WILL CATTLE PRODUCERS BE WILLING TO ADOPT ELECTRONIC CATTLE MONITORING SYSTEMS?

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WILL CATTLE PRODUCERS BE WILLING TO ADOPT

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Abstract: Monitoring animal health and location is an important task for cattle producers. Historically this is done by visually checking animals in their pastures. An electronic cattle monitoring system could allow producers to monitor their animals' health and location remotely. This study examines cattle producers' willingness to adopt an electronic cattle monitoring system comprised of remote frequency identification rumen boluses, GPS, data collection stations, unmanned aerial vehicles (UAV) and a user interface. The system would allow producers to receive real-time data on the location and health of individual animals. The system could also be configured to allow producers to collect live video, rumen temperature, and/or animal behavioral patterns, among other characteristics. Health and location data would allow producers to not only locate missing cattle but also monitor the health of individual animals in their herd. In order to identify which characteristics and components of the monitoring system are desired by producers, an electronic survey containing demographic, choice experiment, and best worst questions was administered to email lists from the Samuel Roberts Noble Foundation and the Oklahoma Beef Council. Conditional and ordered logit models, willingness to pay estimates, importance scores and individual best-worst scores are used to analyze the results of the survey. The results are used to determine producers' preference for system components and characteristics and producer willingness to adopt the system. Demographic data from the questionnaire are used to determine the demographic characteristics of likely adopting producers. The results suggest that producers who have advanced educational degrees, producers with large numbers of cattle, and producers who infrequently check their cattle are most likely to adopt an electronic cattle monitoring system. Also, producers prefer system characteristics and components that allow them to monitor their animals' health and location such as GPS and notification of altered behavioral patterns.

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CHAPTER I

INTRODUCTION

Background

Cattle monitoring is a vital, yet often time-consuming task for cattle producers. With cattle dispersed throughout pastures that can spread large distances, producers spend many hours searching for missing, sick or stolen animals. Currently, cattle are monitored by visually inspecting and counting the number within a pasture, and missing animals are located by manually searching the entire property. Quickly locating missing animals is of utmost importance because an animal in distress frequently needs immediate attention. Quickly diagnosing the cause of the animal's distress can help minimize the severity of the issue. Rapid identification of illness is a vital step in preventing disease spread throughout the herd and ensures the sick animal receives the necessary treatment at the early onset of disease and infection (Thomson and White 2006).

An electronic monitoring system incorporating the use of remote frequency identification (RFID) rumen boluses or ear tags, pasture data collection stations located near water and feed sources, an unmanned aerial vehicle (UAV) to search for animals, and a software user interface could enhance the producer's ability to quickly locate sick or stolen cattle (Figure 1). The system would also allow producers to identify herd behavioral changes that can be indicative of other environmental changes affecting herd health and safety. By allowing producers to remotely track each animal's location, an electronic monitoring system could provide added security and a higher probability of rapidly locating missing animals. Additionally, the system would allow producers to monitor each animal's rumen temperature in order to rapidly detect illness and prevent the spread of disease.

UAVs could be an integral part of an electronic cattle monitoring system because they would allow producers to not only have visual images and GPS locations of their animals, but UAVs could also collect important health statistics and behavioral information about each animal. Recently, UAVs have garnered a great deal of attention in the news, from Amazon's Prime Air product delivery UAVs to bills allowing Deer Trail, Colorado citizens to shoot UAVs because the town considers UAVs entering their airspace an act of war (Barr 2013; Pearce 2014). Many popular news outlets such as the *Huffington Post* and the *Washington Times* have written articles criticizing the use of civilian UAVs (Nickels 2013; Wolfgang 2012). However, other agricultural publications such as *Drover's* and The *Progressive Farmer* have identified the potential benefit of UAVs in agricultural operations (Wessler 2014; Clayton 2013). Popular news sources, such as these could sway the opinion farmers and ranchers have of UAVs, but in which direction?

Agriculture is expected to provide the greatest potential for growth in the UAV industry (Association for Unmanned Vehicle Systems International 2013). UAVs are gaining popularity in the agricultural industry because of their potential crop scouting capabilities. They have the potential to benefit both the livestock and precision agricultural sectors (Wessler 2014). A single UAV could be used by a rancher to monitor both their cattle herd and their range and cropland conditions. However, UAVs are just beginning to enter the agricultural sector and have yet to be widely adopted. This is, in part, due to unclear Federal Aviation Administration (FAA) regulations (Doering 2014). Under current regulations, only hobbyists can use UAVs for non-commercial operations. In agriculture these include checking the condition of a personal garden but do not include scouting fields (Trigden 2014). Under the hobbyist classification, during flight UAVs are required to remain in sight of the pilot and under 400 feet in altitude. The FAA is reviewing proposed regulations to govern the use of UAV in agricultural and other commercial industries (Doering 2014). “Congress instructed the FAA to issue regulations for the “safe integration” of drones into the airspace by September 30, 2015” (Trigden 2014). Once the new FAA regulations have been created, farmers and ranchers will have a clear set of guidelines concerning how they can use UAVs to assist with their daily operations. These regulations will apply to unmanned aircraft weighing less than 55 pounds that are used for commercial gain. Until these regulations are adopted, it is illegal to fly UAVs for commercial use, including the use of UAV for crop scouting and other agricultural activities.

Much of the research regarding agricultural UAVs remains in the crop sector, and adoption rates are unknown for both cropping and livestock sectors. Traditionally, adoption rates for new technologies in the livestock industry have been greatly influenced by producer age, farm size, herd size and income levels (Pruitt et al. 2012). When the National Animal Identification System (NAIS) was introduced in 2004 to track cattle owned by US producers, many cattle producers refused to participate in the program, partially because of concerns regarding information privacy (Schultz and Tonsor 2010). It is unclear if these same concerns will influence cattle producers’ receptivity to electronic cattle monitoring systems. Enhanced privacy safeguards could be installed in electronic cattle monitoring systems in order to ensure protection of information about producers and their operations. It is also unclear what additional system characteristics should be included within the electronic cattle monitoring system to attract the interest of cattle producers.

System Characteristics and Components

This research will examine which combination of components and characteristics of the electronic cattle monitoring system are most desired by cattle producers. The system components evaluated are RFID rumen boluses or ear tags, pasture GPS monitoring stations, a UAV and a software user interface. System characteristics are closely related to the components included in the system (Figure 1). The remote frequency identification rumen boluses would allow producers to remotely monitor the GPS location and the internal rumen temperature of each animal. Internal temperature changes may be related to illness, calving or other stressors. Alternatively, RFID ear tags only allow for the collection of an animal's GPS location. Pasture GPS monitoring stations, would record and report the number of times an animal passed by the station, allowing for behavioral patterns to be determined. From these behavioral patterns, a producer would potentially be able to determine if there is a problem with an individual animal or threat to the herd. UAVs would allow a producer to retrieve GPS data from the RFID bolus and/or RFID ear tag and behavioral patterns from the pasture GPS monitoring stations, and then the UAV would relay that information to the producer's computer, tablet or smart phone for the user interface to interpret. Additionally, UAVs could take live video feed of the cattle herd and/or provide real time thermal images of the herd. Both would help producers monitor overall herd well-being and locate missing animals. The UAV could also be used to monitor a producer's crop and rangeland. UAV flight time could be extended by adding additional battery life or solar power collection device. The software user interface would display animal statistics collected in the field from the monitoring system on a producer's personal computer, smart phone or tablet. The user interface could be designed to function compatibly with leading cattle management software (e.g. CattleMax, Cattleworks, CattlePro) in order for all the producer's herd information to be aggregated in one location.

Research Objectives

In order for the proper combination of electronic monitoring system components and characteristics to be produced and delivered, the wants, needs and opinions of cattle producers in the target market segment will need to be understood. The overall objective of this research is to determine the conditions that would influence electronic cattle monitoring system adoption by cattle producers. The specific research objectives are to determine (1) how enterprise, management and producer demographics are related to producers' willingness to adopt the system; (2) how enterprise, management and producer demographics affect producer utility for individual system characteristics; (3) producers' willingness to pay for individual system characteristics; and (4) the most desired system components and characteristics.

CHAPTER II

REVIEW OF LITERATURE

Cattle Management and Monitoring

Monitoring overall herd well-being and animal health is one of the most important cattle management tasks producers face. Cattle producers spend many hours searching their pastures to ensure all cattle are in the correct locations and visually assess each animal to ensure it is healthy. Rapid recognition of illness and treatment of an affected animal can save the animal and help ensure that the illness is not spread throughout the herd or to neighboring herds (Thomson and White 2006). Producers must also be able to identify their animals to ensure that no cattle are missing from the pasture. Individual animal identification, such as a brand and/or an ear tag, is commonly used to identify animal ownership and differentiate between animals (Pruitt et al., 2012; Ward et al. 2008). According to Pruitt et al. (2012), 80.1 percent of producers use animal identification for identification of ownership and/or for individual animal recordkeeping. While visual identification allows producers to recognize their animals, it does not provide immediate, tangible data indicative of an animal's well-being.

Nominal cattle prices have reached all-time record high levels and herd sizes are significantly depleted due to overwhelming drought conditions (Peel 2014). Reports of cattle thefts in Oklahoma are at record high levels, and surrounding states have also reported increased cattle thefts (Killman 2013; Wessler 2013). The increase in theft could be related to increased cattle prices, as cattle rustlers can earn $1,000 or more per animal (Killman 2013). Increased theft incidences are a serious problem for producers making it important that they are able to locate and identify all of their animals when they are visually surveying a pasture. Producers are unable to maintain a constant watch on their animals, and many ranchers own cattle in pastures that are miles apart (Killman 2013). This means cattle are left relatively unsupervised the majority of the time, providing thieves with the opportunity to rustle cattle. However, an electronic monitoring system would allow producers to more effectively observe, locate, and identify their cattle to prevent theft.

Electronic Cattle Monitoring Systems

Currently, electronic cattle monitoring systems that would provide producers with enhanced supervision of their animals, including immediate GPS location and health statistics, are not widely used by producers. However, the GPS location data and animal health statistics provided by some systems can prove vital to a cattle operation's management program (Nagel et al. 2003). Health statistics can help a producer ensure sick animals receive necessary treatment at the early onset of infection, allowing the producer to treat and/or isolate an affected animal, helping prevent further spread of disease and illness (Thomson and White, 2006). A monitoring system created at Kansas State University allows an animal's temperature, GPS location, pulse rate, respiration rate and blood oxygen saturation to be collected (Nagel et al. 2003). In order for data collection to occur, the system requires the use of a rumen bolus, a Bovine Mobile Observation Operation (BMOO) unit, a pulse oximeter ear tag, and an electrode belt. The GPS device emits a constant signal of the animal's location, while the animal's rumen temperature, respiration rate and pulse rate are only recorded when the animal is near a BMOO unit. In order for an animal's heath statistics to be retrieved, the animal must be within 10 meters of the receiving unit and must stay in range for at least 45 seconds for full data upload to occur. Nagel et al. (2003) recommend the BMOO unit be placed in a pasture near the water supply and feed bunks for data collection. This system is currently used only for research purposes (Nagel et al. 2003). While this unit could potentially provide a producer with important health data, it would not provide a producer with real-time information nor could it be used for remote location of animals throughout a pasture. The external devices that are part of the system may not stay on the animal very long either, thus proving challenging to maintain the system.

A monitoring system researched in the U.K. allows producers to track animal location with a collar affixed to the animal's neck (Kwong et al. 2009). This collar has two antennae and a radio signal transmitter, allowing the location and general movement patterns of the animal to be monitored in real-time (Kwong et al. 2009). Trotter et al. (2010) developed a similar collar-based GPS system to track animal movements in real-time. This system also has store-on-board capabilities allowing data to be stored internally and collected as an aggregate for later interpretation. Trotter et al. (2010) intended for their device to allow producers to monitor animal behavior to better understand the animal to animal interactions within the herd and the animal to environment interactions. Again, this system, much like the system developed at Kansas State, could prove challenging to keep to external hardware attached to the animal.

The electronic cattle monitoring system proposed by Grimsley et al. (2013) would allow producers to track and monitor their cattle remotely by using a rumen bolus, pasture GPS monitoring stations, a software user interface and a UAV. With this electronic monitoring system producers could immediately identify each of their animals, collect each animal’s temperature, identify distressed animals through notification of altered behavioral patterns, monitor cattle through live video feed, and fly search patterns controlled by algorithms to locate missing animals. This electronic monitoring system would provide producers with real time GPS data and health statistics, thus allowing producers to have real time information about the health and well-being of each animal within their herd (Grimsley et al. 2013). The present research examines producer willingness to adopt such technologies and their desire for possible components and characteristics of this electronic cattle monitoring system.

Technology Adoption Theory

The motivation behind a customer's adoption intention can partially be explained by the "Theory of Planned Behavior" and the "Theory of Reasoned Action" (Taylor and Todd 1995). According to Taylor and Todd (1995), the Theories of Reasoned Action and Planned Behavior are a direct function of behavioral intention. Behavioral intention can be defined as a weighted sum of a subjective norm – the individual's belief concerning a referent and their motivation to comply with this referent – and attitude – the belief a behavior will lead to a particular outcome (Taylor and Todd 1995). In the adoption model, perceived behavioral control helps account for external behavioral influences beyond the subjective norm and individual's attitude (Taylor and Todd 1995). Perceived behavioral controls can be defined as facilitating conditions – such as money or resources needed for adoption – and self-efficacy – the customer's confidence in their ability to utilize the product (Taylor and Todd 1995).

In a competitive industry with numerous companies, the first group of people to adopt a product can be defined as innovators (Rogers 1976). These individuals are regarded as leaders among their peers and are generally of a higher socioeconomic class than the later adopters (Rogers 1976). The product or technology then spreads through the rest of the industry. According to Ryan and Gross (1943), in the agricultural industry, interpersonal communication among peers is the most persuasive channel prompting farmers to adopt new technologies. Wozniak (1993) considers gathering information regarding new technologies from peers, extension agents who travel to farms to disseminate information, or other potential adopters to be passive information gathering. While it is more time-consuming, active information gathering – attending trade shows, gathering information via media sources, and attending meetings or demonstrations – is typically seen among the early adopters group within an industry (Wozniak 1993).

Adoption is also highly influenced by the potential adopter's perception of relative advantage, compatibility of the innovation with the technologies they currently use, and complexity of the technology or product they are facing (Rogers 1995; Tornatzky and Klien 1982). Relative advantage can be defined as the ability of the product or technology to advance the user from their current state economically, socially, or productively as a convenience measure. A highly advantageous product is more likely to be adopted than an innovation that provides the customer with little or no advantage. The complexity of a product or technology influences the perceived difficulty to use, learn or adopt it (Taylor and Todd 1995). The less the complex a product or technology is, the more likely an individual is to adopt than not adopt. How well an innovation fits with the processes or products currently in use by the potential adopter can be defined as an innovation's compatibility. Highly compatible products have an increased likelihood of adoption (Taylor and Todd 1995).

Influences on Producers' Adoption Decisions

Adoption of a new technology often comes with risk, uncertainty and required learning for the adopter (Marra, Pannell and Ghadim 2003). Dorfman (1993) noted that risk attitude, farm size, and liquidity constraints could be used to make theoretical predictions regarding the farmer's adoption decision regarding more advanced cropping technologies. In a review of previous literature, Marra, Pannell and Ghadim (2003) found that risk-related issues strongly influence the adoption rate for new technologies. A farmer's assessment of a technology's riskiness, view on handling risks, attitude toward the option value of delaying adoption, and receptiveness of learning and trial opportunities affect the rate at which a farmer adopts a new technology (Marra, Pannell and Ghadim 2003). Farmers carefully consider the information they have about a group of technologies with complimentary components and then adopt the technology with the greatest expected utility of profit (Feder 1982). Providing a farmer with quality information and the opportunity to learn more about a technology can increase the producer's probability of adoption (Marra, Pannell and Ghadim 2003). The authors conclude learning opportunities and potential economic benefits have the greatest influence over farmers' adoption rates of new technologies (Marra, Pannell, and Ghadim 2003). Education has been found to increase adoption rates in numerous studies (Marra, Pannell, and Ghadim 2003 and Wozniak 1993). This is because managers with high education levels tend to be better informed of information sources about innovations, are able to more accurately assess the information, and thus are more prepared to make an informed decision regarding adoption (Wozniak 1993). Wozniak (1993) also found increased education levels makes producers more selective in their information sources, meaning producers who have obtained higher education levels tend to seek out information sources that they hold in high scholarly regard.

Gillespie, Kim and Paudel (2007) conducted a survey to determine adoption rates and reasons for non-adoption of best management practices among cattle producers. They concluded unfamiliarity with or lack of information about an innovation is a great deterrent for producers when considering new technologies (Gillespie, Kim, and Paudel 2007). The authors additionally concluded willingness to adopt is heavily influenced by the cost of adoption. Furthermore, the study determined demographics such as herd size, education levels and producer age can help predict adoption rates. More specifically, increased farm size and education levels positively influenced adoption rates, while age negatively affected adoption rates (Gillespie, Kim and Paudel 2007). Pruitt et al. (2012) and Ward et al. (2008) found similar correlations between adoption rates, income, producer age and farm size. While Wozniak (1993) and Dorfman (1996) found adoption is influenced by the number of hours a producer works at an off-farm job. Producers who spend much of their time at off-farm jobs may consider their farming operation to be a hobby as well as a source of income. Thus, they could be less likely to invest the time and money required to adopt a new technology (Dorfman 1996).

Pruitt et al. (2012) concluded longer retention of animal ownership increases the likelihood producers will adopt new management technologies because increased economic returns for the producer are more probable if the technology is used for a longer duration. Longer retention of animals allows the producer to earn benefits from that decision over a longer period of time, whereas a producer, such as a stocker operation[1], will have a higher turnover rate on their animals and will only benefit from identification for a short period of time. Because these producers only retain the ownership of their animals for short periods of time – from weaning until slaughter or transfer to the feedlot for finishing – they may be less likely to adopt a technology that requires a high upfront cost per animal. The authors also determined purebred producers were 2.81 times more likely than non-purebred producers to adopt recordkeeping and identification management practices (Pruitt et al. 2012). Purebred producers keep detailed records about their animals' lineage in order to enroll offspring in breed registries.

When the 2004 National Animal Identification System (NAIS) program was introduced, many producers refused to participate, in part because of concerns regarding confidential information becoming publicly available (Schultz and Tonsor 2010). While the program gave producers a way to identify their cattle and manage their individual animal records, it also gave government agencies access to much information about the producers' operation (Schultz and Tonsor 2010). Schultz and Tonsor (2010) conducted a producer survey assessing demographics, production practices and beliefs regarding animal traceability. Schultz and Tonsor (2010) found that as the operation size, household income and percentage of off-farm income increased,

[1] "Stockers are produced in the growing phase of beef production, after the cow-calf stage, yet before finishing. Stocker cattle are commonly described as weaned calves in post-weaning growing programs that are intended for sale as commercial feeder cattle and weights range between 300-800 lbs." (Johnson et al. 2008).

likelihood of producer enrollment in the NAIS program decreased. Conversely, education level, membership in the National Cattleman's Beef Association, and on-farm cattle identification increase the likelihood of registration in the NAIS program. Schultz and Tonsor (2010) determined producers consider monitoring and/or managing disease as the most important traceability system component. They concluded cost, system reliability, and information confidentiality are also important to producers (Schultz and Tonsor 2010).

CHAPTER III

METHODOLOGY

Research Objectives and Hypotheses

The overall objective of this research is to determine the conditions that would influence electronic cattle monitoring system adoption by cattle producers. The specific research objectives are to determine (1) how enterprise, management and producer demographics are related to producers' willingness to adopt the system; (2) how enterprise, management and producer demographics affect producer utility for individual system characteristics; (3) producers' willingness to pay for individual system characteristics; and (4) the most desired system components and characteristics.

Specific objective 1 is to determine how enterprise, management and producer demographics are related to producers' willingness to adopt the system. Studies conducted by Schultz and Tonsor (2010), Gillespie, Kim and Paudel (2007), Pruitt et al. (2012), and Ward et al. (2008), indicate livestock producer characteristics greatly influence the adoption of new technologies. Studies also found that producer characteristics such as number of animals in the herd, income levels, education level, and geographic location influence producers' willingness to adopt production and management practices (Gillespie, Kim and Paudel 2007; Pruitt et al. 2012; and Ward et al. 2008). Therefore, Hypothesis 1 is that likelihood of system adoption is positively related to higher education levels among producers.

