category is relatively the same. Raising the abandonment rate got the population to that higher point quicker. Raising abandonment rates slows the decreases in the long-term population of 'Landline Only'. This model is based on social models of infection and networking. If the population of 'Landline and Wireless' drops, there are fewer opportunities for the mobile phone to spread within the population. Therefore stagnation is caused within the legacy system population.

Outside factors that can affect rate of abandonment include the cost of operating both systems, increased trust and improved quality in the wireless system, familiarity with the system, social networks and lack of individual utility in the landline system.

Simulation Situation 3: Modeling Births & Deaths

Since telecommunications systems are open systems and births and deaths affect the system. These two variables can be modeled in the following way (Figure 6-8). Assumptions that were made in this simulation include that deaths only affect the 'Landline Only' population. The death rate only affects a compartments population if it exceeds the birth rate. It is assumed that the death rates of the other two compartments are not impactful on the system. The death rate .008 was determined using the U.S death rate of the year 2015 provided by the CDC.

Given the survey results, the birth rates of the 'Landline Only' and the 'Landline and Wireless' compartments are small and not impactful on the system. Births affected the 'Wireless Only' compartment according to the survey results. The birth rate of .0162 was determined using the U.S. birthrate in 1991. This would put new individuals into the telecommunications system at the age of 25 when entering the system. Since the system's birthrate exceeds the system's death rate, the system's population will grow beyond the original population thus leading to proportions that exceed 1.0.

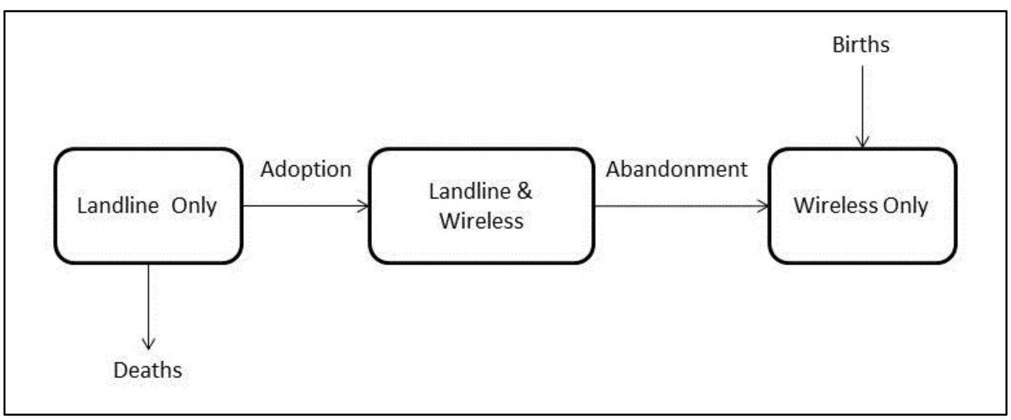


Figure 6-8 Adoption model with likely deaths and births included

Rather than starting this simulation at 2003, it is started given the conditions available in 2015. At that time, 7.4% of the population is in the 'Landline Only' category, 42.6% is in the 'Landline & Wireless' group, and 49.9% reside in 'Wireless Only' category. The rates of adoption and abandonment were kept stable.

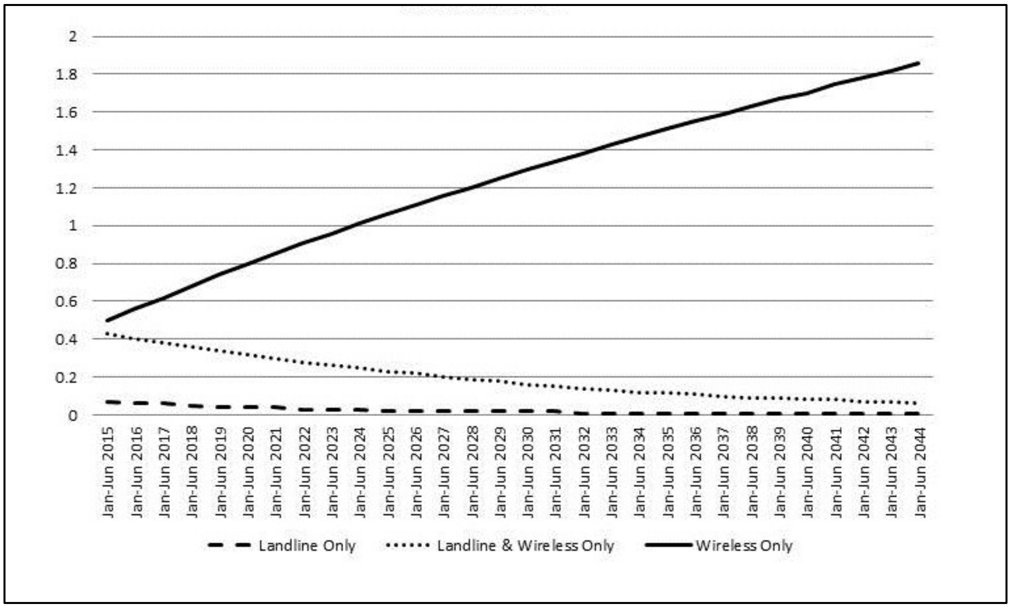


Figure 6-9 Effects of births and deaths on the adoption process

Simulation Situation 4: Changing the adoption path

In the previous simulations, the most probable path was determined from the survey results. Interventions can be used to change the path of adoption. Efforts can be made to encourage individuals to avoid the 'Landline and Wireless' state completely and transition directly to the 'Wireless Only' state (Figure 6-10).

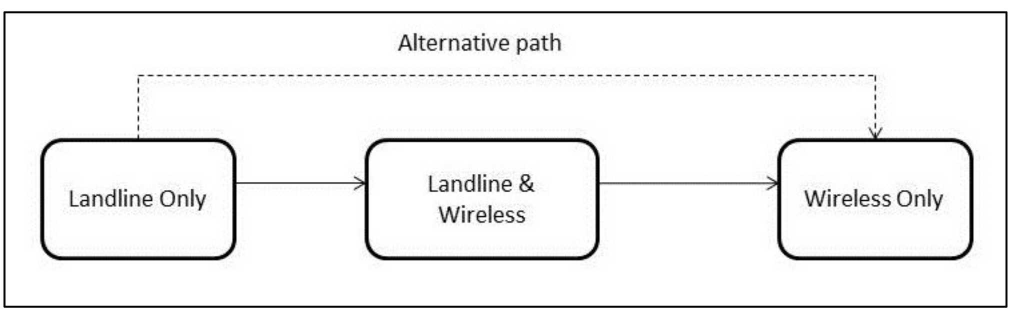


Figure 6-10 Alternative path of landline service abandonment

A simulation was run that explored the effects of an alternative path when the rates and initial proportions were held at the 2003 levels. Assuming an intervention, such as a financial offering, is accepted by 10% of the 'Landline Only' population, the entire population moves to the state of 'Wireless Only' sooner than otherwise (Figure 6-11). The goal of lowering landline system participation is reached using an alternative path.

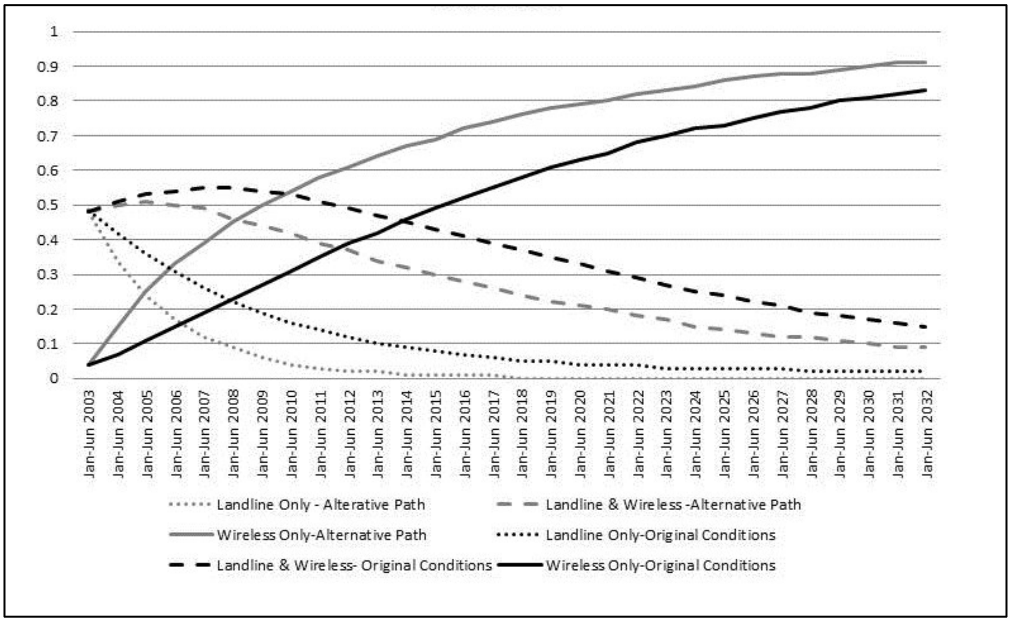


Figure 6-11 Effect of the alternative path on the abandonment of a landline system

The incentive to take an alternative path may have an additional effect of lowering the adoption rate as some who would have transitioned to the 'Landline & Wireless' state instead transitioned directly to the 'Wireless Only' state. This would leave the least likely to abandon a landline system in the 'Landline Only' state. A simulation was run with an intervention that is accepted by 10% of the 'Landline Only' population and a lowering of the adoption rate by 50% to .075 percentage points per period. The overall effect is the same- complete abandonment of the landline system by 2022 (Figure 6-12). The consequence of lowering the adoption rate has the same effect, but it is slower to achieve the goal of lowering landline system participation.

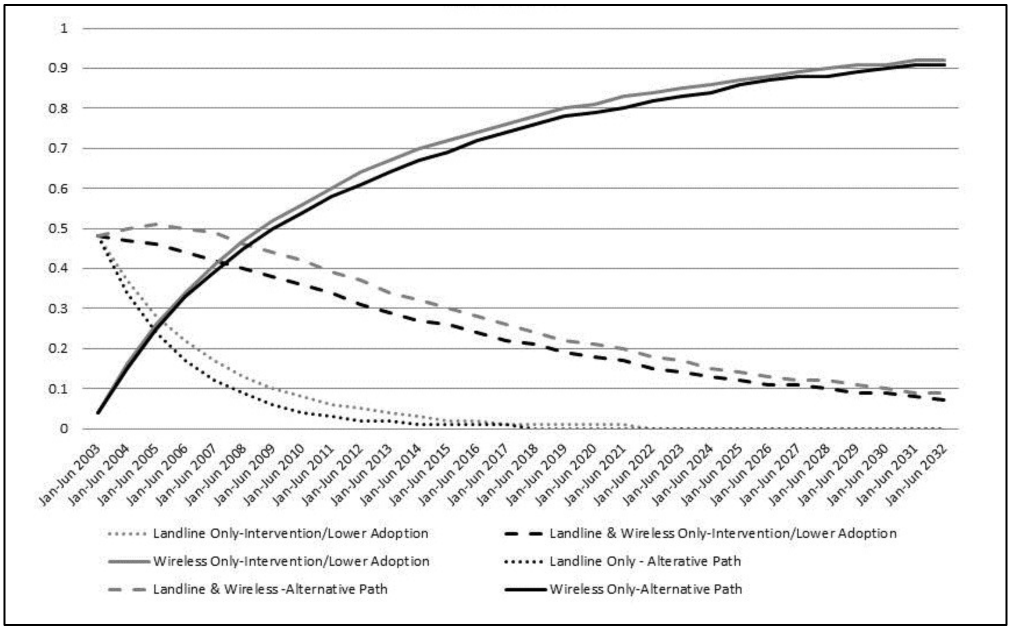


Figure 6-12 Effect of lowering the adoption rate due to the induction of alternative path

If the goal is to lower the overall population of the landline users, which requires both a lowering of the populations of both the 'Landline Only' state and the 'Landline & Wireless' state, along with an alternative path, raising the abandonment rate between the 'Landline & Wireless' state and the 'Wireless Only' state. If an incentive that triples the rate of transition from the 'Landline and Wireless' state to the 'Wireless Only' state was introduced in 2003 and if an alternative path was provided, over 95% of the population would have abandoned landline phones by 2017 (Figure 6-13).

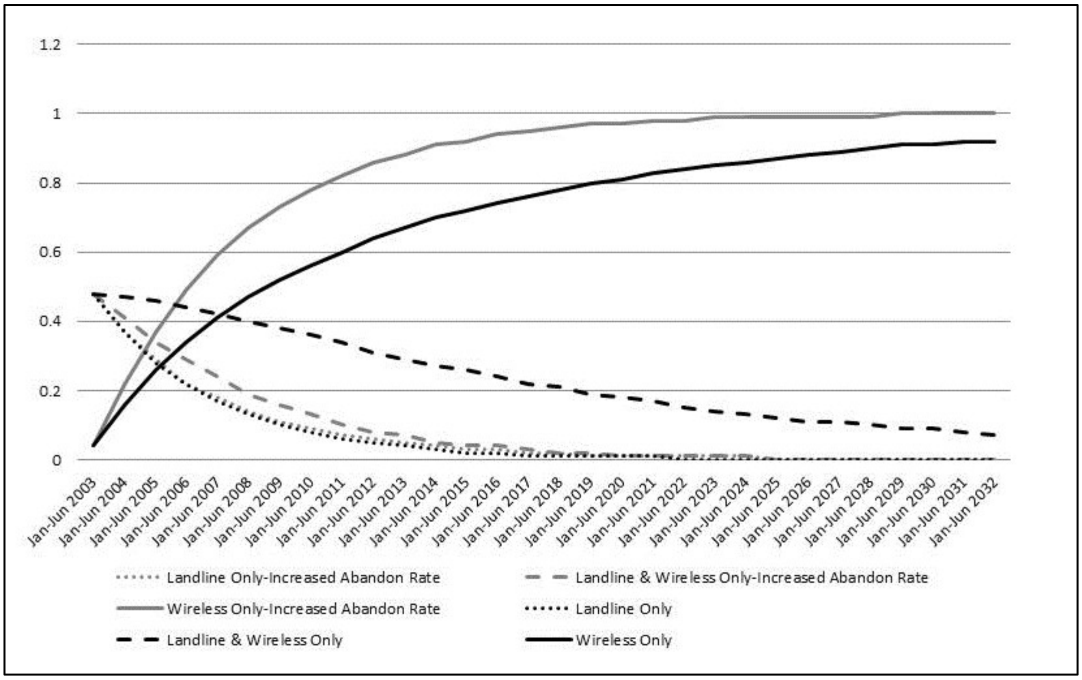


Figure 6-13 Effect of abandonment rate increase and alternative path that lowers adoption rate

In 2003 only 3.7% of the population was estimated to be in the 'Wireless Only' state. Assuming at that time, a goal was set that would require that at least 90% of the population to be using wireless telecommunications service only by 2013. Simulation can be used to determine the best alternative. This goal can be described as the 'Wireless Only' population must equal or exceed 90%.

Alternative paths were compared at levels of acceptance of 20%, 25% and 50%. All resulted in the lowering of the adoption rate by 50%. None increased the level of the 'Wireless Only' state above 80% (Figure 6-14).

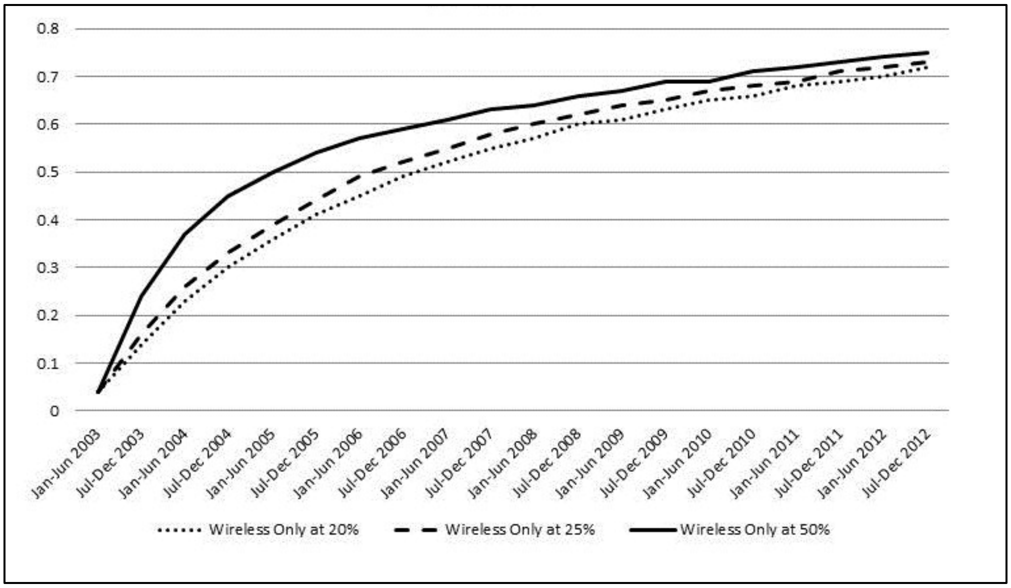


Figure 6-14 Effect of various alternative path acceptance rates on the 'Wireless Only' population

High acceptance of alternative paths may not be realistic. It is more likely that in 2003 only 10% of the 'Landline Only' population was willing to forego the 'Landline & Wireless' state. If high incentives are given to increase the abandonment rate to .15 from .037 along with an alternative path, the goal of having a 'Wireless Only' population that equals or exceeds 90% can be reached. Two options are provided. In the first, the rate of adoption is assumed to fall by 50% to .075 percentage points per period. In the second it is assumed that the adoption rate falls by only 25% to .111 percentage point per period. Both cases increase the 'Wireless Only' population to at least 90% of the total population. In the first option (adoption rate=.075) the population of the 'Wireless Only' state was .906 by 2013. In the second option (adoption rate = .111) the population of the 'Wireless Only' state was .910 by 2013. Both achieved the goal of 90% of the total population using only wireless systems for telecommunications needs.

Simulation Situation 5: Using 2014 rates

When the rates of adoption (.039) and abandonment (.042) in 2014, along with the proportions in each category ('Landline Only'=8%, 'Landline & Wireless'=44%, and 'Wireless

Only' = 47%), are simulated out, a 'Wireless Only' proportion of 90% is not reached until 2045 (Figure 6-15). If the abandonment rate is increased 50% to .630 percentage points per every six-month period, which can easily be done if the providers are allowed to discontinue service to select areas, the US will have 90% 'Wireless Only' population by 2037 or eight years sooner (Table 6-3).

