INDIANA FARMERS' LEVEL OF ADOPTION AND PERCEPTIONS OF MOBILE APPLICATIONS AS AGRICULTURAL MANAGEMENT TOOLS

by

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For Mom & Dad

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ABSTRACT

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Farmers in the digital age require accurate, relevant farm-level data to make sound management decisions for their operations. Mobile applications, or apps, are emerging as a valuable management and decision-making tool for farm operators, but are still in their infancy as a technological innovation. Farmer adoption and use of mobile apps has received relatively little attention in the scholarly literature compared to more established farm management tools and communication media. The researcher examined Indiana farmers' use and perceptions of mobile apps as tools for management and decision-making. A theoretical perspective was developed from the Diffusion of Innovation Theory and the Technology Acceptance Model to guide the investigation. Data on attitudes, behaviors, and demographic characteristics were collected through interviews with 55 Indiana farmers in late 2018 and early 2019. Quantitative interview items were analyzed through descriptive statistics while open-ended items were coded for emergent themes.

Study participants reported a median age of 41 years and an average of 26 years farming. Nearly all study participants (98.2%) considered mobile applications useful to farm operations. A smaller but significant majority (76.4%) of participants rated mobile apps as easy to use. In terms of content, the most common use of apps among study participants was for general purpose utilities such as banking and messaging, followed by weather and agriculture-related apps such as Granular and FieldNet. Ease of use and content of application were among attributes

considered most important by study participants when considering adoption of new apps. About three-fourths (76.4%) of the study participants indicated intentions to adopt additional mobile applications in the future.

A series of items addressed study participants' awareness of open source technology. About three-fourths (72%) indicated not previously having heard of the terminology. When asked to share their thoughts on the term open source, a large majority (84%) of participants provided vague or seemingly unrelated responses ranging from cloud-related, to the capability of apps to exchange information, to software being open to all users.

As part of the analysis, the researcher categorized study participants into one of three adopter categories – early adopters, early majority, or late majority – based on the length of time participants reported using mobile apps, attitudes toward the technology, and intention to adopt apps in the future. Cross-tabulation analysis revealed that early adopters of mobile app technology did not differ significantly at the .05 level from later adopters in terms of age, years farming, or size of operation.

Finally, an empirical test was conducted to assess utility of the Technology Acceptance Model for conceptualizing behavioral intent to adopt mobile agricultural applications. As expected from theory, correlational analysis revealed positive and moderately strong relationships ($p < .05$) between perceived usefulness and attitude toward mobile applications, and between perceived ease of use and attitude toward mobile applications. The relationship between attitude and behavioral intention to adopt additional mobile applications was statistically non-significant at the .05 level, contrary to theory. The importance of exploring alternative theoretical perspectives in future research is discussed.

Results from this research contribute to the growing literature on how farmers assess and use mobile applications as farm management and decision-making tools. Findings have implications for application developers, as well as those involved in education and marketing of mobile agricultural applications.

CHAPTER 1. INTRODUCTION

While US agriculture feeds the United States and the world, US farmers comprise only 2% of the country's population (fb.org). The productivity of modern farming operations depends on adept farm management. Farm management requires attention to grain and livestock markets, weather, machinery, land, buildings, and personnel. While the type of management required depends on the particular farm operation, a high level of knowledge and expert decision-making are required in modern agricultural management. Farmers must keep current on events that could influence markets and input prices. In particular, farmers must constantly keep weather in mind. According to some sources (corteva.com), extreme weather has cost farmers more than $1 trillion since 1980. Repetitive bad weather over multiple seasons, such as from drought or extreme flooding, can be devastating. Depending on location, farmers must worry about tornados, hurricanes, or other damaging weather.

1.1 Farm Management

Farm management is "making and implementing of the decisions involved in organizing and operating a farm for maximum production and profit" (Bliss, 2017, p. 1). Farm management is required in almost every aspect of farm decision-making. Farm management relies on information for prices, markets, agricultural policy, tax law, and, when it comes to money, leasing and credit (Bliss, 2017). However, farm management and decision-making extends beyond economics and includes a wide range of production decisions. Informed decisions are required about soils, seed and fertilizer, control of weeds, insects, and disease (Bliss, 2017). Agricultural engineering is involved in farm management when it comes to decisions on farm buildings, farm machinery, irrigation, crop drying, drainage, and erosion control systems (Bliss, 2017).

Finally, farm management and decision-making can, at times, involve elements of psychology, sociology and communication (Bliss, 2017; Schober 2012). Social awareness and interpersonal communication skills are needed when supervising employees, interacting with consultants or other colleagues, and cooperating with a wide range of others to accomplish farm tasks.

The tasks involved in farm management have become more diverse over time. The field was previously dominated by accounting and economics, making farms more efficient (Darnhofer, 2014). However, Darnhofer also states that farm management rarely is a single concern or decision. Farm management requires decision-making about many business aspects on any given day that could affect the entire farm operation. A primary focus of farm management is on theoretical reasoning and mathematical models, as well as risk (Darnhofer, 2014). Risk is a factor in many decisions about efficiency, insurance, and markets.

A 2011 survey conducted at the Ag Connect Expo in Atlanta measured farmers' attitudes toward leading issues that could impact their operations in the future (Case IH, 2011). The following issues were identified:

- Meeting the growing global demand for commodities as a result of world population growth;
- Availability and price of land for expansion;
- Meeting new government mandates and regulations;
- Managing instability and fluctuations in global financial markets;
- Withstanding the impact of global trade policies on food security and the supply and demand for commodities; and
- Development and use of bio-based fuels (Case IH, 2011).

It is clear from the literature that modern agriculture requires a wide range of farm management and decision-making skills. The challenge is one of maximizing profits and, when possible, reducing risk. What works for one farm will not necessarily work for another. No matter the size of the operation, informed decisions are necessary on a daily basis. Although consultants or other outside parties may assist or advise farmers on agronomic, financial or legal matters, farm managers must still have detailed expertise to keep their operations profitable and sustainable.

Farmers' frame of reference can have a significant impact on farm management strategies. In a 2012 study with Iowa farmers, researchers examined farmers' identity and how they made production decisions relative to conservation and profitability. The authors found that, if properly motivated, farmers' management behaviors could be influenced to include more environmentally sustainable practices.

Farm management analyses are often carried out on farms in order to see what is working and what is not working for the farm operation. It is important to look at the entire farm program when evaluating farm management decisions (Malcolm, 2004). According to Malcolm's study, farm management analyses are done within farm businesses, within public research and development, within private rural input supply and output processing businesses, and regarding sources of information to farmers. Malcolm states that "the key of farm management is making choices between alternatives" (Malcolm, 2004, p. 401).

Mullen (2002) states that productivity will continue to be a key element of farm management into the 21st century, particularly while protecting natural resources. It will become increasingly important to maintain profits while meeting societal expectations to protect the environment. However, as Darnhofer (2014) points out, farm management must remain relevant to farmers.

1.2 Farm Decision-Making Case Study

The late winter and beginning spring of 2019 saw extreme weather across the Midwest. In early March, Nebraska received a large amount of snowfall. Devastation continued as flood levels rose throughout the state. Melting snow and rain swelled the Missouri River and breached levees. Livestock had to be abandoned while grain bins full of the previous year's harvest were compromised. Farmers were forced to watch from afar after evacuating their land and livestock. One farmer in Iowa forecasted that over more than half the farmers in the area would not recover (CNN.com).

Official estimates of initial damage reached $800 million in lost crops and livestock. In eastern Nebraska, one hog farmer reportedly had two feet of water in his barn within 30 minutes. It was not possible to prepare for the devastation. Another farmer noted flooding was occurring in places that had never flooded before (CNN.com). Some farmers were lucky to live on higher ground. Those who were not as lucky saw their grain bins overwhelmed. For perspective on lost revenues from the grain bins, imagine a bushel of corn sells for $3.40. If 10,000 bushels are lost, the farmer lost $34,000. The extent of damage had some farmers wondering if they would be able to plant in 2019. If they are unable to plant, their losses will climb even higher.

Weather-related disasters are an unfortunate but common aspect of farming. In 2011, Iowa endured what was dubbed the 500-year flood (CNN.com). Farmers there in 2019 are facing the same devastation experienced in 2011. They recognize that they will be pinching pennies again in order to survive. Insurance is an option to assist farmers with devastated crops, but only for those who have it. Insurance may not cover lost crops that have been harvested, which is the case for many flooded Midwestern farms. Many may be rebuilding from the ground up and coping with the loss of livestock, damaged land, and ruined grain. Even well-managed farms will be under severe strain to survive the catastrophic weather of 2018-19.

This case study provides additional insight into the challenges of modern farm management. Unpredictable weather extremes pose unavoidable risks. When weather is placed alongside other farm management tasks discussed earlier in the chapter, one can begin to grasp the enormity of the challenge of farm management. In the digital age, farmers can benefit from accurate, relevant farm-level data to make sound management decisions for their operations. Mobile applications, or apps, are emerging as an impactful management and decision-making tool for farm operators, but are still in their infancy as a technological innovation. The following section provides a brief history and overview of the promise and challenges of mobile applications as farm management tools.

1.3 Mobile Applications in Agriculture

Taylor (2011, p.3) defines mobile applications as "small programs that run on a mobile device and perform tasks ranging from banking to gaming and web browsing." With smartphones being owned by 77% (pewresearch.com) of the population, these tools have become an increasingly popular tool for farmers to make decisions. Smart technology allows farmers to see real-time weather and markets as well as to easily connect with employees or other farmers across the area or country. Farmers can choose from 2.1 million apps for the Android or 2 million apps for an Apple product. With the large and growing number of applications available, farmers have the potential to make more accurate and efficient management decisions. According to Amy Bickel of the Hutchinson News, there is an app available for nearly everything in agriculture (Bickel, 2014). Apps are being developed by universities, commercial companies and other organizations (Bickel, 2014) and provide users with accurate, instant information they seek.

According to some experts, if a user is taking more than just a few minutes to figure out and understand an application, the app is not worth keeping (Bickel, 2014). Mobile applications span a full range of farm management needs, including improved decision-making about fertilizer and pesticide applications (Bradshaw, 2018).

Although mobile applications can help improve farm decision-making, they also are still at an early stage of development and face significant technical challenges, including lack of broadband capacity. Mobile applications constantly update real-time information and are unable to function properly without adequate broadband capability. The American Farm Bureau Federation states that rural broadband is crucial to modern agriculture (fb.org). According to the AFBF website, the U.S. Department of Agriculture has estimated that nearly one-third of US farms have no access to the internet (fb.org). Once farmers have quality access to rural broadband, they will be able to use mobile application technology even more efficiently.

As mobile technology has grown, the agriculture industry has adopted it. Farmers are utilizing these apps to increase efficiency and profits (Calderone, 2018). Farmers are utilizing their phones for a range of purposes, from monitoring commodity prices to identifying weeds and checking the weather. Mobile applications are able to provide portability in remote areas, especially during harvest season. Used properly, the tools can "increase effectiveness, improve productivity, and lead to financial gain for farmers" (Calderone, 2018, p. 1).

With mobile applications on the rise, agricultural companies have begun to develop additional applications for use on both Apple and Android products. Based on a survey of more than 1,800 farmers, Farm Journal Media reported that 59% use a smartphone and 44% use a tablet. These statistics surpass the national average of 58% using a smartphone and 42% using a tablet, according to Pew Research (agweb.com). The Farm Journal survey asked farmers to list the apps they use on a daily basis on their mobile devices (agweb.com). The top-rated app was AgWeb which provides markets, news, and weather, encompassing the type of information farmers want most (agweb.com). The top ten apps identified by survey participants were as follows (agweb.com):

10. Grower's Edge (market commentary, weather, farming news)
9. FarmLogs (farm management tool for grain markets)
8. Weather apps (current weather)
7. AgPhD App Suite (farm management tool for fertilizer, a drainage calculator, planting population, harvest loss calculator)
6. Pioneer/Encirca View (market data, market strategies, farming news, weather)
5. TractorHouse (tractor listings for purchase)
4. Farm Futures (news, commentary, podcasts)
3. Climate Basic (tracks weather, field information, soil and crop growth information – from the Climate Corporation)
2. Weed ID (weed identification)
1. AgWeb (market quotes, weather, agricultural news)

As noted, the apps encompass content from weather to markets to purchasing a tractor. It should be noted that the research was sponsored by a media company that manufactures apps. The following list of top 10 (unranked) agricultural applications is provided by smallbiztrends.com:

Sirrus (record keeping, scouting, weather)

FarmLogs (farm management tool for grain markets)

Growers Edge (market commentary, weather, farming news)

FarmFutures (news, commentary, podcasts)

Farm At Hand (farm management tool that captures field data)

Encirca View (market data, market strategies, farming news, weather)

Pocket Rain Gauge (location-specific rainfall measurements)

Tractor House (tractor listings for purchase)

AgWeb (market quotes, weather, agricultural news)

Agrisync (connect with trusted advisors about failing equipment)

The number of mobile users is larger than the number of desktop users, according to Nitin Deshdeep of VWO Blog. Deshdeep discussed in his post why users often prefer mobile apps to mobile websites. The primary reason is better personalization (Deshdeep, 2015). Farmers need to be able to personalize their applications to make content relevant to their farm. With an application, farmers can enter their acreage, animal IDs, seed information, and fertilizer information, just to name a few. These tools can help them stay organized. Deshdeep says users spend more time on apps than mobile websites. For farmers, it makes sense to be able to click an app on a smartphone rather than have to search a website. Deshdeep says that users spend 86 percent of their time on mobile apps. There is also the ease and convenience of receiving notifications from applications. Weather applications send notifications when weather changes. Notifications can provide an instant update when it comes to information that users might need and not even realize.

Another benefit of mobile apps is helping farmers make better land management decisions (sourcetrace.com). Mobile applications, for example, are able to monitor soil conditions as well as weather to enable improved planning during planting and harvest season (sourcetrace.com). As more farmers adopt mobile applications, they are also better able to transfer and share information with other farmers.

1.4 Problem Statement

There is a need to examine how farmers are using mobile applications on their farms. With over 3 million mobile applications available, how do farmers choose the apps they use? Although not all farmers have adopted smartphones, it is becoming increasingly necessary to integrate mobile applications into farm operations. Farmer adoption and use of mobile apps has received relatively little attention in the scholarly literature compared to more established farm management tools and communication media.

The current study examined Indiana farmers' use and perceptions of mobile apps as tools for management and decision-making. A theoretical perspective was developed from the Technology Acceptance Model to guide the investigation. The theoretical perspective and supporting literature are provided in Chapter 2, while study procedures are addressed in Chapter 3.

1.5 Research Questions

The purpose of this study was to describe the level of adoption that Indiana farmers have when it comes to mobile applications as management tools.

The research for this study was guided by the following questions:

1. To what extent do farmers use mobile applications for farm decision-making?
2. What factors are associated with increased use of mobile applications for farm decision-making?

3. What technological capabilities and features of mobile applications do farmers consider most important?

4. What factors hinder use of mobile applications for farm-decision-making?

5. What mobile applications are most commonly used by farmers?

1.6 Need for the Study

Digital and mobile technology are advancing at an aggressive pace. It is crucial to identify mobile applications farmers are using on their farms and the factors associated with their use. Results from this research contribute to the growing literature on how farmers assess and use mobile applications as farm management and decision-making tools.

1.7 Open Ag Technology and Systems Center

The Open Ag Technology and Systems (OATS) Center at Purdue University is led by a group of engineers and farmers who aspire to bring open source culture to agriculture. The ultimate goal is to help data flow more easily and efficiently (ideally in an autonomous fashion) for farmers and organizations through industry partnerships enabling open-source projects and collaborations (Ault, Krogmeier, & Buckmaster, 2018). The group has operated since nominally 2009, but officially launched the center in 2018 with announcement of a significant grant from the Foundation for Food and Agriculture Research (FFAR) and a series of partnerships with prominent industry and agribusiness organizations (oatscenter.org).

The OATS Center, led by three faculty and staff from the Purdue College of Engineering and College Agriculture, includes not only master's and doctoral engineering graduate students, but also an interdisciplinary mix of faculty collaborating in such areas as agronomy, engineering, food science, and statistics.