Taylor and Todd (1995) state producers are more likely to adopt technologies that easily integrate with their current practices. Therefore, Hypothesis 2 is likelihood of adoption of an electronic cattle monitoring system is positively related to frequency that producers check their cattle. There is generally a positive relationship between owning or managing large amounts of land, owning more cattle and earning high profits (U.S. Department of Agriculture, National Agricultural Statistics Service, 2014). Gillespie, Kim and Paudel (2007) found a positive relationship between increased farm size and education levels and adoption rates. Thus, Hypothesis 3 is that likelihood of adoption of an electronic cattle monitoring system is positively related to numbers of cattle in a producers operation.

Specific objective 2 is to determine how enterprise, management and producer demographics affect producer utility for individual system characteristics. Again, as described in Schultz and Tonsor (2010), Gillespie, Kim and Paudel (2007), Pruitt et al. (2012), and Ward et al. (2008), producer and enterprise characteristics can be used to describe adoption intentions. From these studies it can be concluded that the characteristics of individual producers and their enterprises can influence their utility for electronic monitoring system characteristics and components. Thus, Hypothesis 4 is that utility for crop monitoring technology as part of an electronic cattle monitoring system will be greater for producers who grow crops in addition to raising cattle. According to Pruitt et al. (2012) producers with increased purebred percentages in their herds are more likely to adopt recording keeping systems. Thus, Hypothesis 5 is that utility for compatibility with cattle monitoring software (e.g. CattleMax, Cattleworks, and CattlePro) as part of an electronic cattle monitoring system will be positively related to the percentage of purebred cattle in a herd. Again as noted in Gillespie, Kim and Paudel (2007), older producers tend to rely on traditional management methods, and they may have concerns regarding the privacy of an automated cattle management system. Thus, Hypothesis 6 is that utility for privacy safeguards as part of an electronic cattle monitoring system is positively related to producer's age.

Specific objective 3 is to determine producers' willingness to pay for individual system components and characteristics. Schultz and Tonsor (2010) found that health monitoring was very important when developing a traceability system. Live video feed as a component of an electronic monitoring system will allow a producer to visually assess their animals' well-being. Thus, Hypothesis 7 is that producers' willingness to pay is greatest for the live video feed component of an electronic monitoring system.

Specific objective 4 is to determine the most desired system components and characteristics. Again, as found by Schultz and Tonsor (2010), producers have a strong desire to monitor their animals' health and well-being. Because of the producers' need to monitor animal health and well-being, Hypothesis 8 is that producers will rank electronic monitoring system components that allow them to monitor their animals' health and location – RFID rumen bolus and UAV – at the top of the producer important score scale. Similarly, Hypothesis 9 is that producers will rank the electronic monitoring system characteristics that allow them to monitor their animals' health and location – GPS, notification of altered behavioral patterns, live video, and rumen temperature –will rank at the top of the producer important score scale.

Survey Methodology

In order to meet the objectives and test the hypotheses, an online producer survey was created in Qualtrics and administered to email address lists from the Samuel Roberts Noble Foundation and Oklahoma Beef Council. An initial test of the survey with 15 participants – who were selected from outside of the sample and who agreed to provide feedback on the survey draft– was conducted to ensure the survey instrument is able to collect the required information.

Once the pretest results were analyzed, modifications were made to the survey, and the official questionnaire was sent to the selected sample populations on July 1, 2014 (See Appendices 1-4).

In total, the questionnaire consists of 41 questions. The questions were broken into three segments – 18 demographics questions, 9 best-worst analysis questions, and 14 paired product choice questions. Each participant is only asked to complete seven of the choice experiment questions, thus each respondent answers 34 questions. The survey was administered in one version, yet the choice experiment questions were divided into two blocks each containing seven questions. Qualtrics randomly assigned participants to a block version. This allowed the design of the survey to remain efficient while the questionnaire was short enough that producers responded with completed surveys.

Producer and enterprise demographics were collected with 18 demographic questions. This set of questions collects general information about the producer, their enterprise, and how they operate. This information included age, herd size, income levels, crops grown and acreage. These questions are used to meet to Specific Objectives 1, 2 and 3 and test Hypotheses 1-6.

Best-worst questions were used to determine which system components and characteristics were valued more than others by producers (See Appendix 4). The best-worst questions are used to address to Specific Objectives 3 and test Hypotheses 8 and 9. According to Finn and Louviere (1992) the best-worst model capitalizes on a person’s propensity to identify extreme options. Nine best-worst questions were included in the survey. These questions were broken into two sets – one regarding electronic cattle monitoring system components and one regarding electronic monitoring system characteristics. The electronic cattle monitoring system component section consisted of six unique components – RFID ear tags, RFID rumen bolus, unmanned aerial vehicle, pasture data collection stations near feed/water, price, and software package relaying collected data – varied in groups of four components across three questions. In these questions, producers were asked to select which component has the greatest influence on their purchase decision and which component has the least influence on their purchase decision. The electronic cattle monitoring system characteristic set of questions included nine unique characteristics: live video, privacy, rumen temperature, GPS, behavior, compatibility, thermal imaging, UAV flight time and crop scouting. In six questions, respondents evaluated six combinations of the nine characteristics. In this set of six questions, producers were asked to select which of six electronic cattle monitoring characteristic they would most prefer and which component they would least prefer. Descriptions of each component and characteristic were included for producers before their respective section (See Appendix 4).

A balanced incomplete block design (BIBD) was used to create the best-worst question sets (Bradley and Terry 1952). This design is derived from a Latin Square design for *n* items organized by *n* rows and *n* columns. All items were in different positions in the rows and columns, and each row is a block or choice set. The design was balanced if and only if the attribute appears in the same frequency in all choice sets (Weller and Romney 1988). The repeated combinations were removed and the optimal choice sets were determined using SAS (see Appendices 5-8). The computer generated design for the electronic cattle monitoring system components question set has a Block Design D-Efficiency of 99. Each attribute appeared twice in the question set. The computer generated design for the electronic cattle monitoring system characteristic question set has a Block Design D-Efficiency of 99.78, and each attribute occurred four times in the question set. The block design efficiency criterion was considered balanced when it is equal to 100 (Kuhfeld 2005). Therefore these designs can be considered balanced.

The choice experiment questions were meant to mimic the decision between products a producer would face in a marketplace (See Appendix 4). The choice experiment questions address Specific Objectives 2 and 3 and test Hypotheses 4-7. The survey included a unique set of seven paired product profile questions in both blocks, which were randomly assigned to producers. In these questions, producers select which of two products they would prefer to purchase or select a non-purchase option. The fourteen choice experiment questions either include or do not include compatibility with cattle management software, live video feed, crop scouting capabilities, and privacy safeguards. Also for each product profile, rumen bolus price per animal is varied at $10 and $45, and UAV price was varied at $3,000 and $8,000 (See Table 1). Descriptions of how each component works in providing relevant animal health data are included within the survey before the producers are presented with this set of questions.

The choice experiment questions were created using an orthogonal main-effects only design. In order to generate the block design efficiency criterion questions for the survey, a computer generated design maximizing D-efficiency was used (See Appendix 9-10). The attributes in the question each varied at a two-level, where they are either included in the question or not. Because each attribute level was equal, the attributes were balanced. The final D-efficiency for the question set was 95. This is close to a balanced orthogonal design efficiency score, which is defined as 100 (Kuhfeld, Tobias and Garratt 1994).

Sample

The Samuel Roberts Noble Foundation and Oklahoma Beef Council email lists were selected as the sample because the producers on these lists are cattlemen in Oklahoma and north Texas who tend to seek out progressive information to learn and utilize new management practices. This sample was representative of the group who were thought to be most likely early adopters of electronic cattle monitoring systems. The purpose of the questionnaire was to gauge each producer's "progressiveness," through characteristics such as improved pasture lands, herd and pasture management, and education level. The producer's progressiveness characteristics were hypothesized to be related to how likely the producer is to adopt the new electronic cattle monitoring system (Rogers 1976).

The questionnaire was sent to the email list from the Oklahoma Beef Council on July 1, 2014. The Oklahoma Beef Council email list included 1,473 email addresses. A total of 76 email bounce backs were received indicating that the email address was no longer valid, and 4 people replied that they were not producers. In total 1,393 viable email addresses received the survey email. The questionnaire was also sent to the email list from the Samuel Roberts Noble Foundation on July 8, 2014. This list included 2,421 email addresses. A total of 180 email bounce backs were received indicating that the email address was no longer valid, and 3 recipients replied stating they did not own cattle. In total 2,238 live email addresses were sampled. Of this group, some members of the list were not cattle producers. Also, because of the proximity of the two organizations there is some overlap between the two lists. However, because the lists remained in house, there is no way to determine the total number of email address overlap between the two lists. In total, 3,631 viable email addresses were contacted to participate in the survey. The online survey was closed at 11:59 PM on July 31, 2014.

Of the 3,631 email addresses surveyed, 580 individuals completed at least a portion of the survey. This is a 15.97% response rate. After eliminating responses that did not include complete information, 382 observations are used in the analyses. Block 1 of the paired product questions in the survey was completed by 188 respondents, 49%, and Block 2 of the paired product questions in survey was completed by 194 respondents, 51%. Thus these responses are balanced and can be used to interpret results.

Tables 2, 3, and 4 show the demographic characteristics of the respondents. The average survey respondent was male, 54 years old, obtained a college degree, and has been involved in the cattle industry for 29.8 years. Of producers responding to this survey, 85% are male. Of the survey respondents, 53% are between the ages of 50 and 69. Approximately 41% of respondents earned a bachelor's degree, and an additional 31% of respondents obtained a graduate degree. Of the respondents, 61% earn between $60,000 and $100,000 annually. The number years respondents have been involved in the cattle industry varies greatly between 10 and 49 years. Of the respondents, 17% have been involved 40 to 49 years, 18% have been involved 10 to19 years or 30 to 39 years, respectively, and 19% have been involved 20 to 29 years. The majority, 64%, of producers responding to this survey own less than 100 head of cattle. Of the respondents, 57% have a herd that is less than 10% purebred. Most respondents own cattle in either Oklahoma or Texas, with 63% in Oklahoma and 25% in Texas. In addition to raising cattle, 29% of respondents grow crops of some form, and 23% of respondents have acres of wheat.

Methods and Procedures for Data Analysis

Procedures used by both Adamowicz et al. (1998) and Lusk, Roosen and Fox (2003) are followed to create a utility function of the producer's choices for the given alternatives. This function is dependent upon the attributes of the choice alternatives and a stochastic error term (ε_{ij}) accounting for unobserved uncertainty in the producer's preferences that was developed. This utility function assumes that the electronic cattle monitoring system selected by the producer would provide that producer with the greatest utility from the given choice set.

(1) $$U_{ij} = V_{ij} + \varepsilon_{ij}$$

here U_{ij} is individuals i's non-price utility for choosing electronic cattle monitoring system option j. The deterministic term V_{ij} is the systematic portion of the utility function determined by the electronic cattle monitoring system attributes and their values (See Equation 4 and Table 5), and ε_{ij} is a stochastic element. The probability that a producer chooses alternative j from a choice set with J possible choice options is:

(2) $$\text{Prob}\{V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik} \text{ for all } k \neq j\}$$

If the error terms from Equation 1 are independently and identically distributed across the *j* alternatives and *N* individuals with an extreme value distribution, the probability of producer *I* choosing alternative *j* is:

$$\text{(3)} \qquad \text{Prob}\{\text{option } j \text{ is chosen}\} = \frac{e^{V_{ij}}}{\sum_{k=1}^{J} e^{V_{ij}}}$$

Assuming that V_{ij} is linear in parameters, the functional form of the utility function is expressed as:

$$\text{(4)} \quad V_{ij} = \alpha_1 NONE + \alpha_2 PRIVACY + \alpha_3 LIVE + \alpha_4 CROPS + \alpha_5 COMP + \alpha_6 BOLUSPRICE + \alpha_7 UAVPRICE$$

In Equation 4, *NONE* is the non-purchase option; *PRIVACY* is defined as privacy safeguards; *LIVE* is live video feed; *CROPS* is crop scouting capabilities; *COMP* is compatibility with cattle monitoring software; and *BOLUSPRICE* and *UAVPRICE* are the prices of a rumen bolus and a UAV, respectively. Equations 3 and 4 describe a conditional logit model.

In order to test Hypotheses 4, 5 and 6, interaction terms are included in the functional utility form V_{ij} to determine how demographic characteristics influence producers' willingness to adopt certain system characteristics. These include privacy interacted with producer age, if a producer grows crops and crop scouting capabilities, and crop scouting capabilities with the acreage of each crop a producer grows. By including the interaction terms, it can be determined if utility for crop monitoring technology as part of an electronic cattle monitoring system will be greater for producers who grow crops in addition to raising cattle (Hypothesis 4). It can be determined if utility for compatibility with cattle monitoring software (e.g. CattleMax, Cattleworks, and CattlePro) as part of an electronic cattle monitoring system will be positively related to the percentage of purebred cattle in a herd (Hypothesis 5). And, it can be determined if utility for privacy safeguards as part of an electronic cattle monitoring system is positively related to producer's age (Hypothesis 6). The subsequent model is as follows:

$$(5) \qquad V_{ij} = \alpha_1 PRIVACY + \alpha_2 PRIVACY * AGE + \alpha_3 LIVE + \alpha_4 CROPS + \alpha_5 CROPS * GROW + \alpha_6 COMP + \alpha_7 COMP * PUREBRED + \alpha_8 BOLUSPRICE + \alpha_9 UAVPRICE$$

In Equation 5, information privacy safeguard is interacted with producer age, *PRIVACY*AGE;* crop scouting capabilities are interacted with the dummy variable of whether or not the producer grows crops, *CROPS*GROW;* and compatibility with cattle monitoring software interacted with the percentage of the producer's cattle herd that is purebred, *COMP*PUREBRED*.

From the choice experiment data set, willingness to pay is calculated both in regards to UAV price and bolus price. The willingness to pay estimates allow for the determination of the maximum amount a producer is willing to pay for each characteristic to be included within the monitoring system. The willingness to pay estimates allow Hypothesis 7, that producers' willingness to pay is greatest for the live video feed component of an electronic monitoring system, to be tested. Willingness to pay is calculated using Equation 6:

$$(6) \qquad WTP_{Characteristic_i} = \frac{-\beta_{Characteristic_i}}{\beta_{Price_j}}$$

In Equation 6, $Characteristic_i$ is the characteristic of the electronic cattle monitoring system, and $Price_j$ is the price of either the bolus or the UAV. This will allow us to determine the maximum amount more a producer is willing to pay for a bolus and a UAV with a specific component included in the system.

$$(7) \qquad WTP_{Base_i} = \frac{-\sum_{i=1}^{C} \beta_{C_i} - \beta_{None_i}}{\beta_{Price_j}}$$

In Equation 7, C_i is the characteristic of the electronic cattle monitoring system, $None_i$ is the utility for the no purchase option, and $Price_j$ is the price of either the bolus or the UAV. This will allow us to determine the maximum amount more a producer is willing to pay for a bolus and a

UAV with a specific component included in the system.

To calculate the intrinsic value a producer places on one characteristic of the system over another, the best-worst scaling model as described by Finn and Louviere (1992) and Marley and Louviere (2005) is used. The best-worst question data provide a scale of the value producers place on electronic cattle monitoring system characteristics and components. From these sets of paired choices, data indicative of how much producers interpret one characteristic of the electronic cattle monitoring system as more important than another characteristic can be determined.

In order to analyze the best-worst data to achieve Specific Objective 4, the conditional logit approach was again utilized. In this best-worst approach, a producer chooses from a set of *J* components or characteristics with *J(J*-1) possible combinations that could be selected by the producer. The true or latent unobserved level of importance for producer *i* is given by:

(8) $$L_{ij} = C_j + \varepsilon_{ij}$$

In Equation 8, C_j is the location of the value *j* on the underlying importance scale and ε_{ij} is a random error term.

The probability that a producer chooses item *j* as best and item *k* as worst from a choice set with *J* items options is:

(9) $$\text{Prob}\{L_{ij} - L_{ik} > \text{ all other } J(J-1) - 1 \text{ possible differences}\}$$

If the error terms from Equation 8 are independently and identically distributed with an extreme value distribution, the probability of producer *i* choosing items *j* as best and *k* as worst takes the conditional logit form:

(10) $$\text{Prob}\{\, j \text{ is chosen as best and } k \text{ is chosen as worst}\} = \frac{e^{C_j - C_k}}{\sum_{l=1}^{J}\sum_{m=1}^{J} C_l - C_m - J}$$

From these estimates, a model can then be created to determine the producer's value of individual system components and characteristics. In order to determine this value and test Hypotheses 8 and 9, importance scores are calculated for each best-worst characteristic and component in order to determine the percentage of producers who would choose a given characteristic as the most preferred characteristic in the system.

(11) $$Importance\ Score\ for\ Characteristic\ j = \frac{e^{\widehat{\gamma_j}}}{\sum_{k=1}^{J} e^{\widehat{\gamma_i}}}$$

In Equation 11, $\widehat{\gamma_j} = \beta_{Characteristic j}$ and $\widehat{\gamma_i} = \beta_{Video} + \beta_{Privacy} + \beta_{Temp} + \beta_{GPS} + \beta_{Behavior} + \beta_{Comp} + \beta_{TI} + \beta_{FT} + \beta_{Crops}$. In this model, β_{Video} is the coefficient for live video feed; $\beta_{Privacy}$ is the coefficient for privacy safeguards; β_{Temp} is the coefficient for rumen temperature monitoring; β_{GPS} is the coefficient for GPS cattle location monitoring; $\beta_{Behavior}$ is the coefficient for notification of altered behavior patterns; β_{Comp} is the coefficient for compatibility with cattle management software; β_{TI} is the coefficient for thermal imaging; β_{FT} is the coefficient for added UAV flight time; and β_{Crops} is the coefficient for crop monitoring technology.

A similar method is used in order to calculate the importance score for each electronic monitoring system component.

(12) $$Importance\ Score\ for\ Component\ j = \frac{e^{\widehat{\gamma_j}}}{\sum_{k=1}^{J} e^{\widehat{\gamma_i}}}$$

In Equation 12, $\widehat{\gamma_j} = \beta_{Component j}$ and $\widehat{\gamma_i} = \beta_{ET} + \beta_{Bolus} + \beta_{UAV} + \beta_{GS} + \beta_{Price} + \beta_{SW}$. In this model, β_{ET} is the coefficient for RFID ear tags; β_{Bolus} is the coefficient RFID rumen bolus; β_{UAV} is the coefficient for UAV; β_{GS} is the coefficient for pasture GPS data collection stations; β_{Price} is the coefficient for system price; β_{SW} is the coefficient for the software system relaying information to and interpreting information for the rancher.

Using the importance score percentages obtained from Equation 11, characteristics can be ranked from most important to least important; using the importance scores from Equation 12, components can be ranked from most important to least important. With the rankings for components, it can be determined if producers will rank electronic monitoring system components that allow them to monitor their animals' health and location – RFID rumen bolus and UAV – at the top of the producer important score scale (Hypothesis 8). Similarly, using the importance score rankings for characteristics it can be determined if producers will rank the electronic monitoring system characteristics that allow them to monitor their animals' health and location – GPS, notification of altered behavioral patterns, live video, and rumen temperature – will rank at the top of the producer important score scale (Hypothesis 9).

Once the overall importance scores are calculated, individual best-worst scores for each respondent are calculated with the difference method used by Marley and Louviere (2005). In this method, the number of times an item is considered "best" is added together and the number of times that item is considered "worst" is subtracted from it. While this method is not as accurate as the Multinomial Logit approach used to calculate the overall importance scores, it is a close approximation and can be used to explain the relative value a respondent places each characteristic and component (Auger, Devinney and Louviere 2006).

The individual best-worst scores for components and characteristics and producer, enterprise and management characteristics are then compared with the producer's self-described likelihood of adoption using a Chi-square test. The Chi-square test measures the association between each categorical level of the two variables in the test (Waller and Johnson 2013). The Chi-square test will allow it to be determined if personal, enterprise, and management characteristics are correlated with a producer's self-described adoption intention. These tests can be utilized to determine if a producer's self-described adoption intention is related to the value a producer places on individual system components and characteristics. The Chi-square test is conducted using the methods presented by Schumacker and Tomek (2013).