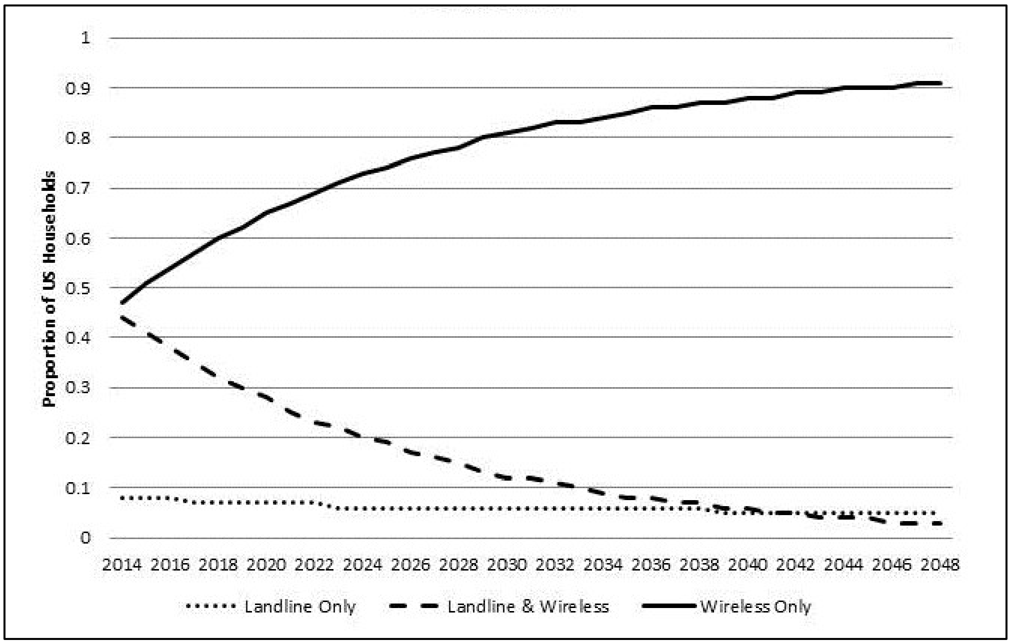


Figure 6-15Adoption behavior using 2014 rates

Table 6-3 Years that 'Wireless Only' reach selected proportions of US households

Beta = .039	Proportion of US Households that are 'Wireless Only'			
Rate of Abandonment	60%	70%	80%	90%
.042 (2014 rates)	2018	2023	2030	2045
.046 (10% over 2014)	2018	2023	2030	2044
.0504 (20% over 2014)	2018	2022	2028	2042
.0546 (30% over 2014)	2018	2021	2026	2040
.0588 (40% over 2014)	2017	2021	2026	2038
.0630 (50% over 2014)	2017	2020	2025	2037

Another alternative is to increase both the rate of abandonment and the rate of adoption, which will move individuals out of the 'Landline Only' category and into wireless service. This can be achieved by announcing the future discontinuation of landline service and encouraging individuals to adopt freely in the time before an adoption becomes mandatory. If the adoption rate is increased by 50% to .059 and the abandonment rate is increased by 50%, 90% of US households would only use wireless telecommunications systems by the year 2035 (Table 6-4). This increase in the adoption rate resulted in a time savings of two years. Since it is unknown the cost of attempting to either encourage adoption or abandonment, the financial benefit is unknown.

Table 6-4 Years with 'Wireless Only' population reach 90% of US households

	Rate of Adoption					
Rate of Abandonment	.039	.043	.0468	.051	.055	.059
.042 (2014 rates)	2046	2045	2044	2044	2044	2044
.046 (10% over 2014)	2044	2043	2043	2042	2042	2042
.0504 (20% over 2014)	2042	2041	2041	2040	2040	2040
.0546 (30% over 2014)	2040	2039	2039	2039	2038	2038
.0588 (40% over 2014)	2038	2038	2038	2037	2037	2037
.0630 (50% over 2014)	2037	2037	2036	2036	2036	2035

The intervention that would greatly drive up the abandonment rate is the discontinuation of service in underutilized areas. This would shift the decision from an optional one to mandatory adoption, which is out of the scope of this research.

Discussion

This model satisfies a very specific problem of service operations – understanding demand. Services are scaled based on demand, not on production (Sampson, 2010). This requires management to have a deep understanding of how service demand behaves. Operations management requires this deep knowledge in order to provide efficient and adequate service levels. Unlike products, service demand can not be satisfied using inventory buffers (Sampson, 2010). A more accurate model of demand behavior and the ability to simulate the system provides management a tool to determine capacity in the presence of a service innovation. The marketing models of innovation adoption focus only on the adoption of an innovation and are designed to measure sales growth. A model that explains how demand would be affected by an innovation provides more information in the decision making process.

An example using retail operations can provide a better explanation of how this model can be used by management. Online competition drove Retailer A to offer an online store (innovation). At the time the online store was opened, all shoppers at Retailer A used a physical store. Over time some consumers continue to use only the physical store while others use both the online store and the physical store. The more consumers use the online store, the less the physical store was being used. The productivity of the physical stores dropped as sales moved to the online store. Over time some consumers stopped using the physical stores all together and moved to the online store completely (Figure 6-5). Some shoppers may use the online service regularly but shop at the physical store occasionally. Not every shopper will transition to the online only category. This change in demand requires Retailer A to adjust its operations and investment to reflect the demand needs. At what point does Retail A invest in the physical stores or the online distribution network? How can the store operations be adjusted to regain efficiency?

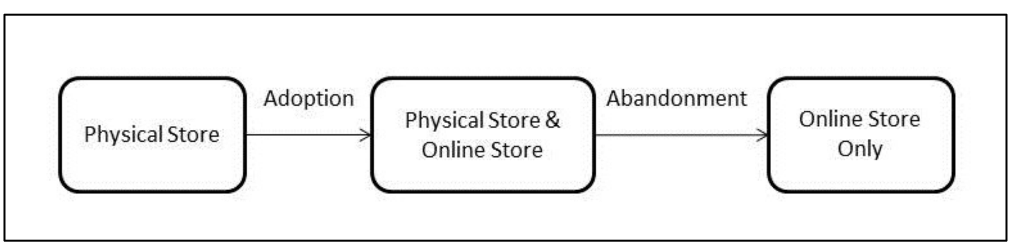


Figure 6-16 Model of three-state adoption of online shopping

Retailers always adjusted operations based on demand requirements such as Christmas sales. There was not a model on how demand reacts in the presence of a substitutable innovation. Demand might drop at the legacy system (physical stores), but not at the same level as growth in the innovation system. If Retailer A has good analytics, this model would be relative easy to construct using the proportions of customers in each compartment over time. The limitations pointed out in the simulation regarding deaths and births can easily be handled by an operation that keeps shopper analytics.

This mathematical model is a population-based model and is adequate to understand the behavior of aggregate demand in order to make corporate level decisions regarding service operations. Public health professionals use SIR simulations to evaluate the effectiveness of possible interventions in stopping the spread of epidemics (Kretzschmar & Wallinga, 2010). Managers and public policy officials can use the mathematical model in a similar manner.

Conclusion

A characteristic of service production is the inability to inventory finished production. As a result, production must equal demand, which can be inventoried in queues or controlled through scheduling. This situation makes forecasting long-term production difficult. It is made more complicated with the introduction of a substitutable service innovation.

Based on the three-state process of service innovation adoption, a mathematical model is developed using the principles of compartmental mathematical models. This model allows service system operators to understand long-term demand behavior when a service innovation is diffusing through a population.

This model contributes the field by explaining how demand behaves in the situation of service innovation adoption. Rather than focusing only on the innovative system, this model also addresses the role of a legacy system. This research can be applied by management when considering future capacity needs.

Limitations

Modeling this as a closed system instead of an open system is a limitation. An open system that includes births and deaths is a more realistic model of the adoption behavior. By 2016 births accounted for an estimated 37 percent of the 'Wireless only' compartment, according to the author's survey. In the early periods of diffusion the birth rate would be negligible. As time passes the number of births increases as new people entering the system are unwilling to adopt the aging technology of landlines.

Quantitative models of the innovation adoption and diffusion processes beyond the two-compartment models are rare because of the difficulties involved in data collection. The CDC started collecting this data in 2003 almost 20 years after Motorola had introduced a mobile phone for the mass distribution. The CDC also collected data about two technologies: landlines and mobile phones. Few agencies are in the position to include questions concerning an innovation on a national survey that is done over a span of thirteen years. Prediction of the success of an innovation such as the mobile phone is impossible thus forcing much innovation research to rely on the recall of adopters or for data gathering to begin in the intermediate or late stages of diffusion.

Acknowledgements

Thank you to Dr. Todd Easton for his suggestions in developing this model.

Chapter 7 - The Use of Routine and Rational Decision Making in Cutting the Landline Cord

Introduction

This chapter focuses on one aspect of the three-state innovation adoption process of mobile telecommunications – the decision to abandon landline service (Figure 7-1). Abandonment requires the optional decision to move from the state of 'Landline & Wireless' to the 'Wireless Only' state. The research question focuses on how an individual chooses to abandon the landline telecommunications service system.

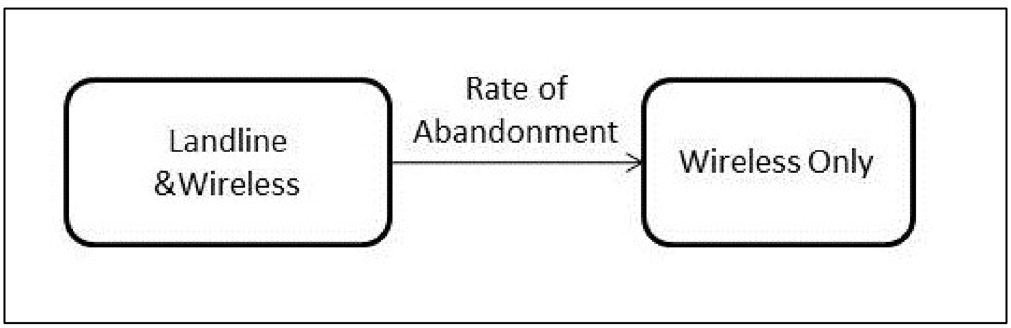


Figure 7-1 The process of abandoning landline service

When consumers abandon a large, complex service system such as healthcare, utilities, or transportation in favor of an innovative system, the legacy system is forced to restructure, contract or close. Consumer abandonment in favor of a service innovation is the story of AM radio (FM), network television (streaming services) and retail department stores (online shopping). Yet this phenomenon has not been explored much. Sometimes the industry finds a niche that allows for continued survival such as AM radio using talk radio formats. Often the legacy system dies a slow death until the management ceases operation. The system can also become a zombie system serving fewer and fewer customers and requiring minimal or public resources. Total consumer abandonment of a service system can take years, making data collection difficult. Historical researchers are left to tell the story of service system abandonment by the consumer and/or the provider.

Only one article was found that addressed the abandonment of a service system by consumers due to the adoption of an innovation and it focuses on reaction of the legacy systems' management. Due (1957) describes the demise of interurban railway service as a result of adoption of automobiles, a self-service alternative. Most interurban railway systems operated beyond the temporal point where the owners' financial position was no longer maximized. Often continued operations reduced the owners' equity to zero. The fatal flaw of the interurban firms was in not recognizing how their consumers and the American population had permanently adopted the automobile. At the time, the interurban service firms "had an almost complete failure … to foresee the expansion of automobile use, and a constant tendency, year after year, to believe that this expansion has ceased and that the interurban business would revive again." p. 364.

While abandoning a service system can have serious repercussions including firm closure, little has been done to explain how consumers arrive at the decision to abandon a legacy service system. This research fills that gap. After using naturalistic decision making tools to analyze survey, interview and historical data, the authors propose that groups of individuals use different decision-making process models when determining to abandon landline service.

Data

Two data sets, survey and an interview data, were used primarily. One set was obtained using a survey that detailed the adoption and abandonment process. The other was collected through interviews that used task analysis with probing techniques. That data was supplemented with population-level survey data collected by the Centers for Disease Control (CDC) between

2003 and 2015. Since the CDC data covers multiple years, trends were revealed that would have been hidden in a single-time study.

Study 1 – Survey

A multiple-choice survey dealing an individual's adoption and abandonment of telecommunications services was created. Using the snowball method, a link to the online questionnaire was distributed through email and Facebook requests to participate and to share the survey with friends and colleagues. The questionnaire was formatted using Qualtrics software and designed for both online and smartphone applications. The 242 participants in this survey included 63 males and 179 females. The descriptive statistics are included in Table 7-1. Questions were specific to the individual's adoption paths. It was distributed in the spring of 2016. Originally 253 individuals had responded, but eleven had never paid for their own service. They were included on someone's, such as a parent's, phone plan. By not purchasing their own service, they had not optionally adopted a telecommunications service, thus disqualifying them from this study.

Table 7-1 Demographics from the Study 1

	Telephone Service					
Age	Landline Only		Landline & Wireless		Wireless Only	
	Males	Females	Males	Females	Males	Females
18-24 years	0	0	0	1	2	8
25-34 years	0	0	1	5	8	25
35-44 years	0	0	1	8	5	19
45-54 years	0	0	12	31	8	24
55-64 years	0	0	7	21	8	15
65-74 years	0	0	4	13	4	5
75 years and older	1	0	2	2	0	2
Total (N=242)	1	0	27	81	35	98

At the time of the survey, 45.9 percent of the potential adopters had abandoned landline service after being in the 'Landline & Wireless' category for at least a year. No one reported abandoning landline service immediately after adopting mobile service. Of the sample of potential adopters, 100 percent who abandoned landline service followed the path described in the Chapter 5.

Study 2 – Interviews

The authors conducted 17 semi-structured interviews with older adults regarding the use of telecommunication systems. The seven questions in this study were structured as a task analysis using critical decision method with probing into the decision to abandon a landline system. Handwritten notes were taken on each interview. Questions focused on reasons to adopt, use and abandon landline and mobile telecommunication services, years using the services and how participants used the services. The interviews ranged in length of 15 to 45 minutes. A mix of participants from rural, suburban and urban locations and that had different service providers were included in the study. Three geographical areas were targeted: suburban Kansas City; the rural, small town of Atchison, Kansas, and residents who lived within a five-mile radius of downtown Denver. The snowball method of sampling was used. The participants had connections to either the University of Kansas Landon Center for Aging, the Riverside, Missouri Community Center or The Atchison County, Kansas Project Concern Center.

Table 7-2 Descriptive statistics from Study 2

	Landline	Mobile	Both	Total
Total	4 (23.5%)	7 (41.2)	6 (35.3)	17 (100%)
Average age (yrs.)	73.5	75.4	79.5	76.1
Males	1 (14.3%)	2(28.6%)	4(57.1%)	7 (100%)
Females	3(30%)	5(50%)	2 (20%)	10 (100%)
Rural	1(14.3%)	5(71.4%)	1(14.3%)	7 (100%)
Suburban	1(14.3%)	1(14.3%)	5(71.4%)	7(100%)
Urban	2(66.7%)	1(33.3%)	0	3(100%)

Study 3 – Historical Data

The federal agency that tracks telephone system usage is the Centers for Disease Control. The data is collected through the National Health Interview Survey. The survey is designed to be a representative sample of the U.S. population. Twice a year the CDC releases data on the usage of telecommunications services. Between 2003 and 2015 the number of households surveyed per time period ranged from 16,524 to 22,438 with an average of 18,239 households. The large sample sizes control for random variation that may be present between and within groups. The data covers the periods between January-June and July-December (Blumberg & Luke, 2007).

The CDC released selected demographic characteristics for the 'Wireless Only' population for the years between 2003 and 2015. The demographic characteristics include race/ethnicity, age, gender, education level, employment status, household structure, household poverty status, geographic region, metropolitan statistical area status and home ownership status. The survey results are presented as a percentage of either households or adults and children living in wireless-only households. The CDC indicated when statistically significant results were found. The authors reviewed the data searching for trends in the rate of change between time periods and for statistically significant differences between groups. When trends or differences were discovered, factors on the causes are suggested for future research. Along with the 'Wireless Only' group, the CDC identified a subset of the 'Landline & Wireless' group, the 'Wireless Mostly'. These households relied on mobile phones for all or almost all calls. For an unexplained reason the 'Wireless Mostly' group continues to have landline service even though it is not used. The CDC monitored this group due to the potential bias it proposed for the National Health Interview Survey.

Analysis

Decision-making studies often make the assumption that individuals use a rational decision-making process in most cases. In that process, a decision maker evaluates a set of options, identifies ways of weighing those options and selects the best option based on the goal of the decision (Lintern, 2010). In economic decisions, the goal may be to optimize economic resources. In reality individuals can use other processes including emotion-based and routine decision-making processes. Naturalistic decision-making (NDM) analysis allows researchers to determine how individuals and teams process decisions in naturalistic settings.

Rather than focus on normative decisions, NDM provides a descriptive model of actual decisions (Schraagen et al, 2008, Klein, 2008; Zsambok,1997). Rather than start with formal decision making models, NDM researchers use field research to determine the decision-making strategies that are employed (Klein, 2008). Naturalistic decision-making methods work well when the decision-making process is not rational or when the individual's goals are vague (Klein, 2008).

Of the NDM methods available, the critical decision method was employed in this study. The critical decision method uses interviews and observation to explore the process of making one particular decision (Klein et al., 1989). In this situation, the critical decision is to abandon landline telecommunications service. The Rasmussen (1983) decision-ladder was used in the analysis. This ladder describes the steps from awareness that a decision is needed through the execution of a task. This analysis focuses only on the activities involved in the situation analysis side of the decision ladder that deals with the current state of the targeted system (Naikar & Pearce, 2003). In particular, the data was coded for points of activation and information required by the decision maker who is scanning cues to diagnose his current state (Figure 7-2). In the case of the CDC population data, insights into the individual decision process are not available. Instead the CDC provides data over a period of time that can be compared between groups who have made the decision to abandon. The options of the decision under analysis are remaining in the 'Landline & Wireless' state or moving to the 'Wireless Only' state.

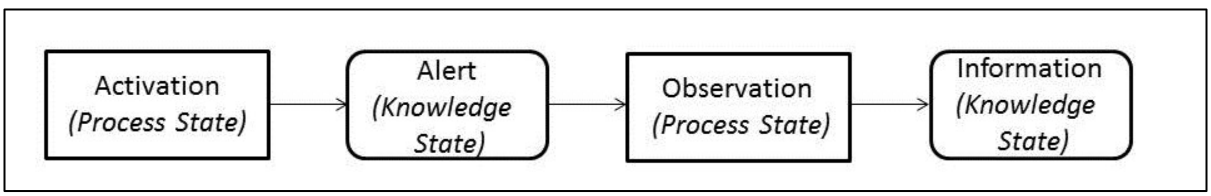


Figure 7-2 Situational analysis portion of the Rasmussen (1983) Decision Ladder

Results

To explore the decision to abandon the landline telecommunications system, the responses were divided into two groups: those who had already abandoned (Wireless Only) and those who had not (Landline & Wireless). Individuals that rented rather than owned their residence were more likely to use only wireless service. Individuals in the Northeast where less like to use only wireless services than those in the rest of the country. Individuals who lived alone, with children or with a related adult were less likely to live in a wireless only household than individuals living with roommates that were not family members. Households classified as poor or near poor were more likely to live in wireless only households than those classified as not poor.