Key current projects include the following:

ISOBlue: ISOBlue collects machine data and seamlessly serve it to the Cloud in near real time when connectivity exists.

Trellis: Trellis is able to help companies get a return on investment from their audit data. This provides a produce-specific framework to help with food safety.

Open Ag Toolkit: Open ATK makes it easier for users to collect and use information. These applications (fieldwork, rock, manure) work together and are open source. These applications are designed from the farmer’s perspective.

A foundational idea behind OATS is that the agricultural industry can and must benefit from the preponderance of data now available in agriculture. Data must be easily accessible, usable, and secure for its users. Achieving these goals will require overcoming such technical challenges as automatable data exchange and interoperability. In addition, the group believes that education and collaboration in the open source community will lead to greater trust, more partnerships and, ultimately, more minds focusing on data solutions for agriculture.

The goal of the OATS Center is to move innovation forward more quickly through open source code and tech stacks that enable analytics focus rather than wrangling and translation focus. The group has three objectives in order to attain the goal:

1. Creation of community anchors that would provide support and networking opportunities to encourage a community development.
2. Design of open educational experiences and materials to promote open source collaboration
3. Development and demonstration of useful open source software/hardware and toolkits

The Center is building an open source community to facilitate and demonstrate data exchange situations. By utilizing demonstrations, there should be an acceleration in innovation by breaking down barriers and making pathways through the power of research, design and prototype, fail or succeed, and revise. The focus of the center will be directly on improving and evaluating projects that can make an impact.

1.8 Common Assumptions

Social science research often relies on assumptions that certain conditions or circumstances will prevail in the conduct of the research. Making explicit these assumptions is recommended. The researcher makes the following assumptions for the current study:

1. Research questions can be addressed through a social science methodology.
2. Participants may decline to participate in the study.
3. Collected data represents honest and unbiased beliefs, thoughts, and experiences of participants.
4. Data were collected with reliable and valid instrumentation.
5. The researcher subscribes to a positivist paradigm. According to this paradigm, it is possible to measure social scientific constructs that exist outside of the researcher. Positivism is based on the view that phenomena can be verified through experiments, observations, and logical/mathematical proof.

1.9 Definition of Terms

Application developer: person who "builds and creates software and applications" (www.techopedia.com)

Mobile application: small programs that run on a mobile device and perform tasks ranging from banking to gaming and web browsing (Taylor, 2011, p. 3)

Open source hardware: hardware that has a public design so that any person can study, change, sell, and make based off one design (www.oshwa.org)

Open source technology: “A new and revolutionary process of producing software based on unconstrained access to source code as opposed to the traditional closed and property-based approach of the commercial world” (Bonaccorsi & Rossi, 2003, p. 1244)

CHAPTER 2. REVIEW OF THE LITERATURE

2.1 Introduction

During the past 10 years, mobile applications have evolved and made their way into a billion-dollar industry. As the literature in this section displays, there truly is "an app for that" in nearly every aspect of play and work, including agriculture. The following sections provide information on mobile applications, agricultural mobile applications, characteristics of apps, and open source technology. The chapter concludes with a discussion of relevant theoretical perspectives, including Diffusion of Innovations and the Technology Acceptance Model. This chapter is designed to inform the reader on recent literature regarding mobile applications, open source technology, and theories guiding this research.

2.2 Research Questions

The research questions guiding this study are as follows:

- To what extent do farmers use mobile applications for farm decision-making?
- What factors are associated with increased use of mobile applications for farm decision-making?
- What technological capabilities and features of mobile applications do farmers consider most important?
- What factors hinder use of mobile applications for farm decision-making?
- What mobile applications are most commonly used by farmers?

2.3 Literature Review Strategy

In reviewing literature for this chapter, the researcher explored several different ways to find relevant information. Searches were conducted through the Purdue University Libraries system. The Google Chrome web browser was also used with literature searches conducted in

Google and Google Scholar. Keywords used in the search included mobile applications, agricultural apps, farm decision-making apps, popularity of mobile applications, open source technology, and farm management. Various noun and adjectival forms of keywords were included to broaden the search, such as agriculture, agricultural, Ag, etc. Searches were similarly conducted on key terms associated with the theoretical perspective used to guide the study.

Relevant author names were also searched during the literature review process. For example, “Lerner and Tirole open source” was searched during the literature review to find publications these authors had completed on open source. Additional authors were searched based on references from papers found using the above mentioned keywords.

2.4 Mobile Applications

Smartphones occupy a prominent place in today’s digital world. As one industry professional notes: “If you haven’t embraced it yet, you probably will since ultimately every smartphone user on the planet is expected to buy into it” (Taylor, 2014; Johnson, 2010, p. 24).

A major point of attraction for smartphones is their ability to operate mobile applications It is first important to define mobile applications. Taylor (2011, p. 1) defines mobile applications as “small programs that run on a mobile device and perform tasks ranging from banking to gaming and web browsing.” Mobile applications “cut through the clutter of domain name servers and uncalibrated information sources” (Johnson, 2010, p. 24). Mobile applications can take users directly to content they are looking for and do it more quickly and efficiently than ever before. Taylor (2011) also reported on a November 2011 study that showed 44% of U.S. mobile users over the age of 13 expect their phones to be able to access the internet. Additionally, 33% of them are using phones to access social networking sites and 72% are sending text messages (Taylor, 2011). Since 2011, numbers and use of smartphones have grown dramatically. A 2018 article from Sales Force states that 77% of adults in the US own a smartphone (Edmonds, 2018), according to Pew Research. Edmonds states that "for every minute consumers spend surfing the web on their phones, they spend six minutes in apps" (Edmonds, 2018, p.1). In another survey, researchers found that 57% of users get their news from apps (Edmonds, 2018).

Apps are increasingly being used to purchase items online, from clothing to take-out to even school supplies that were forgotten in the morning. Mobile apps have tremendous potential when it comes to mobile commerce (Taylor, 2011). The first "smartphone" was introduced in 2002 and was a significant commercial success (JetRuby Agency, 2017). Among other things, the Blackberry allowed users to send emails directly from their phones. As the smartphone evolved and the Blackberry set the precedent, the future looked bright. Apple opened its app store in 2008 and released 552 apps; 132 of them were free (JetRuby Agency, 2017). According to the American Dialect Society, "app" was the 2010 Word of the Year (ADS, 2011). In the first week of Apple's app store being open, users downloaded more than 10 million applications (JetRuby Agency, 2017). As this new technology came to life, it transformed society and industry. Today, there are more than 5 million mobile applications available for purchase.

New digital technologies and the need for more intensive management in the agricultural sector have also boosted mobile application use among farmers. With the implementation of precision farming technologies, Steinberger (2007) notes that agricultural management has become more complex. Not only are farmers implementing precision farming technologies, but they are also expanding farms and acquiring bigger machinery. With these moves comes an increased need for information. Examples include yield mapping and the various compatibility issues farmers have when using these technologies (Blackmore & Moore, 1999).

Steinberger (2007) discusses a related problem whereby farmers may base an app adoption decision primarily on the need for system compatibility rather than to obtain a functionality they need for their specific farm situation. If compatibility or other technical issues prevent farmers from selecting a system that can save time or labor, technology has failed. The ideal situation, according to Steinberger (2007), would be for farm information management systems to embed all needed services into one architecture that allows for information to be automatically linked and processed for further web service technologies. (Steinberger (2007) comments that this would make it easier for farm managers to ask and answer questions of other farm employees and create an interoperability platform for farm work.

Mobile applications constitute a billion-dollar, and growing, industry. As of 2011, the market grew from a zero dollar industry to a $2 billion industry (Taylor, 2011). Apple even has the phrase “there’s an app for that!” (cnn.com, 2010) trademarked due to their more than 350,000 apps that are still growing (Lookout_Mobile_Security, 2011) in the marketplace. A 2010 Nielsen study showed that of all applications, games are the most popular with weather, navigation, and social networking following. Consumers want to be able to download or purchase what they need in a timely manner. A 2012 study noted that smartphone-enabled users “do not care whether they buy online, via mobile or in-store as long as they get the product they want, when they want it at the right price” (Taylor, 2014; Aubrey and Judge 2012, p. 1). Taylor’s 2014 study also notes that “38 percent of smartphone shoppers had used a mobile app to make a purchase from a retailer, and 56 percent said they planned to make a purchase with a retailer app within the next year” (Taylor, 2014; Adobe, 2013, p. 3).

2.5 Open Source Technology

Open source has been described as "one of the most debated phenomena" in the software industry (Morgan & Finnegan, 2007, p. 1). Open source is a continuously evolving piece of technology. However, it is not new. Ehls and Herstatt (2015) describe open source as a *communal* model of technology development and trace its origins as far back as the 1960s. Much of the research on open source software has focused on why its programmers are working in open source and how specific projects and products are organized (Morgan & Finnegan, 2007; Lerner & Tirole, 2002). Open source programmers want people to adopt open source mobile applications. While many believe that open source moving into commercialization is easy, there has been discussion about the value open source can bring to businesses instead of proprietary software (Morgan & Finnegan, 2007). There are many positives to open source as well as drawbacks. Some economic benefits that could impact the adoption of open source include reliability, security, compatibility, quality control, and performance (Forge, 2006). However, it is also important to note potential drawbacks of open source. The following are a list of drawbacks compiled by Morgan and Finnegan (2007): compatibility (Webb, 2001; Guth, 2006), security risks (Herbsleb, 2002; Forrester, 2004), installation problems (Webb, 2001), lack of expertise (Krishnamurthy, 2003), user-friendliness (Kenwood, 2001), lack of user support (Web, 2001), lack of ownership (Kenwood, 2001; Guth 2006), insufficient marketing (Krishnamurthy, 2003), giving away the source code (Hecker, 2000), and higher training investment in OSS (Forrester, 2004).

According to Everett Rogers, five factors in technology influence adoption (Rogers, 2003; Morgan & Finnegan, 2007). The factors are: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003; Morgan and Finnegan, 2007). Environmental factors such as market conditions and skills and services can also influence the adoption of open source (Dedrick & West, 2003; Morgan & Finnegan, 2007). According to Morgan & Finnegan (2007), the literature on open source addressed “improved harmonization, extra functionality, and establishment of de facto standards” (p. 4). Drawbacks included “poor documentation, less functionality, proliferation of interfaces, and problems with finding the right staff and competencies” (Morgan & Finnegan, 2007, p. 4).

Open source began in response to perceived unfair profits being made by software companies. Open source is based on a “loosely knit governance model” (Volpi, 2019, p. 1). Others can see code and add to it to or otherwise modify it for their own purposes. Originally, open source was created for developers by developers. The original software, despite not being user friendly, was robust, flexible, and performed well. Linux became the second most popular open source (behind Windows) for servers. This success led to business ventures. The first venture tried capitalizing on the adoption of open source by making offers like “enterprise grade” support for software distribution. However, Red Hat, Linux, and MySQL had limitations. Their organizers struggled to make money on their ventures. The work was support-service based, but the open source market was getting so big, sizeable companies needed built. With Linux and MySQL successfully being adopted, organizers were able to lay a foundation for the next generation of open source.

“Clouderia and Hortonworks” (Volpi, 2019, p. 1) were considered to be the “poster children” of the second generation. The new generation was different from what came before them. The software was “principally developed within an existing company and not by a broad, unaffiliated community” (Volpi, 2019, p. 1). In other words, none of these new software was started from scratch. Second, the organizers had figured out how to make money this time around. Only certain parts of the project were licensed for free. This time, consumers were charged for using certain parts of the software under a commercial license. Because of this, the open source ventures were profitable, even if there was less demand.

While these developments seemed promising, there were downsides within the open source community. No single company was the recognized authority (Volpi, 2019). Rather, companies competed for profits by offering more and more parts free in the software. The companies also tried to form into smaller groups during the start of the software to differentiate themselves from others. When these companies did this, they did not build with the cloud service in mind. So, in turn, cloud providers could use open source to build SaaS business. SaaS (software as a service) is designed as a software distribution model where there is a third-party provider that has applications and in turn makes them available to consumers via the internet (Rouse, 2016). Amazon is an example of a SaaS.

Open source software is developed within the confines of businesses. About 90 percent of code lines are written by employees of software companies that are commercializing the software. Businesses are also offering their own cloud services. Open source communities are considered to be the most innovative type of community with the most relevant projects (Volpi, 2019).

Open source is growing rapidly. Linux recently reported that in the last five years, membership has increased by more than 400 percent (Nachmany, 2019). Increases in membership lead to higher revenues. In 2018, Microsoft was acquired by GitHub, a service company for computer code. GitHub is also the world's leading software development platform (github.com). GitHub is not an open source developer, but helps push open source out to consumers and accelerates its usage (Nachmany, 2019).

The history of open source is interesting in its own right. When Richard Stallman could no longer work in his MIT lab due to manufacturers withholding their code and proprietary software taking over (Singh, 2018), he started the GNU project. It was 1984. Stallman wanted to create something that had a free operating system and wanted to show something that was going to be a step toward a free software community (Singh, 2018). There were four things a user should be able to do for a software to be truly free:

1. "Run the program as you wish, for any purpose"
2. "Modify the program to suit your needs"
3. "Redistribute copies, either gratis or for a fee"
4. "Distribute modified versions of the program, so that the community can benefit from your improvements" (Singh, 2018, p. 1)

Linux eventually acquired GNU and the project has continued to grow exponentially. In 2003, the popular internet browser Mozilla Firefox was released and was one of the top open source browsers (Singh, 2018).

2.6 Interoperability

Wegner (1996, p. 1) defines interoperability as "the ability of two or more software components to cooperate despite differences in language, interface, and execution platform." Interoperability enables different systems to speak to each other and to speak flawlessly. Chen (2008) states that "inter-operate" refers to a process in which one system is performing an operation for another system. The term is important in the context of mobile agricultural applications where users need access to data or resources from multiple operating systems in simultaneous use. Chen (2008) states that interoperability deals with coexistence, autonomy and federated environment.

Integration is related to but distinct from interoperability. Integration differs from interoperability in that integration is working with "concepts of coordination, coherence, and uniformization" (Chen, 2008, p. 648). Two integrated systems can be interoperable, but two interoperable systems are not always integrated. Further, two systems can be integrated if there is "a detailed standard format for all constituent components" (Chen, 2008, p. 648). Interoperability, on the other hand, uses an approach where there is a common meta-level structure across the models (Chen, 2008). Ouskel and Sheth (1999) treated interoperability in more detail and discussed different levels of interoperability

2.7 Diffusion of Innovations

Implicit in farmers' use of apps is that they have made a conscious decision to adopt mobile apps as a farm management tool. The adoption decision-making process undertaken by individuals, firms and industries is, in fact, one of the most studied phenomena in social sciences. The late Everett Rogers is considered a seminal author in research focused on personal, environmental and technological factors influencing individuals' decisions to adopt or not adopt a given innovation.

According to Rogers, author of the classic and widely cited Diffusion of Innovations textbook, cultural considerations can play a significant role in adoption decisions. His book shares a case study involving Peruvians and their perceptions of boiling water. Despite the preponderance of science supporting the practice, villagers were generally resistant to do so because they associated hot water with being sick. According to the case study, boiling the water would make it "less cold" and that must mean that an individual was sick. For the Peruvians, the stigma of boiling water was based on a cultural belief. Every society has cultural beliefs that can encourage or discourage adoption of innovations.

Rogers argued that individuals are more likely to adopt an innovation endorsed by a trusted person who is judged similar to them. According to Rogers (2004), it is important for change agencies and companies to be client-oriented as well as innovation-oriented.

A unique facet of Rogers' work was the development of the iconic adoption curve that has been applied to countless innovations, including those in the agricultural context. Rogers created the bell-shaped curve based on case studies tracking the adoption of hundreds of innovations. The curve is separated into five sections in which potential adopters are placed according to their innovativeness, or their speed in adopting a particular innovation. Scanning left to right, the five categories of adopters are as follows: innovators, early adopters, early majority, late majority, and laggards.