(13) $$\chi^2 = \sum \frac{(O-E)^2}{E}$$

In Equation 13, O is the observed number of producers in the category, and E, the expected number of producers in the category. In Equation 13, $E = \frac{(\sum_{n=1}^{r} O,n)(\sum_{x=1}^{c} O,x)}{p}$, or the sum of row r multiplied by the sum of column c, divided by the total number of producers p. With H_0: the two variables are independent and have no relation and H_1: the two variables are dependent and are therefore related. The critical region for this test is $\chi^2 obs > \chi^2$ $(0.05, DF)$, where $DF = (c-1)(r-1)$. Here c is the number of categorical levels for the producer's self-described likelihood of adoption and r is the number of categorical levels for the variable it is tested against from best-worst component scores or best-worst characteristic scores or producer characteristics, enterprise characteristics or management characteristics.

Components in the test include against self-described likelihood of adoption are RFID ear tags, RFID rumen bolus, UAV, pasture data collection station, price and software, which vary at five categorical levels – individual best-worst scores of 2, 1, 0, -1, and -2 – with the range determined by the number of times each individual component appeared in the survey questions. Unique characteristics – live video feed, privacy safeguards, rumen temperature collection, GPS cattle location, notification of altered behavioral patterns, compatibility with cattle management software, thermal imaging, increased UAV flight time, and crop monitoring technology – contain nine categorical levels – individual best-worst scores of 4, 3, 2, 1, 0, -1, -2, -3, and -4 – with the range determined by the number of times each individual characteristic appeared in the survey questions. Producer characteristics used to explain categorical levels are education level, varying at a categorical level of three, and location, varying at a categorical level of two. Enterprise characteristics included in the model are the number of cattle owned, varying at a categorical level of three; if crops are grown in addition to raising cattle, varying at a categorical level of two; and how frequently cattle are checked, varying at a categorical level of three. Management characteristics include the use of rotational grazing, introduced pasture, soil testing, stockpiled fall growth and prescribed burns – each varying at a categorical level of two.

Again, using the individual best-worst scores, models can be created to measure how enterprise, management and producer demographics are related to producers' willingness to adopt the system (Specific Objective 1). Because the self-described likelihood of adoption question in the survey yielded an ordered response on a scale of very likely, likely, unlikely or very unlikely, an ordered logit model is used to interpret the data.

Assuming Equation 1 is true for this data set, and assuming that ε_{ij} are distributed with Type 1 Extreme Values, the multinomial logit model where the probability of producer *i* choosing likelihood of adoption option *j* out of a total *J* likelihood of adoption options is estimated (Chang, Lusk, and Norwood 2011):

(14) $$\text{Prob}\,\{j \text{ is chosen}\} = \frac{\exp(V_{ij})}{\sum_{k=1}^{J} \exp(V_{ik})}$$

In order to account for all likelihood of adoption options, the ordered logit model as described by Beggs, Cardell, and Hausman (1981) and by Chang, Lusk, and Norwood (2011) can be developed. The ordered logit is an extension of the multinomial logit model shown in Equation 14. Chang, Lusk, and Norwood (2011) show that out of *J* likelihood of adoption options, the probability that likelihood of adoption option 1 is preferred to likelihood of adoption option 2, likelihood of adoption option 2 is preferred to likelihood of adoption option 3, and likelihood of adoption option 3 is preferred to likelihood of adoption option 4 is given by:

(15) $$\prod_{j=1}^{J-1} \frac{\exp(V_{ij})}{\sum_{k=j}^{J} \exp(V_{ik})}$$

Equation 15 is the product of *J*-1 multinomial logit models.

Assuming that V_{ij} in Equation 14 is linear in parameters, the functional form of the utility function is expressed containing demographics characteristics only:

$$V_{ij} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \boldsymbol{x_1}\beta_1 \quad (16)$$

In Equation 16, α_1 is the log odds of likelihood of adoption, defined as $LO = \frac{p}{(1-p)}$ where p is probability, 1 versus 2 or 3 for $\boldsymbol{x_1}$, and α_2 is the log odds of likelihood of adoption 1 or 2 versus 3 for $\boldsymbol{x_1}$. Thus, the intercepts allow for a measure of likely adoption versus unlikely adoption. Self-defined producer likelihood of adoption is defined as 1, very likely; 2, likely; 3, unlikely; and 4, very unlikely. Self-defined producer likelihood of adoption level 4, very unlikely, is dropped from the model to prevent exact collinearity. In the model, $\boldsymbol{x_1}$ is a 382 x 15 matrix of 15 producer, enterprise and management characteristics (Table 16). Equation 16 allows Hypotheses 1-3 to be tested.

An extension of Equation 16 is created, including both demographics and individual best-worst scores for electronic cattle monitoring system components.

$$V_{ij} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \boldsymbol{x_1}\beta_1 + \boldsymbol{x_2}\beta_2 \quad (17)$$

In this subsequent model, $\boldsymbol{x_2}$ is a 382 x 5 matrix where $\boldsymbol{x_2}$ is comprised of the varying importance score levels, from -2 to 2, of five electronic cattle monitoring system components (Table 13). These components are RFID ear tags, RFID rumen bolus, UAV, GPS data collection station and price. It should be noted the software component has been dropped from the model to prevent exact collinearity.

Again, as an extension of Equation 16, a model is created including demographics and individual best-worst scores for electronic cattle monitoring system characteristics:

(18) $$V_{ij} = \begin{bmatrix}\alpha_1\\ \alpha_2\end{bmatrix} + \boldsymbol{x_1}\beta_1 + \boldsymbol{x_3}\beta_3$$

In this model, $\boldsymbol{x_3}$ is a 382 x 8 matrix where $\boldsymbol{x_3}$ is comprised of the varying importance score levels, from -4 to 4, of eight electronic cattle monitoring system characteristics (Table 14). These characteristics include live video feed, added privacy safeguards, rumen temperature collection, GPS cattle location monitoring, notification of altered behavioral patterns, compatibility with cattle management software, thermal imaging, and increased UAV flight time. It should be noted the crop monitoring technology characteristics has been dropped from the model to prevent exact collinearity.

The parameter estimates and their respective p-values obtained in Equations 16, 17, and 18 can be used to determine which demographic characteristics have a significant correlation with likelihood of adoption. Using the parameter and log likelihood estimates from Equation 16 Hypotheses 1through 3 can be tested.

In order to test which of these models – Equation 16, Equation 17 and Equation 18 – best explains a producer's self-described likelihood of adoption, a likelihood ratio test was conducted using the methods in Judge et al. (1988). Where the null hypothesis is that $H_0: \theta = \theta_0$ and the alternative hypothesis is $H_1: \theta \neq \theta_0$ (Judge et al. 1988).

(20) $$LR = -2\log\lambda = -2\left[L(\theta_0) - L(\hat{\theta})\right] = 2[L(\theta_0) - L(\hat{\theta})]$$

If the null hypothesis is true, Equation 19 is asymptotically distributed as a χ^2 variable with J degrees of freedom equal to the number of hypotheses (Judge et al. 1988). The null hypothesis is rejected if $LR \geq \chi^2_{(\alpha,J)}$.

CHAPTER IV

RESULTS AND DISCUSSION

The results of this survey allow for the interpretation of cattle producer desire for an electronic cattle monitoring system. These results also provide information about the demographic characteristics of producers most willing to adopt the system. Survey respondents were on average younger and more experienced than the national average (Table 2). Producers responding to the survey also, on average, own larger cattle herds than the national average (Table 3). This indicates that while the survey is not a representation of the national average, it may be a more progressive group of producers who have the potential to be early adopters within the industry. Figure 2 shows that 7.85% and 32.98% of producers classify themselves as "very likely" or "likely" adopters, respectively, while 43.72% and 15.45% of producers classify themselves as "unlikely" or "very unlikely" adopters, respectively. This indicates that while, more producers are less likely to adopt, the majority of these producers are not of a polarized opinion for or against the system.

Characteristics of Likely Adopters

Objective 1 of this research was to determine if producers' willingness to adopt the system is related to enterprise, management and producer demographics are related to. In order to achieve this objective, much emphasis was placed on the survey question asking producers to classify their likelihood of adoption of an electronic cattle monitoring system within the next five years. Producers were asked to classify their adoption decision based on a scale ranging from “Very Likely” to “Very Unlikely” with the neutrality option removed from the scale to force producers to make a decision in favor or in opposition of the system. As shown in Figure 2, there is approximately a 60% to 40% split between unlikely and likely adopters, indicating more producers classify themselves as unlikely to adopt the system. It was important to understand the demographic characteristics and values of producers classifying themselves among each scale range. In order to accomplish this objective, Equations 16, 17 and 18 were estimated in order to test which demographic characteristics and/or the values producers place on system characteristics and components best explain their self-described adoption intention.

Individual Best-Worst Scores

The first step in this process was to calculate individual best-worst scores for system characteristics and components using the difference method. This allows determination of the value individual producers place on each system component and characteristic. This was done using data from the best-worst experiment, and the distribution of individual best-worst scores, shown in Tables 10 and 11, supports the overall best-worst importance scores calculated using the conditional logit method. Individual best-worst scores for components range from -2 to 2, with producers having the option twice within the survey to select each component as the least influential (worst) or the most influential (best) towards their purchase decision (Table 11). Individual best-worst scores for characteristics range from -4 to 4. Here, producers had the option four times within the survey to select a characteristic as most preferred (best) or least preferred (worst) (Table 12).

In Table 11 and Figure 6, price is left skewed, with more producers ranking price as the greatest influence on their purchasing decision and very few producers ranking price as the least influence. Conversely, UAV is right skewed, with more producers ranking it having the least influence on their purchasing decision and very few producers ranking UAV as having the greatest influence. In Table 12 and Figure 7, the individual scores are more normally distributed, which may be due to an increased range in best-worst scores. However, GPS is left skewed, supporting its highest importance score ranking. Similarly, notification of altered behavior is left skewed, but it is not as skewed as GPS. This supports notification of altered behavioral patterns as the second most important characteristics. Crop monitoring, which was the least important characteristic is right skewed, with more producers selecting it as least preferred than most preferred. This supports its ranking as least important. Increased UAV flight time is also right skewed, however it is not as skewed as crop monitoring, and is ranked as second least important.

Chi-Square Tests

After the individual best-worst scores were calculated, Chi-square tests were conducted in order to check for correlation between a producer’s self-described likelihood of adoption and their demographic characteristics and individual best-worst scores for components and characteristics. A producer’s demographic characteristics have a stronger correlation with the self-described likelihood of adoption than the individual best-worst scores (Table 15). The number of cattle owned by a producer and how frequently a producer checks their cattle are most strongly correlated with a producer’s adoption intention. Both are significant at a 0.05 level. This, in part, supports Hypothesis 1 that likelihood of system adoption is positively related to higher education levels among producers. A producer's self-described likelihood of adoption is not related to individual best-worst scores for components and characteristics (Tables 13 and 14).

Ordinal Logit Models

Finally, utilizing the information from the simple Chi-square test three models (Equation 16, 17 and 18) were tested using likelihood ratio tests in order to determine which model best described the producers' adoption intention. The likelihood ratio tests were conducted using Equation 19. From Table 26, it can be determined that there is not enough evidence to reject the null hypothesis that the unrestricted models including best worst scores for components in addition to demographic characteristics (Equation 17) and best worst scores for characteristics in addition to demographic characteristics (Equation 18) are jointly zero. Therefore, we can conclude that the model only including demographic characteristics (Equation 16) is the best model.

The model fit statistics from Tables 17, 20 and 23 also indicated that Equation 16 is the optimal model for describing the variables influencing a producer's likelihood of adoption. This is because it has the smallest Akaike Information Criterion (AIC) and Schwarz Criterion (SC), which are indicators of model fit. The demographics only model is the best fit because both the AIC and SC take into account the number of predictors in a model. Since the both models including best-worst scores also include demographic characteristics, it is logical to expect the AIC and SC to be higher than the AIC and SC for a model only including demographic characteristics. The model fit criterion results in Tables 17, 20, and 23 are used to test the significance of all the predictors combined, and to test if the model has significance. The null hypothesis in this test is that producers' self-described likelihood of adoption is not related to the covariates. The null hypothesis is rejected in each model, thus the models do explain a significant amount of variation in to producer self-described likelihood of adoption.

The Wald Tests calculated in Table 17, 20, and 21 indicate whether the parameters of a given effect are jointly zero. For these tests the null hypothesis is that a parameter, individually, improves the model. For each model tested, the number of cattle owned, the level of education obtained by a producer, and where the producer is located all significantly improve the model fit. Again, this supports Hypothesis 1 that likelihood of system adoption is positively related to higher education levels among producers. Similarly, when the individual best-worst scores for components are introduced into the model, the individual best-worst score for price significantly improves the model. This could be because of the importance producers place on price. On the other hand, when individual best-worst scores for characteristics are included in the model, none of the characteristics improve the model fit. From Tables 20, 21, 23, and 24 only one individual best-worst score for a part of the system has an effect on the model and no individual best-worst score for any part of the system showed correlation in the Chi-square tests (Tables 14 and 15).

Therefore, given these results, Equation 16, including only demographic characteristics was used to define the producers' adoption intention. The results from the ordinal logit model, Equation 16, were used to test Hypotheses 1-3. Hypothesis 1 is that likelihood of system adoption is positively related to higher education levels among producers. Hypothesis 2 is likelihood of adoption of and electronic cattle monitoring system is positively related to frequency that producers check their cattle. Hypothesis 3 is that likelihood of adoption of an electronic cattle monitoring system is positively related to numbers of cattle in a producers operation.

Table 18, includes the parameter estimates and significance for each variable in the model. It is important to note these ordinal logistic models are cumulated over the lower ordered values. For the producer's self-described adoption intention in the dataset, 1 is defined as "very likely," 2 is defined as "likely," 3 is defined as "unlikely," and 4 is defined as "very unlikely. In each model, as could be inferred from the Wald Tests, the number of cattle owned, the level of education obtained by a producer, and where the producer is located are all statistically significant. The individual best-worst score for price was also statistically significant in the model where individual best-worst scores for components were included, and in the demographics only model, if a producer checks their cattle 2-3 times per week was significant.

The estimates in Table 18 – the optimal model including only demographic characteristics – indicate that the log odds, or the logarithm of the odds, of producers who have obtained a Ph.D., M.D., or D.V.M. describing themselves as a potential adopter are increasing. Thus, a producer who obtained a Ph.D., M.D., or D.V.M. is most likely to be an adopter of the electronic cattle monitoring system. This supports Hypothesis 1 that that likelihood of system adoption is positively related to higher education levels among producers. The log odds of a producer who frequently checks their cattle describing themselves as a likely adopter are decreasing. This indicates that producers who check their cattle once a week or less are more likely to adopt the technology. This indicates that producers who do not already closely monitor their animals place more value on the system. This does not support Hypothesis 2 that likelihood of adoption of and electronic cattle monitoring system is positively related to frequency that producers check their cattle. For producers owning cattle herds of less than 500 animals, the log odds of a producer describing themselves as favorable toward adopting are decreasing. Therefore, a producer with more than 500 head of cattle is most likely to describe themselves as a potential adopter of the technology. This supports Hypothesis 3 that likelihood of adoption of an electronic cattle monitoring system is positively related to numbers of cattle in a producers operation. Additionally, the log odds of a producer located in Oklahoma as opposed to out-of-state describing themselves as a likely adopter are decreasing. This suggests that producers in Oklahoma are less likely to adopt the technology.

In Table 19, these results can again be interpreted that producers who attended at most some college and producers obtaining a Bachelor's or Master's degree are both approximately 0.41 times less likely to be favorable to adoption than a producer with a Ph.D., M.D. or D.V.M. Again this supports Hypothesis 1. A producer located within Oklahoma is 0.674 times as likely to be in a category more favorable to adoption than a producer not in Oklahoma. A producer that checks their cattle daily is 0.629 times less likely to be favorable to adoption than a producer who checks their animals weekly or less. Similarly, a producer who checks their cattle 2 to 3 times per week is 0.594 times less likely to be favorable to adoption than a producer checking their animals weekly or less. This supports Hypothesis 2. Finally, a producer with less than 100 head of cattle is 0.216 times less likely to be favorable toward adoption than a producer with more than 500 head of cattle. Similarly, if a producer owns 101-500 head of cattle they are 0.488 times less likely to be in category of favorability toward adoption than a producer owning more than 500 head of cattle. It can be inferred that producers in group owning more than 500 head of cattle are most likely to adopt the technology. This indicates that the largest producers in the industry are most likely to adopt the system, and it supports Hypothesis 3.

Desirability of Characteristics and Components

Objectives 2, 3 and 4 of this research relate to which electronic cattle monitoring characteristics and components are most desired by producers and how producer characteristics influence desirability. These objectives are to determine (2) whether producer utility for individual characteristics are related to enterprise, management and producer demographics; (3) producers' willingness to pay for individual system components and characteristics; and (4) the most desired system components and characteristics.

Conditional Logit Models

In order to achieve Objectives 2 and 3, conditional logit models (Equations 4 and 5) were estimated using data from the choice experiment portion of the survey. Results of the initial conditional logit model (Equation 4) are outlined in Table 5. From this model it is determined that both the price coefficient for the RFID rumen bolus and the UAV are negative and significant at the 0.01 level, thus indicating a downward sloping demand curve. As the price for the RFID rumen bolus increases by $10, ceteris paribus, the utility for the electronic monitoring system decreases by 13%, and as the price for UAV increase by $1,000, ceteris paribus, the utility for the system decreases by 22.5% (See Table 5). The estimate for non-purchase is positive, significant and has the largest utility, thus indicating that many producers would choose not to purchase an electronic monitoring system in a true market environment. This is also supported by Figure 2, where 59.17% of producers classify themselves as "Unlikely" or "Very Unlikely" to adopt an electronic cattle monitoring system and Figure 3 where 64.78% of the time the no purchase option was chosen by producers. This means that some producers will choose to not purchase or adopt an electronic cattle monitoring system regardless of the components and characteristics included within the system.

On the other hand, added privacy safeguards, compatibility with cattle management software, and live video feed all positively and significantly influence demand and thus are influential in a producer's decision to purchase the electronic cattle monitoring technology. Crop monitoring technology has a small, positive influence on utility; however this effect is not significant. Inclusion of live video feed in the system increases system utility by 39.62%, ceteris paribus. Added privacy safeguards as a system component increases utility by 30.5%, and compatibility with cattle management software as a system component causes utility to increase by 26.18% (See Table 5).

Interaction terms were added to Equation 4 in order to gauge how demographics influence the demand for privacy, crop monitoring, and compatibility and achieve Objective 2. This allowed for the examination of which producers were more likely to utility individual system characteristics. As seen in Table 6, a producer growing crops in addition to raising cattle had a significant, positive effect on the demand for crop monitoring technology. If the producer grows crops, the utility for crop monitoring technology increases by 53.52%. This supports Hypothesis 4 that utility for crop monitoring technology as part of an electronic cattle monitoring system will be greater for producers who grow crops in addition to raising cattle. Finally, the percentage of a producer's herd that is purebred does not significantly affect utility for compatibility with cattle management software (See Table 6). Thus, Hypothesis 5 is not supported, and producers with higher purebred percentages in their herds do not necessarily have a higher utility for compatibility with cattle management software than producers who have lower purebred percentages. Age had a significant, negative effect on utility when interacted with privacy safeguards. This indicates that as a producer's age increases the utility for privacy safeguards decreases by 2.33%, which does not support Hypothesis 6. Therefore, younger producers are more concerned about privacy. The desire for privacy among younger producers could relate to their increased experience with technology and their familiarization with computer and internet safety programs.

Willingness to Pay Estimates

In order to achieve Objective 3, the willingness to pay for system characteristics and the base price and price effects for RFID bolus and UAV were obtained using parameter estimates from Equation 4. The base price for an RFID bolus and UAV was calculated using Equation 7. This calculation yields an approximation of the maximum amount a producer is willing to pay for a system that only include the base bolus and UAV with no additional components. As shown in Tables 7 and 8, the most a producer is willing to pay for the base price of a bolus is $46.71. The most a producer is willing to pay for the base price of a UAV is $2,699.56. These numbers account for the utility of all system characteristics minus the utility for the no purchase option. Thus, while this is a practical manner in which to calculate the base price, it may not be a true reflection of what a producer would be willing to pay for the system in the marketplace. This is because there is a negative price effect between UAV price and bolus price.

Using estimates from Table 5, the effect that the bolus and UAV prices have on each other can be determined. As the UAV price increases by $1,000, producers are willing to pay $2.00 less for the bolus, and as the bolus price increase by $10, producers are willing to pay $577.80 less for a UAV. Thus, as one price increases, the maximum a producer would be willing to pay for the other system component decreases (See Tables 7 and 8). This indicates that when purchasing a system a producer considers both the UAV and bolus prices. If the base price of either the bolus or UAV increases the producer will be willing to pay less for the other component.