The ‘Wireless Mostly’ population, a subset of the ‘Landline & Wireless’ group, was more likely to include adults with college degrees, adults living with children, adults not living in poverty or near poverty, and adults living in homes owned by a household member. In the second half of 2015, the CDC found that this group accounted for 35.2 percent of the households in the ‘Landline & Wireless’ category and 14.5 percent of all U.S. households (Blumberg & Luke, 2016). During this period this group included an estimated 39 million adults (Blumberg & Luke, 2016).

In decision analysis, researchers often focus on the question of why an individual made the decision. The behavior of ‘Wireless Mostly’ group begs the question of why aren’t these individuals abandoning landline service. The utility that this group receives from landline service is not readily evident. Cognitive engineers question not why but instead focus on how decision makers arrive at a given decision.

In the study using interviews, some respondents who can be classified as ‘Wireless Mostly’ had trouble articulating why they continued to have landline services. When individuals use a rational decision-making process, they can explain the criteria and the corresponding weights used to reach the decision. When individuals can’t explain how they came to a decision, it is often a signal that the rational-decision making process was not used.

Certain events or conditions alert an individual of the need to make a decision. In the abandonment of landlines, the interview data revealed that a residential move triggered an individual to consider abandoning landline service. This was confirmed in the survey data where 20.73 percent of the respondents abandoned landline service when they moved.

Due to recall issues, it was hard to determine how long respondents who abandoned landlines had both a landline and a mobile phone service. For those still using both a mobile and a landline system, 69.4 percent reported having both services for over ten years. Priming of the abandonment decision may have occurred often during the dual use period. This may be significant for those who don't appear to have a discrete activation point. Finding out if and how this decision is primed can be the topic of future research.

The analysis of the CDC data revealed that national economic events coincided with a statistically significant percentage of households abandoning landline service. In the first half of 2007, the CDC recorded the slowest rate of increase (.8 percent) in the number of households having only wireless service. At that time the CDC reported that results suggested that the rate of households entering the 'Wireless Only' state may be slowing but held off making a definite conclusion. In December of 2007, the U.S. economy entered a recession.

During the second half of 2008, the increase of households that only used mobile telecommunications service jumped by 2.7 percentage points from the first half of 2008. This was the largest six-month increase observed by the CDC (Blumberg & Luke, 2009a). This time period coincided with general economic uncertainty including a mortgage loan crisis, a federal bailout of the automobile industry and the bankruptcy of a major investment house. National unemployment increased from 5.2 percent in the first half of 2008 to 6.4 percent in the second half (U.S. Bureau of Labor Statistics, 2016).

The information requirement that the survey respondents and interview participants who were 'Wireless Only' reported consistently was the financial cost of maintaining a landline service. The majority of survey respondents (92.65%; n=63) reported the reason for abandoning landline service was the desire to no longer pay for the service. The CDC data also indicates that availability of economic resources affected who abandoned landline service.

A statistically significant difference exists in the percentages of the people who abandon the landline based on income levels. By 2015, the majority of 'poor' (64.3%) and 'near poor' (54.0%) adults had abandoned the landline in favor of strictly mobile service. This compares with the 45.7 percent of adult who are not poor and who don't have a landline (Figure 7-3). Between 2003 and 2015 the percentage of adults who reported no telecommunications service ranged from 1.5 to 3.1.

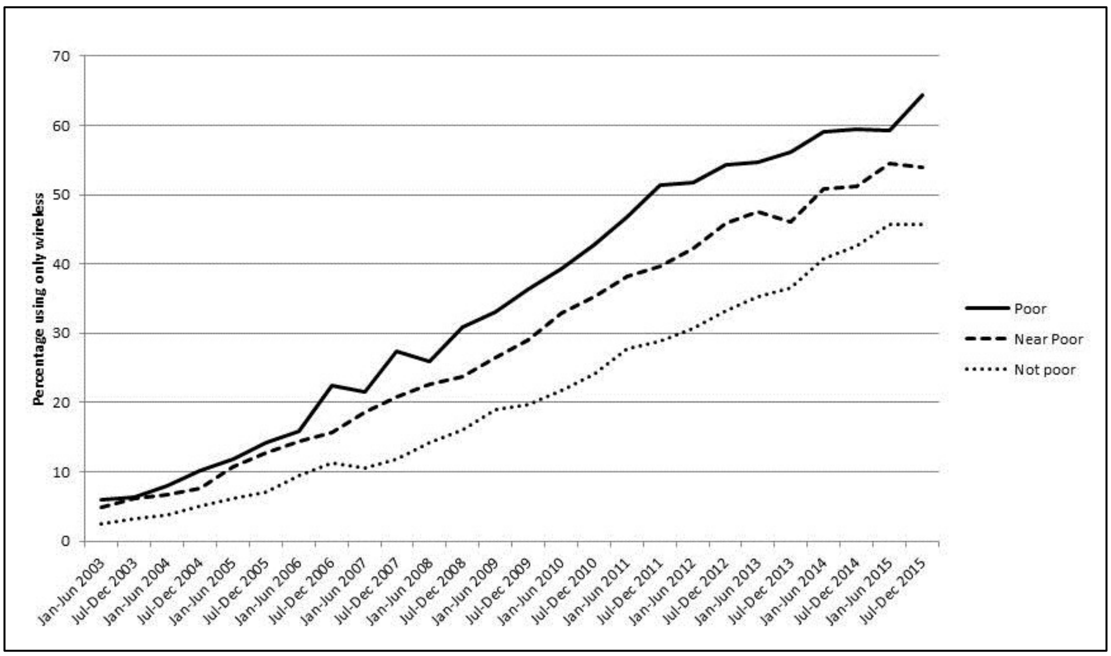


Figure 7-3 Percentage of 'Wireless Only' adults by income

Income is often used as a proxy variable that can be hard to interpret. The CDC uses the income to poverty ratio to determine the poverty status. The income to poverty ratio is based on a family's income relative to the poverty levels that the federal government revises annually to reflect changes in the Consumer Price Index. Households below the poverty level are classified as 'Poor' and those between 100% and 125% of the poverty level are classified as 'Near poor'

(CDC, 2013). In 2015, the national poverty threshold was $24,250 for a family of four and $11,770 for a single-person household (U.S. Dept. of Health and Human Services, 9/3/2015.). 'Near Poor' families of four had incomes ranging from $24,250 and $30,313 depending on the region.

The categories of 'Poor' and 'Near Poor' suggest that economic resources are limited and constrained. In 2003 the 'Poor' and 'Near poor' groups were more likely to be in 'Wireless Only' households than the 'Not poor'. The CDC collects the telephone service data as part of the National Health Interview Survey and releases some health information according to household telephone status. Between 2003 and 2015, a greater percentage of adults under the age of 65 in the 'Wireless Only' category were without health insurance compared to the percentage of that age group living in households with landlines. 'Wireless Only' adults were more likely to have experienced financial barriers to obtaining health care and more likely not to have a usual place to go for medical care than those with landlines.

Discussion

Researchers use naturalistic decision making methods to determine the decision-making process that individuals use in a given situation. Like grounded research, no formal decision making process or model is proposed before the research. In the decision to abandon landline service, individuals use two different decision processes depending on the availability of economic slack. Individuals who have limited economic slack use a rational method where the utility of landline service is determined and considered with other alternatives. Individuals who are not constrained by economic slack often rely on a routine or habitual or System 1 decision process (Figure 7-4).

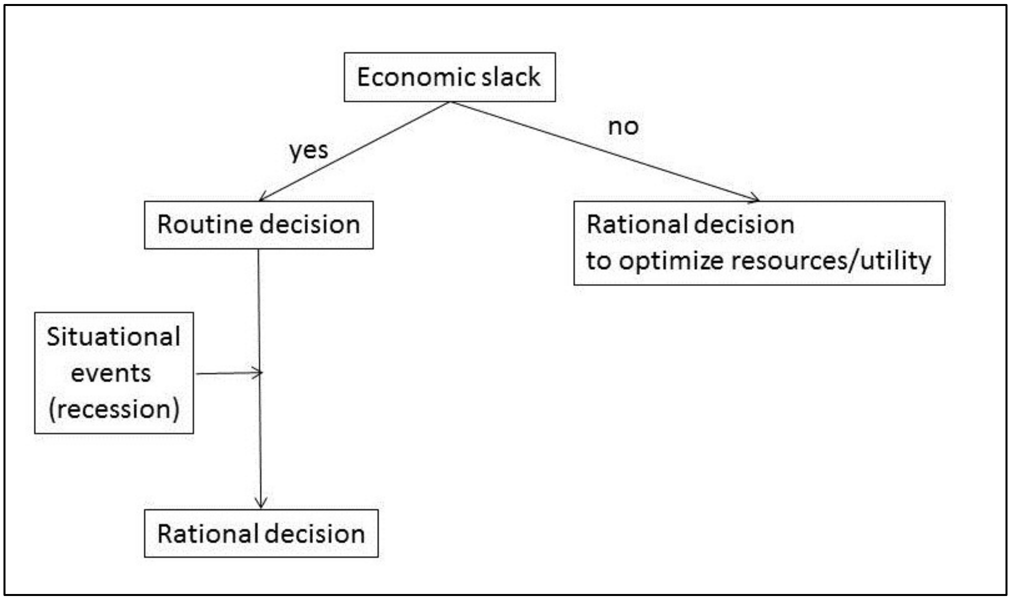


Figure 7-4 Decision model used in abandoning landline telecommunication service

Rational decision process

Individuals are often assumed to use a rational decision process for most decisions but seldom is that true. The rational decision process, which is also classified as a System 2 process, is cognitively expensive (Eysenck & Keane, 2010). System 2 decisions require attention and include the demanding work of complex computations (Kahneman, 2011). Forecasting future needs such as for telecommunication service are considered highly complex cognitive tasks. This process is analytical, rule-based and controlled (Eysenck & Keane, 2010).This process measures utility, which is a consideration in the landline decision.

When those who have abandoned landline service and those who have not were compared in the national data, individuals who lived at or near the poverty level were more likely to abandon landline systems. This in no means identifies all 'Wireless Only' members as having financial constraints. A financial constraint or the alert regarding the utility of the expense can force individuals to examine the decision using a System 2 or rational process. To get to that point, individuals in the survey data indicated that they were not using the service and were tired of paying for it thus indicating they made a calculation of utility, which is a characteristic of a rational decision process.

Proposition 1: Individuals who are economically constrained use a rational decision process when deciding to abandon landline services.

Routine decision process

The routine decision process is used when decisions are frequent and don't require a high expenditure of economic slack (Heiner,1983). The choice seldom involves a conscious consideration of the options (Wansick & Sobel, 2007). The decision making can be rapid and nearly unconscious (Evans, 2003). Individuals are drawn to this process due to the high cognitive cost of the rational decision process (Hamermesh, 2005). This process relies on past behavior choice (Kanhneman & Frederick, 2002). The utility of the item is dependent on past choices (Heckman, 1981).

In the interviews, respondents who had both landline and wireless service mentioned that the cost was low but didn't mention that the use justified the cost. This group doesn't appear to take the cognitive action of analyzing the utility. An interview respondent in the over 65 years of age seemed bewildered when asked why keep a landline that is seldom used. He always had a landline phone so he didn't see the reason to quit.

Proposition 2: Individuals who are not economically constrained are more likely to use a routine decision process when deciding to abandon landline telecommunications services.

Exogenous event

Individuals are often jolted out of the routine decision making by exogenous event (Howard & Shith, 1969). When an event occurs that violates the routine model of the world, an individual will shift into a rational decision model (Kahneman, 2011). This occurred during the economic recession between 2008 and 2013 when the number of individuals moved from dual service usage to a 'Wireless Only' state. The other event that was mentioned that caused individuals to abandon landline service was a residential move.

Proposition 3: Individuals will forsake the routine decision process to abandon landline telecommunications service when faced with outside events that either change the landline location or cause concern about economic slack.

Understanding the decision processes individuals use determines the decision support methods that human factors engineers prescribe for a given situation. For individuals using a routine decision process, creating an event like announcing a price hike or a promotional offer can cause an individual to use to a rational decision process. For those individuals using a rational decision process, decision supports addressing cost/benefit arguments are best. Just suggesting an individual is making a subconscious, routine decision can move an individual into a rational decision model. Not done tactfully it can possibly move an individual into an emotional decision-making model.

In transportation literature, researchers developing strategies to promote the use of mass transit found that matching the decision support to the decision-making process was instrumental to the success of the support (Schneider, 2013; Anable, 2005; Steg, 2005). The decision-making model based on landline telecommunications service abandonment is unique because it focuses on consumer co-production behavior in a service and not a product. It focuses on the process of decision making not criteria in the decision. This finding can be used in a similar manner to the transportation research in moving individuals into and out of specific service systems.

Conclusion

Little research attention has been given to the decision to abandon a service in favor of an innovative system. This research explores the decision-making process individuals used in deciding to abandon landline telecommunications service. When economic slack constrains the decision to maintain both landline and mobile telecommunication services, individuals use a rational decision-making model where utility is determined. When economic slack does not constrain the decision to abandon, individuals rely on a routine-decision process that depends on past behavior and may even be subconscious. The knowledge that different decision-making models are being used can affect the design of decision supports that aid or encourage a particular action. This research can be applied to situations when individuals are encouraged to adopt an innovation such as mass transit.

Limitations

This research did not explore issues beyond the information requirements and activation points on the Rasmussen Decision Ladder. By describing the process, future research can study the determinants that may affect the process. By drawing on three data sets, certain aspects such as quality differences between the regions are identified that may not have been identified if only regional respondents are used. Decision-making research uses smaller sample size and therefore, this highlights the importance of getting a representative sample.

Chapter 8 - The Role of Determinants, Process and Decision-Making in the Adoption of mHealth Services

When designing mobile health services, the adoption process, the decision-making process and the determinants of adoption can vary depending on the presence of a patient's legacy system. As the earlier research found (Chapter 4), legacy systems, whether a similar medical service or a self-service system, affect the process of optional, service innovation adoption. Support systems and technologies should be designed based to match the combination of the adoption process, the decision-making process and the determinants of adoption that affect a patient.

In this section, possible adoption processes a patient may use to adopt a mHealth service are discussed (Figure 1). Following the decision tree in Figure 8-1, the adoption process is determined by access to the necessary platform system, the presence of a legacy service, the superiority of the new service and the satisfaction with the legacy system. All affect the adoption process, the decision-making process of adoption and the determinants of adoption.

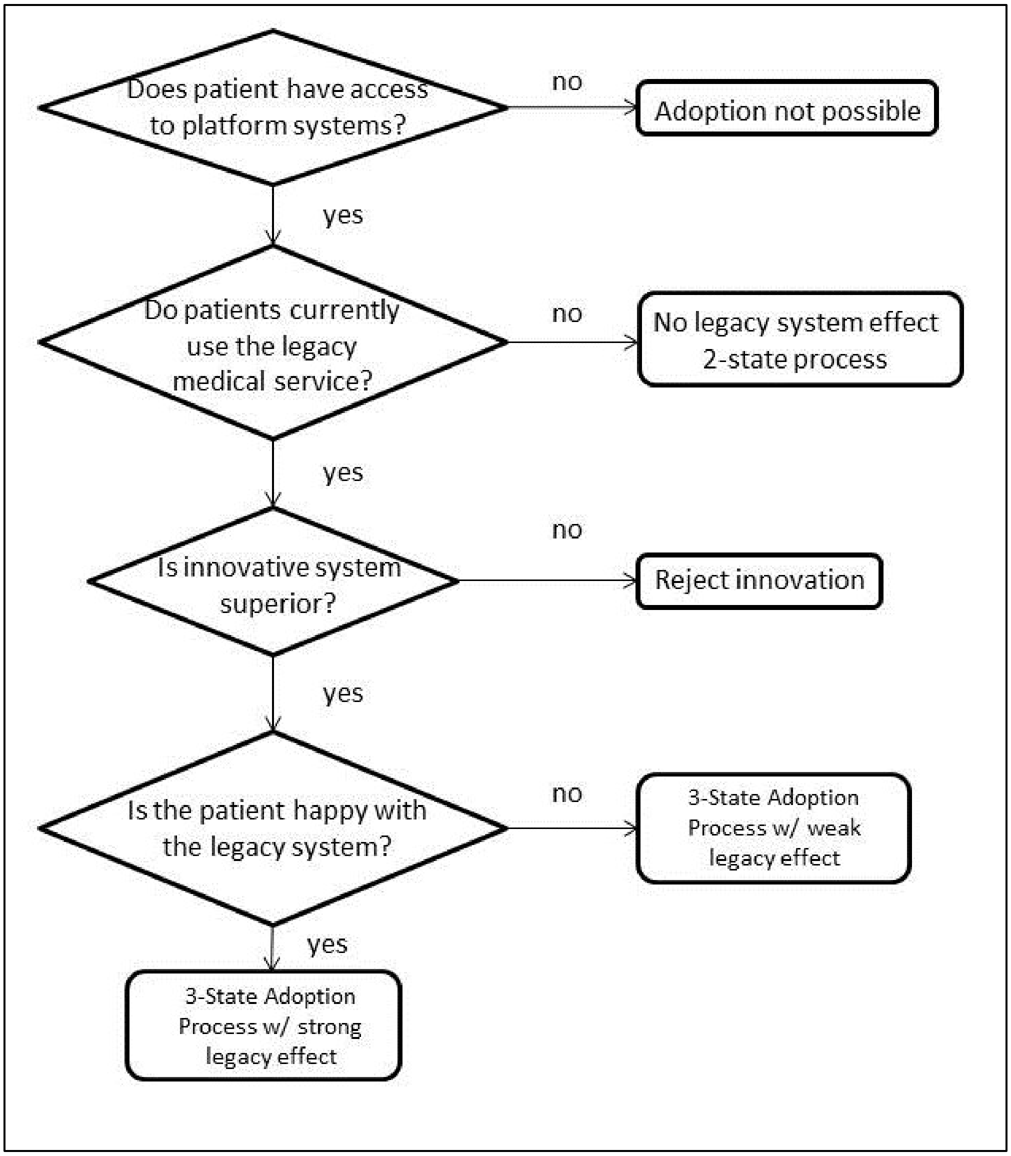


Figure 8-1 Adoptions options of mHealth systems based on legacy system usage

Macro-Environmental Adoption Determinants

As described in Chapter 3, individual-level innovation adoption can be influenced by three categories of determinants: macro-environmental, innovation-specific, and human factors (Figure 8-2).