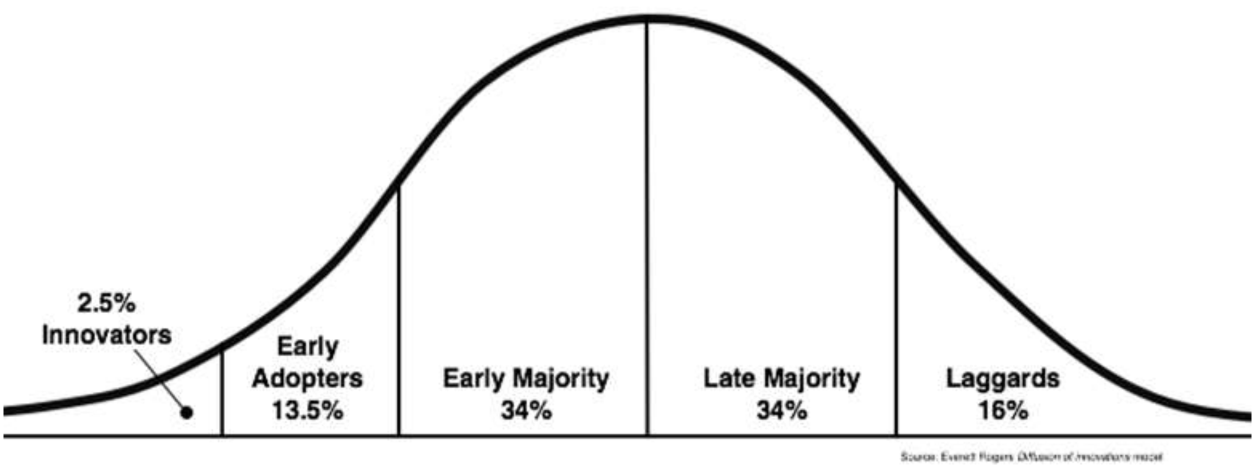


Figure 2.1. Rogers' Curve of Adoption

Innovators are the first to adopt a new technology. When a new technology is introduced, innovators are the ones who first acquire it (Rogers, 1995; Orr, 2003). Innovators are typically well-informed, financially capable, and willing to take risks. The next category, early adopters, glean information from innovators and other sources to support their decision-making. Early adopters are more likely to adopt if they have the means to do so and judge that an innovation is working effectively for innovators (Rogers, 1995; Orr, 2003).

Occupying the middle area of the curve are early majority and late majority adopters. Because of the large amount of space under the curve for these two categories, their adoption of an innovation is associated with a significant increase in an innovation’s overall rate of adoption (Rogers, 1995; Orr, 2003). Individuals in the early majority category may feel pressure to adopt an innovation to keep pace economically or otherwise. Likewise, a decision to adopt on the part of the late majority may be due to the perceived need to maintain economic or social viability (Rogers, 1995; Orr, 2003). The last of the five groups, laggards, tend to be suspicious of innovators and may interact with like-minded others who are resistant to change (Rogers, 1995; Orr, 2003). There are two types of laggards: traditionalists and isolates. Traditionalists tend to interact with those who are like them; isolates tend to lack any social interaction and, thus, are often unaware of the views of innovators or others (Rogers, 1995; Orr, 2003). Laggards take much longer to adopt new technologies or may delay adoption decisions indefinitely.

Diffusion is defined as the “process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 2004, p. 5). Uncertainty is an inevitable feature of the diffusion process as potential adopters rarely have perfect information when considering adoption of a new innovation. Uncertainty implies a lack of surety (Rogers, 2004). Not surprisingly, many individuals opt to wait and see what peers think about innovation. Others may undertake extensive research before making an adoption decision.

Diffusion can have significant societal consequences and even bring about social change (Rogers, 2004). It is important to keep in mind that innovations can be useful and desirable for some, but not for everybody. There may, in fact, be sound reasons for not adopting a given innovation. According to Al-Jabri and Sohail (2012), diffusion of innovation theory may be one of the most prominent theoretical perspectives seeking to understand the how, why, and at what rate a new idea or technology can spread through a society.

The theory is relevant to the study of how individuals adopt and use mobile applications. Taylor (2011, p. 61) states that "users adopt the technology, and individual apps, based largely on the influences of peers and others within their social networks." Users are more likely to listen to people with whom they interact regularly when deciding whether to adopt a certain application. Taylor (2011, p. 61) concluded that "it can be inferred that the adoption of individual apps, as well as the adoption of apps in general, is an organic process driven by peer-to-peer contact."

Mobile application users ideally would like to make sure that an app is going to satisfy their needs and their operation before investing time to download it to their phone or tablet. "Consumers will often turn to their social networks as informational referents" (Taylor, 2011; Burkhardt & Brass, 1990, p. 61). Consumers often trust comments from a user who has no ties to a mobile application over actual information from the developer of the application. Opinion leaders have the power to "either increase the likelihood of adoption, or conversely, prevent the adoption of a product" (Taylor, 2011, p. 61). There are considered to be three components of influence according to Katz (1957) and Weimann (1991). First, "the personification of certain values (or 'who one is')"; second, "competence ('what one knows')"; and third, "strategic social location ('whom one knows')" (Taylor, 2011, p. 61). The third factor examines the question, "Do others within a consumer's social network influence whether or not (s) he will adopt mobile applications?" (Taylor, 2011, p. 62).

Users may choose not to adopt mobile applications due to how difficult they are to learn. McGovern (2017) explains that users want applications that are relevant to their business. Similarly, farmers want to utilize an application that is going to be useful and relevant to their work and help them grow their operation. Social networks may also play a key role in adoption decisions about mobile applications.

2.8 Theory of Reasoned Action

The researcher examined multiple theories during the literature review process. This section examines the Theory of Reasoned Action, which is the basis for the Technology Acceptance Model later employed in this work.

The Theory of Reasoned Action examines an individual's motivation behind certain behavior performances (Montano & Kasprzyk, 2015). The Theory of Reasoned Action has been commonly applied to consumer choices and behavior (Sheppard, 1988). Many articles discuss the theory in studies focused on purchasing decisions at stores. Hansen, Jensen, and Solgaard (2004) examined consumers shopping online for groceries and their intentions to buy. They used the Theory of Reasoned Action to predict the "intention to perform a behavior by consumers' attitude toward that behavior rather than by consumers' attitude toward a product or service" (Hansen, Jensen, Solgaard, 2004, 540).

The theory attempts to examine the rational side of consumer behavior. A behavior is something that a consumer controls. However, this feature of the theory has been criticized. Sheppard, Hartwick, and Warshaw argue in their 1988 study that individuals are not always in control of their behavior. The trio writes that occasionally researchers are more interested in behaviors that are not completely under the consumer's control due to the situation (Sheppard, Hartwick, and Warshaw, 1988). Sheppard also adds that "actions that are at least in part determined by factors beyond individuals' volitional control fall outside the boundary conditions established for the model" (Sheppard, Hartwick, and Warshaw, 1988). An example can be found in the consumer who is shopping online for clothing, food, or cars, but is unable to complete the purchase. It is possible the consumer has determined that the process and system are too complex. It has been argued that that the consumer is not in control of this kind of behavior and that this situation is more appropriately analyzed through the Theory of Planned Behavior (Hansen, 2004).

2.9 Technology Acceptance Model

The Technology Acceptance Model (TAM) was derived from Fishbein and Ajzen's Theory of Reasoned Action. TAM has remained relevant as a theoretical model since its introduction in the 1980s. TAM highlights the importance of two constructs considered by individuals when considering adoption and use of new technologies: perceived usefulness and perceived ease of use. A system is useful if it enhances a user's job performance" (Venkatesh, 2000). Venkatesh (2000) also defines in his study "ease of use" as the degree to which a user thinks learning a system will be free of effort. Essentially, individuals who are buying into new technologies want something that is going to help them be productive and easy to use without training or excessive effort.

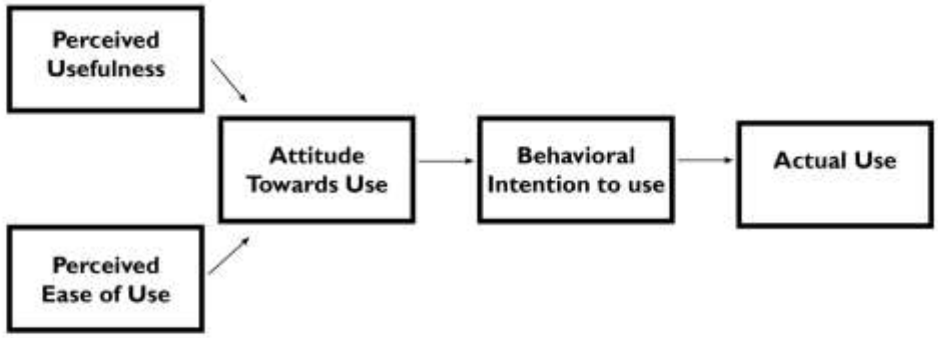


Figure 2.2. Technology Acceptance Model

The graphic shown in Figure 2 illustrates key constructs in the Technology Acceptance Model. The two variables perceived usefulness and perceived ease of use influence the outcome variables. Attitude toward use is defined as how a person evaluates a technology or specific behavior that is associated with the use of technology (Sherer, 2019). Behavior intentional refers to the individual's intention to actually use the technology. The terminal outcome variable is actual use of the technology. A number of variations of the Technology Acceptance Model have been proposed. Between 1986 and 2013, Marangunic and Grains (2015) reviewed the model and the research that used TAM; three different model variations were identified (Scherer, 2019). The Technology Acceptance Model has been used and modified many times over the years. The model is designed to provide a measure that shows whether a new technology will be accepted and adopted by end users (chirr.nlm.nih.gov).

2.10 Application of Theoretical Perspective to the Study

The theoretical perspective guiding this study drew from elements of Diffusion Theory and the Technology Acceptance Model, a conceptual derivative of the Theory of Reasoned Action.

The primary contribution of Diffusion Theory to the current study is Rogers' (1995) conceptualization and description of the five categories of adopters. The five categories (innovators, early adopters, early majority, late majority, laggards) provide an intuitive and empirically sound framework for describing potential adopters of mobile agricultural technologies. The researcher describes in Chapter 4 a procedure for assigning current study participants to three adopter categories. Adopter category assignments are made according to criteria developed by the researcher. Cross tabulations of descriptive data are then analyzed to determine if study participants' adopter category position relative to mobile agricultural technologies is associated with age, years farming, or size of operation, as would be expected from the literature.

The Technology Acceptance Model is used to build a correlational model of behavioral intention to adopt mobile agricultural technologies. The theoretical constructs perceived ease of use, perceived usefulness, attitudes toward use, and behavioral intention to use are operationalized and relationships measured. Results are provided in Chapter 4. The researcher assesses the utility of the theoretical perspective used to guide the study in Chapter 5.

CHAPTER 3. METHODOLOGY

3.1 Introduction

This chapter describes the methodology used for the research. The following sections describe and provide details on research design, instrumentation, the population, data collection, Institutional Review Board approval, and participants.

3.2 Research Design

The purpose of this study was to describe farmers' perceptions and use of mobile applications as management and decision-making tools on their farm. The literature review conducted to support this study established that mobile agricultural applications are still at an early stage in their development. Developing a more complete understanding of how farmers perceive and use these tools could be of benefit to app developers, educators and the agricultural industry.

After examining the peer-reviewed literature on this subject, the researcher made the decision to conduct personal interviews with farmers as a means of collecting attitudinal, behavioral and sociodemographic data. Several key issues were considered by the researcher in the selection of the research design used to carry out the study. Personal interviews have the potential to allow the researcher to build a degree of rapport with study participants. Through this process, the researcher was able to gauge participants' understanding of questions and to provide clarification if needed. The researcher was also able to observe body language and other non-verbal cues that provided a more complete picture of study participants. This was done through observing the participant and noting any confusion or other non-verbal behaviors during the interview process.

Because of the interpersonal nature of the interviews, the researcher was better able to encourage participants to answer all questions fully and to complete the entire interview process. Each interview lasted approximately 10 minutes. It is important to note that users of mobile applications might consider the subject matter of questions as technical. Personal interviews offered an advantage over survey methods in that the researcher was physically present to interact with and ask conference participants if they wished to take part in the research.

Personal interviews also offered an advantage over focus groups in that vocal study participants may sometimes dominate conversations. In such cases, reserved study participants may be less likely to share their thoughts or to meaningfully participate in the dialogue.

In addition, the nature of the personal interviews allows researchers to ask both quantitative and qualitative questions with relative ease. Inclusion of open-ended items through other data collection modes may have resulted in a greater number of skipped questions or incomplete questionnaires. Finally, the use of personal interviews allowed the researcher to have data in hand immediately for transcription and analysis.

The methodology employed in this research was primarily quantitative with deductive reasoning. However, several open-ended questions in the interview protocol were administered by the researcher in an inductive manner using probes and follow-up questions to elicit more complete answers from study participants. These data were analyzed for emergent themes.

3.3 Instrumentation

The researcher developed a semi-structured interview guide for use in this research. The interview guide included 29 structured and open-ended questions as well as 12 Likert-type items assessing perceived ease of use and perceived usefulness of mobile applications (Davis, 1989).

In terms of ordering, the questionnaire began with demographic items to collect data on participants’ age and occupation. Participants were asked how long they had been farming and also the nature of their decision-making with their farm operation. A series of items focused on the farm operation itself, including type of operation and number of acres.

The questions asked early in the interview had a dual goal of collecting information about the participants and their farm operations while also helping participants become comfortable with the interviewer. The next set of questions were more technology-based and focused on mobile apps, such as the content of apps participants used and how they used them. In addition, participants were asked what kind of devices they used (phone or tablet) and what single application they used most on a daily basis. Next, participants were asked about applications they had purchased in the last two years for their farm as well as about applications used for their farm in the last two years. Participants were asked what mobile applications were useful on a farm and why farmers are use mobile applications.

Next, farmers were asked what kind of applications they wish they had, and why. These questions were included to help the researcher better understand participants’ management needs. Participants were asked why mobile applications made life easier, and which applications helped make life easier.

The interview also included items tapping participants’ awareness and knowledge of open source technology. Participants were asked if they had ever heard of open source and what they thought the term open source meant. Based upon their answer to the first open source question, participants were then asked about their impressions of open source. Finally, participants were engaged with questions that measured ease of use and perceived usefulness, key constructs in the Technology Acceptance Model (Davis, 1989). Five items were used from

Davis' model to measure perceived ease of use and five questions were used from the model to measure perceived usefulness. The particular items used from Davis' work were selected by the researcher based on their relevance and appropriateness to the current research on mobile application use among farmers. Item analysis was performed to assess reliability of the two scale items. Resulting alpha coefficients for ease of use and usefulness scales were .92 and .91, respectively, indicating high levels of internal consistency within the two scale items.

The instrumentation concluded with the researcher asking participants if they had any questions or comments about mobile applications in agriculture. The interview instrument used in this research is provided in Appendix A.

3.4 Population

The target population for this research included full- and part-time Indiana farmers who owned or rented land and grew either crops or livestock for profit. This description is consistent with the Census definition of farm. In addition, this population increasingly uses mobile apps for farm management and decision-making on their farm operations. Their perceptions and use of mobile apps is relevant to app developers, educators and the agricultural industry.

Although U.S. farmers are a highly researched population, access to farmer populations for research purposes is not a straightforward process. There is no single generally recognized and accurate list of farmers that is accessible for research purposes. Determining how to gain access to farmers for data collection is a research design issue that must be addressed early in the process. In addition, farming is a highly seasonal business in which farmers are virtually inaccessible for research purposes during certain times of the year, such as harvesting and planting. Finally, many farmers have been interviewed or surveyed for a variety of different purposes and some may be understandably unenthusiastic about participating in new research projects.

After consideration of the challenges posed in accessing the target population, the researcher made the decision to collect data at two state conferences hosted by Indiana Farm Bureau in late 2018 and early 2019. Participants of these conferences include a broad range of full- and part-time Indiana farmers who operate various sizes and types of farm operations throughout the state. The researcher requested and received permission from Indiana Farm Bureau to interview farmer-members at the two conferences in separate messages received December 5, 2018, and January 23, 2019. Indiana Farm Bureau has more than 250,000 members and offices in all 92 Indiana counties. The organization advocates for farmers at local and state levels and sponsors programs to help educate the public on agricultural issues. Indiana Farm Bureau hosts two conferences annually.