Using the conditional logit estimates from Table 5, willingness to pay for individual system components was calculated. As shown in Tables 7 and 8, producers are willing to pay the highest premium for live video feed included in the system. This supports Hypothesis 7 that producers' willingness to pay is greatest for the live video feed component of an electronic monitoring system. A producer is willing to pay up to a $30.48 premium, in addition to the base price, for a bolus and up to a $1,760.89 premium, in addition to the base price, for a UAV if live video feed is included in the electronic monitoring system. The producer is willing to pay up to a $23.46 premium, in addition to the base price, for a bolus and up to a $1,355.56 premium, in addition to the base price, for a UAV if added privacy safeguards are included in the system. A producer is willing to pay up to a $20.14 premium, in addition to the base price, for a bolus and up to a $1,163.56 premium, in addition to the base price, for a UAV if the system includes compatibility with cattle management software. The producer is willing to pay the lowest premium, in addition to the base price, for crop monitoring technology at up to $4.35 for the bolus and up to $251.11 for a UAV.

Best-Worst Analysis

In order to accomplish Specific Objective 4, overall best-worst importance scores for electronic cattle monitoring system components and characteristics were calculated with conditional logit models. Parameter estimates from Table 9 and Table 10 were used in the conditional logit models shown in Equations 11 and 12, respectively. Price was overwhelmingly the most important component influencing a producer's purchase decision, with an importance score of 51.04% (Figure 4 and Table 9). Price is more than three times more important to producers than any other component of the system. RFID ear tags were the second most important component, ranking nearly 9% higher on the importance scale than RFID rumen bolus. This could be because producers view placing ear tags on their animals as an easier process than inserting a bolus into the animal's rumen. Also notable, producers ranked UAV as the least important system component. This contradicts Hypothesis 8 that producers will rank electronic monitoring system components that allow them to monitor their animals' health and location – RFID rumen bolus and UAV – at the top of the producer important score scale. RFID rumen bolus, which would allow for temperature collection, and UAV, which could track animals' locations, track movements, and provide visual images of the animal, are have the two lowest important scores among system components. This is in spite of the fact that they are necessary for health and location monitoring. Even though the connection between these components and their functionality was presented in the questionnaire, when ranking components producers may not have fully understood the importance RFID rumen boluses and UAVs have to animal location and health monitoring.

Among the electronic cattle monitoring characteristics importance scores, animal GPS location and notification of altered behavior are the top two electronic cattle monitoring system characteristics (Table 10). It would be extremely difficult to provide the producer with GPS and behavioral data without the use of a UAV. Therefore, producers are very interested in having health and well-being statistics, yet many do not have a preference for the tools which are required to obtain this information. Even though the questionnaire included information about how the characteristics and components worked in order to provide producers with information about their herd, survey respondents may not have completely understood the relationship between components and characteristics. Also, the low ranking could be related to negative UAV coverage in the media, aversion to adopting a new technology or inexperience with UAVs.

Animal GPS location and notification of altered behavioral patterns are ranked as the most important characteristics, and live video feed and rumen temperature collection fall in the middle of the importance score rankings (Figure 5 and Table 10). Live video feed and rumen temperature are more than four times less importance than GPS. The moderate importance score of live video feed is contradictory to the choice experiment results, where it most highly influenced demand and had the highest willingness to pay estimates. With GPS and notification of altered behavioral patterns as the most highly important characteristics and live video feed and rumen temperature collection only moderately ranked, Hypothesis 9 is only partially supported. Only two of the four characteristics that can be used to monitor animal health and location are highly important to producers. With GPS and behavioral monitoring closely related, it is logical that they are ranked as the two top characteristics, while the relationship between rumen temperature collection and the extremely low component importance score ranking of RFID rumen bolus could explain a moderate scoring of the importance of rumen temperature collection.

Privacy safeguards are the third most important characteristic. This could relate to the negative influence age has on the demand for privacy safeguards as found in Table 6. Because the average age of survey respondents is 54.02 – younger than the national average – it could explain this high desire for privacy. Again, similarly to the results found in the choice experiment, crop monitoring is the least important characteristic in the system, and increased UAV flight time ranks very lowly on the importance scale (Table 10). This correlates with the low importance of UAVs found in the components importance score rankings.

CHAPTER V

SUMMARY AND CONCLUSIONS

Monitoring cattle health and well-being is one of the most time-consuming, yet imperative tasks for cattle producers. Producers spend many hours checking their animals to ensure all are in their proper location and healthy. Yet, when an animal is found to be missing or ill, it is vital that a producer act rapidly to locate and/or treat the animal. Much of the producer's time could be saved and efficiently used. Access to a system would save time and potentially improve the frequency and quality of cattle monitoring and treatment of health issues. An electronic monitoring system incorporating the use of remote frequency identification (RFID) rumen boluses or ear tags, pasture data collection stations located near water and feed sources, a UAV and a software user interface could enhance the producer's ability to quickly locate sick or cattle or recognize if cattle are stolen (Figure 1).

However, before the electronic cattle monitoring system can be fully developed, it is important to understand the producers' willingness to adopt the system and the producers' preferences for system characteristics and components. The overall objective of this research was to determine the conditions that would influence electronic cattle monitoring system adoption by cattle producers. The specific research objectives are to determine (1) how enterprise, management and producer demographics are related to producers' willingness to adopt the system; (2) how enterprise, management and producer demographics affect producer utility for individual system characteristics; (3) producers' willingness to pay for individual system characteristics; and (4) the most desired system components and characteristics.

The results of a survey of cattle producers who actively seek progressive information about the cattle industry from the Samuel Roberts Noble Foundation and the Oklahoma Beef Council provided a better understanding of producers' desires for an electronic cattle monitoring system. The results of this research show that the majority of producers, 59.16%, describe themselves as unlikely adopters within the next five years. However, most producers' opinions were not polarized regarding adoption, thus it could mean that if they were able to see the value of the system, they would potentially consider adoption.

Characteristics of Likely Adopters

It is important to understand the characteristics of producers who describe themselves as likely adopters in order to determine which producer groups would be most likely to purchase the system. Results for each objective of the study are summarized in Table 27. Objective 1 of the study was to determine how enterprise, management and producer demographics are related to producers' willingness to adopt the system demographic characteristics and individual best-worst scores. In order to achieve this objective data from the questionnaire pertaining to producer, enterprise and management demographics, self-described likelihood of adoption, and individual best worst scores calculated using producer responses to the best-worst questions were analyzed. This data was then used to develop three ordinal logit models – producer self-described likelihood of adoption modeled against demographics only; best worst scores for system components and demographics; and best worst scores for system characteristics and demographics, respectively. The p-values from the ordinal logit models and the results of chi-square test suggest that personal, enterprise, and management characteristics best describe a producer's self-described adoption intention. These tests indicate that a producers' self-described adoption intention is not highly correlated to the inherent value producers place on individual system components and characteristics. Producer's self-described likelihood of adoption was related to the best-worst score for price. The individual best-worst score values are limited by the maximum and minimum number of times a producer could choose an item as best or worst, respectively.

The likelihood ratio test of the three ordinal logit models suggest that the model containing only the demographic characteristics (Equation 16) best explains producer self-described adoption intention. Models containing either individual best-worst scores for components or best-worst scores for characteristics did not improve the ability to explain self-reported likelihood of adoption. The results of the ordinal model were used to test Hypotheses 1-3. Hypothesis 1 was that likelihood of system adoption is positively related to higher education levels among producers. The results of the ordinal logit model support this and indicate that producers with advanced degrees (Ph.D., M.D. or D.V.M) are most willing to adopt the system (Table 27). Hypothesis 2 was likelihood of adoption of and electronic cattle monitoring system is positively related to frequency that producers check their cattle. The results of the ordinal logit model do not support this hypothesis. Alternatively, producers who check their cattle weekly or less are most likely to adopt the system (Table 27). This may be because these producers are not able to monitor their animals as frequently as they would like to, and thus they see great value in the ability to monitor their animals more closely. Finally, Hypothesis 3 was that likelihood of adoption of an electronic cattle monitoring system is positively related to numbers of cattle in a producers operation. The results of the ordinal logit model support this hypothesis. Producers with the largest herds, greater than 500 head of cattle, are most likely to adopt the system (Table 27).

The results of this research indicate that the larger than average, college educated producers who may not have the opportunity to regularly monitor monitoring each individual animal find the most value in the system. As the electronic cattle monitoring system goes toward market these producers should be the target customers.

Desirability of Characteristics and Components

It is important to understand which components and characteristics are desired by producers. Full results of the study are presented in Table 27. Objective 2 was to determine how enterprise, management and producer demographics affect producer utility for individual system characteristics. In order to achieve this objective, the choice experiment data from the survey was analyzed with conditional logit models. Demographic characteristic interaction terms were included as independent variables in the conditional logit model (Equation 5) in order to determine how the demographic characteristics influenced demand for system characteristics, the dependent variable, and to test Hypotheses 4-6. Hypothesis 4 was that utility for crop monitoring technology as part of an electronic cattle monitoring system will be greater for producers who grow crops in addition to raising cattle. The conditional logit model indicates that producers who grow crops in addition to raising cattle will have a higher utility for crop monitoring technology as a characteristic of an electronic monitoring system. This supports Hypothesis 4 (Table 27). Hypothesis 5 was that utility for compatibility with cattle monitoring software (e.g. CattleMax, Cattleworks, and CattlePro) as part of an electronic cattle monitoring system will be positively related to the percentage of purebred cattle in a herd. Contradictory to Hypothesis 5, the results of the conditional logit model indicate that as the percentage of purebred cattle in a herd increases, a producer’s utility for compatibility of an electronic cattle monitoring system with cattle monitoring software (e.g. CattleMax, Cattleworks, and CattlePro) decreases. However, purebred percentage of a herd does not have a significant effect on a producer's demand for compatibility with cattle monitoring software (Table 27). Hypothesis 6 was that utility for privacy safeguards as part of an electronic cattle monitoring system is positively related to producer’s age. The results from the model contradict Hypothesis 6 indicating that as producer age increases a producer's utility for an electronic monitoring system with added privacy safeguards decreases (Table 27). This may suggest that older producers are not as accustomed to privacy protection components of technologies such as antivirus or malware protection in computers and cell phones as are younger producers.

Objective 3 was to determine producers' willingness to pay for individual system characteristics. In order to achieve Objective 3, producers' willingness to pay for individual system characteristics was calculated using the conditional logit estimates for system characteristics and UAV and RFID rumen bolus prices obtained from the choice experiment data. Hypothesis 7 was that producers' willingness to pay is greatest for the live video feed component of an electronic monitoring system. Willingness to pay estimates indicate that producers are willing to pay the most for the live video feed component of an electronic monitoring system. This supports Hypothesis 7 and indicates that producers are willing to pay the most for characteristics of the system that allow them to monitor their animals' health and location (Table 27). Notably, the prices for UAV and RFID rumen bolus have a negative effect on each other. Thus, as the price of one of the components increases, producers are willing to pay less for the other component.

Importance scores for electronic cattle monitoring system characteristics and components, respectively, were calculated using conditional logit estimates for the best-worst question data. Importance scores were used to achieve Objective 4, which was to determine the most desired system components and characteristics. Hypothesis 8 was that producers will rank electronic monitoring system components that allow them to monitor their animals' health and location – RFID rumen bolus and UAV – at the top of the producer important score scale. The importance scores indicate that producers consider price as the system component having the greatest effect on their purchase decision, while UAV is the system component having the least impact on their purchase decision. This does not support Hypothesis 8 (Table 27). Even though the connection between the components and their respective capabilities was thoroughly explained in the questionnaire, the argument could be made that producers did not fully grasp the connection.

Hypothesis 9 was that producers will rank the electronic monitoring system characteristics that allow them to monitor their animals' health and location – GPS, notification of altered behavioral patterns, live video, and rumen temperature –will rank at the top of the producer important score scale. The importance scores do not completely support Hypothesis 9 (Table 27). Producers placed the most importance on GPS animal location monitoring and notification of altered behavioral patterns characteristics, while live video feed and rumen temperature are in the middle of the importance score scale. Again, producers may not have fully understood the connection between system components and characteristics. Overall, this suggests that producers are not necessarily concerned with if a UAV is included in the system as long as the system is able to affordably provide them with useful animal health information. This may be because of the lack of familiarity with UAVs and UAV systems.

Further Research Ideas and Final Conclusions

The results of this study enables product developers to better understand the wants and needs of cattle producers in regards to electronic monitoring technologies. Further research could be done to better understand the relationship between current technology usage and producers' likelihood of adoption of electronic cattle monitoring technologies. Also, it would be of interest to determine if there was a correlation between off-farm employment and likelihood of adoption. Furthermore, it could be tested if weighting the individual best-worst scores could result in a higher correlation between these scores and the self-described likelihood of adoption. This study could be recreated among a larger national or even international sample to better understand the wants of the entire population of cattle producers. An international sample would allow it to be tested if markets in Australia or South America are more receptive to the initial technology.

Overall, the results of the research indicate producers are interested in an electronic monitoring that is affordable and enables them to monitor their animals' well-being. Producers place a low importance on UAVs as a system component. Thus, producers are not highly concerned with the method allowing them to collect animal location and health statistics, as long as they are able to collect the desired information. Producers who are highly educated, producers how own large numbers of cattle, and producers who do not frequently check their cattle have the highest likelihood of adoption. An electronic monitoring system allows producers to more closely monitor their animals in a timely manner. Therefore, when creating an electronic cattle monitoring system, it is most important to provide producers with the ability to check their cattle's location and behavior, and producers are willing to pay the most for system characteristics that allow them to do this. Furthermore, initial marketing efforts should be directed toward large operations and producers with higher levels of education.

REFERENCES

Adamowicz, W., R. Boxall, M. Williams, J. Louviere. 1998. “Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation.” *American Journal of Agricultural Economics* 80: 64-75.

Association for Unmanned Vehicle Systems International. 2013. The Economic Impact of Unmanned Aircraft Systems Integration in the United States. Arlington, VA, March.

Auger, P., T.M. Devinney and J.J. Louviere. 2007. “Using Best-Worst Scaling Methodology to Investigate Consumer Ethical Beliefs Across Countries.” *Journal of Business Ethics* 70: 299-326.

Barr, A. 2013. "Amazon testing delivery by drone, CEO Bezos says." *USA Today*, December. Internet site: http://www.usatoday.com/story/tech/2013/12/01/amazon-bezos-drone-delivery/3799021 (accessed February 20, 2014).

Beggs S., Cardell S., and Hausman J. 1981. “Assessing the Potential Demand for Electric Cars.” *Journal of Econometrics* 17:1–19.

Bradley, R.A. and M.E .Terry. 1952. “Rank Analysis of Incomplete Block Designs: I. The Method of Paired Comparisons.” *Biometrika* 39: 324-345.

CattleMax. 2014. “Cattle software – Record Keeping Made Easy by CattleMax – CattleMax.” CattleSoft, Inc. Internet site: http://www.cattlemax.com/ (accessed September 24, 2014).

CattlePro. 2010. “CattlePro.com | Beef Cattle Records Management and Performance Analysis Software.” Global Livestock Management Systems LLC. Internet Site: http://www.cattlepro.com/ (accessed September 24, 2014).

Cattleworks. 2014. “Cattleworks – “Keeping Track” is our business.” Cattleworks, LLC. Internet Site: http://www.cattleworks.com/ (accessed September 24, 2014).

Chang, J.B., J.L. Lusk, and F.B. Norwood. 2009. “How Closely do Hypothetical Surveys and Laboratory Experiments Predict Field Behavior?” *American Journal of Agricultural Economics* 91: 518-534.

Clayton, C. 2013. “New Eyes In The Sky.” *The Progressive Farmer*, August. Internet site: http://dtnpf-digital.com/article/New_Eyes_In_The_Sky/1566918/185130/article.html.

Cohen, E. 2009. "Applying best-worst scaling to wine marketing." *International Journal of Wine Business Research* 21: 8-21.

Cohen, S. and B. Orme. 2004. "What's your preference?." *Marketing Research* 16: 32-7.

Derr, B. 2013. "Ordinal Response Modeling with the LOGISTIC Procedure." *SAS Global Forum 2013 Statistics and Data Analysis.*

Doering, C. 2014. "Growing use of drones poised to transform agriculture." *USA Today*, March. Internet site: http://www.usatoday.com/story/money/business/2014/03/23/drones-agriculture-growth/6665561/ (accessed May 21, 2014).

Dorfman, J.H. 1996. "Modeling Multiple Adoption Decisions a Joint Framework." *American Journal of Agricultural Economics* 78: 547-557.

Feder, G. 1982. "Adoption of Interrelated Agricultural Innovations: Complementarity and the Impacts of Risk, Scale, and Credit." *American Journal of Agricultural Economics* 64: 94-101.

Finn, A. and J.J. Louviere. 1992. "Determining the Appropriate Response to Evidence of Public Concern: The Case of Food Safety." *Journal of Public Policy & Marketing* 11(2):12-25.

Gillespie, J., S.A. Kim, and K. Paudel. 2007. "Why don't producers adopt best management practices? An analysis of the beef cattle industry." *Agricultural Economics* 36: 89-102.

Greene, W.H. 2003. *Econometric Analysis*, 5th Edition. Prentice Hall, Upper Saddle River, NJ.

Grimsley, J.L., D.S. Tilley, J. Jacob, C. Richards, M.S. Calvo-Lorenzo, S. Griggs, and L.D. Allmon. 2013. "Design Intelligence Incorporated, LLC USDA SBIR Grant Proposal." Unpublished, Oklahoma State University.

Hoffman, S.D. and G.J. Duncan. 1988. "Multinomial and Conditional Logit Discrete-Choice Models in Demography." *Demography* 25(3): 415-427.

Jayne, T.S., L. Rubey, F. Lupi, D. Tschirley and M.T. Weber. 1996. "Estimating Consumer Response to Food Market Reform Using Stated Preference Data: Evidence from Eastern and Southern Africa." *American Journal of Agricultural Economics* 78: 820-24.

Johnson, R.J., D. Doye, D.L. Lalman, D.S. Peel, K.C. Raper, and C. Chung. 2008. "Operational Characteristics and Management Practice Adoption in Stocker Cattle Production." Unpublished, Oklahoma State University.

Judge, G.G., R.C. Hill, W.E. Griffiths, H. Lütkepohl, and T.C. Lee. 1988. *Introduction to the Theory and Practice of Econometrics*, 2nd Edition. John Wiley & Sons, Inc., New York, NY.

Killman, C. 2013. "Cattle ranchers report rustling at all-time high." Tulsa World, November. Internet site: http://www.tulsaworld.com/news/cattle-ranchers-report-rustling-at-all-time-high/article_0bcecc3f-3128-5202-ba5f-db51f5f10b52.html (accessed May 28, 2014).

Kuhfeld, W.F. 2005. "Experimental design, efficiency, coding, and choice designs." *Marketing research methods in SAS: Experimental design, choice, conjoint, and graphical techniques*: 47-97.

Kuhfeld, W.F., R.D. Tobias and M. Garratt. 1994. "Efficient Experimental Design with Marketing Research Applications." *Journal of Marketing Research* 74: 545-557.

Kwong, K.H., T.T. Wu, H.G. Goh, B. Stephen, M. Gilroy , C. Michie, and I. Andonovic. 2009. "Wireless Sensor Networks in Agriculture: Cattle Monitoring for Farming Industries." *PIERS Online* 5(1): 31-35.

Louviere, J.J. 1991."Experimental Choice Analysis: Introduction and Overview." *Journal of Business Research* 23:291-297.

Lusk, J.L. 2011. "External validity of the food values scale." *Food Quality and Preference* 22:452-465.

Lusk, J.L., J. Roosen, and J.A Fox. 2003. "Demand for Beef from Cattle Administered Growth Hormones or Fed Genetically Modified Corn: A Comparison of Consumers in France, Germany, the United Kingdom, and the United States." *American Journal of Agricultural Economics* 85(1):16-29.

Marley, A.A and J.J. Louviere. 2005. " Some probabilistic models of best, worst, and best–worst choices." *Journal of Mathematical Psychology* 49(6): 464-480.

Marra, M., D.J. Pannell, and A.A. Ghadimb. 2003. "The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?" *Agricultural Systems* 75(2): 215-234.

Mooi, E. and M. Sarstedt. 2011. "Chapter 9: Cluster Analysis." In *A Concise Guide to Market Research The Process Data, and Methods Using IBM SPSS Statistics.* Springer-Verlag Berlin Heidelberg, pp. 237-284.