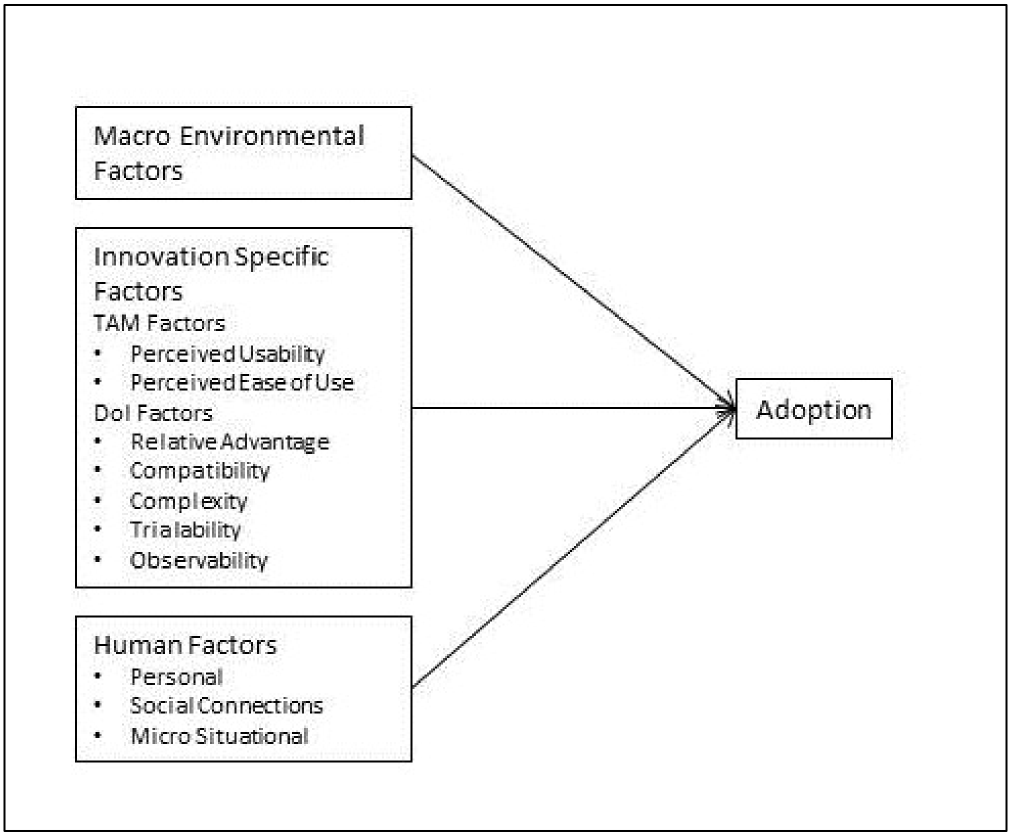


Figure 8-2 Factors of individual-level optional innovation adoption

All optional adoption decisions are affected by larger macro-environmental factors that were discussed in Chapter 3. In the case of mHealth services, Medicare and health insurance coverage will be the largest determinant in adoption. As a result, FDA approval of the service is equally important. Another factor that may affect overall adoption is the security of internet and smart devices.

General economic conditions are expected to have a limited effect on the adoption of mHealth services due to the role of insurance. Economic conditions can affect the adoption and usage of the platform systems. If patients want to continue to use a legacy system, they may need to pay for the service themselves. As was found in Chapter 7, weak economic conditions can encourage abandonment of legacy systems by those feeling the tightening of economic slack.

The presence of a legacy system affects the path of adoption (Chapter 5), the human factors (Chapter 3), that influence adoption and the decision-making process that is used in adoption (Chapter 7).

Platform Systems

Mobile health service systems, by definition, require the platform of mobile telecommunications. If a patient lacks access to the platform system, adoption is not possible. This dependency requires mHealth service designers to verify the mobile telecommunications systems that potential adopters can access.

Mobile health service systems use the underlying platform architecture of smartphone technology or mobile telecommunications services using short messaging services or multi-media message services.

Process

The process of mobile telecommunications service adoption is discussed in chapters 5 and 6.

Human Factors Adoption Determinants

Personal Factors

The CDC found differences in the adoption levels between groups based on both age and culture. Hispanics were more likely than non-Hispanics to adopt mobile telecommunications services (Blumberg & Luke, 2003b). No cause is given for this difference. The CDC also found that older adults were less likely to adopt mobile telecommunications service compared to other age groups (Blumberg & Luke, 2014a). In 2015 78% of adults over 65 owned a cell phone and 30% of adults over 65 owned a smartphone (Anderson, 2015).

As discussed in Chapter 7, another personal factor, geography, may affect mobile phone adoption. Designers need to recognize that mobile telecommunications service adoption is not equally distributed across the U.S. The Northeast has been slower to abandon landline service (Blumberg & Luke, 2016a). This difference may be attributed to poorer service in that region. Unreliable platform service will likely affect the adoption of the mHealth service.

Social Factors

Social factors that affect the adoption of mobile telecommunications service may include social networks. Individuals communicate with social network contacts using mobile telecommunications service. Social learning is a component of technology-knowledge transfer (Bikhchandani, Hirshleifer & Welch, 1998). How a patient and his social network incorporate a service into everyday life may affect the possibility that a patient will use a mobile phone for tasks other than verbal communication (Silverstone & Haddon, 1996).

Micro Situational Factors

The patient's access to smartphones can influence the adoption of mHealth. Many mHealth services utilize Bluetooth technology that transmits information to the cloud via the smartphone. If a patient doesn't have access to the necessary smartphone platform systems, adoption is not an option. Therefore, it is imperative that healthcare providers considering mHealth service systems verify that patients have smartphones and not just mobile phones.

The interview data from Chapter 2 indicated that individuals were concerned about the cost of telephone services when adopting. As a result it is likely that the smartphone systems may be cost prohibitive to some individuals. While insurance and Medicare will likely pay for FDA-approved mHealth service systems, the cost of smartphones and other platform systems will be the responsibility of the patient.

The data demands of mHealth will also be the responsibility of the user and must match the data usage behavior of the patient. Smartphone internet usage is replacing home broadband subscriptions that have fewer data restrictions. As a result, smartphone internet users are beginning to demonstrate data optimization behavior that can affect the decision to use a mobile health service based on its data demands. This behavior is breaking down on income levels (Pew Research Center, 2015).

Legacy System Effects

If the patient has access to the required platform systems, then the effects of legacy systems need to be explored. Legacy systems include any tools or processes that a patient uses in the behavior related to the healthcare tasks that a mHealth service could replace. Legacy systems are often viewed as technological systems, but they can include social systems and task behavior as was found in the interview research in Chapter 2. In the case of medical tasks, regularly visiting a clinic to have blood levels checked is considered the legacy system. These systems can include a complex network of caregivers. A mHeatlh medication monitoring system may replace the activities a spouse provided. The unique combination of social supports, task behaviors and technological systems can make predicting effects difficult. This can be further complicated by the various utilities a patient may receive from the legacy system. A regular trip to a clinic for a blood test may satisfy social needs that will go unmet with a mHealth service system. For that reason assuming blanket adoption of a mHealth service is unrealistic in optional situations since it may not satisfy all the patient needs.

No Existing Legacy System

Process

If a mHealth service is the first treatment option a patient is given, no legacy system effect is present. Patients in this situation do not have past experience in the task behavior that the service is offering. Patients adopt both the mHealth service and the task behavior associated with their healthcare. These patients will likely use a two-state adoption process that is commonly used to model single innovation adoption as discussed in Chapter 4 (Figure 8-3). In this process the patient transitions from the state of 'Potential Adopter' to 'Active Adopter'. After trying the mHealth system, patients have the option of abandoning the mHealth service and leaving the system.

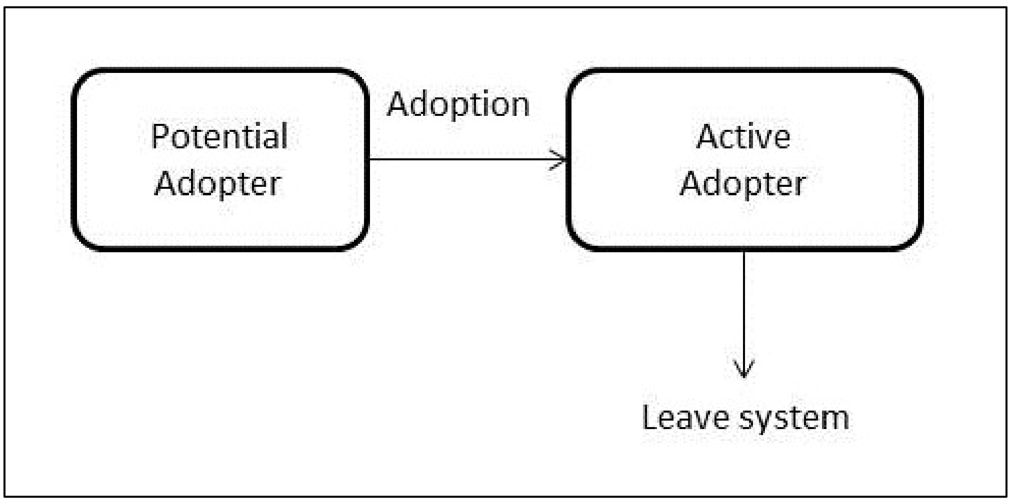


Figure 8-3 Two-state adoption process

Human Factors Adoption Determinants

In the situation where a legacy system is not present, the following factors discussed in Chapter 3 may affect the adoption process.

Personal Factors

When a patient is in a new situation (new medical condition) and learning a new system (mHealth), certain cognitive factors may be influential including the ability to create a schema (Mandler & DeForest, 1979), memory processing (Atkinson & Shiffin, 1968; Winn, 2004), sense-making (Prasad, 1993) and frustration (Amsel, 1992). Checklists, education interventions and opportunities to practice the new system can help in these situations. It is important that the cognitive map the patient creates centers around the medical condition and not on the mHealth service (Gentner, 1983). The first concern of medical caregivers should be the patient's understanding of the medical condition and not mastery of the technology used to treat the condition.

Social Connection Factors

Knowing others who can provide support or mentor a patient through the mHealth service system can help in the adoption process (Bikhchandani, Hirshleifer & Welch, 1988, Lave & Wenger, 1991). Social meanings can also determine how the patient reacts to the service and the medical condition (McGuire, 1969). With a health service, symbolic adoption (Klonglan & Coward, 1970) affects the patient's attitude and acceptance of the mHealth service and the medical condition. The individual needs to admit that a health circumstance exists. This may be more difficult than the adoption of mHealth services. Suggested interventions include the mHealth provider creating social networks either real or in a virtual space. Healthcare providers can also provide educators to help mentor the patients through the medical system.

Micro-Situational Factors

Without a legacy system, an individual will not have a benchmark to compare any task behavior. The mHealth service will be judged on its own innovation-specific merits. A large body of adoption research exists regarding the importance of creating products that are both easy to use and that satisfy the needs of the adopter (Venkatesh, Morris, Davis & Davis, 2003b). With many service systems, the user can achieve the same result doing the task himself (self-service). In those cases, the service system needs to be more beneficial than any self-service system the individual can create. A smart scale can record the daily weight of an individual. An individual can also record daily weight using a bathroom scale and a pen and paper. It just depends on the individual's goal and circumstances.

An aversion to the ambiguity relating to both the service and the health condition may exist (Ellsberg, 1961). Long-term adoption will depend on the fit of the task and the service (Goodhue & Thompson, 1995). As the patient gets more comfortable with both the task and the medical condition, he will adapt the system to his needs and situation (Silverstone & Haddon, 1996). While the system may not be exactly as the medical community may have expected, this adaption often leads to continued usage (Rogers, 2003).

Decision-Making Process

The innovation adoption process often includes the abandonment of a previous product, process or idea (Chapter 5). In Chapter 7, individuals who abandoned a legacy service system used a rational decision-making process. In the rational model, a patient will measure the benefits and costs of accepting both the health condition and the mHealth system as a treatment option.

Emotional responses in stressful situations such as health conditions can affect the decision-making process (Kahneman, 2011). The benefits and costs determined in a rational process can be greatly distorted by an emotional response to the health condition. If an individual doesn't want to acknowledge the health condition, an emotional response can convince an individual that the service is not required. Rather than encourage rational behavior, a suggested intervention would be to explore and address the drivers of the emotional response.

Legacy System Superiority

Process

If a patient uses a legacy health system and is faced with the decision to switch to a mHealth service, a legacy system effect can influence the adoption process. This process can be modeled using a three-compartment model from Chapter 5. When the model is employed with the mHealth service situation, the three compartments are described in Figure 8-4. The path of adoption will vary according to the strength of the legacy system effect, which is determined by the patient's satisfaction with the legacy system.

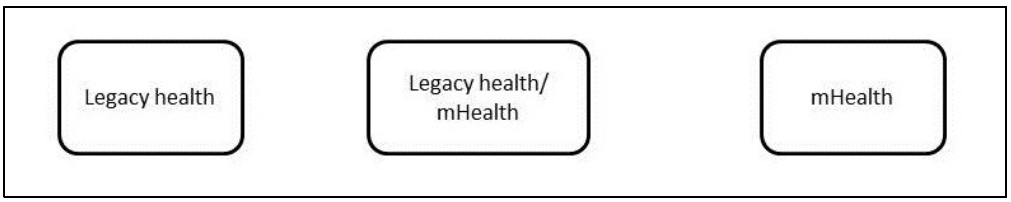


Figure 8-4 Three-compartments of mHealth adoption process when legacy system is present

Feelings of satisfaction with the legacy system can create a strong legacy effect that may determine the path of adoption. In this situation, it is assumed that the patient can continue to use the legacy system.

Those who are most satisfied with the legacy system may never try the mHealth service and continue to use the legacy system (Figure 8-5).

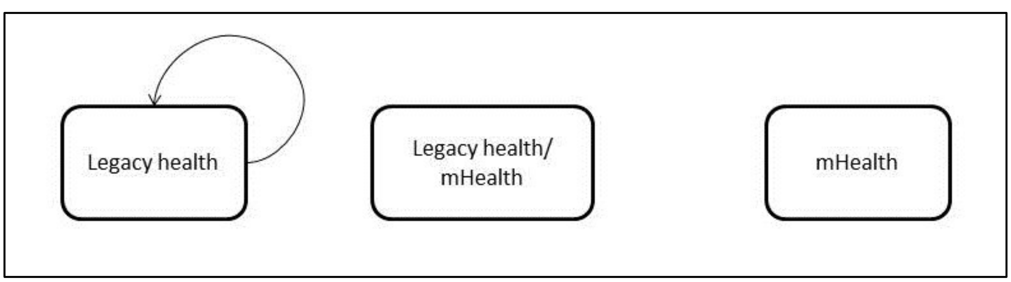


Figure 8-5 Adoption path when legacy system is not abandoned

Another possible path is to adopt mHealth indefinitely and continue to use the legacy health system when needed (Figure 8-6). This path requires enough slack resources to sustain both service systems. From the survey data used in Chapter 5, 44% (108) of the 244 respondents reported this behavior regarding mobile telecommunications service adoption. Of the 108 respondents using this path, 80% (86) originally got mobile telecommunications to use away from home. Over time that group began using the mobile telecommunications system at home and at the time of the survey, 59% (51) considered the mobile system their primary telecommunications system. This is similar to the behavior the CDC found with the 'Wireless Mostly' group (Chapter 7).

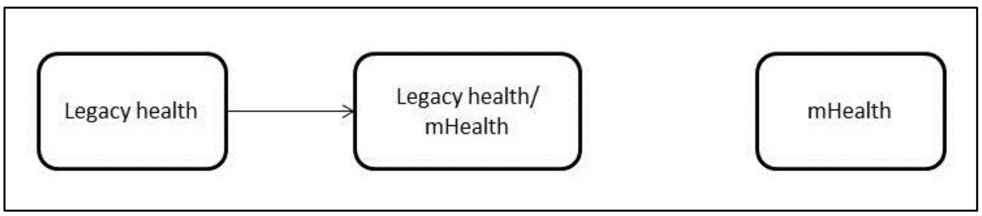


Figure 8-6 Adoption path when mHealth is adopted but a legacy system is not abandoned

A patient can adopt the mHealth service then revert back to the legacy system, completely abandoning the mHealth service (Figure 8-7). This path suggests the individual adopted the innovative system, then for whatever reason decided to discontinue the innovative system's usage.

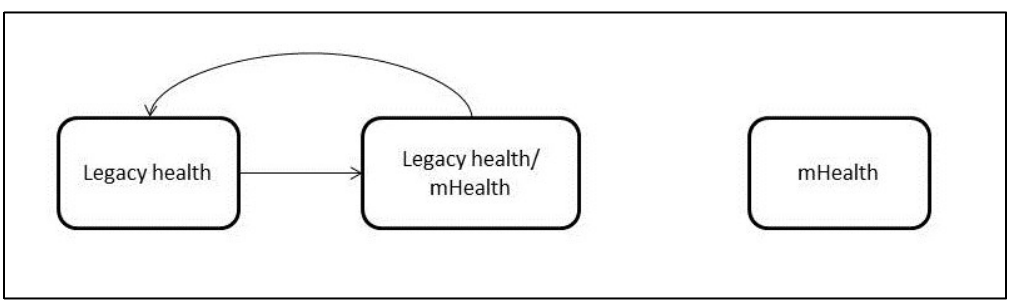


Figure 8-7 Abandonment of a mHealth service and reverting to legacy service

Finally patients may use the path mobile telecommunications adopters followed as they moved through all three states as described in Chapter 5 (Figure 8-8). This path as been discussed in Chapters 5, 6 and 7 and will not be discussed further here.

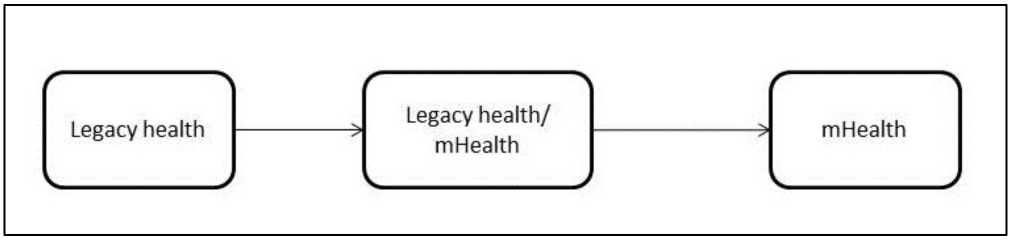


Figure 8-8 Adoption path from period of dual service system usage to abandonment of a legacy service

When the patient is not satisfied with the legacy system, a weak legacy system effect would exist. Adoption could be encouraged by a willingness to abandon the legacy system. An additional adoption path avoids the period of dual usage and the patient moves directly to full adoption of mHealth (Figure 8- 9). Along with dissatisfaction with a legacy system, this path may result when financial conditions do not allow for the dual use of a legacy system and a mHealth service at the same time.