Data collection from the two state conferences constitutes convenience sampling. Farmers participating in the research are not assumed representative of Indiana Farm Bureau or Indiana farmers. Results are generalized only to the farmers participating in the research.

3.5 Field Test

The interview guide was field-tested in October 2018. Five farmers from the researcher's network who met study criteria were interviewed in northeast Indiana. Participants were contacted by phone the week prior to inquire if they would be willing to participate in the field test. The researcher explained that answers to interview questions would be used solely to improve the research process and would not be used in the actual study. Interviews took place at all five participants' farms. Participants were asked to answer the questions with which they were comfortable and were informed that interviews would be recorded for accurate record-keeping.

The purpose of the field test was to ensure that participants were able to understand questions without having to ask for additional clarification. The researcher also wanted to assess the order of questions and to confirm the amount of time needed to complete interviews.

As a result of the field test, the researcher determined that interview questions could be answered without added clarification, but that it was important to fully explain the purpose of the study to participants. This feedback was used to improve the interview process in subsequent data collection.

3.6 Data Collection

Data for this study were collected in December 2018 and January 2019 during two state conferences hosted by Indiana Farm Bureau. The researcher was on-site at each of the two conferences and recruited farmers for participation in the study. Farmers were randomly selected for recruitment. The researcher approached individuals in the conference lobby, introduced herself, briefly explained the purpose of the study, and asked if the person would be willing to participate in the research. Individuals had to be at least 18 years of age and involved with agriculture in the state of Indiana to be eligible. In some cases, individuals suggested that friends or colleagues also be interviewed by the researcher. The researcher obliged if the selected individuals met the study criteria.

Individuals who agreed to participate in the research were asked if the researcher could record the interview. The interviews were semi-structured and generally required 10 to 12 minutes to complete. There were no refusals – all recruited individuals agreed to be interviewed.

Interviews began with basic demographic items and ultimately transitioned to more in-depth attitudinal and behavioral questions relative to mobile agricultural applications. One of the goals of the early questions in the interview was to help make participants comfortable with the researcher and the goals of the study. Interviews were adapted for retired participants in that questions were administered in past tense rather than present tense.

As a token of thanks, the researcher offered participants a novelty wrench-shaped pen at the conclusion of the interview.

3.7 Research Approval

The researcher submitted IRB exemption requests to Purdue University's Human Research Protection Program during November 2018, January 2019, and February 2019. The IRB package included the IRB exemption determination form, participant recruitment script, interview instrumentation, and permission letters from Indiana Farm Bureau.

In November 2018, forms and documentation were submitted electronically via the COEUS portal on the Purdue IRB web site. The initial submission pertaining to data collection at the first conference was deemed exempt and approved November 21, 2018. A second submission was made seeking permission to collect data at the second conference. This submission was deemed exempt and approved January 14, 2019. IRB approval letters are provided in Appendix B.

3.8 Limitations

Limitations were encountered in the course of this research that could influence internal and external validity. These limitations are discussed in this section.

1. Data were collected during two multi-day conferences. Because interviews ranged in length and participants were attending sessions during the conference, there were constraints to the number of interviews that could be conducted by the researcher.
2. Another limitation arose during the second conference data collection. During this event, the researcher recognized some of the participants as having participated in the first conference. Because of the anonymity promised during data collection, the researcher did not keep track of participant identities. Therefore, it was not possible to track definitively who had already been interviewed and who had not. Further, it was difficult for the researcher to remember who had been interviewed at the first conference.
3. As discussed in the chapter, the research employs convenience sampling, which limits external validity. Findings from this research may not be generalized beyond study participants.
4. As a part of the project data collection, it was decided that the researcher would interview a small number of key informants. A pool of key informants was identified by the researcher's graduate advisory committee on the basis of individuals' knowledge of mobile technology use in agriculture. Because these were busy individuals who were operating businesses, it was difficult to set interview times. Several canceled interviews due to work schedules and others missed interviews due to having forgotten about them. It was difficult to re-establish contact with after the initial meeting was missed. Ultimately, the researcher was able to complete only one key informant interview. The single interview was not included in the analysis.

CHAPTER 4. RESULTS

4.1 Introduction

In this section, results of the study are discussed. The chapter begins with a presentation of research questions. Next, the chapter provides results for each interview item organized according to content. According to this scheme, the chapter first presents characteristics of respondents and respondents' farm operations, followed by various attitudinal and behavioral items measured through the interview process. Where appropriate, findings include direct quotations from study participants to help illustrate and clarify responses.

4.2 Research Questions

Five research questions guided this study, as follows:

1. To what extent do farmers use mobile applications for farm decision-making?
2. What factors are associated with increased use of mobile applications for farm decision-making?
3. What technological capabilities and features of mobile applications do farmers consider most important?
4. What factors hinder use of mobile applications for farm decision-making?
5. What mobile applications are most commonly used by farmers?

4.3 Results

A total of 55 interviews were conducted with Indiana farmers at two locations in the state. The researcher attended two conferences sponsored by Indiana Farm Bureau to collect data from conference participants on December 6-8, 2018, and January 26, 2019. Participants were recruited by the researcher on-site through a script explaining the purpose of the research and asking if they would agree to be interviewed. The research protocol employed in this study ensured that each participant was asked the same questions and given the same amount of time to answer questions.

Because of the convenience sampling methodology employed, findings are generalized only to study participants.

4.4 Characteristics of Study Participants

Study respondents were 84% male (*n= 46*) and 16% female (*n=9*) with a mean age of 46 and a median age of 41.

About one-third (*n=18*) of the participants reported farming as their sole source of income. An additional one-third (*n=19*) of participants reported holding a non-farm position or job in addition to farming. About one-fifth (*n=12*) reported their primary income from an outside (nonfarm) source but indicated they also farmed on the side. Finally, three participants identified as retired farmers. These participants were no longer farming, but were still involved with agriculture. A listing of participants by occupational status is provided in Table 4.1. Subsequent references to particular participants will use the participant numbering scheme in this table.

Table 4.1. Respondent occupations: Respondents reporting farming as their sole occupation. (n=18)

Participant	**Occupation**
1	Full-time Farmer
3	Full-time Farmer
4	Full-time Farmer
5	Full-time Farmer
13	Full-time Farmer
15	Full-time Farmer
16	Full-time Farmer
16	Full-time Farmer
21	Full-time Farmer
26	Full-time Farmer
28	Full-time Farmer
29	Full-time Farmer
34	Full-time Farmer
36	Full-time Farmer
38	Full-time Farmer
45	Full-time Farmer
50	Full-time Farmer
51	Full-time Farmer

Table 4.2. Respondent occupations: Respondents reporting secondary income outside of farming. (n=19)

Participant	**Non-Farm Occupation**
2	Regional Manager-INFB
6	Regional Manager-INFB
8	Self-Employed
10	Farm Crop Specialist
11	Loan Officer
12	Manager of Grain Facility
14	Engineering Consultant
17	Excavator
30	Self-Employed
33	Retired Teacher
37	Semi Driver
39	Livestock Feed Specialist
40	Hair Dresser
41	Regional Manager-INFB
42	Commercial Real Estate
43	Commodities Trader
44	Agriculture Businessman
48	Self-Employed
49	Critical Care Nurse

Table 4.3. Respondent occupations: Respondents reporting primary income outside of farming. (n=12)

Participant	**Occupation**
9	Logistics Coordinator
20	Community Wellness Coordinator
24	State Gov't Agency
25	Manager at a Farm
27	Farm Business Owner
31	Vice President at Farm Management Company
32	Appraiser, Farm Manager, Real Estate Sales
46	Executive Vice President
47	Technology Specialist for a Retail Outlet
52	Sales Support Representative
53	Management Trainee
54	Ag Retail Sales

As indicated, three individuals (Participants 18, 23, and 55) identified as retired farmers. Appendix C provides a complete list of study participants by participant number, age and occupation.

Participants were asked how many years they had been actively farming. Answers ranged from two years to 68 years. One participant did not answer this question. The average number of years farming was almost 26 (25.63).

Participants were asked if they owned a mobile device, smartphone, iPad, or tablet. More than one-fourth (n=15) of the participants reporting owning a smartphone and did not specify what type. Nearly one-fourth (n=13) of the participants reporting having both a smartphone and a tablet. Six participants indicated having an iPhone.

4.5 Characteristics of Farm Operation

Participants were asked to describe their farm operations. About two-thirds (n=37) of the participants reported operating mixed crop and livestock operations. Twelve participants reported a crops-only operation and four participants reported livestock only.

Participants were asked if they rented land to other farmers. Nearly three-fourths (n=39) of study participants indicated they did not rent land, while more than one-third (n=15) of the participants indicated they did rent land to other farmers. One participant did not answer the question.

In terms of total acreage farmed, participant responses ranged from five acres to 6,000 acres with a median response of 800 acres. One participant did not answer this question. Table 4.4 provides data for acres farmed by study participants.

Table 4.4. Acres farmed by study participants (n=55)

Acres	**F**	**%**
0-499	19	34.5
500-1,499	17	30.9
1500 or more	18	32.7
Missing	1	1.8

Participants were asked if they had employees associated with their operation. With 52 total responses for the question, more than half (n=28) of the participants indicated they had no employees, while 24 participants indicated having part time, seasonal, or full-time employees. Three participants did not answer the question.

Participants who answered yes to having employees were asked if their employees used a mobile device to communicate regularly with them. Twenty-one participants answered yes to this question, while two answered no. These participants were also asked if they utilized mobile applications with their employees. Six participants indicated using mobile apps for messaging and accessing Google Drive and Time Keeper. Fifteen participants indicated they did not use mobile apps with their employees.

Participants were asked if they were a primary decision maker on their farm as well as about farm ownership arrangements. Slightly more than half (n=29) of the participants stated that they were the owner and primary decision maker on their farm. Ten participants reported they were co-owners involved in a farm partnership of some kind, such as an LLC, a corporate partnership, or an informal contract. Finally, about one-fourth (n=14) of the participants reported they were not owners and not in any kind of partnership. This group encompassed farm managers, retired farmers, and business owners.

4.6 Adopter Categories

As a part of the analysis, the researcher categorized each study participant into one of three adopter categories on the basis of his or her speed in adopting mobile agricultural applications and other criteria described below. The three categories used in the current analysis were adapted from Rogers (2003) and included the following: Early adopter, (2) Early majority, and (3) Late majority. Criteria for placement of study participants in the three adopter categories were developed by the researcher and are described below:

- Early adopters: Have had information about applications since their inception, expressed desire to adopt additional apps, well-informed on apps if someone wishes to consult with them.
- Early majority: Adopted mobile apps within three years of their introduction, cited more positive attributes of apps than negative attributes.

- Late majority: Adopted apps within the last six years, adopted apps because they thought they had to do so, expressed hesitation in adopting additional apps, cite more negative attributes of apps than positive attributes.

Table 4.5 displays the placement of participants into the three adopter categories. As shown, a majority of participants were classified in the early-majority category.

Table 4.5. Classification of Study Participants According to Adoption of Mobile Agricultural Applications, Adapted from Rogers (2003) (*n=54*)

Adopter	**f**	**%**	**Participant Number**
Early Adopter	8	14.5	8, 11, 14, 25, 38, 42, 43, 51
Early Majority	32	58.2	1, 3, 4, 7, 10, 12, 13, 15, 16, 17, 19, 21, 22, 24, 27, 28, 29, 30, 32, 33, 34, 35, 36, 37, 41, 44, 45, 48, 50, 52, 53, 54
Late Majority	14	25.5	2, 5, 6, 9, 18, 20, 23, 26, 31, 39, 40, 47, 49, 55
Missing	1	1.8	
Total	55	100.0	

Cross-tabulation analysis was performed to assess whether earlier adopters of agricultural apps differed from other participants according to age, years farming, or size of operation. Chi-square results revealed that early adopters of mobile app technology did not differ significantly from later adopters according to these variables.

4.7 Use of Mobile Applications

Participants were asked what factors determined if they will use a particular mobile application on their farm. The purpose of the question was to determine the factors considered by farmers when choosing certain applications over others. Responses could be grouped into four categories: (1) apps should be applicable (*n=17*), (2) apps should be easy to use (*n=16*), (3) apps should be accurate and reliable (*n=7*), and (4) other desired characteristics (*n=15*).

Regarding the desire for apps to be applicable, participants indicated a need to for the app to perform a relevant function in their operation. According to Participant 6: “That it’s applicable to the type of operation that we have.”

Ease of use focused on how easy an application is to use and how accessible it is. Seven participants simply stated “ease of use” or “easy to use” when asked this question. Participant 42 stated:

> “I think it comes back to ease of use, how smooth it is, how practical it is. There are some applications, they try to do too much, and so for not only myself but other farmers, it gets to be cumbersome. So, simplicity and ease of use is a big one.”

Accuracy and reliability were mentioned by several participants as a top priority for apps. Especially valued among participants is the time-sensitive data and information that applications can provide:

> “Because the data is so specific and it’s very time-sensitive. It’s up to date. It’s valuable now.” (Participant 1)

> “I need to know what’s happening.” (Participant 19)

Finally, participants mentioned a host of other attributes they value in applications, including content, cost, and how others influenced what they chose. According to Participant 31: “My business partners use the same apps.” Said Participant 36: “Who we work with.” These statements show the influence that colleagues and peers can have when it comes to selecting mobile applications. Content and ease of use were important factors among many participants. According to Participant 54:

> “Either it was the first one I found that worked or I just liked the user interface of a particular one better than another one.”

4.8 Mobile Application Information Exchange

Participants were also asked the question: “Have you ever had a need for one application to exchange or use information to another application?” They were then asked to elaborate if they answered affirmatively. Table 4.6 presents participants’ responses for those answering “yes.”

Table 4.6. Participants' responses regarding the need for one application to exchange or use information from another application (n=20)

Participant	Answer
6	Yes, but we've done it manually. I guess I've tried to. I didn't know it existed.
12	Yes, top of my head, the Bar Chart app. There is some cases I want it to talk with Excel or another program like that to kind of translate some things for me.
14	Yes, I need to export from Pioneer Encirca to a better map point system.
20	Yeah, because I'll forward information with co-workers. Sometimes we'll be at a meeting and will need to send a picture to them. I use my orders to get things done too.
24	Yes, downloading data from yield monitor and uploading it to see the seed variety best used.
25	I wouldn't say a need, but it is a desire. I don't really have a need though.
31	I would love for my bank information to go seamlessly into Quick Books. It does it, but I have to go into each item and categorize and it's a pain. It's easier to just type it in.
34	Yes, I would like that.
35	Well I think the FieldView has done that. They seem to pull a lot more information in from that.
36	Yeah, like John Deere talking to Encirca.
38	Yes, all the time. I talked about the Encirca app being able to communicate across different platforms. It's feeding one type of data sheets into it. If I had a way to put Case IH file types and John Deere's APEX and all those different things, there just needs to be a streamline across the platforms.
42	I really just use Google to do that.
43	Yeah, so I bank with multiple banks and you cannot transfer funds from one bank to another. So, if I have a personal savings and a farm checking, well I have to make a transaction to get those funds to move.
46	Yes, occasionally with charts and graphs or even documents, sometimes a document that is generated on Microsoft, sometimes it is hard to edit and send things back if you are working on an Apple or Mac based product
47	Most definitely. So, this kind of broad stroke, but whenever you're working with mobile applications and your field monitors in your vehicles, your monitors aren't always the same. The ability to get the data available across all platforms is critical for farming today.
48	Yes, in banking.
49	Yes, there's ability for some of them to communicate if you put in yield totals. If it can communicate to a cloud and then you're pulling from the cloud into another. That's the biggest thing, like yield totals and fertilizer applications. It's really nice if they could communicate across programs rather than having to put it in.

Table 4.6 continued

50	I guess one of those, if I'm understanding, we use all hybrid variety tracking, so in the corn planter, we have to keep track of all the varieties, where they are planted, and then that all goes into the combine for harvesting data. There's currently several steps to make that happen, but I think with the adoption of like an iPad where it is more cloud-based, it would streamline that where it could go from one right into the other a lot easier than what we are currently doing. With having to use computer software to make it work.
51	Auto steer.
54	Yes, so an example would be, we soil sample for a customer and we send results to the lab. I believe that, at first, we would have to upload the results into a computer and just have them saved and use them there. The lab now is able to dump them into our proprietary program so I don't have to do any of that.