Nagel, L., R. Schmitz, S. Warren, T.S. Hildreth, H. Erickson, and D. Andresen. 2003. "Wearable sensor system for wireless state-of-health determination in cattle." Paper presented at the 25th Annual International Conference of the IEEE EMBS, Cancun Mexico, 17-25 September.

Nickels, T. 2013. "The Orwellian Age Is Here." *Huffington Post*, March. Internet site: http://www.huffingtonpost.com/thom-nickels/the-orwellian-age-is-here_b_2830483.html.

Peel, D.S. 2014. "Record feeder prices supported by latest data." Drovers Cattle Network, May. Internet site: http://www.cattlenetwork.com/cattle-news/Record-feeder-prices-supported-by-latest-data-259806051.html?source=related (accessed May 28, 2014).

Pearce, M. 2014. "Colorado town declares open season on drones." *Los Angeles Times*, January. Internet site: http://www.latimes.com/nation/la-na-c1-colorado-drones-20140116-dto,0,3033130.htmlstory#axzz2rwbbOvDA (accessed February 20, 2014).

Poulsen, R. 2013. “Multivariate Statistical Analysis in SAS: Segmentation and Classification of Behavioral Data.” *SAS Global Forum 2013 Statistics and Data Analysis.*

Pruitt, J.R., J.M. Gillespie, R.F. Nehring, and B. Qushim. 2012. “Adoption of Technology, Management Practices, and Production Systems by U.S. Beef Cow-Calf Producers.” *Journal of Agricultural and Applied Economics* 44(2): 203-222.

Rogers, E.M. 1976. “New Product Adoption and Diffusion.” *Journal of Consumer Research* 2(4):290-301.

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

Ryan, B. and N.C. Gross 1943. "The Diffusion of Hybrid Seed Corn in Two Iowa Communities," *Rural Sociology* 8: 15-24.

Schultz, L. L. and G.T. Tonsor. 2010. “Cow-Calf Producer Perceptions Regarding Individual Animal Traceability.” *Journal of Agricultural and Applied Economics* 42(5): 659–677.

Schumacker, R. and S. Tomek. 2013. " *Understanding Statistics Using R*. Springer Science and Business Media, New York, NY.

Taylor, S. and P. Todd. 1995. “Decomposition and crossover effects in the theory of planned behavior: A study of consumer adoption intentions.” *International Journal of Research in Marketing* 12: 137-155.

Thomson, D.U. and B.J. White. 2006. "Backgrounding Beef Cattle." *Veterinary Clinics of North America: Food Animal Practice* 22: 373-398.

Tornatzky, L.G. and K.J. Klein. 1982. “Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings.” *IEEE Transactions on Engineering Management* 29(1): 28-45.

Trigden, K.A. 2014. “Agricultural Drones Need New Regulations to Take Off.” Iowa State University Center for Agricultural Law and Taxation, July. Internet site: http://www.calt.iastate.edu/article/agricultural-drones-need-new-regulations-take (accessed August 25, 2014).

Trotter, M.G., D.W. Lamb, G.N. Hinch, and C.N. Guppy. 2010. “Global navigation satellite system livestock tracking: system development and data interpretation.” *Animal Production Science* 50: 616-623.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2014. 2012 Census of Agriculture. USDA NASS, Washington DC, May.

Waller, J.L. and M.H. Johnson. 2013. “Chi-Square and T-Tests Using SAS®: Performance and Interpretation.” *SAS Global Forum 2013 Statistics and Data Analysis.*

Ward, C., M.K. Vestal, D.G. Doye, and D.L. Lalman. 2008. "Factors Affecting Adoption of Cow-Calf Production Practices in Oklahoma." *Journal of Agricultural and Applied Economics* 40(3): 851-863.

Weller, S.W. and A.K. Romney. 1988. *Systematic Data Collection*. Sage, Newbury Park, CA.

Wessler, B. 2013. "2013 brings record number of cattle thefts in Oklahoma." Drovers Cattle Network, November. Internet site: http://www.cattlenetwork.com/cattle-resources/hot-topics/livestock-theft/2013-brings-record-number-of-cattle-thefts-in-Oklahoma-232387701.html (accessed May 28, 2014).

Wessler, B. 2014. "Drones technology a few steps away from farm application." Drovers Cattle Network. January. Internet site: http://www.cattlenetwork.com/e-newsletters/drovers-daily/Drones-technology-a-few-steps-away-from-farm-application-239970721.html?utm_source=9908C5509689A2S&utm_medium=eNL&utm_campaign=Drovers+CattleNe (accessed February 18, 2014).

Wolfgang, B. 2012. "High anxiety on the Hill about civilian drone use." *The Washington Times*, July. Internet site: http://www.washingtontimes.com/news/2012/jul/19/high-anxiety-on-the-hill-about-civilian-drone-use/?page=all.

Wozniak, G.D. 1993. "Joint Information Acquisition and New Technology Adoption: Late Versus Early Adoption." *The Review of Economics and Statistics* 75(3): 438-445.

TABLES

Table Page

Table 1. Attributes and Attribute Levels Used in Survey Choice Questions

Attribute	Levels
Privacy safeguards	Included in system; Not included in system
Compatibility with cattle management software	Included in system; Not included in system
Crop monitoring technology	Included in system; Not included in system
Live video feed	Included in system; Not included in system
UAV price	$3,000; $8,000
RFID rumen bolus price	$10; $45

Table 2. Producer Characteristics of Survey Participants

Variable	Definition	Sample[1]	Ag Census[2]
		(%)	*(%)*
Gender	Male	85.34	86.33
Income1	Household income <$20,000	2.36	-
Income2	Household income $20,000 - $39,000	5.76	-
Income3	Household income $40,000 - $59,000	12.30	-
Income4	Household income $60,000 - $79,000	15.71	-
Income5	Household income $80,000 - $89,000	16.49	-
Income6	Household income $90,000 - $199,000	30.89	-
Income7	Household income <$200,000	12.30	-
Income8	No income revealed	4.19	-
High School	Obtained high school diploma or less	7.07	-
College	Attended college	20.68	-
Bachelors	Obtained Bachelor's Degree	41.36	-
Masters	Obtained Master's Degree	19.90	-
PhD	Obtained Ph.D.	5.76	-
DVM	Obtained D.V.M.	2.88	-
MD	Obtained M.D., D.O., or D.D.	2.36	-
Oklahoma	Located in Oklahoma	63.09	-
Texas	Located in Texas	25.39	-
Other State	Not in Oklahoma or Texas	11.52	-
		(years)	*(years)*
Age	Producer age in years	54.02	58.30
IYears	Years producer involved in industry	29.78	25.00

[1]Number of observations is 382

[2](U.S. Department of Agriculture, National Agricultural Statistics Service 2014)

Table 3. Enterprise Characteristics of Survey Participants

Variable	Definition	Sample[1]	Ag Census[2]
		(%)	*(%)*
Purebred	Percentage of herd that is purebred	26.90	-
Cattle1	<50 head	45.91	69.78
Cattle2	51-100 head	18.32	12.96
Cattle3	101-500 head	27.23	14.19
Cattle4	501-1000 head	5.50	1.91
Cattle5	>1,000 head	3.14	1.15
Cow Calf	Cow-calf operation	88.48	-
Stocker	Stocker operation	9.95	-
Feedlot	Feedlot operation	1.57	-
Wheat	Produces wheat in addition to cattle	23.04	-
Corn	Produces corn in addition to cattle	1.83	-
Soybeans	Produces soybeans in addition to cattle	2.88	-
Canola	Produces canola in addition to cattle	1.57	-
Cotton	Produces cotton in addition to cattle	0.52	-
Daily	Checks cattle daily	47.91	-
2-3 Week	Checks cattle 2-3 times per week	39.01	-
Weekly	Checks cattle weekly	11.52	-
Bi-weekly	Checks cattle bi-weekly	0.79	-
Monthly	Checks cattle monthly or less	0.78	-

[1]Number of observations is 382

[2](U.S. Department of Agriculture, National Agricultural Statistics Service 2014)

Table 4. Management Characteristics of Survey Participants

Variable	Definition	Sample[1]
		(%)
Count	Manually count cattle for cattle ID	80.10
Number Tags	Use numbered ear tags for cattle ID	87.67
Passive Tags	Use passive ear tags for cattle ID	4.19
Active Tags	Use active ear tags for cattle ID	0.79
Hot Brand	Use hot brands for cattle ID	55.50
Freeze Brand	Use freeze brands for cattle ID	8.38
Electronic Bolus	Use electronic bolus for cattle ID	0.26
Rotate Graze	Rotation graze pasture management	87.96
Intro Pasture	Introduce grasses into pasture	40.57
Soil Test	Use soil testing for pasture management	69.37
Stock Growth	Stockpile fall growth for winter	54.97
Prescribed Burn	Prescribed burns for pasture management	26.96
Other MGMT	Use other pasture management	32.46
No MGMT	Do not manage pastures	3.40
Use Crop Monit	Use UAV for crop monitoring	0.00
Other Crop Monit	Friend uses UAV crop monitoring	4.19

[1]Number of observations is 382

Table 5. Choice Experiment Parameter Estimates

Variable	Definition	Estimate	Error	t-value	p-value
None	No purchase option	0.4121***	0.1172	3.52	0.0004
Privacy	Added privacy safeguards	0.3050***	0.0753	4.05	<0.0001
Compatibility	Compatibility with cattle management software	0.2618***	0.0807	3.24	0.0012
Crops	Crop monitoring technology	0.0565	0.0735	0.77	0.4424
Live	Live video feed	0.3962***	0.0721	5.50	<0.0001
UAV Price	RFID rumen bolus price	-0.000225***	0.0000197	-11.41	<0.0001
Bolus Price	Unmanned aerial vehicle price	-0.0130***	0.002645	-4.92	<0.0001

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.
The estimates were obtained using the conditional logit model $U_{ij} = V_{ij} + \varepsilon_{ij}$, here U_{ij} is individuals i's non-price utility for choosing electronic cattle monitoring system option j. The deterministic term V_{ij} is the systematic portion of the utility function determined by the electronic cattle monitoring system attributes and their values $V_{ij} = \alpha_1 NONE + \alpha_2 PRIVACY + \alpha_3 LIVE + \alpha_4 CROPS + \alpha_5 COMP + \alpha_6 BOLUSPRICE + \alpha_7 UAVPRICE$

Table 6. Choice Experiment Parameter Estimates with Interaction Terms

Variable	Definition	Estimate	Error	t-value	p-value
None	No purchase option	0.4075***	0.11178	3.46	0.0005
Privacy	Added privacy safeguards	1.5459***	0.2235	6.92	<0.0001
Privacy&Age	The effect of age on added privacy safeguards	-0.0233***	0.004015	-5.81	<0.0001
Compatibility	Compatibility with cattle management software	0.2998***	0.0900	3.33	0.0009
Comp&PureBred	The effect of purebred % on compatibility	-0.001060	0.00149	-0.71	0.4769
Crops	Crop monitoring technology	-0.1116	0.0838	-1.33	0.1831
Crops&Grow	The effect of growing crops on crop monitoring	0.5352***	0.1160	4.61	<0.0001
Live	Live video feed	0.4027***	0.0725	5.55	<0.0001
UAV Price	RFID rumen bolus price	-0.000226***	0.0000198	-11.43	<0.0001
Bolus Price	Unmanned aerial vehicle price	-0.0133***	0.002655	-5.01	<0.0001

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.
The estimates were obtained using the conditional logit model $U_{ij} = V_{ij} + \varepsilon_{ij}$, here U_{ij} is individuals i's non-price utility for choosing electronic cattle monitoring system option j. The deterministic term V_{ij} is the systematic portion of the utility function determined by the electronic cattle monitoring system attributes and their values $V_{ij} = \alpha_1 PRIVACY + \alpha_2 PRIVACY * AGE + \alpha_3 LIVE + \alpha_4 CROPS + \alpha_5 CROPS * GROW + \alpha_6 COMP + \alpha_7 COMP * PUREBRED + \alpha_8 BOLUSPRICE + \alpha_9 UAVPRICE$

Table 7. Willingness to Pay (WTP) with Respect to Per Cow Bolus Price

Premium	WTP
	($)
Base price for bolus	46.71
Premium for added privacy safeguards	23.46
Premium for compatibility with cattle management software	20.14
Premium for crop monitoring technology	4.35
Premium for live video feed	30.48
Effect on UAV price	-0.02

Willingness to pay estimates are calculated using Equation 6: $WTP_{Characteristic_i} = \frac{-\beta_{Characteristic_i}}{\beta_{Price_j}}$; Equation 7: $WTP_{Base_i} = \frac{-\sum_{i=1}^{C}\beta_{C_i} - \beta_{None_i}}{\beta_{Price_j}}$, where C_i is the characteristic of the electronic cattle monitoring system, $None_i$ is the utility for the no purchase option, and $Price_j$ is the price of either the bolus or the UAV; and demand estimates from Table 5.

Table 8. Willingness to Pay (WTP) with Respect to UAV Price

Premium	WTP
	($)
Base price for UAV	2699.56
Premium for added privacy safeguards	1355.56
Premium for compatibility with cattle management software	1163.56
Premium for crop monitoring technology	251.11
Premium for live video feed	1760.89
Effect on per cow RFID rumen bolus price	-57.78

Willingness to pay estimates are calculated using Equation 6: $WTP_{Characteristic_i} = \frac{-\beta_{Characteristic_i}}{\beta_{Price_j}}$; Equation 7: $WTP_{Base_i} = \frac{-\sum_{i=1}^{C}\beta_{C_i} - \beta_{None_i}}{\beta_{Price_j}}$, where C_i is the characteristic of the electronic cattle monitoring system, $None_i$ is the utility for the no purchase option, and $Price_j$ is the price of either the bolus or the UAV; and demand estimates from Table 5.

Table 9. Component Relative Importance Scores

Variable	Definition	Score *(%)*	Estimate	Error	t-value	p-value
Price	Price of cattle monitoring system	51.04	1.5116***	0.0875	17.27	<0.0001
Ear tags	RFID ear tags	14.75	0.2705***	0.0822	3.29	0.0010
Data station	Pasture Data collection station	12.32	0.0905	0.0742	1.22	0.2225
Software[1]	Software system to record data	11.26	-	-	-	-
Bolus	RFID rumen bolus	5.97	-0.6345***	0.0698	-9.09	<0.0001
UAV	Unmanned aerial vehicle	4.65	-0.8834***	0.0775	-11.40	<0.0001

[1]Dropped from the model to prevent exact collinearity

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

The true or latent unobserved level of importance for producer i is given by Equation 7: $L_{ij} = C_j + \varepsilon_{ij}$, where C_j is the location of the value j on the underlying importance scale and ε_{ij} is a random error term. These conditional logit estimates were used in Equation 10: $Importance\ Score\ for\ Component\ j = \frac{e^{\widehat{\gamma_J}}}{\sum_{k=1}^{J} e^{\widehat{\gamma_i}}}$, where $\widehat{\gamma_J} = \beta_{Component j}$ and $\widehat{\gamma_i} = \beta_{ET} + \beta_{Bolus} + \beta_{UAV} + \beta_{GS} + \beta_{Price} + \beta_{SW}$.

Table 10. Characteristic Relative Importance Scores

Variable	Definition	Score *(%)*	Estimate	Error	t-value	p-value
GPS	GPS location monitoring	29.61	2.5333***	0.0679	37.33	<0.0001
Behavior	Notification of altered behavioral patterns	17.60	2.0130***	0.0675	29.84	<0.0001
Privacy	Privacy safeguards	14.45	1.8158***	0.0669	27.14	<0.0001
Compatibility	Compatibility with cattle management software	11.59	1.5956***	0.0663	24.07	<0.0001
Video	Live video feed	7.36	1.1418***	0.0640	17.84	<0.0001
Temp	Rumen temperature monitoring	7.30	1.1326***	0.0634	17.86	<0.0001
Thermal Img	Thermal imaging	6.03	0.9420***	0.0635	14.84	<0.0001
Flight Time	Increased UAV flight time	3.70	0.4526***	0.0611	7.41	<0.0001
Crops[1]	Crop monitoring technology	2.35	-	-	-	-

[1]Dropped from the model to prevent exact collinearity

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

The true or latent unobserved level of importance for producer i is given by Equation 7: $L_{ij} = C_j + \varepsilon_{ij}$, where C_j is the location of the value j on the underlying importance scale and ε_{ij} is a random error term. These conditional logit estimates were used in Equation 11: $Importance\ Score\ for\ Characteristic\ j = \frac{e^{\widehat{\gamma_J}}}{\sum_{k=1}^{J} e^{\widehat{\gamma_i}}}$, where $\widehat{\gamma_J} = \beta_{Characteristic j}$ and $\widehat{\gamma_i} = \beta_{Video} + \beta_{Privacy} + \beta_{Temp} + \beta_{GPS} + \beta_{Behavior} + \beta_{Comp} + \beta_{TI} + \beta_{FT} + \beta_{Crops}$.

Table 11. Distribution of Producer's Individual Best-Worst Scores for Components

		Individual Best-Worst Score				
Variable	Definition	-2	-1	0	1	2
		(%)	*(%)*	*(%)*	*(%)*	*(%)*
Price	Price of cattle monitoring system	1.31	2.62	16.49	24.35	55.24
Ear tags	RFID ear tags	10.47	14.92	48.69	18.06	7.85
Data station	Pasture Data collection station	6.54	14.40	39.27	32.20	7.59
Software	Software system to record data	5.50	21.73	38.22	29.32	5.24
Bolus	RFID rumen bolus	19.37	37.43	32.72	9.42	1.05
UAV	Unmanned aerial vehicle	45.03	21.20	15.97	14.14	3.66

To calculate individual best-worst scores, the number of times a component is considered “best” is added together and the number of times that item is considered “worst” is subtracted from it.

Table 12. Distribution of Producer's Individual Best-Worst Scores for Characteristics

		Individual Best-Worst Score								
Variable	Definition	-4	-3	-2	-1	0	1	2	3	4
		(%)	*(%)*	*(%)*	*(%)*	*(%)*	*(%)*	*(%)*	*(%)*	*(%)*
GPS	GPS location monitoring	0.00	0.52	2.09	4.19	23.56	22.51	15.18	14.40	17.54
Behavior	Notification of altered behavioral patterns	0.26	0.79	2.62	6.81	35.60	25.65	14.92	4.97	8.38
Privacy	Privacy safeguards	3.14	3.40	3.93	8.90	35.60	18.85	7.85	5.24	13.09
Compatibility	Compatibility with cattle MGMT software	2.62	2.62	7.85	8.38	37.70	12.30	17.02	6.02	5.50
Video	Live video feed	1.83	3.66	12.57	17.28	37.96	12.04	7.33	3.40	3.93
Temp	Rumen temperature monitoring	1.57	2.36	9.69	13.87	52.88	10.73	4.19	3.40	1.31
Thermal Img	Thermal imaging	2.62	3.40	9.16	23.04	50.52	8.64	2.09	0.26	0.26
Flight Time	Increase UAV flight time	5.50	12.83	19.63	23.82	31.41	3.93	1.83	0.52	0.52
Crops	Crop monitoring technology	22.51	14.66	16.49	16.23	23.04	4.45	1.31	1.05	0.26

To calculate individual best-worst scores, the number of times a characteristic is considered “best” is added together and the number of times that item is considered “worst” is subtracted from it.

Table 13. Chi-Square Estimates of Variable Linear Association of Component Best-Worst Score Variables with Self-Described Producer Likelihood of Adoption

Variable	Definition	χ^2	p-value
Ear Tags	RFID ear tags	6.4122	0.8939
Bolus	RFID bolus	9.8980	0.6249
UAV	Unmanned aerial vehicle	7.1841	0.8452
Data station	Pasture GPS data collection station	16.2370	0.1806
Price	Price of the system	15.0354	0.2395
Software	Software system to record data	10.8541	0.5415

χ^2 tests calculated with Equation 13: $\chi^2 = \sum \frac{(O-E)^2}{E}$. O is the observed and E is the expected number of producers in the category.