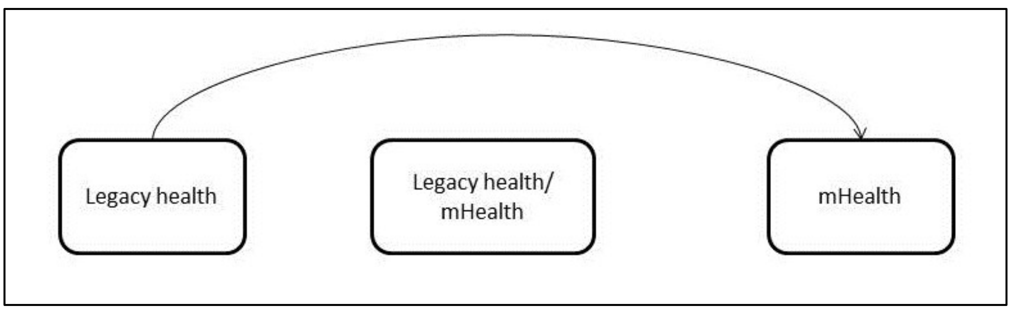


Figure 8-9Adoption path when adoption of mHealth is simultaneous with abandonment of the legacy system

Human Factors Adoption Determinants

Many of the factors that were applied when a legacy effect was not present also apply in this situation.

Personal Factors

Regardless of the adoption path, a legacy system can affect the mental model patients use regarding a healthcare task. These mental models can be strong and hard to overwrite if the mHealth service differs greatly from the legacy system (Mandler & DeForest, 1979). If a patient is satisfied with the legacy system, the patient's desire to create a new mental model may not be strong. Cognitive frustration can be disguised as resistance to the innovation (Ram, 1987; Ram & Sheth, 1989). If the mHealth system requires a great deal of learning, the patient must require the necessary cognitive and temporal slack to satisfy the learning and memory requirements (Rogers, 2003). Opportunities to practice new skills and educational supports can help in this situation.

How the patient judges his own ability to use technology can affect the adoption of a mHealth system (Ashcraft, 2013). In that same line, how a patient views his occupational identity regarding medical or healthcare task may also affect adoption (Freidson, 1984).

Social Connection Factors

Who benefits from the system is an important consideration. Often the mHealth systems, which allow some tasks such as monitoring to be done remotely, are designed to benefit the caregivers, healthcare providers and social network of the patient. The interactions and relationships between the patient and others who may be encouraging adoption can affect adoption (Putney & Bengtson, 2002; Di Leonardo, 1987; Zappala, 2000).

If the legacy system satisfied social needs that will be unmet with the mHealth network, the patient's adoption will be affected (Kaptelinin & Nardi, 2006). Social networks will help define how the mHealth service fits into the life of the patient (Sliverstone & Haddon, 1996). If the service is a good fit, adoption is more likely.

Interventions that can help with social connections include enlisting social supports early in the adoption process. Having social supports in place can prevent future frustration and will help in the adoption process. When someone is frustrated, emotional responses are more likely to influence the decision-making process (Kahneman, 2011).

Micro Situational Factors

In optional, innovation adoption decisions, the innovative service must provide some benefit above the legacy service in order to sustain adoption. The determination that an innovative service system is superior to a legacy system is determined by the individual user and is specific to a particular time. If the decision to adopt is made by another party, it is no longer optional, therefore, innovation adoption is outside of the scope of this research. The decision of superiority may be a factor of time and dependent of improvements to the mHealth service that occur during the service lifespan.

Using the three-state model, the patient who determines a mHealth service is not superior and rejects the innovation remains in the first state of 'Legacy health'. This is a common situation when an innovation is relatively new and the adopters wait until the system has been tested and improved before adopting (Rogers, 2003). Over time the possible advantages of the mHealth service may drive the patient to reverse the decision and accept mHealth services. The amount of time required before a patient is willing to try a mHealth service that is new and untested will vary according to the patient's level of risk aversion (Pratt, 1964) and anticipated regret (Janis & Mann, 1977). Once the mHealth service has been adopted by a threshold population, adoption by the individual is much easier (Granovetter, 1978).

Satisfaction is a function of the situation and needs, which can change over time. Like mobile telecommunications service, the overarching benefit of mHealth services is mobility. This innovation-specific condition will appeal to those who are not tied to a location as it did with mobile telecommunications service (Blumberg & Luke, 2015b).

Some possible factors of adoption when a legacy system is present include new product uncertainty (Hoeffler, 2003) and anticipated regret over the decision to adopt (Janis & Mann, 1977). The regret over the adoption decision may be intensified if the platform service such as a smartphone experiences any glitches after using the mHealth service.

Flexibility in task behavior that allows for the new service to fit the patient's lifestyle is required when moving away from an established legacy system (Goodhue & Thompson, 1995). Many of the micro-situational factors affecting adoption can be countered by education campaigns that expose the patient to the mHealth service before being asked to adopt.

Decision-Making Process

As found in Chapter 7, the decision-making process plays a role in adoption. Rational models allow patients to weigh the benefits and consequences of adoption. Again emotional response can affect the comparisons between the legacy service and the innovative service (Kahneman, 2011). In this case, the response may be driven by fear of the new system or, equally likely, contentment and satisfaction with the legacy system.

The desire to continue with routine decision-making may encourage a patient to reject mHealth to avoid the cognitive stress rational decision-making can cause (Chapter 7).

Implications for the mHealth companies and policy makers

This chapter has focused on the individual-level adoption and how the process, the decision-making and determinants are influenced by a legacy system. The management of mHealth companies and U.S. policy makers, who are hoping to lower healthcare costs through the adoption of mHealth systems, are concerned with the national diffusion of these systems.

The simulations in chapter 6 revealed that adjustments to the adoption and abandonment rates can lead to projected modest increases in the proportions using the system. The most predictable path to guarantee adoption of mHealth systems is to restrict and eliminate the usage of some legacy systems. Either through limiting production or limiting insurance payments, legacy system usage can be curtailed. This strategy moves the decision from that of an optional decision to that of a mandatory decision to adopt. The dynamics surrounding mandatory adoption are out of the scope of this research.

Conclusion

Early research found that the adoption of mobile telecommunications service was affected by the presence of legacy systems. The adoption of mHealth service is likely to also experience the same effects.

The adoption of mHealth service is dependent on the adoption of the platform system, which will likely be smartphone technology, and macro-environmental factors such as insurance and Medicare payment policies. If mHealth services are paid for by insurance, the cost of the platform and data requirements will be the responsibility of the patients and may hinder adoption.

Different adoption behavior will result if a legacy system is present. Patients who are newly diagnosed and do not have a legacy system will face the acceptance of a medical condition, the adoption of a mHealth service and the establishment of task behavior related to the medical condition. In this situation, the adoption of the mHealth service may have the lowest priority.

If a mHealth service hopes to be adopted, it must be superior to the legacy system or it faces rejection. Superiority will be judged by the patient on a variety of criteria including cost, ease of use and function. When a service is deemed superior, the patient's satisfaction with the legacy system can determine the strength of the legacy effect on adoption.

The legacy effect and the availability of slack resources can affect the determinants of adoption, the adoption process, and the decision-making process that is used in adoption.

Interventions in these three areas (determinants, process or decision-making) can be applied to either encourage or discourage the adoption of a mHealth service.

Future research is called for in the design and adoption of mHealth services. As more mHealth services get approved by the FDA, more opportunities will be available to test the effects of a legacy system and the interaction between determinants, the adoption process and the decision-making process of service adoption.

Chapter 9 - Conclusion

The multidisciplinary aspect of the human factors fields allows for research to contribute to both the areas of human factors and service science.

This research contributed to the young field of service science by creating a descriptive model and a quantitative model of service innovation adoption. A descriptive model of the process of service innovation adoption was proposed. This model accounted for the role of legacy systems in the adoption process and more accurately described the behavior that was found in grounded research with older adults and by the Centers for Disease Control. Individuals who adopted mobile telecommunications service didn’t immediately abandon the legacy service of landline telecommunication service. Individuals slowly migrated from a period of having both landline and mobile phones before fully abandoning landline phones. Using data from the Centers of Disease Control and a survey administered by the researchers, the most-probable path of adoption was determined. Legacy service providers can apply this model when faced with an innovation that can possibly replace the legacy service.

Along with a descriptive model, a quantitative model was developed using compartmental mathematical principles that rely on first-order derivatives. In manufacturing, a finished goods inventory allows a buffer between production and demand. Service production doesn’t allow for a finished goods inventory. Matching production capacity to demand requirements when a service innovation is present can be difficult for legacy service providers. The three-state mathematical model of service innovation adoption can forecast long-term demand and production levels. Simulations were run for both the legacy system and the innovative system using abandonment and adoption rates.

The descriptive model and the mathematical model were both specific to service production and are not extensions of models used in the goods production. Service-dominant logic rather than goods-dominant logic was used in this research.

The unique contributions that older adults provide to the co-production of healthcare services were addressed. As engineers build and design new service systems to address the care of the growing population of older adults, the metrics employed to quantify the contributions of older adults were analyzed. The proxies of income and education were used to measure available resources and cognitive and sensory abilities. These measurements were problematic when applied the population of older adults. If the goal is to build responsive service systems, new, or at least more accurate, metrics and proxies are needed to accurately measure the input of older adults. This work contributed to the knowledge of service design for older adults.

In the field of human factors, a typology of factors of innovation adoption was designed. This typology identified three categories of factors of individual-level innovation adoption including macro-environmental, innovation specific and human factors. The human factors category was broken down further into personal, social connections and micro-situational categories. The contribution of this research was to provide human factors professionals an easily accessible reference when working in the field. This is most applicable to those working in user experience applications.

Decision making falls under the domain of human factors. The decision of interest was the abandonment of the legacy system of landline telecommunications and full adoption of mobile telecommunications. Two different decision-making processes, rational and routine, were used in the abandonment of the landline telecommunications service. This finding is believed to be the first to explore the cognitive processes used in the abandonment decision in innovation adoption.

An analysis in how the adoption process, decision-making process and determinants of adoption may affect the adoption of mHealth systems is included. This ties together the adoption process, the human factors determinants of adoption and the decision-making process involved in adoption.

Future research

With an accurate description of the process of service innovation adoption and legacy system abandonment, future research will explore and determine service system designs that encourage adoption and abandonment. Building on the knowledge developed in this research and incorporating the knowledge of human-centered design from physical product development, successful design models can be explored and tested that go beyond the traditional user interface and experience (A/B) testing that is currently used. Complex service systems such as healthcare offer potential research opportunities since embedded and platform systems are heavily used in complex systems.

Research in the cognitive switching behavior in service adoption and abandonment needs to be tested more thoroughly. Understanding when consumers are using routine behavior and rational behavior allows for better service designs. When behavior becomes routine, consumers can allocate cognitive resources on other activities. This is significant for older adults who may be experiencing changes in cognitive resources.

References

Administration on Aging. (2013). *A Profile of Older Americans:2013.* Washington D.C.: Department of Health and Human Services.

Ahuja, G. (2000). Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative Science Quarterly*, *45*(3), 425-455.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior.*

Álvarez, J.F. (2010). Colombian family farmers' adaptations to new conditions in the world coffee market. *Latin American Perspectives, 37*(2), 93-110.

Amsel, A. (1992). Frustration theory: An analysis of dispositional learning and memory. Cambridge: University Press.

Anable, J. (2005). 'Complacent car addicts' or 'aspiring environmentalists'? Identifying travel behaviour segments using attitude theory. Transport Policy, 12, 65-78.

Anand, P., & Sternthal, B., (1990). Ease of message processing as a moderator of repetition effects in advertising. Journal of Marketing Research, 27(3), 345-353.

Anderson, M. (2015). *Technology Device Ownership: 2015*. Washington D.C.: Pew Research Center.

Andreassen T, Kristensson P, Lervik-Olsen L, Parasuraman A, McColl-Kennedy J, Edvardsson B, Colurcio M (2016) Linking service design to value creation and service research. Journal of Service Management, 27(1), 21-29.

Ashcraft, K.L. (2013). The glass slipper: "Incorporating" occupational identity in management studies. *Academy of Management Review, 38*(1), 6-31.

Atkinson, R.C., & Shiffrin, R.M. (1968). Human memory: A proposed system and its control processes. *The Psychology of Learning and Motivation, 2,* 89-195.

Aubert, P., Caroli, E., & Roger, M. (2006). New technologies, organization and age: Firm-level evidence. *Economic Journal, 116*(509), F73-F93. doi: 10.1111/j.1468-0297.2006.01065.x

Baker, D. (2006). The meaning and the measure of health literacy. *Journal of General Internal Medicine, 21*(8), 878-883.

Barham, B.L., Chavas, J., Fitz, D., Salas, V.R., & Schechter, L. (2014). The roles of risk and ambiguity in technology adoption. *Journal of Economic Behavior & Organization, 97,* 204-218.

Barron, J. (2003, August 15). The Blackout of 2003: The overview; Power surge blacks out Northeast, hitting cities in 8 states and Canada; Midday shutdowns disrupt millions. *New York Times, August 15, 2003*. Retrieved from http://www.nytimes.com/2003/08/15/nyregion/blackout-2003-overview-power-surge-blacks-northeast-hitting-cities-8-states.html?_r=0

Bass, F.M. (1969). A new product growth for model of consumer durable. *Management Science, 15*(5), 215-227.

Beaudry, A., & Pinsonneault, A. (2005). Understanding user responses to information technology: A coping model of user adaption. *MIS Quarterly,29*(3), 493-524.

Becker, G.S. (1964). *Human capital: A theoretical and empirical analysis, with special reference to schooling.* New York: Columbia University.

Bikhchandani, S., Hirshleifer, D., & Welch, I. (1998). Learning from the behavior of others: Conformity, fads, and informational cascades. *The Journal of Economic Perspectives,12*(3), 151-170.

Biswas, D. (2009). The effects of option framework on consumer choices: Making decisions in rational versus experimental processing modes. *Journal of Consumer Behaviour, 8*, 284-299.

Blumberg, S.J. & Luke, J.V. (2007a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2006.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2007b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2007.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2008a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2007.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2008b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2008.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2009a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2008.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2009b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2009.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2010a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2009.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2010b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2010.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2011a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2010.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2011b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2011.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2012a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2011.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2012b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2012.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2013a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2012.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2013b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2013.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2014a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2013.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2014b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2014.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2015a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2014.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2015b). *Wireless substitution: Early release of estimates from the National Health Interview Survey, January-June 2015.* Atlanta, GA: National Center for Health Statistics.

Blumberg, S.J. & Luke, J.V. (2016a). *Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2015.* Atlanta, GA: National Center for Health Statistics.

Breidbach, C.F., Smith, P., & Callagher, L.J. (2013). Advancing innovation in professional service firms: Insights from the service-dominant logic. *Service Science, 5*(3), 263-275.

Brown, J.J., & Reingen, P.H. (1987). Social ties and word-of-mouth referral behavior. *Journal of Consumer Research,14*(3), 350-362.

Burt, R.S. (2000). Decay functions. *Social Networks, 22*(1), 1-28.

Chacos, B. (2016, May 22). How Microsoft's tricky new Windows 10 pop-up deceives you into upgrading. *PC World.*

Chase, R. (1981). The customer contact approach to services: Theoretical bases and practical extensions. *Operations research, 29*(4), 698-706.

Chase, R. & Tansik, D. (1983). The customer contact model for organization design. *Management science, 29*(9), 1037-1050.

Chong, K.C. & Zee, B.C. (2014). Compartmental Models in SAS: Application to Model Epidemics.Hong Kong: PharmaSUG China. Retrieved from http://www.lexjansen.com/pharmasug-cn/2014/SP/PharmaSUG-China-2014-SP03.pdf

Christou, C., Eliophotou-Menon, M., & Philippou, G. (2004). Teachers' concerns regarding the adoption of a new mathematics curriculum: An application of CBAM. *Educational Studies in Mathematics, 57*(2), 157-176.

Clark, T. (1990). International marketing and national character: A review and proposal for an integrative theory. *The Journal of Marketing,54*(4), 66-79.

Coleman, J.S. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94,* S95-S120.

Collier, J.E. & Kimes, S.E. (2013). Only if it is convenient: Understanding how convenience influences self-service technology evaluation. *Journal of Service Research, 16*(1), 39-51.

Conte, R. (1999). Social intelligence among autonomous agents. *Computational & Mathematical Organization Theory, 5*(3), 203-228.

Crosby, L.A., Evans, K.R., & Cowles, D. (1990). Relationship quality in services selling: An interpersonal influence perspective. *The Journal of Marketing, 54*(3), 68-81.

Daft, R.L., & Lengel, R.H. (1986). Organizational information requirements, media richness and structural design. *Management Science, 32*(5), 554-571.

D'Ambra, J., Wilson, C.S., & Akter, S. (2013). Application of the task-technology fit model to structure and evaluate the adoption of E-books by academics. *Journal of American Society for Information Science & Technology, 64*(1), 48-64.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Davis, F.D., Bagozzi, R.P., & Warshaw, P.R. (1989). Users acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003.

de Bruin, W., Parker, A. & Fischholff, B. (2012). Explaining adult age differences in decision-making competence. *Journal of behavioral decision making, 25*(4), 352-360.

Deffuant, G. (2005). An individual-based model of innovation diffusion mixing social value and individual benefit. *American Journal of Sociology, 110*(4), 1041-1069.

Denver Post. (2016, September 19). With decline in landline phone service, CenturyLink asks for volunteers in new round of 3,000 layoffs. Retrieved at http://www.denverpost.com/2016/09/19/decline-in-landline-phone-service-centurylink-ask-volunteers-3000-layoffs/

Di Leonardo, M. (1987). The female world of cards and holidays: Women, families, and the work of kinship. *Signs, 12*(3), 440-453.

Dictionary, O.E. (2004). Oxford English Dictionary online. *Mount Royal College Lib., Calgary, 14.*

Dos Santos, B.L. (1991). Justifying investments in new information technologies. *Journal of Management of Information Systems, 7*(4), 71-89.

Drucker, P.F. (1998). The discipline of innovation. *Harvard Business Review, 76*(6), 149-157.

Due, J.F. (1959). An empirical study of abandonment decisions. *Journal of Finance, 14*(3), 361-372.

Edison Electric Institute. (2013). *Disruptive challenges: Financial implications and strategic responses to a changing retail electronic business.* Washington, DC: Kind, P.

Eichler, K., Wieser, S., & Brugger, U. (2009). The costs of limited health literacy: A systematic review. *International Journal of Public Health, 54*(5), 313-324.

Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532-550.

Elie-Dit-Cosaque, C.M., & Straub, D.W. (2011). Opening the black box of system usage: User adaptation to disruptive IT. *European Journal of Information Systems, 20*(5), 589-607.