4.9 Perceived Attributes of Mobile Applications

Participants were asked what attributes, positive or negative, that they believed mobile applications have.

Many participants elaborated on positive characteristics of mobile applications. They occasionally summed up both positive and negative attributes into one answer. For example, Participant 34 stated:

> "Just the quickness and ease of comfort. The disadvantage is how secure are the apps? The security part."

Participant 38 also shared positive and negative attributes:

> "Positive, better productivity. Negative would be employees using them for other activities while they are supposed to be working."

While many participants shared both positive and negative attributes of apps they used, some shared only positives:

> "I didn't get rained out on spring this year so my weather app was accurate and helpful. That's something that is very evidence based. Before mobile apps, you watched your weather in the morning, you planned your day, you watched the sky, and you went and did your work. You might get rained out. Now with the mobile app, with radar, everything right up to it. I think within five or ten minutes. You can be super accurate." (Participant 1)

Other participants thought that there might be more negatives than positives when it comes to mobile applications:

> "We don't have good reception. Our Wi-Fi is very weak, our cell signals are very weak and it drives us crazy." (Participant 45)

According to another participant:

> "I guess one of the bigger challenges I see today are that there are very few barriers of entry so it's actually weeding through all the technologies that are available to find something that is sustainable and dependable and regularly updated." (Participant 51)

4.10 Data Security

Participants were asked their level of concern about their farm data being shared or distributed by agricultural companies. The statement on the instrument was phrased, "Are you concerned with how your shared data is being used by ag companies?" Possible response were scaled and read to participants as follows: 1=strongly disagree, 2=disagree, 3=slightly disagree, 4=slightly agree, 5=agree, and 6= strongly agree. One participant did not answer the question. Findings are provided in Table 4.7.

Table 4.7. Level of concern for how farm data is being used by agricultural companies, presented in frequencies (percentages) (n=54)

Strongly Disagree	**Disagree**	**Slightly Disagree**	**Slightly Agree**	**Agree**	**Strongly Agree**
5 (9.1)	4 (7.3)	3 (5.5)	15 (27.4)	12 (21.8)	15 (27.3)

Mean = 4.30; SD = 1.57
Items scaled 1 to 6, strongly disagree to strongly agree.

4.11 Farm Data

Participants were asked where they keep their farm data. Five response categories were provided, as follows: (1) Most of my farm data is consolidated into a single farm management system, (2) Most of my farm data is consolidated into my personal computer or my personal file storage system, (3) My farm data is not consolidated; it resides in multiple systems, (4) Not sure, or (5) Other. Farm management systems suggested were MyJohnDeere, Climate FieldView, Ag Data Coalition, Granular, and WinField R7.

Nearly half (*n=23*) of the participants indicated storing their farm data in their personal computer and file system. Fifteen participants said their farm data was in in multiple systems, and 11 said the data was stored in a single farm management system.

4.12 Usefulness of Mobile Applications

Participants were asked to rate the usefulness of mobile applications on their farm operations. Possible response were scaled and read to participants as follows: 1=strongly disagree, 2=disagree, 3=slightly disagree, 4=slightly agree, 5=agree, and 6= strongly agree. One participant did not answer the question. Findings are provided in Table 4.8.

Table 4.8. Perceived usefulness of mobile applications to farm operations, presented in frequencies (percentages) (n=55)

Strongly Disagree	**Disagree**	**Slightly Disagree**	**Slightly Agree**	**Agree**	**Strongly Agree**
0 (0)	0 (0)	2 (3.6)	6 (10.9)	15 (27.3)	32 (58.2)

Mean = 5.40; SD = 0.83
Items scaled 1 to 6, strongly disagree to strongly agree.

4.13 Perceived Ease of Use and Perceived Usefulness

As a part of the interview, participants were asked to provide their level of agreement with 10 statements regarding perceived ease of use and perceived usefulness of mobile apps. These items were modified from Davis' (1989) seminal work with the Technology Acceptance Model (TAM). Measurement of these items is discussed in Chapter 3.

Means and standard deviations for the 10 items are displayed in Table 4.9. Items were scaled 1 to 6, as follows: 1=strongly disagree, 2=disagree, 3=slightly disagree, 4=slightly agree, 5=agree, and 6=strongly agree. As shown, items for ease of use ranged from 4.04 to 4.49, indicating slight to moderate levels of agreement that mobile apps were easy to learn, use, and understand.

Items for perceived usefulness ranged from 4.63 to 5.33, indicating moderate levels of agreement that mobile apps make participants' jobs easier and increase productivity. The statement "Overall, I find mobile applications useful to my job" had the highest mean (5.33) and lowest standard deviation (0.72), indicating high relative agreement with the statement among participants.

Table 4.9. Respondent perceptions of mobile agricultural applications, ease of use and usefulness, Technology Acceptance Model items adapted from Davis (1989) (n=55)

Statement	**Mean[1]**	**SD**
Ease of Use		
Learning to operate mobile applications is easy for me	4.49	1.26
It is easy for me to remember how to perform procedures using mobile applications	4.45	1.37
Overall, I find mobile applications easy to use	**4.36**	**1.25**
My interaction with mobile applications is clear and understandable	4.24	1.22
I find it easy to get mobile applications to do what I want them to do	4.04	1.12
Usefulness		
Overall, I find mobile applications useful to my job	**5.33**	**.72**
Using mobile applications makes it easier to do my job	5.20	.85
Using mobile applications increases my productivity	5.00	.98
Using mobile applications allows me to accomplish more work than would otherwise be possible	4.85	1.16
Mobile applications support critical aspects of my farm	4.63	1.14

[1] Scale: 1, Strongly disagree; 2, Disagree; 3, Slightly disagree; 4, Slightly agree; 5, Agree; 6, Strongly agree.

4.14 Most Used Mobile Applications

Participants were asked to identify the mobile applications they used most. Participants named a variety of applications either by their brand name or as a general category of application (e.g., social media). After examining all responses, the researcher coded the data into four categories: (1) Weather, (2) Social media, (3) Ag related, and (4) Other. The latter category included a wide range of utilities such as calendar, stocks, banking, specialty apps, radio, calculator, mail, and messages. The number of responses exceeded the number of participants because participants could identify more than category of apps.

Applications in the agriculture-related category were further categorized into four groups based on the application's function. Table 4.10 shows the applications by category. Within the farm management category, the applications perform a multitude of functions. The farm management group shows the applications that farmers are using daily for farm decision-making. The Agri-news category includes applications that focus primarily on agriculture-related news and information. The livestock category includes applications with a livestock focus, and the weather category includes only applications focusing on that topic.

Table 4.10. Agriculture-related applications by category

Farm Management	**Agri-News**	**Livestock**	**Weather**
Granular	AgWeb	Angus Mobile	DTN
Bunge Mobile	Hoosier Ag Today		
Trimble Ag Mobile			
FARM Server			
Grower's Edge			
Climate FieldView			
Ag PhD			
Spray Smart			
My Operations-John Deere			
Ag Leader			
Winfield R7			
Premier Crop			
Grainger			
ADM FarmView			
Field Net			

The Granular application is a farm management and analytics tool that helps users improve their efficiency, profit, and yield (Apple Store). Bunge Mobile is an application from

Bunge North America. This application encompasses news, prices, and account information for users. The application also focuses on cash bids, futures, locations, and offers.

Trimble Ag Mobile or Ag Mobile performs field records, crop scouting, mapping, grid sampling, contracts, and crop inputs. FARM Server is an application that can update any crop scouting notes, yield or as-applied data from tractors, and can view crop health imagery. The application was created by Beck's Hybrids. This application also has weather tools and a live weather radar. Grower's Edge is an application that can give local cash bids, markets, and news.

Climate FieldView is designed from the Climate Corporation. The application collects and stores field data as well as measuring "the impact of agronomic decisions on crop performance, manage field variability by building customized fertility and seeding plans" (Apple Store) that can maximize profit and yield. An application encompassing all parts of farm decision-making is Ag PhD. This application includes soils, crop, fertilizer, planting, spraying, calculator, harvest, and drainage functions. The application also encompasses a full website that includes a show and radio broadcast. Spray Smart helps farmers determine spraying conditions. It provides "field-specific spraying conditions, current wind speed and direction, and temperature inversion potential for current location" (Apple Store).

The My Operations-John Deere application is designed by John Deere for users with John Deere equipment. The application offers users remote management of both field operations and equipment. This application allows users to view their fields, the location history of each machine, fuel levels, and the performance of a machine. Ag Leader is a precision farming tool that collects information from a field and connects an entire operation. WinField United's R7 tool allows users to view fields, data, and soil variability.

Premier Crop is a cloud-based application that focuses on inputs, fertility, seed, soil type, and farm management. The Grainger application allows users to check account pricing, item availability, or manage costs of items. The ADM FarmView application looks at commodity bids, provides elevator announcements, contracts, payments, and storage to users. Finally, the Field NET application is an irrigation-management tool.

Roughly half (*n=28*) of the participants identified one or more apps from the “other” category. The next most-often-cited category of apps was weather. Twenty-three participants identified weather apps as most used.

Next in order of use were apps in the ag-related category, which were identified by about one-third (*n=19*) of the participants. Social media composed the fourth most cited category of apps. Thirteen participants said that they used these apps to access Facebook, Twitter, Snapchat, and Instagram.

Next, participants were asked to identify applications used for farm decision-making. The four response categories previously identified – weather, social media, Ag related, and other – were used to code participant responses. Ag-related applications were cited by 31 participants as useful in assisting with farm decision-making. Examples include Granular, FieldNet, FieldView, Ag Mobile, and Farm Server. A complete listing of agricultural apps cited by respondents is provided in Table 4.11.

Table 4.11. Agriculture applications given by respondents with descriptions.

Application	Description
ADM FarmView	Commodity bids, elevator announcements, contracts, payments, storage
Ag Leader	Precision farming tools that collect valuable info from the field and connects the entire operation
Ag PhD	Soils, crop, fertilizer, planting, spraying, corn, soybean, calculator, harvest, drainage
AgWeb	Agribusiness news and advice on management news, farm business blogs, and articles
Angus Mobile	News, record keeping, sale reports, and show results
Bunge Mobile	News, prices, and account information. Focuses on account information, cash bids, futures, offers, locations, and news and weather.
Climate FieldView	Collect and store critical field data, monitor and measure the impact of agronomic decisions on crop performance, manage field variability by building customized fertility and seeding plans for each of your fields to optimize yield and maximize profit
DTN	Weather tool
FARM Server	Record geo-referenced data from the field, focused on weather and live weather radar tools. Can update crop scouting notes, yield or as-applied data from tractors, and view crop health imagery (Beck's created this)
Field Net	Irrigation management tool
Grainger	Check account pricing, item availability, or manage costs
Granular	Farm management and analytics platform. Helps improve efficiency, profit, and yield
Grower's Edge	Local cash bids, corn prices, best cash bid, soybean prices, markets, market commentary, weather, Ag news
Hoosier Ag Today	Ag news, updated commodity market information, real-time market analysis, a customized Indiana agricultural weather forecast
My Operations-John Deere	Remote management of field operations and equipment. View fields and field boundaries, view location history for each machine, view machine security, fuel levels, performance
Premier Crop	Cloud based, inputs, fertility, seed, soil type, management
Spray Smart	Provides field-specific spraying conditions, current wind speed and direction, and temperature inversion potential for current location
Trimble Ag Mobile	Field records, crop scouting, mapping, grid sampling, Re-entry alerts, fleet management, bins, contracts, crop inputs
Winfield R7	Field variability

Apps listed in the “other” category were cited by 23 participants as being helpful for farm decision-making. Apps in this category included news sources, calculators, and messaging.

Weather apps were cited by 22 participants as helpful in making farm management decisions. Finally, four participants indicated using social media apps to help make farm management decisions.

4.15 Mobile App Purchases

Participants were asked if they had purchased mobile applications in the last two years for their operation. About one-third (*n=19*) of the participants indicated having done so. Representative responses from participants who had purchased apps are as follows:

> “There were one or two weather ones that I purchased. I had to purchase this open VPN for my drain dryer.” (Participant 8)

> “We have 20/20 and that app is on my phone, but don’t know how long ago we purchased it.” (Participant 21)

> “Avira Mobile Security, I think that is the only purchased one.” (Participant 25)

Participants who reported not having purchased applications within the last two years indicated they usually looked for free applications.

4.16 Mobile Applications: Two-year use

Participants were asked what applications they had used in the last two years. Responses ranged from grain elevator applications to banking applications and Cargill applications. Participant 11 stated:

> “Oh gosh, Ag Web, Cargill’s got an app, we use that, the precision app. I know there’s more. Farm Credit has an app I use for banking. First Bank of Berne has an app I use for banking also. Ag Direct has an app for a loan calculator. Land Glide – it’s a digital plat book on our phone. I use that one quite a bit for farming. I have a crop calculator that does conversions between metric and U.S. for spraying chemicals and stuff like that.”

Participant 16 reported using only a search engine, messaging, and weather apps over the last two years. Participant 19 answered similarly, stating only having used a weather app, market app, and calculator.

Other participants' responses focused more on apps to help them with their operations. Participant 25 reported using apps that ranged from weather to delivery of product apps:

> "Weather, My Radar, WTHR Weather, NOAA Weather, Weather from Yahoo, Bar Chart, Yahoo Finance, Ag Web, CME Group, Gavalon, Successful Farming, Ag Mobile, Grower's Edge, Stock Finance. We also use the general News Application. So Fox News, the INTFL Stone Group. We use Amazon for purchases on the farm. Reuters TV, ADM Farm. We use Google Drive to share documents across the space. The IFB app. I use online banking so I can go into online banking for things. UPS, Fox Business News. I also have a measuring application and the State Farm App to manage some of the risk management."

4.17 Decision-making

Participants were asked about typical decisions made on their farms. Answers varied widely as they involved decisions made on small farms as well as those made in partnerships. Participant responses were viewed separately by those who were sole owners of their operation and those who shared ownership.

Participant 10 stated:

> "Since we are just small farmers, we're looking at our cow herd. So we are looking at AI decisions, what to breed the cattle to, feeding operations, when to sell calves, that type of thing."

Participant 38 was also not in partnership and was the sole owner of an operation. This participant stated that he/she made decisions related only to row crop. However, he/she had employees that also made decisions.

Similarly, Participant 45 was not in a partnership and was sole owner of the farm. Participant 45 reported relying heavily on consultants:

> "Crop mix, fertilizer rates with a consultant, herbicides with a consultant, fungicide with a consultant's help, and all the marketing with a consultant."

Participant 24, also a primary decision maker, had another job outside of farming. He/she made decisions based on selling grain, seed use, technology use, chemical, herbicide, and a fertilizer program.

Other participants reported being in partnerships. Participant 30 was involved with an S corporation and considered the primary decision maker on the operation. Participant 30 stated his/her responsibilities involved the farm’s crops and nutrient management.

Participant 19 was in a partnership, but was not the primary decision maker. Participant 19 stated that his/her main decisions focused on day-to-day concerns.

Participant 32 was involved in a partnership and considered himself/herself to share responsibilities with a cousin. The participant stated that their responsibilities revolved around grain marketing, seed, and chemicals.

Additionally, Participant 33 was involved in an LLC. This participant reported sharing responsibilities on the operation but with primary decision-making for equipment purchases, banking, and employees.

4.18 Apps to Make Job and Life Easier

Participants were asked what mobile applications on the farm make the job and life easier. Eighteen participants stated that weather applications were among the most helpful when making farm management decisions. One participant stated that the application associated with the operation’s hog barn made their life easier:

> “Well the app that does the controller, it makes it easier that I don’t have to generate actual paperwork for reports. I can just, well the controller fills them out for me and I just forward it to the office. So, if there is an error, it’s the controller that made the issue and not myself.” (Participant 7)

Other participants stated that their applications made life easier. Participant 9 stated he/she did not think applications made life easier, but then stated he/she may just be so in tune with them that they did not realize how helpful they are.

Many participants stated their applications were useful and made their life and job easier. Some participants focused on GPS and Google, while others such as Participant 38 had more simple answers:

"All of them. I wouldn't use them if they weren't making life easier."