Table 14. Chi-Square Estimates of Variable Linear Association of Characteristic Best-Worst Score Variables with Self-Described Producer Likelihood of Adoption

Variable	Definition	χ^2	p-value
Video	Live video feed	19.0233	0.7507
Privacy	Privacy safeguards	19.7123	0.7123
Temp	Rumen temperature collection	25.2821	0.3906
GPS	GPS cattle location monitoring	28.2733	0.1326
Behavior	Notification of altered behavioral patterns	21.2280	0.6252
Compatibility	Compatibility with cattle management software	23.9058	0.4670
Thermal Img	Thermal imaging	22.2398	0.5650
Flight time	Increased UAV flight time	10.3852	0.9928
Crops	Crop monitoring technology	25.1601	0.3971

χ^2 tests calculated with Equation 13: $\chi^2 = \sum \frac{(O-E)^2}{E}$. O is the observed and E is the expected number of producers in the category.

Table 15. Chi-Square Estimates of Variable Linear Association of Demographic Characteristics with Self-Described Producer Likelihood of Adoption

Variable	Definition	χ^2	p-value
Head	The number of cattle owned	18.4935***	0.0051
Grow	Crops grown in addition to cattle	0.9947	0.8025
Education	The level of education attained by producer	10.2795	0.1134
Check	The frequency the producer monitors cattle	17.7002***	0.0070
Oklahoma	Producer located in Oklahoma	4.9133	0.1783
Rotate Graze	Rotation graze pasture management	4.7159	0.1938
Intro Pasture	Introduce grasses into pasture	3.7346	0.2916
Soil Test	Use soil testing for pasture management	4.5313	0.2095
Stock Growth	Stockpile fall growth for winter	4.0072	0.2607
Prescribed Burn	Prescribed burns for pasture management	6.0654	0.1085

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

χ^2 tests calculated with Equation 13: $\chi^2 = \sum \frac{(O-E)^2}{E}$. O is the observed and E is the expected number of producers in the category.

Table 16. Distribution of Demographic Characteristics Included in Ordinal Models

Variable	Definition	Sample[1]
		(%)
Purebred	Percentage of herd that is purebred	26.90
Head1	<100 head of cattle owned	64.23
Head2	101-500 head of cattle owned	27.23
Head3[2]	>500 head of cattle owned	8.64
Grow	Crops grown in addition to cattle	28.53
Check1	Producer checks cattle daily	47.91
Check2	Producer checks cattle 2-3 times per week	39.01
Check3[2]	Producer checks cattle weekly or less	13.09
Oklahoma	Producer located in Oklahoma	63.09
Education1	At most producer attended college	27.75
Education2	Producer obtained a Bachelor's or Master's	61.26
Education3[2]	Producer obtained a Ph.D., M.D., or D.V.M.	10.99
Rotate Graze	Rotation graze pasture management	87.96
Intro Pasture	Introduce grasses into pasture	40.57
Soil Test	Use soil testing for pasture management	69.37
Stock Growth	Stockpile fall growth for winter	54.97
Prescribed Burn	Prescribed burns for pasture management	26.96
		(years)
IYears	Years producer involved in industry	29.78

[1]Number of observations is 382

[2]Dropped from the model to prevent exact collinearity

Table 17. Analysis of Effects for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics

Variable	Definition	Wald χ^2	p-value
Purebred	Percentage of herd that is purebred	0.1576	0.6914
IYears	Years of producer involvement in industry	0.0145	0.9041
Head	The number of cattle owned	30.2563	<0.0001***
Grow	Crops grown in addition to cattle	0.8118	0.3976
Education	The level of education obtained by producer	9.8685	0.0072***
Check	The frequency the producer monitors cattle	3.0081	0.2222
Oklahoma	Producer located in Oklahoma	3.5813	0.0584*
Rotate Graze	Rotation graze pasture management	0.0837	0.7724
Intro Pasture	Introduce grasses into pasture	0.4190	0.5175
Soil Test	Use soil testing for pasture management	1.1116	0.2917
Stock Growth	Stockpile fall growth for winter	0.5080	0.4760
Prescribed Burn	Prescribed burns for pasture management	0.0229	0.8796

Model Fit Statistics

	Criterion	*Without Covariates*	*With Covariates*
	AIC	1252.258	939.628
	SC	1260.149	1006.700
	-2 Log L	1248.258	905.628
	Test	*Chi-square*	*p-value*
	Likelihood Ratio	342.6303	<0.0001
	Score	284.2690	<0.0001
	Wald	189.7626	<0.0001

One asterisk (*) denotes values that are statistically significant at the 0.1 level.
Three asterisks (***) denotes values that are statistically significant at the 0.01 level.
The estimates were obtained using the ordinal logit model $U_{ij} = V_{ij} + \varepsilon_{ij}$, here U_{ij} is individuals *i*'s non-price utility for choosing option *j*. The deterministic term V_{ij} is the systematic portion of the utility function determined by the electronic cattle monitoring system attributes and their values $V_{ij} = \begin{bmatrix}\alpha_1\\ \alpha_2\end{bmatrix} + \boldsymbol{x_1}\beta_1$, where $\boldsymbol{x_1}$ is the 382 x 15 matrix of demographic characteristics.

Table 18. Parameter Estimates for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics

Variable	Definition	Estimate	Error	Wald χ^2	p-value
Intercept		2.1002***	0.1786	138.2927	<0.0001
Intercept		4.2931***	0.2290	351.5633	<0.0001
Purebred	Percentage of herd that is purebred	0.00104	0.00261	0.1576	0.6914
IYears	Years of producer involvement in industry	-0.00065	0.00539	0.0145	0.9041
Head1	<100 head of cattle owned	-1.5304***	0.3135	23.8348	<0.0001
Head2	101-500 head of cattle owned	-0.7184**	0.3495	4.2251	0.0398
Grow	Crops grown in addition to cattle	-0.2083	0.2312	0.8118	0.3676
Education1	At most the producer attended some college	-0.8774***	0.3237	7.3468	0.0067
Education2	Producer obtained a Bachelor's or Master's	-0.8848***	0.2882	9.4242	0.0021
Check1	Producer checks cattle daily	-0.4644	0.3022	2.3617	0.1244
Check2	Producer checks cattle 2-3 times per week	-0.5211*	0.3077	2.8694	0.0903
Oklahoma	Producer located in Oklahoma	-0.3942*	0.2083	3.5813	0.0584
Rotate Graze	Rotation graze pasture management	0.0845	0.2921	0.0837	0.7724
Intro Pasture	Introduce grasses into pasture	0.1404	0.2170	0.4190	0.5175
Soil Test	Use soil testing for pasture management	0.2390	0.2267	1.1116	0.2917
Stock Growth	Stockpile fall growth for winter	-0.1506	0.2113	0.5080	0.4760
Prescribed Burn	Prescribed burns for pasture management	0.0340	0.2245	0.0229	0.8796

One asterisk (*) denotes values that are statistically significant at the 0.1 level.
Two asterisks (**) denotes values that are statistically significant at the 0.05 level.
Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

Table 19. Odds Ratio Estimates for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics

Variable	Definition	Point Estimate	95 %Wald Confidence Limits	
Purebred	Percentage of herd that is purebred	1.001	0.996	1.006
IYears	Years of producer involvement in industry	0.999	0.989	1.010
Head 1 v 3	<100 head of cattle owned v >500 head	0.216	0.117	0.400
Head 2 v 3	101-500 head of cattle owned v >500 head	0.488	0.246	0.967
Grow 1 v 0	Crops grown in addition to cattle v no crops	0.812	0.516	1.277
Education 1 v 3	At most some college v Ph.D., M.D or D.V.M.	0.416	0.221	0.784
Education 2 v 3	Bachelor's or Master's v Ph.D., M.D or D.V.M.	0.413	0.235	0.726
Check 1 v 3	Cattle checked daily v weekly or less	0.629	0.348	1.136
Check 2 v 3	Cattle checked 2-3 times per week v weekly or less	0.594	0.325	1.085
Oklahoma 1 v 0	Producer located in Oklahoma v out-of-state	0.674	0.448	1.014
Rotate Graze 1 v 0	Rotation graze pasture management v not	1.088	0.614	1.929
Intro Pasture 1 v 0	Introduce grasses into pasture v not	1.151	0.752	1.761
Soil Test 1 v 0	Use soil testing for pasture management v not	1.270	0.814	1.981
S Growth 1 v 0	Stockpile fall growth for winter v not	0.860	0.569	1.301
P Burn 1 v 0	Prescribed burns for pasture management v not	1.035	0.666	1.606

Table 20. Analysis of Effects for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics and Component Best-Worst Scores

Variable	Definition	Wald χ^2	p-value
Purebred	Percentage of herd that is purebred	0.0753	0.7838
IYears	Years of producer involvement in industry	0.1317	0.7167
Head	The number of cattle owned	26.0022	<0.0001***
Grow	Crops grown in addition to cattle	0.6222	0.4302
Education	The level of education obtained by producer	8.9947	0.0111**
Check	The frequency the producer monitors cattle	2.7785	0.2493
Oklahoma	Producer located in Oklahoma	3.5488	0.0596*
Rotate Graze	Rotation graze pasture management	0.2889	0.5909
Intro Pasture	Introduce grasses into pasture	0.6293	0.4276
Soil Test	Use soil testing for pasture management	1.4070	0.2356
Stock Growth	Stockpile fall growth for winter	0.4784	0.4891
Prescribed Burn	Prescribed burns for pasture management	0.0094	0.9227
Ear Tags	BW score for RFID ear tags	0.8251	0.3637
Bolus	BW score for RFID bolus	0.1809	0.6706
UAV	BW score for Unmanned aerial vehicle	0.0407	0.8401
Data station	BW score for pasture GPS data collection station	0.0468	0.8287
Price	BW score for price of the system	4.4201	0.0355**
Software[1]	BW score for software system to record data	-	-

Model Fit Statistics

Criterion	*Without Covariates*	*With Covariates*
AIC	1252.258	944.466
SC	1260.149	1031.265
-2 Log L	1248.258	900.466
Test	*Chi-square*	*p-value*
Likelihood Ratio	347.7923	<0.0001
Score	285.8935	<0.0001
Wald	192.7068	<0.0001

[1]Dropped from the model to prevent exact collinearity

One asterisk (*) denotes values that are statistically significant at the 0.1 level.

Two asterisks (**) denotes values that are statistically significant at the 0.05 level.

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

The estimates were obtained using the ordinal logit model $U_{ij} = V_{ij} + \varepsilon_{ij}$, here U_{ij} is individuals *i*'s non-price utility for choosing option *j*. The deterministic term V_{ij} is the systematic portion of the utility function determined by the electronic cattle monitoring system attributes and their values $V_{ij} = \begin{bmatrix}\alpha_1 \\ \alpha_2\end{bmatrix} + \boldsymbol{x_1}\beta_1 + \boldsymbol{x_2}\beta_2$, where $\boldsymbol{x_1}$ is the 382 x 15 matrix of demographic characteristics and $\boldsymbol{x_2}$ is a 382 x 5 matrix of component best-worst scores.

Table 21. Parameter Estimates for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics and Component Best-Worst Scores

Variable	Definition	Estimate	Error	Wald χ^2	p-value
Intercept		2.1343***	0.1806	139.7044	<0.0001
Intercept		4.3478***	0.2319	351.5936	<0.0001
Purebred	Percentage of herd that is purebred	0.000719	0.00262	0.0753	0.7838
IYears	Years of producer involvement in industry	0.00202	0.00556	0.1317	0.7167
Head1	<100 head of cattle owned	-1.4370***	0.3186	20.3889	<0.0001
Head2	101-500 head of cattle owned	-0.6609*	0.3525	3.5154	0.0608
Grow	Crops grown in addition to cattle	-0.1831	0.2322	0.36222	0.4302
Education1	At most the producer attended some college	-0.8875***	0.3283	7.3092	0.0069
Education2	Producer obtained a Bachelor's or Master's	-0.8338***	0.2913	8.1923	0.0042
Check1	Producer checks cattle daily	-0.4528	0.3036	2.2248	0.1358
Check2	Producer checks cattle 2-3 times per week	-0.4999	0.3086	2.6244	0.1052
Oklahoma	Producer located in Oklahoma	-0.3953*	0.2098	3.5488	0.0596
Rotate Graze	Rotation graze pasture management	0.1611	0.2998	0.2889	0.5909
Intro Pasture	Introduce grasses into pasture	0.1732	0.2183	0.6293	0.4276
Soil Test	Use soil testing for pasture management	0.2709	0.2284	1.4070	0.2356
Stock Growth	Stockpile fall growth for winter	-0.1464	0.2117	0.4784	0.4891
Prescribed Burn	Prescribed burns for pasture management	0.0219	0.2256	0.0094	0.9227
Ear Tags	BW scores for RFID ear tags	-0.1279	0.1408	0.8251	0.3637
Bolus	BW scores for RFID bolus	-0.0508	0.1194	0.1809	0.6706
UAV	BW scores for Unmanned aerial vehicle	-0.0261	0.1294	0.0407	0.8401
Data station	BW scores for GPS data collection station	-0.0296	0.1368	0.0468	0.8287
Price	BW scores for price of the system	-0.2975**	0.1415	4.4201	0.0355
Software[1]	BW scores for software system to record data	-	-	-	-

[1]Dropped from the model to prevent exact collinearity
One asterisk (*) denotes values that are statistically significant at the 0.1 level.
Two asterisks (**) denotes values that are statistically significant at the 0.05 level.
Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

Table 22. Odds Ratio Estimates for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics and Component Best-Worst Scores

Variable	Definition	Point Estimate	95 %Wald Confidence Limits	
Purebred	Percentage of herd that is purebred	1.001	0.996	1.006
IYears	Years of producer involvement in industry	1.002	0.991	1.013
Head 1 v 3	<100 head of cattle owned v >500 head	0.238	0.127	0.443
Head 2 v 3	101-500 head of cattle owned v >500 head	0.516	0.259	1.030
Grow 1 v 0	Crops grown in addition to cattle v no crops	0.833	0.528	1.312
Education 1 v 3	At most some college v Ph.D., M.D or D.V.M.	0.412	0.216	0.783
Education 2 v 3	Bachelor's or Master's v Ph.D., M.D or D.V.M.	0.434	0.245	0.769
Check 1 v 3	Cattle checked daily v weekly or less	0.636	0.351	1.153
Check 2 v 3	Cattle checked 2-3 times per week v weekly or less	0.607	0.331	1.111
Oklahoma 1 v 0	Producer located in Oklahoma v out-of-state	0.674	0.446	1.016
Rotate Graze 1 v 0	Rotation graze pasture management v not	1.175	0.653	2.114
Intro Pasture 1 v 0	Introduce grasses into pasture v not	1.189	0.775	1.824
Soil Test 1 v 0	Use soil testing for pasture management v not	1.311	0.838	2.051
S Growth 1 v 0	Stockpile fall growth for winter v not	0.864	0.570	1.308
P Burn 1 v 0	Prescribed burns for pasture management v not	1.022	0.657	1.591
Ear Tags	BW scores for RFID ear tags	0.880	0.668	1.160
Bolus	BW scores for RFID bolus	0.950	0.752	1.201
UAV	BW scores for Unmanned aerial vehicle	0.974	0.756	1.255
Data station	BW scores for GPS data collection station	0.971	0.743	1.269
Price	BW scores for price of the system	0.743	0.563	0.980
Software[1]	BW scores for software system	-	-	-

[1]Dropped from the model to prevent exact collinearity

Table 23. Analysis of Effects for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics and Characteristic Best-Worst Scores

Variable	Definition	Wald χ^2	p-value
Purebred	Percentage of herd that is purebred	0.0910	0.7629
IYears	Years of producer involvement in industry	0.0063	0.9368
Head	The number of cattle owned	26.4951	<0.0001***
Grow	Crops grown in addition to cattle	0.6465	0.4214
Education	The level of education obtained by producer	10.2832	0.0058***
Check	The frequency the producer monitors cattle	2.5245	0.2830
Oklahoma	Producer located in Oklahoma	4.1483	0.0417**
Rotate Graze	Rotation graze pasture management	0.0514	0.8206
Intro Pasture	Introduce grasses into pasture	0.3669	0.5447
Soil Test	Use soil testing for pasture management	1.1007	0.2941
Stock Growth	Stockpile fall growth for winter	0.6869	0.4072
Prescribed Burn	Prescribed burns for pasture management	0.0890	0.7655
Video	BW score for live video feed	0.7443	0.3883
Privacy	BW score for privacy safeguards	0.0040	0.9498
Temp	BW score for rumen temperature collection	2.4365	0.1185
GPS	BW score for GPS cattle location monitoring	0.7777	0.3779
Behavior	BW score for behavior monitoring	1.2655	0.2606
Compatibility	BW score for compatibility with MGMT software	1.0013	0.3170
Thermal Img	BW score for thermal imaging	0.1242	0.7245
Flight Time	BW score for increased UAV flight time	0.0981	0.7542
Crops[1]	BW score for crop monitoring technology	-	-

Model Fit Statistics

	Criterion	*Without Covariates*	*With Covariates*
	AIC	1252.258	947.817
	SC	1260.149	1046.452
	-2 Log L	1248.258	897.817
	Test	*Chi-square*	*p-value*
	Likelihood Ratio	350.4415	<0.0001
	Score	287.2666	<0.0001
	Wald	194.2570	<0.0001

[1]Dropped from the model to prevent exact collinearity

Two asterisks (**) denotes values that are statistically significant at the 0.05 level.

Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

The estimates were obtained using the ordinal logit model $U_{ij} = V_{ij} + \varepsilon_{ij}$, here U_{ij} is individuals *i*'s non-price utility for choosing option *j*. The deterministic term V_{ij} is the systematic portion of the utility function determined by the electronic cattle monitoring system attributes and their values $V_{ij} = \begin{bmatrix}\alpha_1 \\ \alpha_2\end{bmatrix} + \boldsymbol{x_1}\beta_1 + \boldsymbol{x_3}\beta_3$, where $\boldsymbol{x_1}$ is the 382 x 15 matrix of demographic characteristics and $\boldsymbol{x_3}$ is a 382 x 8 matrix of characteristic best-worst scores.

Table 24. Parameter Estimates for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics and Characteristic Best-Worst Scores

Variable	Definition	Estimate	Error	Wald χ^2	p-value
Intercept		2.1263***	0.1803	138.7828	<0.0001
Intercept		4.3535***	0.2326	350.2208	<0.0001
Purebred	Percentage of herd that is purebred	0.000802	0.00266	0.0910	0.7629
IYears	Years of producer involvement in industry	-0.00044	0.00549	0.0063	0.0018
Head1	<100 head of cattle owned	-1.4957***	0.3258	21.0773	<0.0001
Head2	101-500 head of cattle owned	-0.7172**	0.3593	3.9856	0.0459
Grow	Crops grown in addition to cattle	-0.1976	0.2457	0.6465	0.4214
Education1	At most the producer attended some college	-0.9097***	0.3274	7.7202	0.0055
Education2	Producer obtained a Bachelor's or Master's	-0.9124***	0.2916	9.7931	0.0018
Check1	Producer checks cattle daily	-0.4273	0.3043	1.9718	0.1603
Check2	Producer checks cattle 2-3 times per week	-0.4833	0.3114	2.4089	0.1206
Oklahoma	Producer located in Oklahoma	-0.4336**	0.2129	4.1483	0.0417
Rotate Graze	Rotation graze pasture management	0.0678	0.2992	0.0514	0.8206
Intro Pasture	Introduce grasses into pasture	0.1339	0.2210	0.3669	0.5447
Soil Test	Use soil testing for pasture management	0.2409	0.2296	1.1007	0.2941
Stock Growth	Stockpile fall growth for winter	-0.1787	0.2156	0.6869	0.4072
Prescribed Burn	Prescribed burns for pasture management	0.0675	0.2264	0.0890	0.7655
Video	BW scores for live video feed	0.0687	0.0797	0.7443	0.3833
Privacy	BW scores for privacy safeguards	-0.00446	0.0708	0.0040	0.9498
Temp	BW scores for rumen temperature collection	0.1399	0.0896	2.4365	0.1185
GPS	BW scores for GPS cattle location monitoring	0.0686	0.0778	0.7777	0.3779
Behavior	BW scores for behavior monitoring	-0.0914	0.0813	1.2655	0.2606
Compatibility	BW scores for compatibility with MGMT software	0.0848	0.0848	1.0013	0.3170
Thermal Img	BW scores for thermal imaging	0.0374	0.1062	0.1242	0.7245
Flight Time	BW scores for increased UAV flight time	0.0287	0.0917	0.0981	0.7542
Crops[1]	BW scores for crop monitoring technology	-	-	-	-

[1]Dropped from the model to prevent exact collinearity
Two asterisks (**) denotes values that are statistically significant at the 0.05 level.
Three asterisks (***) denotes values that are statistically significant at the 0.01 level.