Ellsberg, D. (1961). Risk, ambiguity, and savage axioms. *The Quarterly Journal of Economics,75*(4), 643-669.

Epstein, S. Lipson, A., Holstein, C. & Huh, E. (1992). Irrational reactions to negative outcomes: Evidence for two conceptual systems. *Journal of Personality and Social Psychology, 62*(2): 328-339.

Epstein, S. Pacini, R., Denes-Raj, V. (1996). Individual differences in intuitive-experiential and analytical-rational thinking styles. *Journal of Personality and Social Psychology, 71,* 390-405.

Evans, J. (2003). In two minds: Dual-process accounts of reasoning. *Trends in Cognitive Science, 7*, 454-59.

Eysenck, M. & Keane, M. (2010). *Cognitive psychology.* New York, NY: Psychology Press.

Fairley, P. (2013, March 28). Residential solar power heads toward grid parity. *IEEE Spectrum,*

Feleke, S. & Zegeye, T. (2006). Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. *Food Policy, 31*(5), 442-457.

Ferber, J. (1999). *Multi-agent systems: An introduction to distributed artificial intelligence.* Harlow:Addison Wesley Longman.

Fisk, A., Rogers, W., Charness, N., Czaja, S. & Sharit, J. (2009). Designing for older adults: Principles and creative human factors approaches (2nd ed). Florida: CRC Press.

Fox, N.J. (2011). Boundary objects, social meanings and the success of new technologies. *Sociology, 45*(1), 70-85.

Freidson, E. (1984). The changing nature of professional control. *Annual Review of Sociology, 10,* 1-20.

Freund, L. & Spohrer, J. (2013). The human side of service engineering. *Human Factors and Ergonomics in Manufacturing & Service Industries. 23*(1). 2-10.

Gang, L., Wong, K.F., Song, H., & Witt, S.F. (2006). Tourism demand forecasting: A time varying parameter error correction model. *Journal of Travel Research, 45*(2), 175-185.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*(2), 155-170.

Glass, R.L. (1999). The realities of software technology payoffs. *Communications of the ACM, 42*(2), 74-79.

Godfrey, K. (1983). *Compartmental models and their applications.* New York, NY: Academic Press.

Godin, B. (2008). In the shadow of Schumpeter: W. Rupert McLaurin and the study of technological innovation. *Minerva, 46*(3), 343-360.

Goldenberg, J., Han, S., Lehmann, D.R., & Hong, J.W. (2009). The role of hubs in the adoption process. *Journal of Marketing, 73*(2), 1-13.

Goodale, J.C., Verma, R. & Pullman, M.E. (2003). A market utility-based model for capacity scheduling in mass services. *Production & Operations Management, 12*(2), 165-185.

Goodhue, D.L. (1995). Understanding user evaluations of information systems. *Management Science, 41*(12), 1827-1844.

Goodhue, D.L. (1997). The model underlying the measurement of the impacts of the IIC on the end-users, *Journal of the American Society for Information Science, 48*(5), 449-453.

Goodhue, D.L., & Thompson, R.L. (1995). Task-technology fit and individual performance. *MIS Quarterly, 19*(2), 213-236.

Gounaris, S., & Koritos, C.D. (2012). Adoption of technologically based innovations: The neglected role of bounded rationality. *Journal of Product Innovation Management, 29*(5), 821-838.

Granovetter, M. (1978). Threshold models of collective behavior. *American Journal of Sociology, 83(*6), 1420-1443.

Granovetter, M.S. (1973). The strength of weak ties [on social networks]. *American Journal of Sociology, 78*(6), 1360-1380.

Greene, J. (2016, June 29). Windows 10 adoption grows as Microsoft promotes operating system. *The Wall Street Journal*

Grego-Nagel, A. & Rys, M. (2016). Exploring the adoption of telecommunications service by older adults. *Proceedings from 60th Annual Meeting Human Factors and Ergonomics Society*. Washington DC.

Hall, G.E., & Hord, S.M. (2006). *Implementing change: Patterns, principles, and potholes*. Retrieved from http://www.mathedleadership.org/docs/coaching/PL-B-HALL.pdf.

Hamermesh, D.S., (2005). Routine. *European Economic Review*, 49, 29-53.

Heckman, J.J. (1981) The incidental parameters problem and the problem of initial conditions in estimating a discrete time-discrete data stochastic process. In C.F. Manski and D. McFadden (Eds*.), Structural Analysis of Discrete Data with Econometric Applications*. Cambridge, MA: MIT Press.

Heiner, R.A. (1983). The origin of predictable behavior. *American Economic Review*, 73, 560-95.

Hirschman, E.C. (1980). Innovativeness, novelty seeking, and consumer creativity. *Journal of Consumer Research, 7*(3), 282-295.

History of Motorola (n.d.). Retrieved from http://www.motorola.com/us/consumers/about-motorola-us/About_Motorola-History-Timeline/About_Motorola-History-Timeline.html#1980.

Hoeffler, S. (2003). Measuring preferences for really new products. *Journal of Marketing Research, 40*(4), 406-420.

Hofsteade, G. (1983). The cultural relativity of organizational practices and theories. *Journal of International Business Studies,14*(2), 75-89.

Holyoak, K.J., & Thagard, P. (1989). Analogical mapping by constraint satisfaction. *Cognitive Science, 13*(3), 295-355.

Hopp, W.J. & Spearman, M.L. (2011). *Factory physics.* Long Grove, IL: Waveland Press.

Howard, J.S. & Sheth, J.N. (1969). *The theory of buyer behavior*. New York, NY: Wiley.

Im, S., Mason, C.H., & Houston, M.B. (2007). Does innate consumer innovativeness relate to new product/service adoption behavior? The intervening role of social learning via vicarious innovativeness. *Journal of the Academy of Marketing Science, 35*(1), 63-75.

Institute of Medicine (IOM). (2012). *Ten attributes of health literate health care organizations* [Roundtable discussion paper]. Washington, DC: The National Academies Press.

Janis, I.L.& Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice, and commitment.* New York: Free Press.

Jin, C. (2013). The effects of individual innovativeness on users' adoption of internet content filtering software and attitudes toward children's internet use. *Computers in Human Behavior, 29*(5), 1904-1916.

Jones, L.R., Cherry, C.R., Vu, T.A., & Nguyen, Q.N. (2013). The effect of incentives and technology on the adoption of electric motorcycles: A stated choice experiment in Vietnam. *Transportation Research Part A: Policy & Practice, 57*, 1-11.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrical, 47*(2), 263-291.

Kallio, K. & Lappalainen, I. (2014). Learning about service orientation in KIBS: Understanding the customer as an active actor. Service Science, 6(2), 78-91.

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Macmillan.

Kahneman, D. & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgements. In T.Gilovich, T.D. Griffin & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgement.* Cambridge: Cambridge University Press.

Kaptelinin, V., & Nardi, B.A. (2006). *Acting with technology: Activity theory and interaction design*. Cambridge, MA: MIT Press.

Katona, Z., Zubcsek, P.P., & Sarvary, M. (2011). Network effects and personal influences: The diffusion of an online social network. *Journal of Marketing Research, 48*(3), 425-443.

Katz, E. (1957). The two-step flow of communication: An up-to-date report on an hypothesis. *Public Opinion Quarterly, 21*(1), 61-78.

Katz, E., & Lazarsfeld, P.F. (1955). *Personal influence, the part played by people in the flow of mass communications*. Transaction Publishers.

Katz, E., Blumler, J.G., & Gurevitch, M. (1973). Uses and gratifications research. *The Public Opinion Quarterly, 37*(4), 509-523.

Kermack, W. & McKendrick, A. (1927). Contributions to the mathematical theory of epidemics, *Proceedings of the Royal Society, 115*(A) 700-721. Reprinted, *Bulletin of Mathematical Biology (1991),* 53(1-2), 33-35.

Kim, S. (2011). The diffusion of the Internet: Trend and causes. *Social Science Research, 40*(2), 602-613.

Kim, S., & Park, H.J. (2011). Effects of social influence on consumers' voluntary adoption of innovations prompted by others. *Journal of Business Research, 64*(11), 1190-1194.

Kim, S.S. (2009). The integrative framework of technology use: An extension and test. *MIS Quarterly, 33*(3), 513-537.

Kirton, M. (1976). Adopters and innovators: A description and measure. *Journal of Applied Psychology, 61*(5), 622-629.

Klein, G. (2008). Naturalistic decision making. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50* (3), 456-460.

Klein, G. (1989). Recognition-primed decisions. In W.B. Rouse (Ed.), *Advances in man-machine systems research* (Vol. 5, pp. 47-92). Greenwich, CT: JAI Press.

Klonglan, G.E., & Coward, E.W. (1970). Concept of symbolic adoption: A suggested interpretation. *Rural Sociology,35*(1), 77.

Koenig-Lewis, N., Marquet, M., Palmer, A, & Zhao, A.L. (2015). Enjoyment and social influence: Predicting mobile payment adoption. *Service Industries Journal, 35*(10), 537-554.

Koenigstorfer, J., & Groeppel-Klein, A. (2012). Consumer acceptance of the mobile internet. *Marketing Letters, 23*(4), 917-928.

Korica, M. & Molloy, E. (2010). Making sense of professional identities: Stories of medical professionals and new technologies. *Human Relations, 63*(12), 1879-1901.

Kretzschmar, M. & Wallinga, J. (2010). Mathematical models in infectious disease epidemiology. In Kramer, A., Kretzschmar, M, & Krickeberg, K. (Eds.), *Modern Infectious Disease Epidemiology* (209-221). New York, NY: Springer.

Krishnan, V., Maki, K., Castillo, E.M. & Guss, D. (2015). Service design for improved satisfaction: Decoding the mechanism for impact of patient callback. *Service Science, 7*(4), 315-330.

Lam, S.Y., Chiang, J., & Parasuraman, A. (2008). The effects of the dimensions of technology readiness on technology acceptance: An empirical analysis. *Journal of Interactive Marketing, 22*(4), 19-39.

LaMonica, M. (2014, September 20). Rooftop solar's threat to utilities by the numbers. *IEEE Spectrum.*

Lancaster, K. (1971). Consumer demand: A new approach.

Lang, J.C. & De Sterck, H. (2014). The Arab spring: A simple compartmental model for the dynamics of a revolution. *Mathematical Social Sciences, 69*, 12-21.

Langyintuo, A.S., & Mungoma, C. (2008). The effect of household wealth on the adoption of improved maize varieties in Zambia. *Food Policy, 33*(6), 550-559.

Lascu, D., & Zinkhan, G. (1999). Consumer conformity: Review and applications for marketing theory and practice. *Journal of Marketing Theory and Practice,7*(3), 1-12.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lave, L.B., & Weber, W.E. (1970). A benefit-cost analysis of auto safety features. *Applied Economics, 2*(4), 265-275.

Lee, C. & Coughlin, J. (2015). Older adults' adoption of technology: An integrated approach to identifying determinants and barriers. *Journal of Product Innovation Management. 32*(5), 747-759.

Lee, E., Lee, J., & Schumann, D. (2002). The influence of communication source and mode on consumer adoption of technological innovations. *Journal of Consumer Affairs, 36*(1), 1-27.

Lessard, L. (2015). Modeling value co-creation processes and outcomes in knowledge-intensive business service engagements. *Service Science, 7*(3), 181-195.

Li, G., Field, J., Jiang, H., He, T. & Pang, Y. (2015). Decision models for workforce and technology planning in services. *Service Science, 7*(1), 29-47.

Li, L. & Zhang, H. (2000). The multistage service facility start-up and capacity model. *Operations Research, 48*(3), 490.

Lichtenstein, A., & Rosenfeld, L. (1984). Normative expectations and individual decisions concerning media gratification choices. *Communication Research, 11*(3), 393-413.

Lintern,G.(2010). A comparison of the decision ladder and the recognition-primed decision model. *Journal of Cognitive Engineering and Decision Making, 4*(4), 304-327.

Lovelock, C. (1992). Managing services: Marketing,operations and human resources (2^{nd} ed.). New Jersey: Prentice Hall.

Lusch, R.F. & Nambisan, S. (2015). Service innovation: A service-dominant logic perspective. *MIS Quarterly, 39*(1), 155-175.

Ma, T. & Chen, H. (2015). Adoption of an emerging infrastructure with uncertain technological learning and spatial reconfiguration. *European Journal of Operational Research, 243*(3), 995-1003.

MacGregor, J.N. (1987). Short-term memory capacity: Limitation or optimization? *Psychological Review, 94*(1), 107-108.

Maglio, P.P., Kwan, S.K. & Spohrer, J. (2015). Toward a research agenda for human-centered service system innovation. *Service Science, 7*(1), 1-10.

Maglio, P.P., Vargo, S.L., Caswell, N. & Spohrer, J. (2009). The service system is the basic abstraction of service science. *Information Systems & E-Business Management, 7*(4), 395-406.

Maglio, P.P. & Spohrer, J. (2008). Fundamentals of service science. *Journal of the Academy of Marketing Science, 36*(1), 18-20.

Maglio, P., Srinivason, S., Kreulen, J., & Spohrer, J. (2006). Service systems, service scientists, SSME and innovation. *Communications of the ACM, 49*(7), 81-85.

Malhotra, A. & Malhorta, C.K. (2009). A relevancy-based services view for driving adoption of wireless web services in the U.S., *Communications of the ACM, 52*(7), 130-134.

Mandler, J.M., & DeForest, M. (1979). Is there more than one way to recall a story? *Child Development,50*(3), 886-889.

March, J.G., & Simon, H.A. (1958). *Organizations.* Oxford, England: Wiley.

McDermid, R. (2016, May 24). AT&T wants to pull plug on land-line service. *San Francisco Business Times.* Retrieved at http://www.bizjournals.com/sanfrancisco/blog/techflash/2016/05/at-t-pushes-to-end-landline-service.html

McFadden, D., & Zarembka, P. (1974). *Conditional Logit Analysis of Qualitative Choice Behavior* in Frontiers in Econometrics, ed. by P. Zarembka.

McGuire, W.J. (1969). The nature of attitudes and attitude change. *The Handbook of Social Psychology, 3*(2), 136-314.

Medearis, J. (2009). *Joseph A. Schumpeter.* USA: Bloomsbury Publishing.

Messner, S., & Strubegger, M. (1994). The energy model MESSAGE III. *Advances in Systems Analysis: Modelling Energy-Related Emissions on a National and Global Level', Forschungszentrum J ulich, Germany.*

Moreau, C.P., Lehmann, D.R., & Markman, A.B. (2001). Entrenched knowledge structures and consumer response to new products. *Journal of Marketing Research, 38*(1), 14-29.

Müller, J. P. (1996). *The design of intelligent agents: A layered approach.* Springer Science & Business Media.

Naikar, N. & Pearce, B. (2003). Analysing activity for future systems. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 47, No. 17, pp. 1928-1932). SAGE Publications.

Nam, S., Manchanda, P., & Chintagunta, P.K. (2010). The effect of signal quality and contiguous word of mouth on customer acquisition for a video-on-demand service. *Marketing Science, 29*(4), 690-700

Nelson, A.J., & Irwin, J. (2014). Defining what we do –all over again: Occupational identity, technological change, and the librarian/internet-search relationship. *Academy of Management Journal, 57*(3), 892-928.

Newman, J. (2015, October 1). Windows 10 adoption has slowed down considerably. *PCWorld.* Retrieved from http://www.pcworld.com/article/2988223/windows/windows-10-adoption-has-slowed-down-considerably.html

Ng. I. L. (2007). Advance demand and a critical analysis of revenue management. *Service Industries Journal, 27*(5), 525-548.

Ng, I., Wirtz, J. & Lee, K.S. (1999). The strategic role of unused service capacity. *International Journal of Service Industry Management, 10*(2), 211-245.

Oliva, R. & Sterman, J.D. (2010). Death spirals and virtuous cycles. In *Handbook of Service Science (pp. 321-358).* Springer US.

Oliver, R.L. (1980). A cognitive model of the antcedents and consequences of satisfaction decisions. *Journal of Marketing Research,17*(4), 460-469.

Ordanini, A., Parasuraman, A. & Rubera, G. (2014). When the recipe is more important than the ingredients: A qualitative comparative analysis (QCA) of service innovation configurations. *Journal of Service Research, 17*(2), 134-149.

Pai, P. & Arnott, D. (2013). User adoption of social networking sites: Eliciting uses and gratifications through a means-end approach. *Computers in Human Behavior, 29*(3), 1039-1053.

Parasuraman, A. (2000). Technology readiness index (TRI) a multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research, 2*(4), 307-320.

Parker, M. (2016, August 2). *Best and worst of cities mobile network performance: The full Rootmetrics rankings.* Retrieved from http://www.rootmetrics.com/en-US/content/2016-1h-metro-ranking

Pew Research Center. (2014). *Older adults and technology use.* Washington, DC.

Pew Research Center. (2015). *Home Broadband:2015.* Washinton, DC.

Pew Research Center. (2016). *Pew Research Center will call 75% cellphones for surveys in* Mattelmäki *2016.* Washington, DC: McGeeney, K.

Portes, A. (2000). Social capital: Its origins and applications in modern sociology. In E. Lesser (ed.), *Knowledge and social capital* (pp. 43-67). Boston: Butterworth-Heinemann.

Postman, N. (1985). *Amusing ourselves to death.* New York: Viking.

Prasad, P. (1993). Symbolic processes in the implementation of technological change: A symbolic interactionist study of work computerization. *Academy of Management Journal, 36*(6), 1400-1429.

Pratt, J.W. (1964). Risk aversion in the small and in the large. *Econometrica: Journal of the Econometric Society,32*(1/2), 122-136.

Putney, N.M., & Bengtson, V.L. (2002). Socialization and the family revisited. *Advances in Life Course Research, 7,* 165-194.

Qin, R. (2011). Workforce planning over the service life cycle. *Service Science, 3*(1), 22-40.

Ram, S. (1987). A model of innovation resistance. *Advances in Consumer Research, 14*(1), 208-212.

Ram, S., & Sheth, J.N. (1989). Consumer resistance to innovations: The marketing problem and its solutions. *Journal of Consumer Marketing, 6*(2), 5-14.

Ramirez, V. & Todd, J. (2016, July 5). Top Mobile-Friendly U.S. Cities. *Nerdwallet,*Retrieved from https://www.nerdwallet.com/blog/utilities/top-mobile-friendly-cities-2016/

Rasmussen, J. (1983). Skills, rules, and knowledge; Signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man, and Cybernetics, 13*, 257-66.

Ratchford, B.T. (2001). The economics of consumer knowledge. *Journal of Consumer Research, 27*(4), 397-411.

Reardon, M. (2011, Sept. 7). Can we count on cell networks in disasters? *CBS News,* Retrieved from http://www.cbsnews.com/news/can-we-count-on-cell-networks-in-disasters/

Reinders, M., Dabholkar, P. & Frambach, R. (2008). Consequences of forcing consumers to use technology-based self-service. *Journal of Service Research, 11*(2), 107-123.