4.19 Use of Mobile Applications

Participants were asked what makes them want to use mobile applications on their farm. After examining responses, the researcher coded answers into four categories: (1) speed/efficiency, (2) ease of use, (3) convenience/accessibility, and (4) other. The "other" category included general items such as awareness of trends, knowledge, marketing, and money.

Ease of use was cited by more than one-third (*n=21*) of the participants. These participants indicated apps were helpful only if they were easy to use and understand.

More than one-fourth (*n=16*) of the participants indicated using mobile applications because of the speed and efficiency they bring to the operation. Similarly, 16 participants cited convenience/accessibility as the reason for using mobile applications on their farm.

Nine participants cited other reasons for using a mobile application on their farm.

4.20 Desired Mobile Apps

Participants were asked if there were any mobile applications they wished they had on their farm. Twenty-four participants answered affirmatively.

According to Participant 2:

> “One that would quote all of the sheep prices in the area at the same point in time.”

Said Participant 38:

> “If there could be an augmented reality app that I could walk through a feed lot, something like that, and I could see through the lens, it could look at the ear tags and be able to pull all the cattle data on that calf and it could pop up on my phone and I wouldn’t have to scroll through all the spreadsheets and things like that. I’m thinking field level too. They are starting to get apps like Encirca. We use Encirca too, where you can pull up the layers of the field as you are scouting in the field. Just for the development of that.”

Conversely, 23 participants answered that they did not have a need for additional apps. Most cited the reason as already having enough apps, being unsure exactly what they would want, or simply, no. Six participants indicated they might be interested in having a particular app, but they could not identify what it might be. Participant 13 stated:

> “Hmm, that’s a good question. It goes back to the grain, so not everybody that we haul to has an app. It would be nice. So, I know POET, I think they are getting ready to come out with one next year. We haul a lot of corn there. I’m always calling them going hey, how many bushels without having to add up all my tickets, I call and ask how many bushels is left on here and now they are going to have an app for that. For grain marketing and end users, it’s nice having those apps where you can pull up and say here’s where we are on this contract, I’ve got so many bushels on this contract. You can put offers in. Then, see your scale tickets right there on the phone. A lot of times, we’ve got somebody else hauling in from the fields.”

4.21 Years Using Mobile Applications

Participants were asked how long they had been using mobile applications for their operations. Answers ranged from one year to 28 years. About one-fifth (*n=12*) of the participants reporting having had applications for five years. Eight participants reported having had mobile applications for eight years, while seven participants indicated having mobile applications for nine years.

4.22 Future Adoption of Mobile Applications

Participants were asked if they were likely to adopt more mobile applications. About three-fourths (*n=42*) of the participants answered affirmatively. Participant 1 stated:

> "Yes, just because there is more data that is being made available to the farmer and with the speed of information transfer that we have now, it's so helpful."

Many participants reported the perception that it was necessary to adopt more applications in order to keep up in farming.

About one-tenth (*n=6*) of the participants stated that they were unlikely to adopt more mobile applications. The general sentiments expressed by these participants were that their current needs were being addressed or that they just did not want any additional apps.

Five participants answered that they might adopt additional apps in the future. Many stated that the decision would be dependent on what options were available. Participant 2 stated:

> "A strong maybe because a friend advised me about the vet specialist one and it's made life so much easier so if I found other sheep-related ones, I would definitely turn to them."

4.23 Perceptions of Open Source Technology

Three interview items focused on participants' awareness and perceptions of open source technology in agriculture. Participants were asked if they had ever heard of open source technology, what they thought open source means, and, depending on their first two answers, participants were asked their impressions of open source.

Regarding whether participants had heard of open source, nearly three-fourths (*n=40*) reported they had not. Thirteen participants reported they had, while two respondents said they had heard of it but had no additional knowledge of it.

A wide range of answers was received to the question asking participants what they thought the phrase “open source” meant. Responses ranged from knowing what the terminology meant to having no idea or never having heard of the terminology.

Participants who were unsure often readily admitted that they did not know. Some additionally displayed body language indicating they were ready to move to the next question. Said one participant, “I’m behind the times,” indicating he was ready to move to the next question.

Participant 32 stated: “Open to the public? I don’t know.” This participant has previously answered that he/she had not heard of the term.

Participant 33 included concerns about security in his/her response:

> “I hope it doesn’t mean that anybody can see everything you have, being open. Because that is my information, my business.”

Other participants shared similar concerns about security. Participant 1 referred to open source as unregulated while Participant 37 said he/she believed they no longer have control over their information.

Said another:

> “I would say that anybody can basically see the data as it is coming across. It’s not really a protected source of, it’s kind of like having a Facebook account set to public rather than private.” (Participant 50)

Similar responses were voiced by other participants who expressed concerns that data could be viewed by others and questioned whether that was acceptable.

In some cases, participants linked this question to a prior question in the interview: “Have you ever had a need for one application to exchange information with another application?” This question was placed two questions ahead of the second open source question. Some participants apparently thought this question was related to open source. Participant 8 stated:

> “Probably being able to share data from app to app. I don’t know.”

Participant 22 answered the question similarly. This participant stated:

> "Probably open source would be apps that talk to each other and know what is going on with each other. If I had to guess."

Several participants demonstrated knowledge of what open source was and how it operates. Participant 14, as stated earlier, was a farmer and engineering consultant. He/she said:

> "Open source means that the original code is free to edit and that it is a non-billed system where you can take, if you're smart enough, you can modify it to what you need it to and you don't have to pay for it because it is free."

Another participant was a farmer who discussed how he coded in open source platforms:

> "I program Arduino and Raspberry Pies for a hobby so that, they use an open source architecture to code in. So, I'm very familiar with that, like the Linux, being able to code in those environments. If it is closed, you can't draw on other people's experiences. I have no background in coding, but I've taught myself and it had to be through that open source architecture to be able to learn how to do it. So, we have deployed sensors across the farm of temperature, humidity, and built bin monitors that function around that architecture. I'm very familiar. I haven't learned the app coding and things like that, but, I'm going to get there."

Finally, the 12 participants who indicated in a prior interview question that they knew the definition of open source were asked to share their impressions of the terminology. Some participants responded with rather short answers such as "I'm aware of it" (Participant 27), or "just the different way to crack the nut. Everything doesn't have to be Microsoft" (Participant 25). Said another: "I haven't used it that much. We've used it in our CRM tool, but that's about it" (Participant 31). According to Participant 13: "I really haven't thought that much about it, so I can't say."

Other participants provided highly optimistic responses about open source technology, while also recognizing there were unresolved issues. Participant 38 stated:

> "I like it. The problem is, you're limited on the open source by the people that are developing the open source. Until the people that are developing it move further, you can't move any further than what they move. The benefit of close source is that they are able to, there is a monetary tie to it so they can do what they want with it and then charge for it. Open source tends to be free. There is very little in open source that is charged. There is a limiting factor there. Some people see it as a negative, some see it as a positive."

Participant 43 discussed innovative features of open source.

> "I mean, it fosters innovation and allows the software market to react to customer demand without the platform provider having to have all the answers."

Participant 47 stated:

> "I'm highly optimistic about open source. That concept is what drives innovation and adoption."

4.24 Test of Theory

As part of the analysis, the researcher tested the Technology Acceptance Model using variables that were measured quantitatively through the farmer interviews. In the test of the model, the variable "behavioral intention to use" were treated as the terminal variable. That is, the test of the model did not include "actual use." The reason for this omission is that study eligibility was based on individuals having smartphones and already having adopted apps. Therefore, the sample did not include study respondents who had not adopted smartphones or apps and it was not possible to test adoption. Rather, the test of the model focused on behavioral intent to adopt additional apps in the future.

Descriptive findings for variables used in the model were provided earlier in this chapter. Measurement of variables is discussed in Chapter 3, but provided again here for reader convenience:

> Perceived Usefulness: Five items from the Technology Acceptance Model were used to create this variable: ("Mobile applications support critical aspects of my farm", "Using mobile applications makes it easier to do my job", "Using mobile applications increase my productivity", "Using mobile applications allow me to accomplish more work than would otherwise be possible", "Overall, I find mobile applications useful to my job"). Reliability

for these five items, previously calculated, was .92. The items were summed to form a scale measure of perceived usefulness.

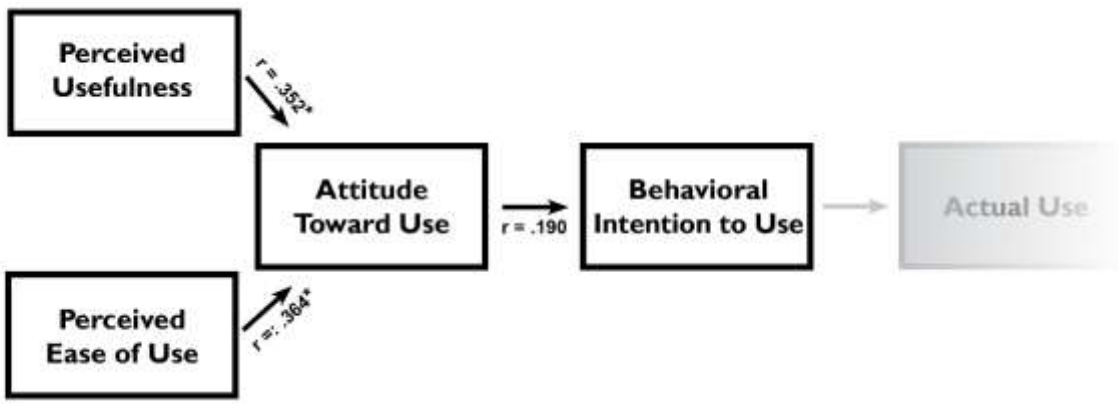
Perceived Ease of Use: Five items from the Technology Acceptance Model were used to create this variable: (“It is easy for me to remember how to perform procedures using mobile applications”, “Learning to operate mobile applications is easy for me”, “I find it easy to get mobile applications to what I want them to do”, “My interaction with mobile applications is clear and understandable”, and “Overall, I find mobile applications easy to use”). Reliability for these five items, previously calculated, was .91. The items were summed to form a scale measure of perceived ease of use.

Attitude Toward Use: This variable was a single-item measure that asked respondents, “Do you think mobile applications are useful to your operation?” The measure was deemed an appropriate proxy for attitude toward use because respondents were asked to assess the usefulness of apps for their particular farm operation. Response values were scaled 1 to 6; strongly disagree to strongly agree so that higher values represented more positive assessments of usefulness to their operations.

Behavioral Intention: This variable was a single-item measure that asked respondents “Are you likely to adopt more mobile applications for your operation?” The measure tapped respondents’ intentions to adopt additional apps in the future for their operation. Response values were scaled as follows: no =1; maybe = 2; yes = 3. According to this coding scheme, higher values are associated with greater intention to adopt mobile apps in the future.

Actual Use: As indicated, this variable was not included in the test of the model because respondents were recruited based on their adoption of mobile applications.

Bivariate zero-order correlation coefficients were calculated to measure relationships among variables in the model. Pearson correlation coefficients were calculated to test relationships between perceived usefulness and attitude toward use and between perceived ease of use and attitude toward use. As shown in Fig. 3, respective correlations were .352 and .364. Both correlations were significant at the .05 level, indicating moderate, positive relationships in each case, consistent with theory.



* Correlation significant at .05 level

Figure 4.1. Test of Technology Acceptance Model in Predicting Intention to Adopt Additional Mobile Applications for Farm Operations, Zero-Order Correlation Coefficients (n = 55)

The relationship between attitude toward use and behavioral intention was tested using a Spearman Rho correlation due to ordinal measurement of behavioral intention. Results showed that the relationship between these variables was not significant at the .05 level, contrary to theory.

Direct quotations from study participants supported the correlational findings. The correlation coefficient between perceived ease of use and attitude toward use was .364. During the participant interviews, subjects repeatedly emphasized the importance of mobile applications being easy for them to use. Ease of use was frequently paired with such descriptors as accessibility and convenience. Participant 13 said, "… just the ease, accessibility. I mean it's right there. You always have your phone on you so you can pull it up and it's there." Said, Participant 15, "Well they make it easy, more accessible, easier to get to the site I want to go to." Participant 34 said, "Just the ease and convenience. It's always with you." The correlation coefficient between perceived usefulness and attitude toward use was .352. Participants' responses stressed the necessity of applications useful to their specific farm operations to help them succeed. Participant 25 stated "the ones that fill my needs" when describing useful applications. Participant 1 stated, "… the data is so specific and it's very time sensitive. It's up to date. It's valuable," when describing useful applications. Participant 22 stated "more accurate information" as being necessary for effective farm decision-making.

In further descriptive analyses, the researcher tested additional attitudinal, demographic, and farm structure variables for possible relationships with behavioral intention. Variables tested were as follows: years farming, age, adopter category, privacy factors, type of farm, farm employees, and acres farmed. Measurement of these variables is provided in Chapter 3. As shown in Table 4.12, only two variables – adopter category and farm employees – were shown to have a statistically significant relationship with behavioral intention. According to these results, farmers who were early adopters were more likely than other farmers to indicate an intention to adopt more mobile apps for their operation in the future. In addition, those who reported having farm employees were more likely to indicate an intention to adopt more mobile apps.

Table 4.12. Relationship Between Behavioral Intention and Attitudinal, Demographic and Farm Structure Variables, Zero-Order Correlation Coefficients (n=55)

Adopter Category	-.381*
Farm Employees	.290*
Acres	.149
Age	-.199
Privacy Factors	.072
Type of Farm	.069
Years Farming	.014

* Statistically significant relationship ($p < .05$).

CHAPTER 5. DISCUSSION AND CONCLUSIONS

5.1 Introduction

This chapter opens with a listing of research questions and a condensed summary of study findings. A discussion of findings is then provided, including implications for future educational and marketing efforts around mobile agricultural applications and open source technology. The chapter concludes with an assessment of the theoretical perspective and methodology used in the study and implications for future research.

This study was designed to address the following research questions:

1. To what extent do farmers use mobile applications for farm decision-making?
2. What factors are associated with increased use of mobile applications for farm decision-making?
3. What technological capabilities and features of mobile applications do farmers consider most important?
4. What factors hinder use of mobile applications for farm decision-making?
5. What mobile applications are most commonly used by farmers?

5.2 Summary of Findings

The results of 55 structured participant interviews are discussed in this section. A summary of participants' demographic and occupational characteristics are provided, as well a summary of results for each guiding research question.

An interview guide was developed for use by the researcher, reviewed by the advisory committee, and field-tested prior to data collection. Structured interviews were conducted with 55 individuals participating in the Indiana Farm Bureau State Convention and The Indiana Young Farmers Conference. To be eligible to participate in the research, individuals had to be a smartphone user, 18 or older, and involved in agriculture. The venues selected for data collection provided ready access to farmers representing a wide range of farm sizes and operations. As the methodology involved convenience sampling, study participants are not assumed representative of Indiana farmers or of farmers participating in the two events. Findings are generalized only to research participants.

Participants represented four occupational groups: full-time farmers (*n=21*); part-time farmers reporting nonfarm secondary income (*n=19*); part-time farmers reporting nonfarm primary nonfarm (*n=12*); and retirees (*n=3*).

Research Question 1 asked: ***To what extent do farmers use mobile applications for farm decision-making?*** Findings from this study suggest that participants varied in how many apps they used and the degree to which they used mobile applications for farm decision-making. Weather applications were reported as playing a significant role in participants' decision-making process. However, among applications used only for farm decision-making, agriculture-related applications were used by a majority of the participants. Included in the category of applications were those focused on markets, fertilizer, or seed.

Research Question 2 asked: ***What factors are associated with increased use of mobile applications for farm decision-making?*** Results showed that most participants wanted easy-to-use mobile applications. In addition, more than three-fourths (76.4%) of participants indicated intentions to adopt additional mobile applications for their operations. Participant responses revealed the perception that, in order to stay relevant, farmers needed to be able to adopt more applications or upgrade applications as their operations grew. Participants often cited the importance of timeliness that mobile applications can provide with specific data relevant to their operations.