Table 25. Odds Ratio Estimates for Producer Self-Described Likelihood of Adoption as a Function of Demographic Characteristics and Characteristic Best-Worst Scores

Variable	Definition	Point Estimate	95 %Wald Confidence Limits	
Purebred	Percentage of herd that is purebred	1.001	0.996	1.006
IYears	Years of producer involvement in industry	1.000	0.989	1.010
Head 1 v 3	<100 head of cattle owned v >500 head	0.224	0.118	0.424
Head 2 v 3	101-500 head of cattle owned v >500 head	0.488	0.241	0.987
Grow 1 v 0	Crops grown in addition to cattle v no crops	0.821	0.507	1.328
Education 1 v 3	At most some college v Ph.D., M.D or D.V.M.	0.403	0.212	0.765
Education 2 v 3	Bachelor's or Master's v Ph.D., M.D or D.V.M.	0.402	0.227	0.711
Check 1 v 3	Cattle checked daily v weekly or less	0.652	0.359	1.184
Check 2 v 3	Cattle checked 2-3 times per week v weekly or less	0.617	0.335	1.135
Oklahoma 1 v 0	Producer located in Oklahoma v out-of-state	0.648	0.427	0.984
Rotate Graze 1 v 0	Rotation graze pasture management v not	1.070	0.595	1.924
Intro Pasture 1 v 0	Introduce grasses into pasture v not	1.143	0.741	1.763
Soil Test 1 v 0	Use soil testing for pasture management v not	1.272	0.811	1.995
S Growth 1 v 0	Stockpile fall growth for winter v not	0.836	0.548	1.276
P Burn 1 v 0	Prescribed burns for pasture management v not	1.070	0.686	1.667
Video	BW scores for live video feed	1.071	0.916	1.252
Privacy	BW scores for privacy safeguards	0.996	0.867	1.144
Temp	BW scores for rumen temperature collection	1.150	0.965	1.371
GPS	BW scores for GPS cattle location monitoring	1.071	0.920	1.248
Behavior	BW scores for behavior monitoring	0.913	0.778	1.070
Compatibility	BW scores for compatibility with MGMT software	1.089	0.922	1.285
Thermal Img	BW scores for thermal imaging	1.038	0.843	1.278
Flight Time	BW scores for increased UAV flight time	1.029	0.860	1.262
Crops[1]	BW scores for crop monitoring technology	-	-	-

[1]Dropped from the model to prevent exact collinearity

Table 26. Likelihood Ratio Tests for Ordinal Logit Models

Model	-2 Log L	LR[1]	J[2]	$\chi^2_{(0.05,J)}$	$\chi^2_{(0.01,J)}$
Demographics	905.628				
Demographics and Component B-W Scores	900.466	5.162	5	11.0705	15.0863
Demographics and Characteristics B-W Scores	897.817	7.811	8	15.5073	20.0902

[1]LR is the Likelihood Ratio Statistic calculated with $LR = -2\log\lambda = -2[L(\theta_0) - L(\hat{\theta})] = 2[L(\theta_0) - L(\hat{\theta})]$

[1]J is the degrees of freedom for $\chi^2_{(\alpha,J)}$

Table 27: Relationship of Objectives and Hypotheses

Obj #	Objective	Background	Hyp #	Hypothesis	Survey Questions	Methodology	Outcome
1	Determine how enterprise, management and producer demographics are related to producers' willingness to adopt the system.	Schultz and Tonsor (2010); Gillespie, Kim and Paudel (2007); Pruitt et al. (2012); and Ward et al. (2008)	1	Likelihood of system adoption is positively related to higher education levels among producers.	Producer demographics; Self-described likelihood of adoption	Ordinal Logit model (Equation 16)	Supported: Producers with a Ph.D., M.D. or D.V.M. most likely to adopt.
1	Determine how enterprise, management and producer demographics are related to producers' willingness to adopt the system.	Taylor and Todd (1995)	2	Likelihood of adoption of and electronic cattle monitoring system is positively related to frequency that producers check their cattle.	Management demographics; Self-described likelihood of adoption	Ordinal Logit model (Equation 16)	Not supported: Producers checking cattle weekly or less most likely to adopt.
1	Determine how enterprise, management and producer demographics are related to producers' willingness to adopt the system.	Gillespie, Kim and Paudel (2007)	3	Likelihood of adoption of an electronic cattle monitoring system is positively related to numbers of cattle in a producers operation.	Enterprise demographics; Self-described likelihood of adoption	Ordinal Logit model (Equation 16)	Supported: Producers with >500 most likely to adopt.
2	Determine how enterprise, management and producer demographics affect producer utility for individual characteristics.	Schultz and Tonsor (2010); Gillespie, Kim and Paudel (2007); Pruitt et al. (2012); and Ward et al. (2008)	4	Producers who grow crops in addition to raising cattle will have a higher utility for crop monitoring technology as a characteristic of an electronic monitoring system.	Enterprise Demographics; Choice Experiment	Conditional Logit Model (Equation 5)	Supported: If producer grows crops, demand for crop monitoring technology increases by 53.52%.
2	Determine how enterprise, management and producer demographics affect producer utility for individual characteristics.	Pruitt et al. (2012)	5	As the percentage of purebred cattle in a herd increases, a producer's utility for compatibility of an electronic cattle monitoring system with cattle monitoring software will also increase.	Enterprise Demographics; Choice Experiment	Conditional Logit Model (Equation 5)	Not supported: Purebred percentage has no significant effect on producer desire for compatibility.

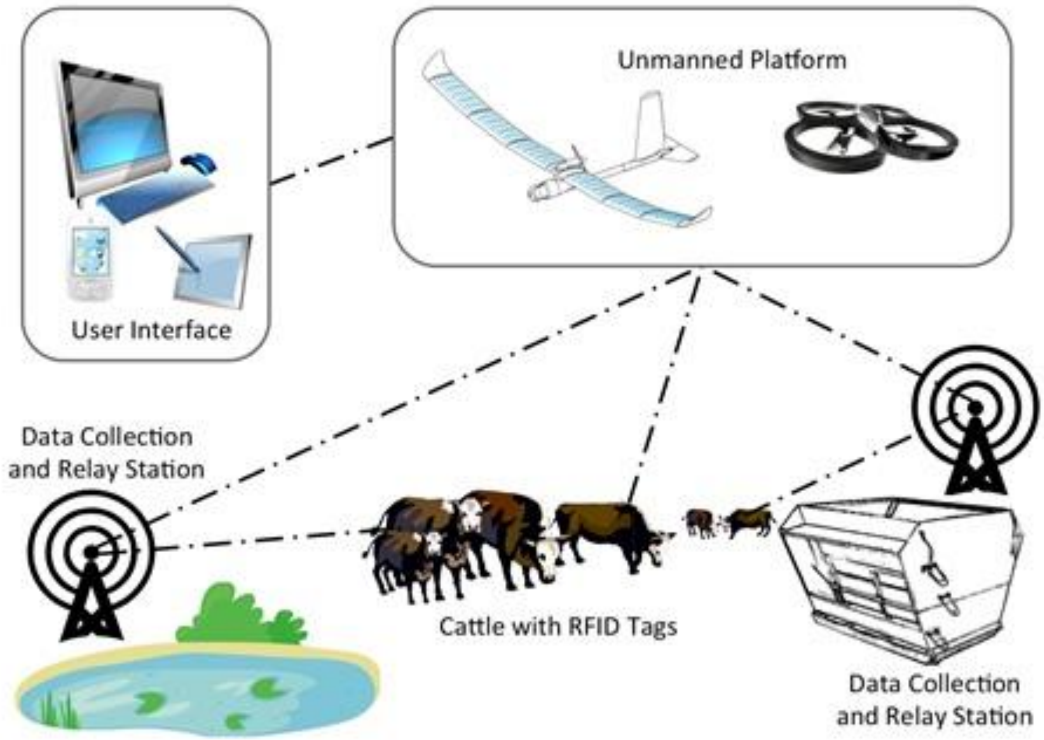
Table 27: Relationship of Objectives and Hypotheses continued

Obj #	Objective	Background	Hyp #	Hypothesis	Survey Questions	Methodology	Outcome
2	Determine how enterprise, management and producer demographics affect producer utility for individual characteristics.	Gillespie, Kim and Paudel (2007)	6	As producer age increases, a producer's utility for an electronic monitoring system with added privacy safeguards will increase.	Producer Demographics; Choice Experiment	Conditional Logit Model (Equation 5)	Not supported: As producer age increases, demand for privacy safeguards decreases by 2.33%
3	Determine producers' willingness to pay for individual system components and characteristics	Schultz and Tonsor (2010)	7	Producers will be willing to pay the most for the live video feed component of an electronic monitoring system.	Choice Experiment	Conditional Logit Model (Equation 4); Willingness to pay (Equation 6 and 7)	Supported: The producer is willing to pay the greatest premium for live video.
4	Determine the most desired system components and characteristics	Schultz and Tonsor (2010)	8	Electronic monitoring system components – RFID rumen bolus and UAV – that allow a producer to monitor their animals' health and location will rank at the top of the producer important score scale.	Best-worst	Conditional Logit Model (Equation 8); Importance Score for Components (Equation 12)	Not supported: Bolus and UAV are ranked at the bottom of the importance score scale.
4	Determine the most desired system components and characteristics	Schultz and Tonsor (2010)	9	Electronic monitoring system characteristics – GPS, notification of altered behavioral patterns, live video, and rumen temperature – that allow a producer to monitor their animals' health and location will rank at the top of the producer important score scale.	Best-worst	Conditional Logit Model (Equation 8); Importance Score for Characteristics (Equation 11)	Not supported: GPS and behavior are ranked at the top of the important score scale, while live video and temperature fall in the middle of the important score scale.

FIGURES

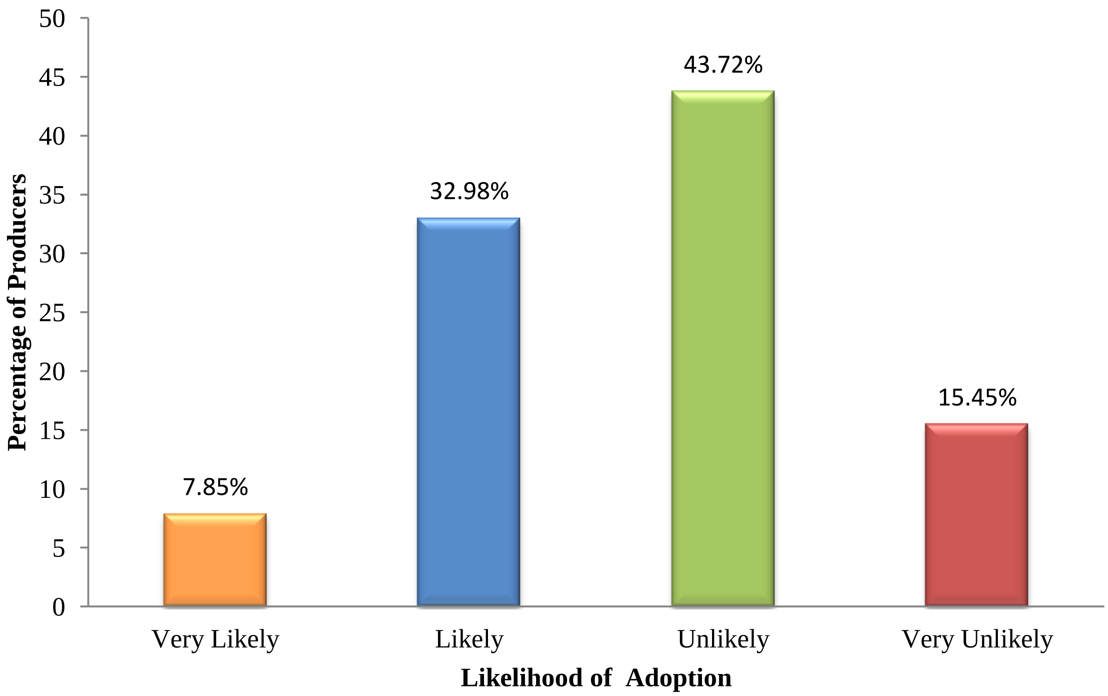
Figure Page

Figure 1: Electronic Cattle Monitoring System Diagram



(Grimsley et al., 2013)

Figure 2: Cattle Producer Likelihood of Adoption of Electronic Cattle Monitoring Systems



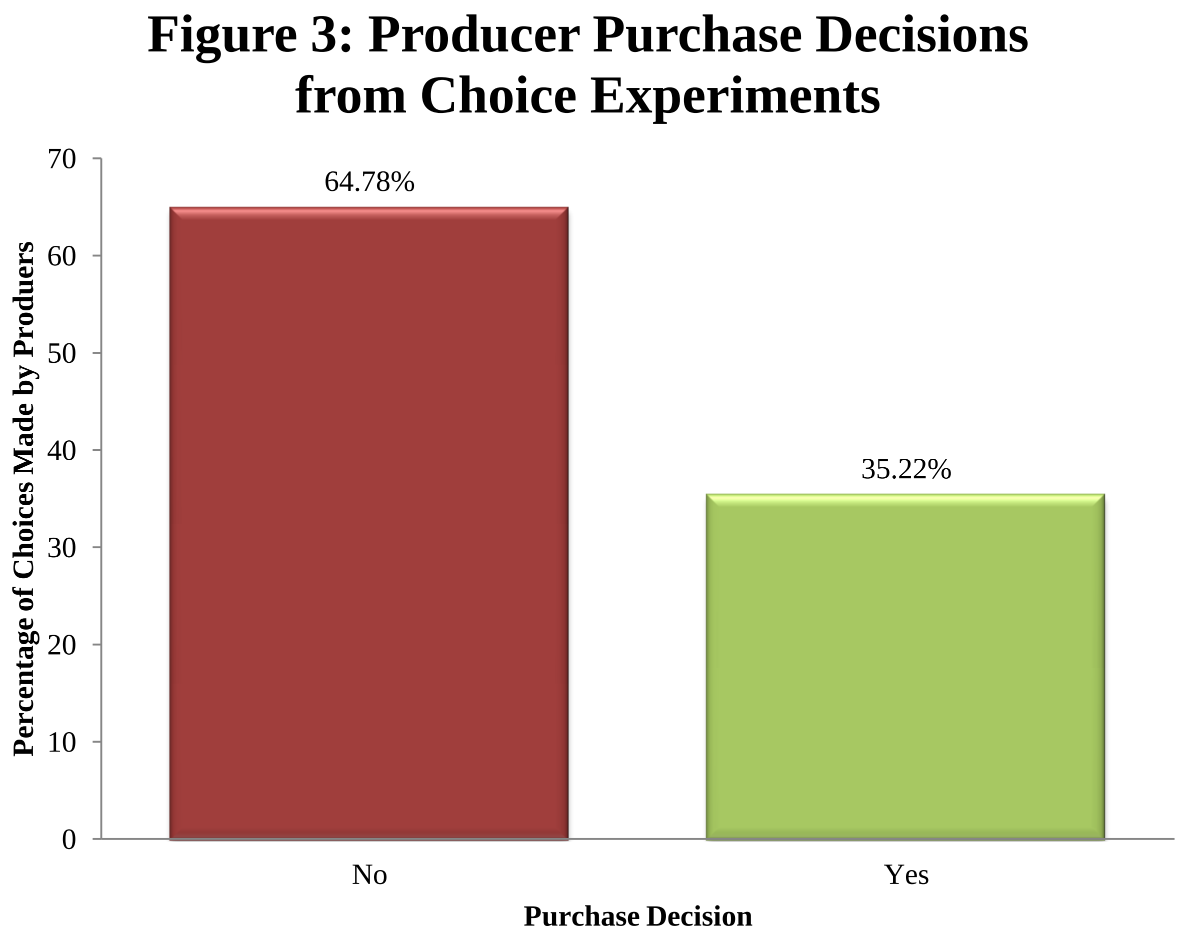
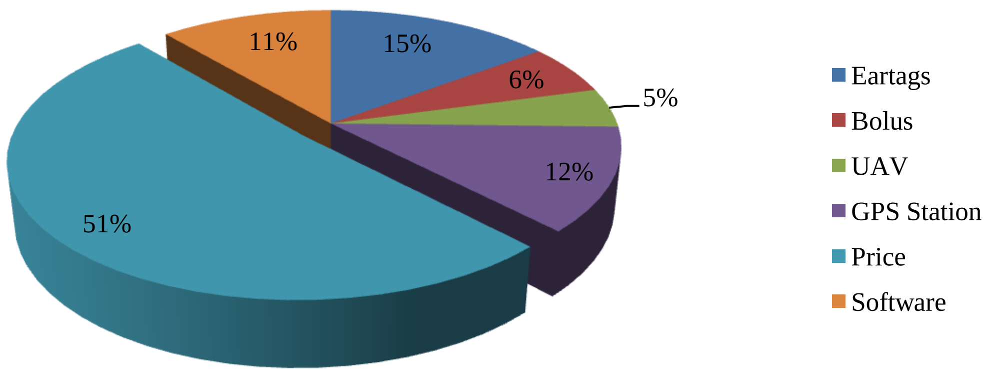


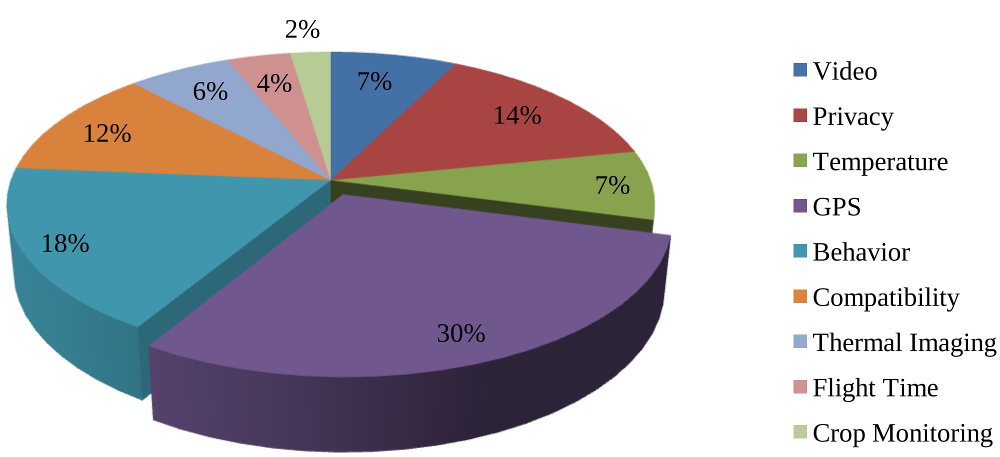
Figure 3: Producer Purchase Decisions from Choice Experiments
70
60
50
40
30
20
10
0
64.78%
35.22%
Percentage of Choices Made by Produers
No
Yes
Purchase Decision

Figure 4: Comparison of Relative Importance Score for Components



$Importance\ Score\ for\ Component\ j = \frac{e^{\hat{\gamma}_j}}{\sum_{k=1}^{J} e^{\hat{\gamma}_i}}$, where $\hat{\gamma}_j = \beta_{Component j}$ and $\hat{\gamma}_i = \beta_{ET} + \beta_{Bolus} + \beta_{UAV} + \beta_{GS} + \beta_{Price} + \beta_{SW}$.