Robbins, T. & Harrison, T. (2011). New project staffing for outsourced call centers with global service level agreements. *Service Science, 3*(1), 41-66.

Rogers, E.M. (2003). *Diffusion of innovations* (5th ed.) New York: Free Press.

Rossman, G., Chiu, M.M., & Mol, J.M. (2008). Modeling diffusion of multiple innovations via multilevel diffusion curves: Payola in pop music radio. *Sociological Methodology, 38*(1), 201-230.

Rudd, R. (2010). Improving Americans health literacy. *New England Journal of Medicine, 363*(24), 2283-2285.

Ryan, B. & Gross, N. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology, 8*, 15-24.

Sampson, S.E. (2010). The unified service theory: A paradigm for service science. In P. Maglio, C. Kieliszewski & J. Spohrer (Eds.). *Handbook of service science.* (pp.107-131). New York, NY:Springer.

Sampson, S.E. & Froehle, C. M. (2006). Foundations and implications of a proposed unified services theory. *Production and operations management,* 15(2), 329-343.

Sawatani, Y. & Fujigaki, Y. (2014). Transformation of R&D into a driver of service innovation: Conceptual model & empirical analysis. *Service Science, 6(*1), 1-14.

Schneider, R. (2013). Theory of routine mode choice decisions: An operations framework to increase sustainable transportation. *Transport Policy, 25,* 128-137.

Schraagen, J.M., Klein, G. & Hoffman, R.R. (2008). The macrocognition framework of naturalistic decision making. In J.M. Schraagen (Ed.) *Naturalistic Decision Making and Macrocognition,* (3-25). Burlington, VT: Ashgate Publishing.

Schunn, C.D., McGregor, M.U., & Saner, L.D. (2005). Expertise in ill-defined problem-solving domains as effective strategy use. *Memory & Cognition, 33*(8), 1377-1387.

Shih, E. & Schau, H.J. (2011) To justify or not to justify: The role of anticipated regret on consumers' decisions to upgrade technological innovations. *Journal of Retailing, 87*(2), 242-251.

Shklovski, I., Burke, M., Kiesler, S., & Kraut, R. (2010). Technology adoption and use in the aftermath of Hurricane Katrina in New Orleans. *American Behavioral Scientist, 53*(8), 1228-1246.

Silverstone, R., & Haddon, L. (1996). Design and the domestication of ICTs: Technical change and everyday life. In Silverstone, R., & Mansell, R. (eds). *Communication by Design the politics of information and communication technologies* (pp. 44-74). Oxford: Oxford Press.

Silverstone, R., Hirsch, E., & Morley,D. (1992). Information and communication technologies and the moral economy of the household in Silverstone, R. (ed). *Consuming Technologies, Media and Information in Domestic Spaces* (pp. 5-31). New York: Routledge.

Simon, H.A. (1955). A behavioral model of rational choice. *Quarterly Journal of Economics, 69*(1), 99-118.

Sims, C. (1990, January 28). All about/ Cellular telephones: A gadget that may soon become the latest necessity. *The New York Times.*

Social Security Administration. (n.d). *History of SSA 1993-2000.* Retrieved from https://www.ssa.gov/history/ssa/ssa2000chapter5.html

Soule, S. (1999). The diffusion of an unsuccessful innovation. *Annals of the American Academy of Political & Social Science, 566*(1), 120-131.

Spangler, T. (2015, July 15). Password Sharing: Are Netflix, HBO, Missing $500 million by not cracking down? *Variety.* Retrieved from http://variety.com/2015/digital/news/netflix-hbo-password-sharing-illegal-1201538908/

Spohrer, J. & Maglio, P. (2008). The emergence of service science: Toward systematic service innovations to accelerate co-creation of value. *Production and Operations Management,17*(3), 238-246.

Spohrer, J., Vargo, S., Caswell, N., & Maglio, P. (2009). The service system is the basic abstraction of service science. *Information Systems and e-Business Management, 7*(4). 395-406.

Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A, 39,* 147-162.

Sterman, J.D. (2000). *Business dynamics: Systems thinking and modeling for a complex world.* New York, NY: McGraw-Hill.

Suarez, F.F. (2005). Network effects revisited: The role of strong ties in technology selection. *Academy of Management Journal, 48*(4), 710-720.

Tarde, G. (1969). *The laws of imitation.* (E.C. Parsons, Trans.). Chicago, IL: University of Chicago.

Thøgersen, J., Haugaard, P., & Olesen, A. (2010). Consumer responses to ecolabels. *European Journal of Marketing, 44*(11), 1787-1810.

Thompson, D.V., Hamilton, R.W., & Rust, R.T. (2005). Feature fatigue: When product capabilities become too much of a good thing. *Journal of Marketing Research, 42*(4), 431-442.

Thune, T. & Mina, A. (2016). Hospitals as innovators in the health-care system: A literature review and research agenda. *Research Policy, 45*(8), 1545-1557.

Trope, Y., & Liberman, N. (2003). Temporal construal. *Psychological Review, 110*(3), 403-421.

Tversky, A. & Kahneman, D. (1974). Judgment under uncertainty: heuristics and biases. *Science, 185,* 1124-1131.

Tunks, J., & Weller, K. (2009). Changing practice, changing minds, from arithmetical to algebraic thinking: An application of the concerns-based adoption model (CBAM). *Educational Studies in Mathematics, 72*(2), 161-183.

U.S. Bureau of Labor Statistics. (2016). Labor force statistics from the current population survey [Data file]. Retrieved from http://data.bls.gov/timeseries/LNS14000000

U.S. Census Bureau, P23-212, *65+ in the United States: 2010,* U.S. Government Printing Office, Washington, DC, 2014.

U.S. Central Intelligence Agency. (2014). *GDP-Composition, by Sector of Origin* [Data file]. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html

U.S. Department of Health and Human Services. (2013). *Healthy People 2010.* Washington, DC: US Government Printing Office.

U.S. Federal Communications Commission. (2008). *Annual report and analysis of competitive market conditions with respect to commercial mobile services* (FCC 08-28). Washington, DC: U.S. Government Printing Office.

van Rijnsoever, F.J., & Donders, A.R.T. (2009). The effect of innovativeness on different levels of technology adoption. *Journal of American Society for Information Science & Technology, 60*(5), 984-996.

Vargo, S. & Lusch, R., (2004). Evolving to a new dominant logic for marketing. *Journal of Marketing. 68,* (1-17).

Venkatesh, V., & Davis, F.D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186-204.

Venkatesh, V., Morris, M.G., Davis, G.B., & Davis, F.D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly,27*(3), 425-478.

Villarreal, M.C., Goldsman, D. & Keskinocak, P. (2015). Workforce management and scheduling under flexible demand. *Service Science, 7(*4), 331-351.

Vishwanath, A., & Chen, H. (2008), Personal communication technologies as an extension of the self: A cross-cultural comparison of people's associations with technology and their symbolic proximity with others. *Journal of the American Society for Information Science & Technology, 59*(11), 1761-1775.

Vishwanath, A., & LaVail, K.H. (2013). The role of attributional judgments when adopted computing technology fails: A comparison of Microsoft Windows pc user perceptions of Windows and Macs. *Behaviour & Information Technology, 32*(11), 1155-1167.

Von Bertalanffy, L. (1968). *General System Theory.* New York, NY: Braziller.

Vroom, V.H. (1964). *Work and motivation.* Oxford, England: Wiley.

Wallin, A., Harjumaa, M, Pussinen, P. & Isomursu, M. (2015). Challenges of new service development: Case video-supported home care service. *Service Science, 7*(2), 110-118.

Wansink, B. & Sobel, J. (2007). Mindless eating: The 200 daily food decision we overlook. *Environment and Behavior, 39*(1), 106-23.

Ward, T.B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cognitive Psychology, 27*(1), 1-40.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review, 92*(4), 548-573.

Weinstein, N.D. (1980). Unrealistic optimism about future life events. *Journal of Personality and Social Psychology, 39*(5), 806-820.

Wemmerlov, U. (1990). A taxonomy for service processes and its implications for system design. *International Journal of Service Industry Management, 1*(3), 13-27.

Wetter-Edman, K., Sangiorgi, D., Edvardsson, B., Holmlid, S., Grönroos, C. & Mattelmäki, T.(2014). Designing for value co-creation: Exploring synergies between design for service and service logic. *Service Science, 6*(2), 106-121.

White House. (2015, August 24). Fact sheet: President Obama announces new actions to bring renewable energy and energy efficiency to households across the country [Press release]. Washington, DC: The White House).

Wright, P., & Weitz, B. (1977). Time horizon effects on product evaluation strategies. *Journal of Marketing Research,14*(4), 429-443.

Wünderlich, N.V., Wangenheim, F.V., & Bitner, M.J. (2013). High tech and high touch: A framework for understanding user attitudes and behaviors related to smart interactive services. *Journal of Service Research, 16*(1), 3-20.

Xiuli, C., Hong, C., & Shaohui, Z. (2009). Dynamic capacity expansion for service firm with capacity deterioration and supply uncertainty. *Operations Research, 57*(1), 82-93.

Yang, B., & Ching, A.T. (2014). Dynamics of consumer adoption of financial innovation: The case of ATM cards. *Management Science, 60*(4), 903-922.

Zahodne, L., Glymour, M., Sparks, C., Bontempo, D., Dixon, R., MacDonald, S. & Manly, J. (2011). Education does not slow cognitive decline with aging: 12-year evidence from the Victoria longitudinal study. *Journal of international neuropsychology, 17*(6), 1039-1046.

Zappala, G., (2000). The economic and social dimensions of the new *economy*. Camperdown, AU: The Smith Family.

Zsambok, C.E. (1997). Naturalistic decision making research and improving team decision making. In C.E. Zsambok & G. Klein (Eds), *Naturalistic decision making* (111-120). New York, NY: Psychology Press.

Appendix A - Interview Questions for Chapter 2

1. Age

2. Gender

3. Do you have a cell phone?

NO

3n-1. Can you tell me where the phones are around your home and why you put them there?

3n-2. What is your primary use for your phone? Social or business (ie calling the doctor's office)?

3n-3. When did you originally get your landline?

3n-4. Did you have a landline while growing up?

3n-5. Who do you mainly communicate with on your phone? family, friends, caregivers, etc.

3n-6. Have you ever had a cell phone? If yes, why don't you have it now?

3n-7. Why do you choose not to have a cell phone now?

3n-8. What do you like about your landline?

YES

3y-1. What types of phone do you have now?

3y-2. When did you get your cell phone? When did you get a landline phone?

3y-3. Why did you originally get a cell phone?

3y-4. How often do you currently use the cell phone and how do you use it?

3y-5. Do you currently have a landline phone?

NO

3y5n-1. How long did you have both a landline and a cell phone?

3y5n-2. What made you get rid of the landline phone?

YES

3y5y-1. Can you tell me where the phones are around your home and why you put them there?

3y5y-2. What is your primary use for your phone? Social or business (ie calling the doctor's office)?

3y5y-3. When did you originally get your landline?

3y5y-4. Did you have a landline while growing up?

3y5y-5. Who do you mainly communicate with on your phone? family, friends, caregivers, etc.

3y5y-6. Have you ever had a cell phone? If yes, why don't you have it now?

3y5y-7. Why do you choose not to have a cell phone now?

3y5y-8. What do you like about your landline?

3y5y-9. Why do you keep both a cell and a landline phone?

3y5y-10. Which phone do you prefer? Why?

Appendix B - A Typology of Innovation Adoption Factors for Human Factors Engineers

This paper was published in *Proceeding of the 2016 Industrial and Systems Engineering Research Conference, H. Yang, Z. Kong, and MD Sarder, eds.*

Abstract

In the current technology landscape, customers, suppliers and employees regularly adopt innovations. Designing systems especially Internet of Things (IoT) systems that incorporate new technology falls in the human factors domain. A large body of innovation adoption research exists in multiple disciplines including psychology, marketing and information studies. This research is not organized in a framework that makes the information accessible to field engineers. To address this gap, the authors searched over 1,000 journals in eight disciplines for papers that explored the factors of innovation adoption or the process of adoption. Using that search's results, a typology that organizes individual-level innovation adoption research in a practical manner is proposed. Three overarching categories of human factors that affect an individual's decision to adopt an innovation are proposed including personal, social connections and micro situational factors. The objective of this paper is to suggest a theoretical framework and examples of applications addressing innovation adoption issues that occur in the field. This paper also serves as an example of applying multidisciplinary research to a human factors situation.

Keywords Human factors engineers, innovation adoption, service design

Introduction

Researchers and marketers have struggled to understand the complicated decision-making process that people use when trying something new. The decision to abandon something familiar for something new can be affected by many dimensions of the human condition and life in a society. As a result, the study of adopting something new and its counterpart, spreading something new, is found in numerous disciplines. But the research has not been drawn together in a manner that makes the application by field human factors engineers practical. This situation has caused human factors engineers to ignore or under apply this rich research stream. To fill this gap, a typology is proposed that categorizes the various research of innovation adoption so that human factors engineers can apply this research stream to situations in the field.

Because innovation adoption research is found in a many disciplines, the definition of an ‘innovation’ varies between disciplines. Often the word ‘innovation’ is thought to be a new product or some form of technology. The broader definition that an ‘innovation’ is something new is used in this study. It can be an idea, process, practice, object or tool that is new, at least, to the individual adopting it [1]. The criterion for an idea, process, product or practice to be considered an innovation is strictly the newness to the adopter, not newness to the market.

By focusing on the criterion of ‘newness’ to the individual, the authors avoided issues dealing with measuring newness to the marketplace. This distinction allows the individual to remain the center of the analysis. It is important to note that a research stream does exist that studies the adoption of innovations by organizations or industries. When the individual is the unit of analysis, often the type of innovation decision that is being explored is an optional decision, where an individual’s decision is independent of the decisions of the other members in the system [1]. In the past most situations that human factors engineers encountered were authority-driven adoption where management dictated the change and employees obliged. So as not to confuse an innovation’s adoption with awareness of an innovation, adoption is considered full use the innovation and not strictly knowledge of the innovation [1].

As technology has become common place in many aspects of life, businesses can no longer demand innovation adoption from customers and must design systems that encourage adoption. One example that has been studied using different lenses is online banking [2-6]. Banking existed long before the Internet. Banking services can be accessed by interacting with a teller, writing a check, or having employers directly depositing checks. The Internet allows customers to access banking services similar to how the ATM allowed customers to access banking services without regard to a physical location or bank employee's involvement. Typically human factors engineers focus primarily on the user interface and experience with a web page. But a tool design's is not necessarily the only aspect that encourages a person to use it. Using the illustration of online banking, the authors demonstrate how human factors engineers can provide valuable insight on the adoption of a tool such as an online portal.

The goal of this paper is to provide engineers with a theoretical framework for the human factors of innovation adoption. First the authors explain the methods used to review the literature from a number of disciplines. Then a typology of the various factors that can aid when dealing with innovation adoption situations is proposed.

Method

Human factors engineers often search for physical barriers to using a tool. When designing a service, barriers to adopting a service may not be physical. As an example, why do some people adopt online banking while others don't? One customer may enjoy the convenience of online banking, but another customer may not have Internet access to use online banking. Numerous reasons and theories in multiple disciples are provided to explain the decision to adopt an innovation. Popular innovation adoption models such as the Diffusion of Innovation model (DoI) and the Technology Acceptance Model (TAM) account for the effect of factors such as characteristics of the innovation, personality factors, communication behavior or norms of the social systems [1,7,8]. These theories represent the fields of management of information studies and sociology, but other fields have also addressed innovation adoption.

The authors undertook a large multidisciplinary literature review. Using the lens of human factors, this study focused on the adoption of tools and technology. Therefore the disciplines searched were agriculture, marketing, economics, psychology, management, human factors, education, sociology, anthropology, and information studies. Journals that were ranked in the top quarter of the SCImago Journal and Country Ranking for each discipline were searched. SCImago Journal and County Rank uses the SCOPUS database for its rankings and uses the number of weighted citations of the journal's published papers. The top quarter were chosen to control for quality of research published in these journals. The authors searched 917 journals that where published between January 2000 and April 2015.

Keywords are not standardized between journals or disciplines. Therefore, journals were first searched using the keywords of 'innovation' and resulted in over 15,000 hits. Over 30% of the journals had no articles on innovation. When the search was narrowed to articles covering user adoption, the number of articles dropped to under 1,400. From this list articles that used 'intention to use an innovation' rather than actually usage of an innovation as a dependent variable were removed. The Technology Acceptance Model and the Theory of Reasoned Behavior use 'intention to use' as a proxy for the actual usage of the innovation [7-9]. Only articles that focused on actual usage were reviewed since that variable provides a true picture of the phenomena of individual innovation adoption. Ninety six articles were reviewed.

Typology of Individual-Level Innovation Adoption Factors

Human Factors Categories

The classification scheme for human factors for innovation adoption includes three categories. This classification scheme allows human factors engineers to draw on theories from multiple disciplines. Human factors affecting the decision to adopt an innovation can be divided into personal, social connections and micro situational. The factors identified in the literature review are listed in Table 1.

Table 1: Categories of human factors for innovation adoption decisions

Personal Factors	Social Connections Factors	Micro Situational Factors
Age	Collaboration	Attitude toward an Innovation
Behavioral Heuristics	Family & Social Structure	Economic Substitutes
Cognitive Processing	Network Effects	Geography
National Culture	Network Hubs	Risk, Ambiguity & Uncertainty
Occupational Identity	Network Ties	Utility of an Innovation
Personality Traits	Social Learning	Resource Efficiency, Allocation &
Prior Knowledge	Social Prompts & Meanings	Optimization
Rational Behavior/Logic		

Personal Factors

Variation between people can lead to different adoption behaviors. For this study's purposes, these factors do not change between situations or the innovations. This group of factors highlights physical, biological, psychological or cultural differences between individuals. These factors are specific to the person. Within a group, some people will adopt an innovation while others do not. When dealing with technologies such as the Internet, how individuals process information or prior knowledge and experience may significantly affect the probability of adoption. Rogers included many of these factors in his characteristics of the decision-making unit [1]. Behavioral economics researchers explored the role of an individual's decision-making process [10]. Management researchers studied how occupation identity of surgeons affects the adoption of new surgical techniques [11]. These factors, especially the cognitive factors, are considered the domain of human factors engineers.

Using the example of Internet banking, Gounaris & Koritos found that non-adopters experienced cognitive strain due to information overload in determining adoption benefits [4]. Translating these results into practice, engineers can structure the communication and training of Internet banking portals in a clear manner that limits complexity.