Research Question 3 asked: ***What technological capabilities and features of mobile applications do farmers consider most important?*** Responses reiterated that participants wanted mobile applications that are easy for them to use – if an app was not simple to use, it was not wanted. Participants also indicated wanting mobile applications that were always up-to-date and applicable to the needs of their specific operation. Convenience of use was also cited by participants. Some participants elaborated on the importance of efficiency of use, especially when working in the fields. The valued and importance of the weather applications, especially during planting and harvest season, was also frequently cited.

Research Question 4 asked: ***What factors hinder use of mobile applications for farm decision-making?*** Several factors were cited by participants as deterrents to use of mobile applications. Among the deterrents was the need for cellular service. Lack of reliable access to broadband, especially connectivity when working in the field, was cited as problematic. Another cited deterrent involved applications that did not consistently work as well as lack of compatibility across all platforms. Participants indicated wanting applications to work in both IOS and Android devices. Data security was another hindering factor. Participants were generally guarded about their farm business and data – some expressed concerns about their data being visible to or shared by others. If there was a possibility that their data was not secure, some indicated they would not use the application. Concerns were also mentioned about possible breaches of data security.

The final research question asked: ***What mobile applications are most commonly used by farmers?*** When it comes to commonly used applications, more than half of the participants reported using general applications for email, messaging, and other uses. The next most-used category included weather applications. For application use in farm decision-making, agriculture-related applications were commonly mentioned, including those offered by seed companies, equipment manufacturers, and universities.

Selected theory constructs from Diffusion of Innovations literature and the Technology Acceptance Model perspective were incorporated into the analysis. Study participants were categorized into three adopter categories (early adopter, early majority, late majority) using criteria developed by the researcher. A chi-square test was conducted to determine whether earlier adopters of agricultural apps differed from other participants according to demographic and farm structure variables identified in the diffusion literature (age, years farming, and size of operation). Based on the test, early adopters of mobile app technology were not shown to differ significantly from later adopters at the .05 level according to these variables.

An empirical test was also performed on the Technology Acceptance Model wherein perceived ease of use, perceived usefulness, attitude toward use, and behavioral intention were operationalized from variables included in the interviews. Correlational analyses were performed to assess relationships between model variables. Results showed positive, moderately strong relationships at the .05 level between perceived ease of use and attitude toward use, and between perceived usefulness and attitude toward use. Both findings are consistent with theory. Contrary to expectations, the correlation between attitude toward use and behavioral intention was statistically insignificant at the .05 level.

5.3 Discussion and Recommendations

Findings from this research reinforced insights discovered through the review of literature. Users want applications that are easy to use and those that are relevant to their specific farm operations. In general, users do not expect to pay for applications due to their widespread availability. While users considered mobile applications extremely helpful for farm management, some indicated they did not have plans to adopt additional applications. For these farmers, access to a small number of functional and easy to use apps was preferable to acquiring more apps.

Participants who rated ease of use lower than their counterparts continued to rate apps favorably in terms of usefulness. In this situation, it is possible that the users recognize the value of mobile applications to their employees and their overall operations even if they encounter personal difficulties in their use. It is also possible that users recognize that mobile apps, including those for farm management, will continue to evolve and believe it is important to continue to use them in the meantime.

Findings from this research are relevant for application developers. Clearly, it is important that applications are designed with user interfaces and capabilities that farmers like and find easy to use. In addition, developers should be aware of the types of apps farmers use and how they use them for farm decision-making. Highly rated among study participants were applications focused on field management, weather, news, and markets, and particularly those that offered multiple functions through one interface. Such findings should be considered as developers conceptualize and design new mobile applications.

Not surprisingly, data security emerged as a significant concern among study participants. Farmers feel strongly that their data should be kept confidential. While it is important to continue to stress security features during messaging, it should also be acknowledged that security breaches can and do occur. Based on best practices in risk communication, it is recommended that this fact be stated and information provided as to what is being done by app developers and sponsoring organizations to help minimize such risks.

Additionally, messaging should routine inform and remind users of steps they might take, if any, to minimize data security risks.

Regarding terminology, findings show that users were typically not familiar with the phrase open source. Those who offered guesses to its meaning often incorrectly associated the phrase with apps being open to or communicating with each other or, in some cases, data being open or accessible to other users. This finding suggests that farmers, as well as the open source community, might benefit from an awareness campaign designed to inform users on what open source is and what it is not. The benefits of open source should be included in relevant messaging, including its state of the art features. Importantly, educational materials should emphasize steps taken by developers and sponsoring organizations to ensure that data are maintained and transmitted in a secure, private manner. It is recommended that Extension educators be actively involved in the educational effort, as farmers use and trust Extension as a source of information.

Regarding the concept of trust, study participants frequently mentioned Purdue University as a valued source of information and expertise. The high level of regard that Indiana residents have for Purdue University expertise is confirmed through recent survey research in the state (Rice, 2019). This finding has implications for marketing and messaging strategies by Purdue’s Open Ag Technology and Systems (OATS) Center. It is recommended that the OATS Center take advantage of the social and reputational capital of Purdue University by highlighting its institutional affiliation on the center’s website, promotional materials, and news stories.

Finally, insights gained through this study have implications for others planning future research on mobile agricultural applications and open source technology. The interview procedure employed in this research allowed the researcher to collect data from subjects literally in their own words. The range of responses to various questions about agricultural application can be valuable in developing valid measure in future work. For example, the list of agricultural applications used by farmers could be used to develop closed-ended questions in future interviews or in survey research. Such items can be completed by farmers with relative ease in the research setting, saving time and allowing for inclusion of important study items.

In addition, findings from this research provide valuable baseline farmer data for such topics as perceived security of data and awareness of open source. If awareness campaigns are developed around these topics as recommended, it would be valuable to track responses to these and other items over time among Indiana farmers. Longitudinal measures would provide data needed to assess awareness campaign impacts.

5.4 Assessment of Theoretical Perspective and Study Procedures

While not stated as a research objective, valuable insights were gained about the theoretical perspective and methodology employed in this study. In terms of theory, the researcher employed key constructs from Diffusion of Innovation Theory and the Technology Acceptance Model. In general, the two theories were useful in helping the researcher to frame key study concepts. Diffusion Theory’s adopter categories continue to provide an intuitive method for conceptualizing how and when individuals make a decision to adopt or not adopt specific innovations. At the same time, the framework is dated and there is a need to bring new ways of thinking to how individuals make a decision to adopt mobile agricultural apps. For example, it was noted that none of the farm operator or farm structure variables tested in the current analysis were related to participants’ position on the adopter curve, contrary to the theory. It is clear that other factors are at work that are possibly beyond the scope of Diffusion Theory.

Similarly, the Technology Acceptance Model served a valuable purpose in identifying key antecedent variables, notably perceived ease of use and perceived usefulness. However, the test of the model revealed that perceived attitude was not associated with behavioral intent, contrary to theory. In this particular case, it would seem that there are other variables, perhaps outside the scope of the model, associated with behavioral intent. This is a significant shortcoming of the model, as it would be valuable to identify factors associated with users' intent to adopt mobile applications. As with the case of Diffusion Theory, the researcher was led to conclude that alternative theoretical perspectives should be explored in future research.

The methodology utilized in this study, personal interviews, proved useful in collecting participants' candid perceptions of mobile applications. Having the researcher on-site and interacting directly with farmers likely encouraged individuals to participate. Indeed, there were no participant refusals. The researcher felt the affiliation with Purdue University further encouraged participation. In terms of actual data collection, the researcher's impression was that some participants may have been slightly uncomfortable at the beginning of the interviews, but became more comfortable with the questions and process as the interview continued. Another advantage of the interview methodology employed in this research was that it allowed participants to expand on their answers. They could also ask for clarification as needed, and some took advantage of this feature.

Still, there were limitations encountered with the study methodology. While the study was purposefully designed to address research objectives, the effort was constrained in a few capacities. For example, the researcher was limited in the number of personal interviews she could conduct in the allotted time allotted. Conducting more interviews would have been beneficial, but it was not possible to do so with only one researcher collecting data. It should be noted that the relatively small number of farmer responses in the current research (n=55) may have led to some of the relationships and other tests being statistically insignificant.

In addition, the researcher found it necessary during the interviews to be alert to whom she might next interview. This situation created a distraction for the researcher that could have been avoided if additional trained interviewers were involved. Another interview limitation was that the two conferences were hosted by the same sponsor and some of the same farmers attended both conferences. Because of researcher's pledge to assure confidentiality, no identifying data was collected and it was therefore difficult to assure that the same farmers were not interviewed at both venues.

Finally, it was noted that the research design for the current study originally called for a number of key informant interviews with individuals known to have expertise with open source and other mobile technology. Due to scheduling difficulties with the key informants and their lack of response to follow-up calls, it was possible for the researcher to conduct only one interview (not reported in this document). It may have been beneficial to initiate this phase of research earlier in the study.

5.5 Implications for Future Research

Based on the findings from this research, a few recommendations can be made for future research concerning mobile application use in agriculture. As previously stated, results from this study can be used improve measurement in future research, regardless of data collection mode.

To increase the number of farmer participants in future research, the researcher recommends that electronic and postal mail surveys be explored. While there are advantages and disadvantages to electronic and postal mail data collection, either method has the potential to generate an increased number of farmer responses. Having a larger number of responses would not only increase external validity but also allow for statistical tests and modeling not possible in the current research.

Further, it is recommended that future instrumentation be designed with a goal of subjects completing the research process in a shorter time span, such as five to seven minutes. Farmers are busy professionals and may refuse to devote more time to completing a questionnaire, particularly for topics in which they are not highly invested. Ensuring that subjects start and finish the questionnaire is crucial to having adequate response. When possible, it is recommended that researchers partner or work with an organization that may be able to offer access to a specific group of farmers at a conference or other event.

REFERENCES

Adenle, A.A., Sowe, S.K., Paraylil, G., & Aginam, O. (2012). Analysis of open source biotechnology in developing countries: An emerging framework for sustainable agriculture. *Technology in Society, 34*(3), 256-269.

Agland, A. B. (2014, November 26). An app is available for everything in agriculture. Retrieved from https://www.hutchnews.com/article/20141125/News/311259874?template=ampart.

Al-Jabri, I.M. & Sohail, M. (2014). Mobile banking adoption: Application of diffusion of innovation theory. *Journal of Electronic Commerce Research, 13*(4), 379-391.

American Farm Bureau Federation - The Voice of Agriculture. (n.d.). Retrieved from https://www.fb.org/.

Apple App Store (2019). Retrieved from www.apple.com/ios/apple-store.

Ault, A., Krogmeier, J., Buckmaster, D. (2018). Ag's future belongs to open source. *Resource: Engineering and Technology for a Sustainable World*.

Bassellier, G., Reich, B. H., & Benbasat, I. (2001). Information Technology Competence of Business Managers: A Definition and Research Model. Journal of Management Information Systems, 17(4), 159-182. doi:10.1080/07421222.2001.11045660.

Bliss, M. E. (2017, March 10). Farm management. Retrieved from https://www.britannica.com/topic/farm-management.

Bonaccorsi, A., & Rossi, C. (2003). Why Open Source software can succeed. Research Policy, 32(7), 1243-1258. doi:10.1016/S0048-7333(03)00051-.

Brief history of mobile apps (2017, September 28). JetRuby Agency. Retrieved from https://expertise.jetruby.com/brief-history-of-mobile-apps-286fbbf766a9.

Calderone, L. (2018, October 11). Farmers are Growing Comfortable with Mobile Apps. Retrieved from https://www.agritechtomorrow.com/article/2018/10/farmers-are-growing-comfortable-with-mobile-apps/11056.

Chen, D., Doumeingts, G., Vernadat, F. (2008). Architectures for enterprise integration and interoperability: Past, present, and future. *Computers in industry, 59*(7), 647-659.

Consumer Health Informatics Research Resource - Technological Acceptance Model. (n.d.). U.S. National Library of Medicine, National Institutes of Health. Retrieved from chirr.nlm.nih.gov/tam.php.

Corteva (2019). Retrieved from corteva.com.

Darnhofer, I. (2014). Resilience and why it matters for farm management. *European Review of Agricultural Economics, 41*(3), 461-484.

De Mendiburu, F., & Simon, R. (2015). *Agricolae-ten years of an open source statistical tool for experiments in breeding, agriculture and biology* (No. e1748). *PeereJ PrePrints*.

De Silva, L.N., Goonetillake, J.S., Wikramanayake, G.N., & Ginige, A. (2013). Farmer response towards the initial agriculture information dissemination mobile prototype. *International Conference on Computational Science and Its Applications* (264-278).

Deshdeep, N. (2018, May 18). 10 Reasons mobile apps are better than mobile websites. Retrieved from https://vwo.com/blog/10-reasons-mobile-apps-are-better.

Dogtiev, A. (2019, February 28). App stores list 2018. Business of Apps. Retrieved from http://www.businessofapps.com/guide/app-stores-list/.

Edmonds, S. (2018). What are consumers doing on their smartphones anyways? Retrieved from https://www.salesforce.com/blog/2018/02/consumer-smartphone-use.html.

Farm Progress (2011). Farmers list top issues impacting agriculture. Retrieved from https://www.farmprogress.com/management/farmers-list-top-issues-impacting-agriculture.

Gamalielsson, J., & Lundell, B. (2014). Sustainability of open source software communities beyond a fork: How and why has the LibreOffice project evolved?” *Journal of systems and Software*, *89*, 128-145.

Gross, D. (2010, October 12). Apple trademarks 'There's an app for that'. Retrieved from http://www.cnn.com/2010/TECH/mobile/10/12/app.for.that/index.html.

Hanna, J., & Baldacci, M. (2019, March 27). The Midwest flooding has killed livestock, ruined harvests and has farmers worried for their future. Retrieved from https://www.cnn.com/2019/03/21/us/floods-nebraska-iowa-agriculture-farm-loss/index.html.

Hansen, T., Jensen, J. M., & Solgaard, H.S. (2004). Predicting online grocery buying intention: A comparison of the theory of reasoned action and the theory of planned behavior. *International Journal of Information Management, 24*(6), 539-550.

Hauge, O., Ayala, C., & Conradi, R. (2010). Adoption of open source software in software-intensive organizations: A systematic literature review. *Information and Software Technology*, *52*(11), 1133-1154.

Herstatt, C., & Ehls, D. (2015). Open Source Innovation: The Phenomenon, Participant's Behaviour, Business Implications. New York, NY: Routledge.

History of the OSI. (n.d.). History of the OSI | Open Source Initiative. Retrieved from https://opensource.org/history.

Kang, S., & Lee, K. (2013). Mobile app approach by open source stack for satellite images utilization. *Remote sensing letters, 4*(7), 648-656.

Kim, S.C., Yoon, D., & Han, E.K. (2016). Antecedents of mobile app usage among smartphone users. *Journal of marketing communications, 22*(6), 653-670.

Lerner, J., & Tirole, J. (2001). The open source movement: Key research questions. *European economic review, 45*(4-6), 819-826.

Li, D., Guo, B., Shen, Y., Li, J., & Huang, Y. (2017). The evolution of open-source mobile applications: An empirical study. *Journal of software: evolution of process, 29*(7), e1855.

Lleras, N. O., Brennan, S., Murphy, D., Klena, M.J., Garvey, P.M., & Sommer III, H. J. (2016) Development of an open-source tractor driving simulator for tractor stability tests. *Journal of agricultural safety and health, 22*(4), 227-246.

Lou, J. (2018, February 1). The Rise and Fall (and Rise Again?) of BlackBerry. Digital Innovation and Transformation. Retrieved from digit.hbs.org/submission/the-rise-and-fall-and-rise-again-of-blackberry.

Luna-Nevarez, C., & McGovern, E. (2018). On the use of mobile apps in education: The impact of digital magazines on student learning. *Journal of Educational Technology Systems, 47*(1), 17-31.

Lundell, B., Lings, B., & Syberfeldt, A. (2011). Practitioner perceptions of open source software in the embedded systems area. *The Journal of Systems and Software*, *84*(9), 1540-1549.

Madden, T.J., Ellen, P.S., Ajzen, I. (1992). A comparison of the theory of planned behavior and the theory of reasoned action. *Personality and Social Psychology Bulletin, I18*(1), 3-9.

Malcolm, B. (2000). Farm management economic analysis: A few disciplines, a few perspectives, a few figuring's, a few futures. (No. 411-2016-25766).