Social Connections Factors

A person's social system has a variety of effects on the decision to adopt an innovation. Social networks provide information about innovations and support in the decision to adopt [1]. Often social factors are considered when studying the diffusion of an innovation, but they are instrumental in the adoption of an innovation. This category highlights who is influencing the decision and how that influence works. Social networks can introduce an innovation and provide technical support in using the innovation such as with computer help. Network theory grounds many studies exploring these factors. Researchers have studied the role of families in adoption decisions such as the extent that children affect their parents' adoption of the Internet [12].

Research of how social factors affected the adoption of online banking was not found in our review. But an example could be generalized using Soule [13]. The decision to use Internet banking can be affected by the ability to use one's social network to learn to operate the online portal. If an adopter does not know someone else who has adopted and knows how to operate the innovation, product designers may have to develop supports such as providing an owner's manual or a customer support hotline.

Micro Situational Factors

This last category focuses on factors that are a reflection of the circumstances that the individual is in. When individuals move or the situations change, they may adopt an innovation. Someone who grew up in New York City may have no need to adopt an automobile until he moves to Los Angeles. These factors, which are external to the individual and are temporal, include the economic factors such as availability of substitutes, resource efficiency and risk [14-17]. While an individual might not adopt online bill payment on day 1, he might be willing to adopt it on day 60 after a company provided a financial incentive to adopt. TAM research found that usefulness and ease of use of an innovation affect adoption [7,8]. Other research found that utility of an innovation and attitude to an innovation affect adoption [18-21]. Gilbert, Karaholios & Sandvig found that the geographical difference in residence, urban and rural, can determine if a personal adopts an innovation [22].

Researchers searching to understand the adoption of Internet banking found that availability of branches and ATMs (substitutes) did not affect the adoption decision. Concerns about cyber security drive Internet adoption [2]. If the adoption of Internet banking is interrupted by an event such as a vacation, the customer is less likely to adopt for a long period of time [5].

Potential Applications

While many innovation models focus on factors from one area such as personal or micro-situational, this typology acknowledges that innovation decisions are multidimensional. With the availability of big data, researchers have the possibility of developing more refined models. This typology hopefully provides researchers with a starting point of what variables might affect particular adoption decisions.

Exploring the potential adoption of an automatous automobile provides an application of this research. Human factors researchers look at cognitive processing and prior knowledge in the user interface development. The cognitive requirements of the technology must match the adopter's abilities. Beyond cognitive ability, the adopter may not identify himself as a potential adopter or user of the technology. Older adults have rejected medical alert systems when they identify the technology as belonging to the helpless. Social networks can affect adopters by not supporting the adoption. Social networks allow people to seek help when learning a technology. Social norms evident through the use of fees or vehicle registration may discourage adoption of the technology. Situational factors of adoption can include the ownership of a functional automobile and therefore, the lack of utility for the technology. At the time the adopter may have low risk tolerance for a radical innovation. The user may have financial allocation priorities above the innovation. The adopter may live where automatous operation is inappropriate such as a mountainous, rural environment. The factors can interact. The perception of risk can be affected by a social network that either warns against or encourages the adoption of the technology. This interaction may affect those with low risk tolerance. Human factors engineers can explore the many dimensions of an adopter rather than viewing the adoption through a narrow disciplinary lens.

Conclusion

By focusing on the person adopting an innovation, human factors that affect innovation adoption can be divided into three categories: personal, social connections and micro situational. While this information can be used in a variety of situations, one area, the development of IoT systems, provides system design opportunities for human factors engineers. These systems, which are service systems with embedded technology, move human factors engineers into consumer homes and into a role that goes beyond strictly user interface and experience. Instead of viewing adoption as a marketing question, human factors engineers can explore individual-level innovation adoption by searching what factors are creating barriers to adoption. Human factors engineers are in a unique position to look to multiple disciplines to solve the problems involving the rapidly changing technology developments. The challenge of multidisciplinary research is pulling the information into a framework that is accessible. The authors provided a typology of the human factors of individual-level innovation adoption to address this gap.

Limitations

As with all interdisciplinary work, comparison between studies is difficult due to varying research methods and standards. As a result, this typology does not comment on the significance of individual factors. This study presents the current state of individual-level innovation adoption research and organizes the factors to be used by human factors professionals.

References

1. Rogers, E.M., 2003, Diffusion of Innovation, 5th Edition, Free Press, New York.
2. Lee, E., Lee, J., and Eastwood, D., 2003, "A Two-Step Estimation of Consumer Adoption of Technology-based Service Innovations," Journal of Consumer Affairs, 37 (2), 256-82.
3. Lee, E., Lee, J., and Schumann, D.W., 2002, "The Influence of Communication Source and Mode on Consumer Adoption of Technological Innovations," Journal of Consumer Affairs, 36(1), 1.
4. Gounaris, S. and Koritos, C.D., 2012, "Adoption of Technologically Based Innovations: The Neglected Role of Bounded Rationality," Journal of Product Innovation Management, 29(5), 821-38.
5. Lambrecht, A., Seim, K., and Tucker, C., 2011, "Stuck in the Adoption Funnel: The Effect of Interruptions in the Adoption Process on Usage," Marketing Science, 30(2), 355-67.
6. Xue, M., Hitt, L.M., and Chen, P., 2011, "Determinants and Outcomes of Internet Banking Adoption," Management Science, 57(2), 291-307.
7. Venkatesh, V., Morris, M.G., Davis, G.B., and Davis, F.D., 2003, "User Acceptance of Information Technology: Toward a Unifed View," MIS Quarterly, 425-78.
8. Davis, F.D., 1989, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," MIS Quarterly, 13(3), 319-340.
9. Ajzen, I. and Fishbein, M., 1980, Understanding Attitudes and Predicting Social Behavior, 1st Edition, Pearson, New Jersey.
10. Lunn, P.D., 2013, "Telecommunications Consumers: A Behavioral Economic Analysis," Journal of Consumer Affairs, 47(1), 167-89.

11. Korica, M. and Molloy, E., 2010, "Making Sense of Professional Identities: Stories of Medical Professionals and New Technologies," Human Relations, 63(12), 1879-901.
12. Correa, T., Straubhaar, J.D., Chen, W., and Spence, J., 2015, "Brokering New Technologies: The Role of Children in their Parents' Usage of the Internet," New Media & Society, 17(4), 483-500.
13. Soule, S.A., 1999, "The Diffusion of an Unsuccessful Innovation," Annals of the American Academy of Political & Social Science," 566(1), 120-131.
14. Barham, B.L., Chavas, J., Fitz, D., Salas, V.R., and Schechter, L., 2014, "The Roles of Risk and Ambiguity in Technology Adoption," Journal of Economic Behavior & Organization, 97(1), 2004-18.
15. Collier, J.E. and Kimes, S.E., 2013, "Only If It Is Convenient: Understanding How Convenience Influences Self-Service Technology Evaluation," Journal of Service Research, 16(1), 39-51.
16. Alvarez, J.F., 2010, "Colombian Family Farmers' Adaptions to New Conditions in the World Coffee Market," Latin American Perspectives, 37(2), 93-110.
17. Feleke, S. and Zegeye, T., 2006, "Adoption of Improved Maize Varieties in Southern Ethiopia: Factors and Strategy Options," Food Policy, 31(5), 442-57.
18. Kim, S., 2011, "The Diffusion of the Internet: Trend and Causes," Social Science Research, 40(2), 602-613.
19. Dresselhaus, A. and Shrode, F., 2012, "Mobile Technologies & Academics: Do Students Use Mobile Technologies in their Academic Lives and Are Librarians Ready to Meet this Challenge?" Information Technology & Libraries, 31(2), 82-101.
20. Christou, C., Eliophotou-Menon, M., and Philippou, G., 2004, "Teachers' Concerns Regarding the Adoption of a New Mathematics Curriculum: An Application of CBAM," Educational Studies in Mathematics, 57(2), 157-76.
21. Tunks, J. and Weller, K., 2009, "Changing Practice, Changing Minds, From Arithmetical to Algebraic Thinking: An Application of the Concerns-Based Adoption Model (CBAM)," Educational Studies in Mathematics, 72(2), 161-83.
22. Gilbert, E., Karahlios, K., and Sandvig, C., 2010, "The Network in the Garden: Designing Social Media for Rural Life," American Behavioral Scientist, 53(9), 1367-88.

Appendix C - Qualtrics Survey Questions

Thank you for taking the time to provide helpful information about mobile phone adoption.

Your response will be used in developing strategies to move new technology from the development stage to the marketplace.

Mobile phones have been used widely by consumers since the mid-1990s. This survey explores how people adopted or rejected mobile phone technology. Please answer the questions to the best of you r memory. This survey should take less than 10 minutes.

This project is part of a PhD dissertation in the Industrial and Manufacturing Systems Engineering Department. The goal is to understand how technology fits people's lives in the long term. Thank you for your participation.

Q1. What is your gender?

Male

Female

Q2. What is your age?

18-24

25-34

35-44

45-54

55-64

65-74

75 and older

Q3. Which best describes your living situation?

Adult living alone

Adult living with other adult family members

Adult living with minor children

Adult living with unrelated adult roommates

Q4. Which best describes your living situation?

Rent

Own

Other

Q5. How do you usually access the internet?

Home personal computer

Tablet

Mobile phone

I don't use the internet.

Q6. Is your community?

Rural

Urban

Q7. As an adult, what was the first phone service you paid for

Landline phone

Mobile phone

Bundled package including landline and mobile

I've never paid for phone service. I'm included on someone's plan.

Q8. Which best describes your phone service today?

No telephone service

Landline only

Landline and mobile phone service

Mobile phone service only

If on Q8 answer was Landline only.

Q8LO-Q13. Which best describes you?

I have never had a mobile phone.

I had a mobile phone but got rid of it.

Q8LO-Q21 How long have you had you landline phone service?

Less than 1 year

1-2 years

3-5 years

6-10 years

More than 10 years

Q8LO-Q13Never-Q22 Please indicate which best describes you.

	Agree	Neither agree nor disagree	Disagree
Mobile phone reception is not good where I live			
Mobile phones don't fit my lifestyle.			
Mobile phones are not worth the expense.			
My landline is part of my internet/cable package			
Mobile phones are difficult to use.			

Q8LO-Q13Rid-Q23 How long did you have a mobile phone?

Less than 1 year

1-2 years

3-5 years

6-10 years

More than 10years

Q8LO-Q13Rid-Q16 Please indicate which best describes you?

	Agree	Neither agree nor disagree	Disagree
I originally got my mobile phone to use when I traveled.			
I originally got my mobile phone in case of emergencies.			
I originally got my mobile phone as a gift.			
While I had a mobile phone, most people still contacted me on my landline.			
I had trouble hearing people on my mobile phone.			
I got rid of my mobile phone because of the cost.			
My landline is included in my cable television/internet package.			
My mobile phone had a multiple year contract.			
I regularly used the text function on my mobile phone.			

My spouse/partner has a mobile phone.			
I got my mobile phone for work.			
I got rid of my mobile phone because I wasn't using it.			

If on Q8 answer was Landline and mobile phone.

Q8LM-Q14 Which best describes you?

I first had a landline then got a mobile phone.

I first had a mobile phone then got a landline.

Q8LMQ24 How long have you had a landline phone?

Less than 1 year

1-2 years

3-5 years

6-10 years

11 – 15 years

More than 15 years

Q8LMQ25 How long have you had your mobile phone?

Less than 1 year

1-2 years

3-5 years

6-10 years

11 – 15 years

More than 15 years

Q8LMQ27 How long have you had both a mobile phone and a landline?

Less than 1 year

1-2 years

3-5 years

6-10 years

11 – 15 years

More than 15 years

Q8LMQ10 Please indicate which describes you best

	Agree	Neither agree nor disagree	Disagree
I originally got my mobile phone to communicate when away from home.			
I originally got my mobile phone in case of emergencies.			
I originally got my mobile phone as a gift.			
My parents got me my first mobile phone.			
I consider the mobile phone as my primary phone.			
People usually contact me on my mobile phone.			
My mobile phone is convenient to use.			
My landline phone is convenient to use.			
I more often use my landline phone than my mobile phone.			
I use my landline to avoid using minutes on my mobile phone.			
My landline phone is part of my cable/internet package.			
I can’t imagine getting rid of my mobile phone.			
My mobile phone is easy to use.			

If on Q8 answer was ‘Mobile phone service only’

Q8MO-Q20 How long have you had a mobile phone?

Less than 1 year

1-2 years

3-5 years

6-10 years

11 – 15 years

More than 15 years

Q8MO-Q15 Which best describes you?

I never paid for landline. (Signaling ‘Births’)

I paid for landline service but got rid of it. (Path of adoption L-LM-M)

Q8MO-Q15Paid-Q17 How long did you have a landline before you got rid of it?

Less than 1 year

1-2 years

3-5 years

6-10 years

11 – 15 years

More than 15 years

Q8MO-Q15Paid-Q18 Which best describes you?

	Agree	Neither agree nor disagree	Disagree
I originally got my mobile phone to communicate when away from home.			
I originally got my mobile phone in case of emergencies.			
I originally got my mobile phone as a gift.			
When I got my mobile phone, I still considered my landline my primary phone.			
When I first got my mobile phone, people contacted me on my mobile phone.			
My landline phone was part of my cable television/internet package.			
When I first got my mobile phone, I considered it my primary phone.			
I got rid of my landline because I wasn't using it anymore.			
I got rid of my landline because I moved.			
I got rid of my landline because I didn't want to keep paying for it.			
I use my mobile phone for business.			

Q8MO-Q15NeverPaid-Please indicate which describes you best

	Agree	Neither agree nor disagree	Disagree
I originally got my mobile phone to communicate when away from home.			
I originally got my mobile phone in case of emergencies.			
I originally got my mobile phone as a gift.			
My parents got me my first mobile phone.			
I consider the mobile phone as my primary phone.			
People usually contact me through my mobile phone.			
My mobile phone is easy to use.			
I lived with my parents when I first got a mobile phone.			
My first phone was a mobile phone.			
I don't think I'll ever need a landline.			

To all participants:

Q30-What is the maximum amount you are willing to pay for a landline?

$0

$1-$10

$11-$25

$26-$50

$51-$75

Over $76

We thank you for you r time spent taking this survey. Your response has been recorded.

Appendix D - SAS code for simulation

To simulate the diffusion of mobile telecommunications service through the U.S. population, a three-compartment model using the variables of 'Landline' 'Landwireless' and 'Wireless' to describe the compartments.

Using the CDC data and regression models, the average rate of adoption was determined to be .149 percentage points per 6-month period and the average rate of abandonment was determined to be .037 percentage points per 6-month period.

```
**household simulation of innovation;
data householdsim;
Landline=485;  **485 is the proportion of households using landline only
*1000 at t=0;
Landwireless=479; **Proportion of households using both landline & mobile
*1000 at t=0;
Wireless=36; **proportion of households using only mobile * 1000 at t=0;
do time = 1 to 60;**sim out 60 6-month periods; output;
end;
run;

proc model data=householdsim;
parms N 1000 R0 4.027 inf 27.027; **N=total number of households R0=average
rate of adoption/average rate of abandonment;
**infection rate = 1/adoption rate;
**in this case average adoption rate = .149 average abandonment rate = .037;
gamma = 1/inf;
beta= R0*gamma/N;



dert.Landline=-1*beta*Landline*Landwireless;
dert.Landwireless=beta*Landline*Landwireless-gamma*Landwireless;
dert.Wireless=gamma*Landwireless;

solve Landline Landwireless Wireless / out=hhsim;
run;

proc sgplot data=hhsim;
Title 'Simulation of Households starting at Jan-Jun 2004';
series x=time Y=Landline;
series x=time y=Landwireless;
series x=time y=Wireless;
xaxis label='Time';
yaxis label='Proportion of Users X 1000';
run;

proc print data=hhsim;
run;
```

Appendix E - IRB Approval

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Malgorzata Rys
IMSE
2015 Durland

Proposal Number: 7637

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 04/01/2015

RE: Approval of Proposal Entitled, "Exploratory study of the adoption of smartphone technology by older American adults."

The Committee on Research Involving Human Subjects has reviewed your proposal and has granted full approval. This proposal is **approved for <u>one year</u> from the date of this correspondence, pending "continuing review."**

APPROVAL DATE: 04/01/2015

EXPIRATION DATE: 04/01/2016

Several months prior to the expiration date listed, the IRB will solicit information from you for federally mandated "**continuing review" of the research**. Based on the review, the IRB may approve the activity for another year. **If continuing IRB approval is <u>not</u> granted, or the IRB fails to perform the continuing review before the expiration date noted above, the project will expire and the activity involving human subjects must be terminated on that date. Consequently, it is critical that you are responsive to the IRB request for information for continuing review if you want your project to continue.**

In giving its approval, the Committee has determined that:

- ☒ There is no more than minimal risk to the subjects.
- ☐ There is greater than minimal risk to the subjects.

This approval applies only to the proposal currently on file as written. Any change or modification affecting human subjects must be approved by the IRB prior to implementation. All approved proposals are subject to continuing review at least annually, which may include the examination of records connected with the project. Announced post-approval monitoring may be performed during the course of this approval period by URCO staff. Injuries, unanticipated problems or adverse events involving risk to subjects or to others must be reported immediately to the Chair of the IRB and / or the URCO.

203 Fairchild Hall, Lower Mezzanine, Manhattan, KS 66506-1103 | 785-532-3224 | fax: 785-532-3278 | k-state.edu/research/comply | comply@ksu.edu

Appendix F - Abstract submitted to 2017 Industrial and Systems Engineering Research Conference

Early exploratory research indicated that individuals did not adopt service innovations in the manner described by the traditional two-state model. The two-state model suggests the potential adopters move from the state of non-adoption to a state of adoption. Drawing on data collected by the United States government and supplemented by survey data collected by the authors, a three-state model is proposed that describes the adoption process of a service innovation. In this model, individuals transition from a state of using a legacy system exclusively to a second state where both the legacy system and the innovative system are used. Finally individuals transition from the dual-use state to a third state where they rely exclusively on the innovative system and completely abandon the legacy system. This model is based on the adoption of mobile telecommunications service in the United States where people who adopted a mobile phone kept their landline phones. After a period of time, the landline phones were abandoned and the mobile phones were used exclusively. This model can be applied by management of service systems to the forecast demand and capacity needs of legacy systems when faced with a service innovation.

Appendix G - Abstract submitted to 2017 Frontiers in Service Conference

This research presents a mathematical model that can be used to forecast demand and production requirements of a legacy system when a service innovation is diffusing through a population. Rather than rely on a traditional non-adopter\adopter model of innovation adoption, a three-state model is employed. The three-states are based on the system the consumer participates in – legacy system only, legacy & innovative systems, and innovative system only. This model was developed using multiple-year data from the United States Centers on Disease Control on the usage of mobile telecommunications service. A compartmental mathematical model is proposed that relies on the first-order derivatives. This model is similar to SIR models that are used in epidemiology to understand the spread of infectious diseases. This model satisfies a very specific problem of forecast demand in the presence of a service innovation.