Malcolm, B. (2004). Where's the economics? The core discipline of farm management has gone missing!. *Australian Journal of Agricultural and Resource Economics, 48*(3), 395-417.

Marangunic, N. & Granic, A. (2015). Technology acceptance model: a literature review from 1986 to 2013. *Universal Access in the Information Society, 14*(1), 81-95.

McGovern, E. F., Luna-Nevarez, C., & Baruca, A. (2017). Utilizing mobile devices to enrich the learning style of students. *Journal of Education for Business, 92*(2), 89-95.

McGuire, J., Morton, L.W., & Cast, A.D. (2013). Reconstructing the good farmer identity: shifts in farmer identities and farm management practices to improve water quality. *Agriculture and Humna Values, 30*(1), 57-69.

Mesas-Carrascosa, F.J., Santano, D.V., Merono, J.E., de la Orden, M.S., & Garcia-Ferrer. Open source hardware to monitor environmental parameters in precision agriculture. *Biosystems engineering, 137*, 73-83.

Metcalf, A. (2011, January 7). App 2010 word of the year, as voted by American Dialect Society. Retrieved from https://www.americandialect.org/app-voted-2010-word-of-the-year-by-the-american-dialect-society-updated.

Midha, V., & Palvia, P. (2012). Factors affecting the success of open source software. *Journal of Systems and Software, 85*(4), 895-905.

Mobile Security Resources, Reports, and More from Lookout. (n.d.). Retrieved from https://www.lookout.com/insights.

Montoya, F.G., Gomez, J., Cama, A., Zapata-Sierra, A., Martinez, F., De La Cruz, J.L., & Manzano-Agugliaro, F. (2013). A monitoring system for intensive agriculture based on mesh networks and the android system. *Computers and Electronics in Agriculture, 99*, 14-20.

Morgan, L., & Finnegan, P. (2007). How perceptions of open source software influence adoption: an exploratory study. *University of Limerick.*

Mullen, J.D. (2002). Farm management in the 21st Century (No. 413-2016-25938)

Nachmany, U. (2019, January 18). Open Source Software at a Crossroads. Forbes Magazine. Retrieved from www.forbes.com/sites/udinachmany/2019/01/16/thoughts-about-2018-the-year-of-open-source-teenagedom/#33df210a393b.

Nah, F.F.H., Siau, K., & Sheng, H. (2005). The value of mobile applications: a utility company study. *Communications of the ACM, 48*(2), 85-90.

Nuthall, P.L. (2010). Farm business management: The human factor. *CAB International: United Kingdom.*

Open Source Hardware Association. (2019, March 13). Open Source Hardware Association. Retrieved from www.oshwa.org/.

Orr, G. (2003, March 18). Diffusion of Innovations, by Everett Rogers (1995) Reviewed by Greg Orr. TeamLead. Retrieved from teamlead.duke-nus.edu.sg/vapfiles_ocs/2011/edu/Diffusion_of_Innovations_by_Everett_Rogers_1995.pdf.

Ouksel, A. M., & Sheth, A. (1999). Semantic interoperability in global information systems. *ACM Sigmod Record, 28*(1), 5-12.

Patel, N. (2015, March 31). 11 Revenue Streams For SaaS Business. Forbes Magazine. Retrieved from www.forbes.com/sites/neilpatel/2015/03/26/11-revenue-streams-for-saas-business/#69d9e6253de0.

Pavlou, P.A. (2003). Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model. *International journal of electronic commerce, 7*(3), 101-134.

Pickard-Whitehead, Gabrielle (2019). *20 agricultural apps for your farm business.* Retrieved from https://smallbiztrends.com/2018/09/agricultural-apps.html.

Purdue University-College of Engineering & College of Agriculture-OATS (2019). OATS-The open ag technology and systems center. Retrieved from https://oatscenter.org.

Quora. (2019, February 7). Two Pieces Of Technology That Will Change The World Over The Next Decade. Forbes Magazine. Retrieved from www.forbes.com/sites/quora/2019/02/07/two-pieces-of-technology-that-will-change-the-world-over-the-next-decade/#61c1ee0f3162.

Raymond, E. S. (2000). The cathedral and the bazaar. Retrieved from http://www.unterstein.net/su/docs/CathBaz.pdf.

Rice, A. (2019). Factors influencing Indiana resident's level of interest in engaging with Purdue University.

Rogers, E. M. (2010). Diffusion of innovations. New York: Free Press.

Rouse, M. (2019). “What Is Software as a Service (SaaS)? - Definition from WhatIs.com.” SearchCloudComputing. Retrieved from searchcloudcomputing.techtarget.com/definition/Software-as-a-Service.

Sandoval-Almazan, R., Gil-Garcia, J.R., Luna-Reyes, L.F., Luna, D.E., & Rojas-Romero, Y. (2012). Open government 2.0: citizen empowerment through open data, web, and mobile apps. *Proceedings of the 6th International Conference on Theory and Practice of Electronic Governance (*pp. 30-33). ACM.

Sarker, S., & Wells, J.D. (2003). Understanding mobile handheld device use and adoption. *Communications of the ACM, 46*(12), 35-40.

Sarver, V.T. (1983). Ajzen and Fishbein’s “theory of reasoned action”: a critical assessment. *Journal of the Theory of Social Behaviour.*

Scherer, R., Siddiq, F., & Tondeur, J. (2019). The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers’ adoption of digital technology in education. *Computers & Education, 128,* 13-35.

Schober, M. (2012, July 29). Importance of Farm Management. Ag Web. Retrieved from https://www.agweb.com/importance-of-farm-management/.

Singh, V. (2018, January 10). A brief history of open source. Retrieved from https://medium.com/gitcoin/a-brief-history-of-open-source-3928cb451767.

Smyth, G. (2019, February 8). Open for Business: How Open Source Is Changing the Technology Industry. Idgconnect. Retrieved from www.idgconnect.com/opinion/1501155/business-source-changing-technology-industry.

Software. (n.d.). Merriam-Webster. Retrieved from https://www.merriam-webster.com/dictionary/software?utm_campaign=sd&utm_medium=serp&utm_source=jsonld.

Steinberger, G., Rothmund, M., & Auernhammer, H. (2009). Mobile farm equipment as a data source in an agricultural service architecture. *Computers and Electronics in Agriculture, 65*(2), 238-246.

Taylor, D. G. (2014). “Predicting mobile app usage for purchasing and information-sharing.” *International Journal of Retail & Distribution Management, 42*(8), 759-774.

Taylor, D.G., Voelker, T.A., & Pentina. (2011). Mobile application adoption by young adults: A social network perspective. *Digital Commons@SHU. 6*(2), 60-70.

Techopedia. (2019). Retrieved from https://www.techopedia.com.

Tella, A., & Olasina, G. (2014). Predicting users' continuance intention toward e-payment system: An extension of the technology acceptance model. International Journal of Information Systems and Social Change (IJISSC), *5*(1), 47-67.

The State of Mobile Apps. (2010, June 1). What People Watch, Listen To and Buy. Retrieved from www.nielsen.com/us/en/insights/news/2010/the-state-of-mobile-apps.html.

Van den Bulte, C., & Wuyts, S. H. K. (2007). Social networks in marketing. MSI Relevant Knowledge Series.

Van Es, H. & Woodard, J. (2011). Innovation in agriculture and food systems in the digital age. Retrieved from https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2017-chapter4.pdf.

Volpi, M. (2019, January 12). How Open-Source Software Took over the World. TechCrunch. Retrieved from techcrunch.com/2019/01/12/how-open-source-software-took-over-the-world/.

Wegner, P. (1996). Interoperability. *ACM Computing Surveys.*

What Is Interoperability? (2019, March 23). HIMSS. Retrieved from www.himss.org/library/interoperability-standards/what-is-interoperability.

Yang, H.C. (2013). Bon Appetit for apps: young American consumers’ acceptance of mobile applications. *Journal of Computer Information Systems, 53*(3), 85-96.

APPENDIX A. INSTRUMENTATION

Mobile Application Adoption in Agriculture

Agriculture Sciences Education & Communications Department
College of Agriculture—Purdue University

This study is for my Master's thesis project at Purdue University. This is a structured interview so I will be reading off the questions and listening to you answer them and make notes as we go throughout the interview. This interview will take approximately 10 minutes. The purpose of this study is to see how farmers are adopting mobile applications for their farm and why they are adopting the mobile apps. For this study, I am defining mobile apps or mobile applications as "small programs that run on a mobile device and perform tasks ranging from banking to gaming to web browsing. If at any point you would like for me to restate the definition of mobile applications or mobile apps, please feel free to let me know. I will be starting with a few simple demographic questions and then we will move into the rest of the questions. If at any point you don't want to answer a question, please let me know. Are you willing to volunteer to help me today? Also, I will be recording our interview to make sure I do not miss anything. These recordings will only be heard by me. Is it okay if I record your voice?

Age: _________

Occupation: ____

Duration of interview: _______

Purpose of this study: The main purpose of our research is to see how farmers are adopting mobile applications for their farm and why they are adopting the mobile apps.

Mobile Application definition for this study: small programs that run on a mobile device and perform tasks ranging from banking to gaming to web browsing.

Questions:

1. How long have you been actively farming?
2. Would you consider yourself to be the primary decision maker on your farm?
    a. What are some typical decisions you're making on the farm?
    b. Are you in a partnership?
    c. Do you have any employees?
3. About how many acres of farmland are you farming now?
4. Are you renting any ground out to other farmers?
5. What type of farm are you running?

6. Do you own a mobile device/smartphone/tablet? (iPhone, iPad, surface, etc.)
7. Do your employees have a mobile device/smartphone that they can communicate regularly with you?
    a. What mobile application do you use the most?
    b. What mobile applications do you use for farm decision making?
    c. Do you utilize applications with your employees?
    d. What kind of apps?
8. How long have you used mobile applications for your farm?
    a. What mobile applications have you **PURCHASED** in the last two years for your farm?
    b. What mobile applications have you **USED** in the last two years for your farm?
9. Do you think mobile applications are useful to your operation?

    1 2 3 4 5 6
10. What makes you want to use mobile applications on your farm?
11. What makes you want to use a certain mobile application on your farm?
12. Are there any mobile applications you wish you had to utilize on your farm? Which ones?
13. What mobile applications on the farm make your job and life easier?
14. Are you likely to adopt more mobile applications for your farm? Why or why not?
15. What are some attributes (positive or negative) that you think your mobile applications have?
    a. Have you ever had a need for one application to exchange or use information to another application?
    b. If yes, example.
16. Have you ever heard of open source technology or the phrase "open source"?
    a. What do you think open source technology or "open source" means?
17. What are some impressions you have about open source? Which one of the following best describes where your farm data reside? Farm data includes planting data, machine data, as-applied data, soil sampling, scouting, weather, images, yield data, etc.

    a. _____ most of my farm data is consolidated into a single farm management system (e.g., MyJohnDeere, Climate FieldView, Ag Data Coalition, Granular, WinField R7, etc)
    b. _____ most of my farm data is consolidated into my personal computer or my personal file storage system
    c. ______ My farm data is not consolidated; it resides in multiple systems.
    d. ______ Not sure

    a. ______ Other ____________________________

Now we are transitioning into the final portion of the questions. I'm going to make 10 statements about mobile applications. You will answer on a 1-6 scale with one being strongly disagree, 2 disagree, 3 being slightly disagree, 4 being slightly agree, 5 being agree, and six being strongly agree. Let's try it.

18. Please rate the following questions on the scale.

19.

1. Strongly disagree
2. disagree
3. Slightly disagree
4. Slightly Agree
5. Agree
6. Strongly Agree

20. Are you concerned about how your shared data is being used by ag retail/companies?

1 2 3 4 5 6

21. It is easy for me to remember how to perform procedures using mobile applications.

1 2 3 4 5 6

22. Learning to operate mobile applications is easy for me

1 2 3 4 5 6

23. I find it easy to get mobile applications to what I want them to do

1 2 3 4 5 6

24. My interaction with mobile applications is clear and understandable

1 2 3 4 5 6

25. Overall, I find mobile applications easy to use

1 2 3 4 5 6

26. Mobile applications supports critical aspects of my farm

1 2 3 4 5 6

27. Using mobile applications makes it easier to do my job

1 2 3 4 5 6

28. Using mobile applications increases my productivity

1 2 3 4 5 6

29. Using mobile applications allows me to accomplish more work than would otherwise be possible

1 2 3 4 5 6

30. Overall, I find mobile applications useful to my job.

1 2 3 4 5 6

28. Do you have any other questions or comments about mobile applications in agriculture?

APPENDIX B. INSTITUTIONAL REVIEW BOARD APPROVAL

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	TUCKER, MARK A
From:	DICLEMENTI, JEANNIE D, Chair Social Science IRB
Date:	11/21/2018
Committee Action:(2)	Determined Exempt, Category (2)
IRB Action Date:	11 / 21 / 2018
IRB Protocol #:	1811021327
Study Title:	Mobile Application Adoption in Agriculture

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b).

Before making changes to the study procedures, please submit an Amendment to ensure that the regulatory status of the study has not changed. Changes in key research personnel should also be submitted to the IRB through an amendment.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). Submit this documentation as an FYI through Coeus. This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

You are required to retain a copy of this letter for your records. We appreciate your commitment towards ensuring the ethical conduct of human subjects research and wish you luck with your study.

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	MARK TUCKER LILY
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	01/14/2019
Committee Action:	Amended Exemption Granted
Action Date:	01/14/2019
Protocol Number:	1811021327
Study Title:	Mobile Application Adoption in Agriculture

The Institutional Review Board (IRB) has reviewed the above-referenced amended project and has determined that it remains exempt. Before making changes to the study procedures, please submit an Amendment to ensure that the regulatory status of the study has not changed. Changes in key research personnel should also be submitted to the IRB through an amendment.

Please retain a copy of this letter for your regulatory records. We appreciate your commitment towards ensuring the ethical conduct of human subject research and wish you well with this study.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

APPENDIX C. CHAPTER 4 TABLES

Table 4.4: Respondent ages, years farming, and occupations (n=55)

Respondent ages, years farming, and occupations (n=55)

Participant	Age	Years Farming	Occupation
1	52	44	Farmer
2	57	40	Regional Manager-INFB
3	51	31	Farmer
4	29	9	Farmer
5	24	2	Farmer
6	47	43	Regional Manager-INFB
7	54	32	Farmer
8	35	20	Farmer/Self-employed
9	31	15	Logistics Coordinator
10	59	35	Farm Crop Specialist-INFB
11	31	13	Loan Officer & Grain Farmer
12	37	14	Manage a Grain Facility
13	30	9	Farmer
14	36	36	Farmer & Engineering Consultant
15	57	40	Farmer
16	24	8	Farmer
17	37	37	Excavating & Farmer
18	75	20	(Retired) Farmer
19	65	10	Farmer
20	73	50	Community Wellness Coordinator
21	65	45	Farmer
22	37	17	Farmer/Farmhand
23	66	40	(Retired) Farmer
24	27	8	State Gov’t Agency
25	62	52	Manager at a farm
26	54	40	Farmer
27	62	45	Farm Business Owner
28	57	34	Farmer
29	43	30	Farmer
30	68	68	Self-employed/Farmer
31	57	35	Vice President-Farm Management
32	48	25	Appraiser, Farm Manager, & Real Estate
33	66	43	Farm Owner
34	41	20	Farmer
35	60	44	Partner in a Farm
36	36	13	Farmer

37	38	20	Semi Driver
38	30	5	Farmer
39	35	18	Livestock Feed Specialist
40	35	18	Hair Dresser & Farmer
41	43	20	Regional Manager-INFB
42	22	22	Commercial Real Estate
43	37	9	Commodities Trader & Farmer
44	66	60	Agriculture Business
45	68	46	Farmer
46	61		Executive VP of Agriculture Company
47	31	10	Technology Specialist for a Retail Outlet
48	35	10	Self-employed
49	34	4	Critical Care Nurse & Farmer
50	29	7	Farmer
51	38	5	Farmer
52	23	23	Sales Support Rep
53	23	23	Management Trainee
54	30	5	Ag Retail Sales
55	70	28	(Retired) Farmer