Figure 5: Comparison of Relative Importance Score for Characteristics



$Importance\ Score\ for\ Characteristic\ j = \frac{e^{\hat{\gamma}_j}}{\sum_{k=1}^{J} e^{\hat{\gamma}_i}}$, where $\hat{\gamma}_j = \beta_{Characteristic j}$ and $\hat{\gamma}_i = \beta_{Video} + \beta_{Privacy} + \beta_{Temp} + \beta_{GPS} + \beta_{Behavior} + \beta_{Comp} + \beta_{TI} + \beta_{FT} + \beta_{Crops}$

Figure 6: Distribution of Individual Best-Worst Scores for Components

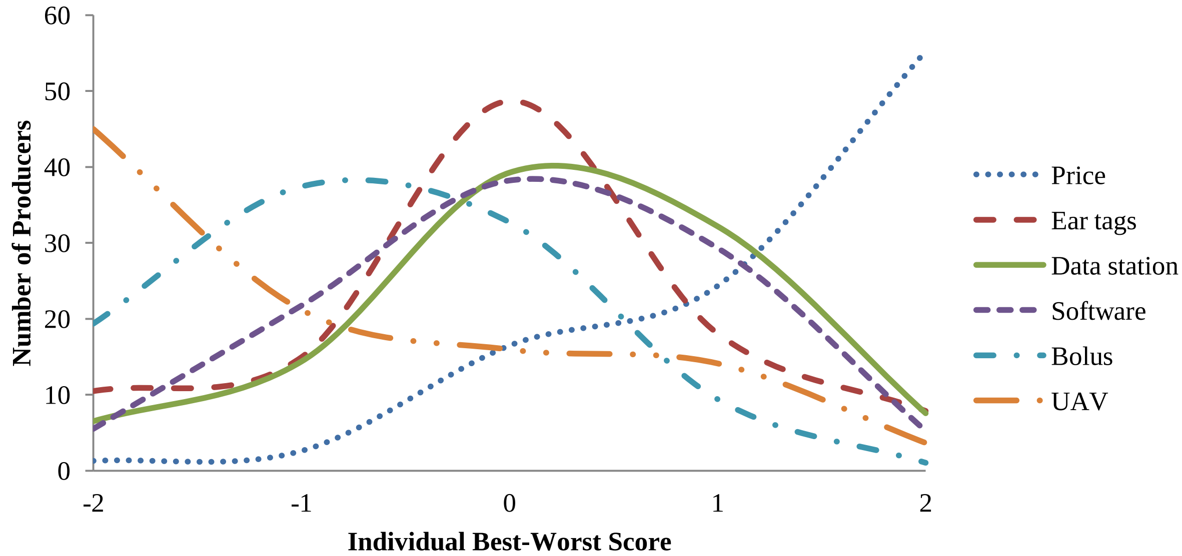
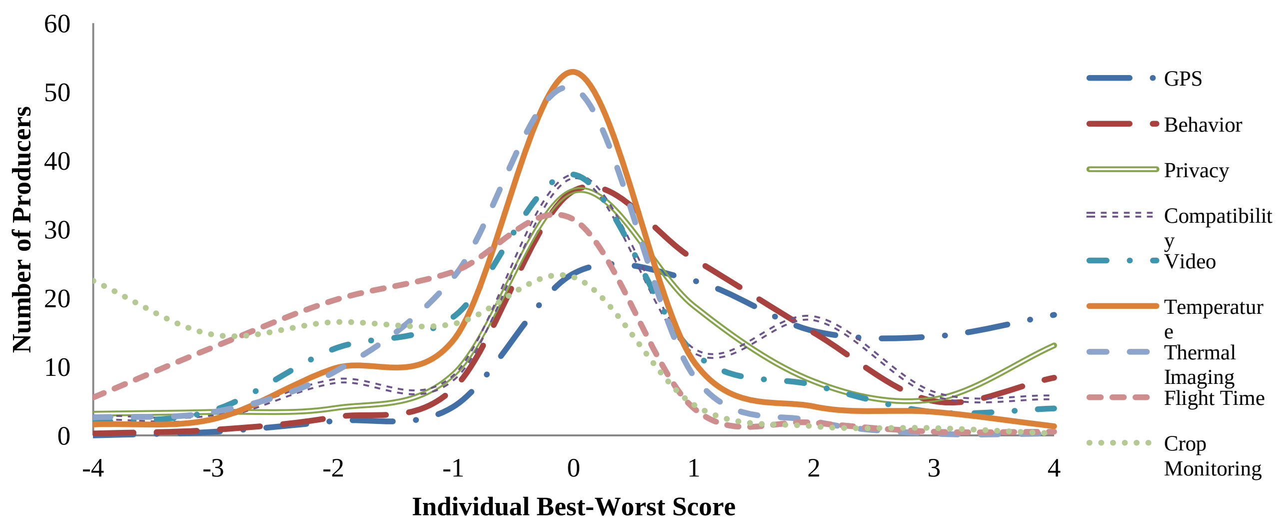


Figure 7: Distribution of Individual Best-Worst Scores for Characteristics



APPENDICES

Appendix Page

Appendix 1: OSU Institutional Review Board Survey Approval

Oklahoma State University Institutional Review Board

Date:	Thursday, June 19, 2014	**Protocol Expires:**	**6/9/2017**
IRB Application No:	AG1432		
Proposal Title:	Cattle Producer Willingness to Adopt Electronic Monitoring Systems		
Reviewed and Processed as:	Exempt **Modification**		

Status Recommended by Reviewer(s): **Approved**

Principal Investigator(s):

Lori Allmon
421-J Ag Hall
Stillwater, OK 74078

Dan Tilley
422 Ag Hall
Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

- The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Modification to 1) split the paired profile questions into two different blocks or 7 questions each. 2) modify instructions in the best worst question block, 3) notify subjects that their email address will not be linked to their responses, 4) send separate emails for each email list, and 5) add Department of Agricultural Economics to Lori's title. No increased risks.

Signature :

Shelia K

Shelia Kennison, Chair, Institutional Review Board

Thursday, June 19, 2014
Date

Appendix 2: Online Cattle Producer Survey Oklahoma Beef Council Email

Dear Cattle Producer:

I am writing to ask your assistance with a study of cattle producer's monitoring practices. The study is part of an effort to understand how producers currently monitor their cattle and their willingness or unwillingness to use and implement electronic monitoring technologies. You were selected for survey participation because you are a member the Oklahoma Beef Council email list.

Results from this survey will be used to better understand the desire for electronic cattle monitoring systems. By better understanding producer desires in regards to electronic monitoring systems, we will be able to determine the need for system development.

Your answers will be completely confidential and only released in summaries where no individual response can be determined. This survey is completely voluntary, and you must be over 18 years of age to participate. There are no known risks associated with this project greater than those ordinarily encountered in daily life. Your participation in this research is voluntary, and there is no penalty for refusal to participate. You are free to withdraw your consent and participation in this project at any time. However, your responses and opinions will be very helpful with this research.

If you have any questions regarding the survey, feel free to contact me via email at lori.allmon@okstate.edu.

The survey should take 15 to 20 minutes to complete. Your timely response is greatly appreciated.

To access the survey, you may click on the below link labeled “Take the Survey.” By clicking on the link, you are giving your consent to participate in the survey.

Take the Survey

Thank you,

Lori Allmon
Graduate Research Assistant
Department of Agricultural Economics
Oklahoma State University
lori.allmon@okstate.edu

Appendix 3: Online Cattle Producer Survey Samuel Roberts Noble Foundation Email

Dear Cattle Producer:

I am writing to ask your assistance with a study of cattle producer's monitoring practices. The study is part of an effort to understand how producers currently monitor their cattle and their willingness or unwillingness to use and implement electronic monitoring technologies. You were selected for survey participation because you are a member the Noble Foundation email list.

Results from this survey will be used to better understand the desire for electronic cattle monitoring systems. By better understanding producer desires in regards to electronic monitoring systems, we will be able to determine the need for system development.

Your answers will be completely confidential and only released in summaries where no individual response can be determined. This survey is completely voluntary, and you must be over 18 years of age to participate. There are no known risks associated with this project greater than those ordinarily encountered in daily life. Your participation in this research is voluntary, and there is no penalty for refusal to participate. You are free to withdraw your consent and participation in this project at any time. However, your responses and opinions will be very helpful with this research.

If you have any questions regarding the survey, feel free to contact me via email at lori.allmon@okstate.edu.

The survey should take 15 to 20 minutes to complete. Your timely response is greatly appreciated.

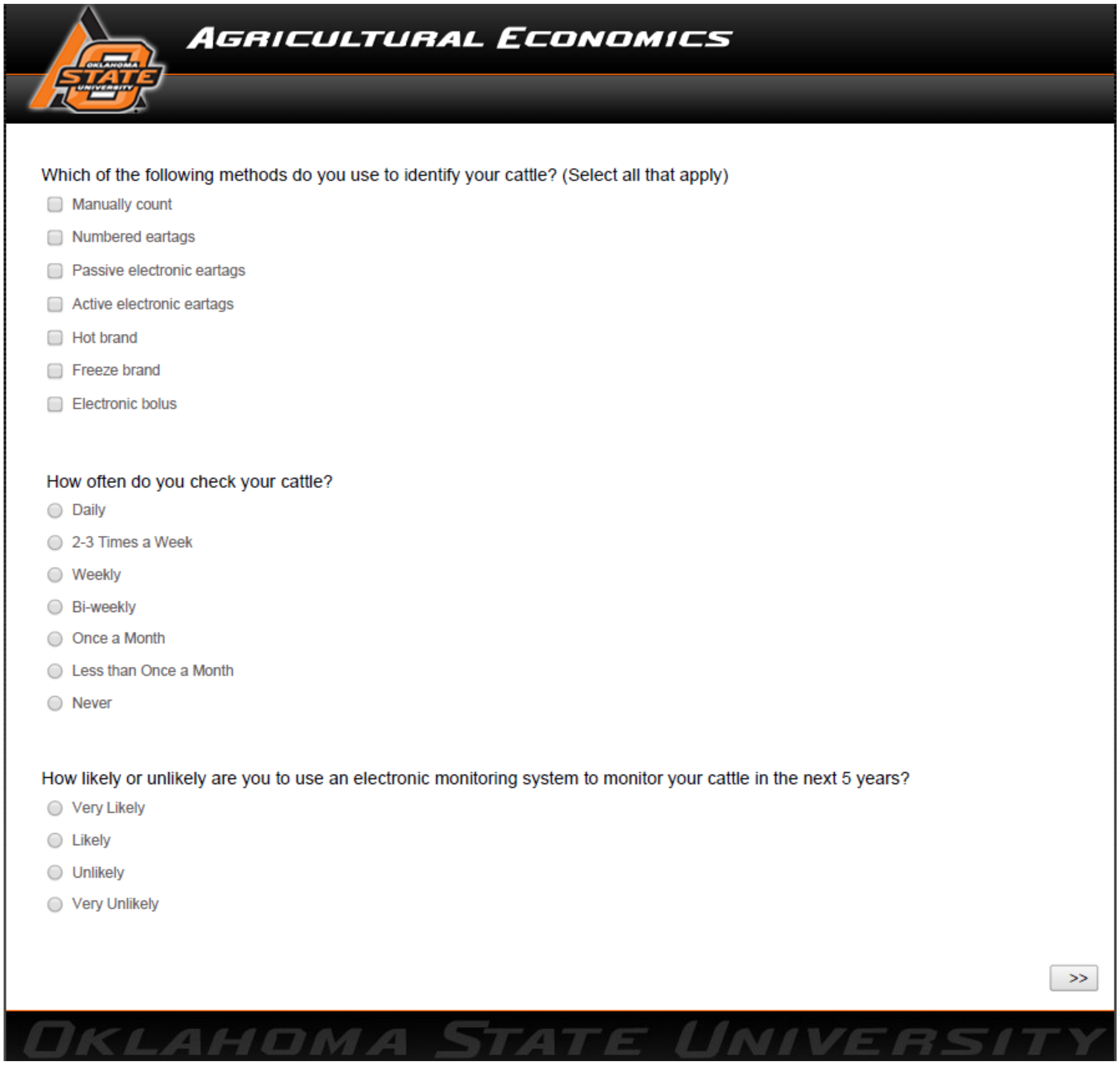
To access the survey, you may click on the below link labeled "Take the Survey." By clicking on the link, you are giving your consent to participate in the survey.

Take the Survey

Thank you,

Lori Allmon
Graduate Research Assistant
Department of Agricultural Economics
Oklahoma State University
lori.allmon@okstate.edu

Appendix 4: Online Cattle Producer Survey Question



AGRICULTURAL ECONOMICS

Which of the following methods do you use to identify your cattle? (Select all that apply)

- ☐ Manually count
- ☐ Numbered eartags
- ☐ Passive electronic eartags
- ☐ Active electronic eartags
- ☐ Hot brand
- ☐ Freeze brand
- ☐ Electronic bolus

How often do you check your cattle?

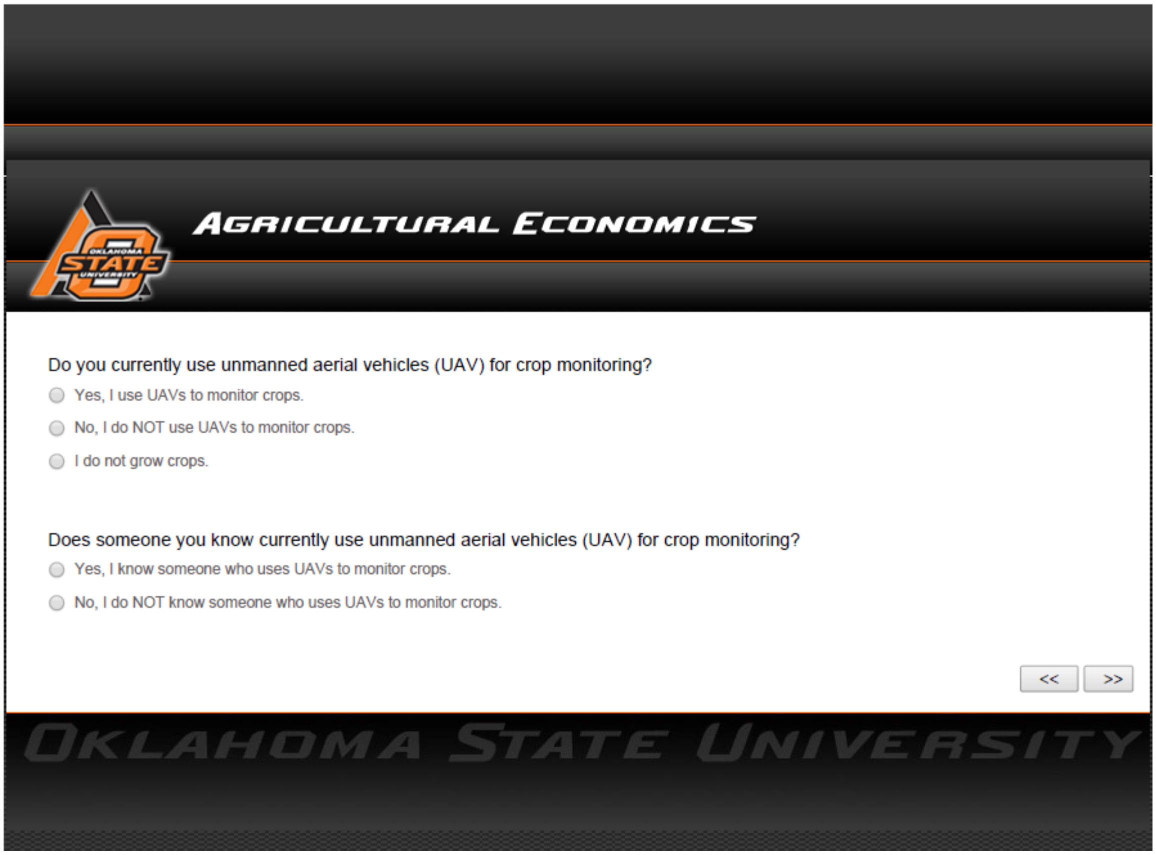
- ○ Daily
- ○ 2-3 Times a Week
- ○ Weekly
- ○ Bi-weekly
- ○ Once a Month
- ○ Less than Once a Month
- ○ Never

How likely or unlikely are you to use an electronic monitoring system to monitor your cattle in the next 5 years?

- ○ Very Likely
- ○ Likely
- ○ Unlikely
- ○ Very Unlikely

>>

OKLAHOMA STATE UNIVERSITY



AGRICULTURAL ECONOMICS

Do you currently use unmanned aerial vehicles (UAV) for crop monitoring?

- Yes, I use UAVs to monitor crops.
- No, I do NOT use UAVs to monitor crops.
- I do not grow crops.

Does someone you know currently use unmanned aerial vehicles (UAV) for crop monitoring?

- Yes, I know someone who uses UAVs to monitor crops.
- No, I do NOT know someone who uses UAVs to monitor crops.

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AGRICULTURAL ECONOMICS

In addition to raising cattle do you have land in crops (e.g. wheat, corn, soybeans etc.)?

- Yes
- No

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AGRICULTURAL ECONOMICS

How many acres of wheat did you produce last year?

How many acres of corn did you produce last year?

How many acres of soybeans did you produce last year?

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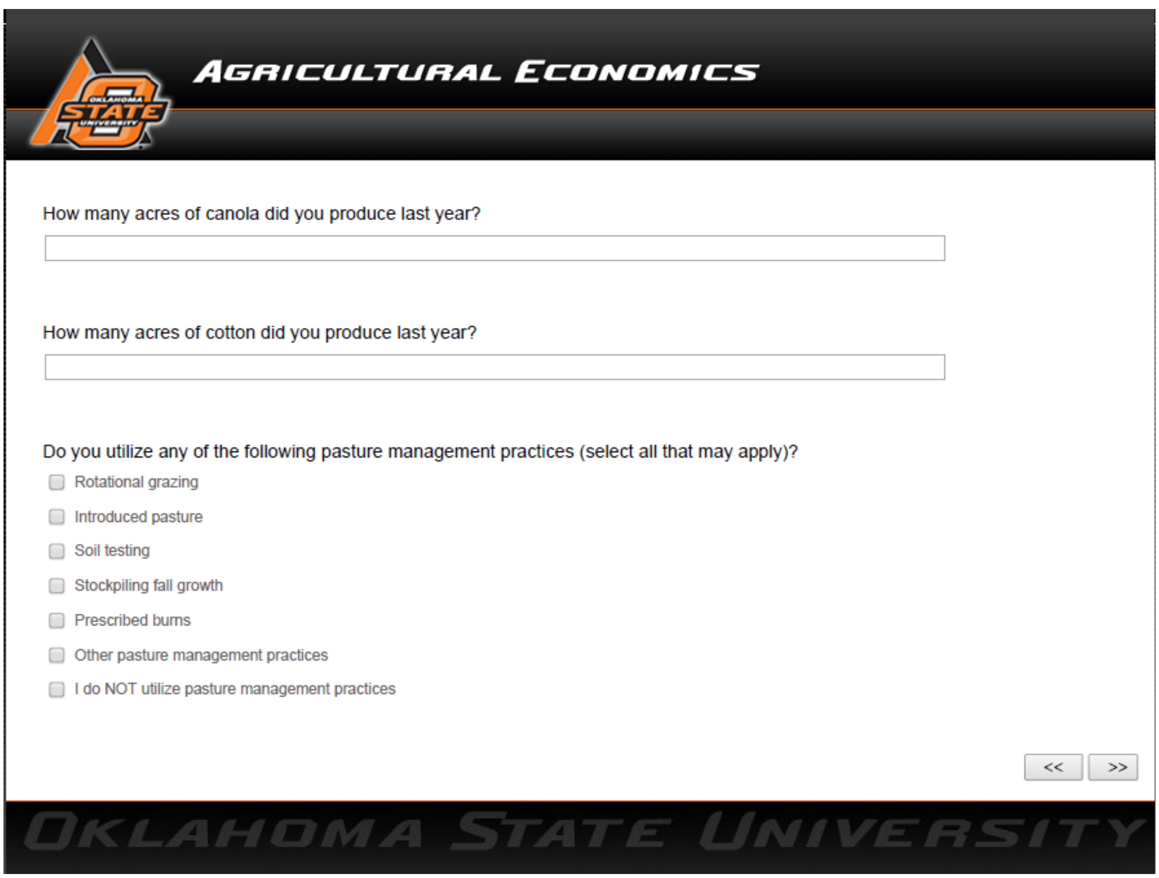
AGRICULTURAL ECONOMICS

How many acres of canola did you produce last year?

How many acres of cotton did you produce last year?

Do you utilize any of the following pasture management practices (select all that may apply)?

- Rotational grazing
- Introduced pasture
- Soil testing
- Stockpiling fall growth
- Prescribed burns
- Other pasture management practices
- I do NOT utilize pasture management practices

<< >>

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AGRICULTURAL ECONOMICS

Electronic Cattle Monitoring Systems

You will now be asked a series of questions regarding the creation of an electronic cattle management system. The following information is to assist you in answering these questions.

Unmanned aerial vehicles (UAV) are “capable of operating without an internal pilot; are tethered by a radio control link; and can be preprogrammed for both flight and payload operations prior to launch” (Unmanned Aerial Vehicle Systems Association). This system could be used to better determine the location of missing and/or ill cattle through GPS technology and visual imaging.

“Radio frequency identification, or RFID, is a generic term for technologies that use radio waves to automatically identify animals or objects. There are several methods of identification, but the most common is to store a serial number that identifies a person or object, and perhaps other information, on a microchip that is attached to an antenna. The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers that can make use of it” (RFID Journal). A RFID chip is placed in a rumen bolus to collect GPS and rumen temperature information. A RFID chip placed in an ear tag provides GPS information or assists with the signal transmission from the rumen bolus.

GPS stations could read signals from active RFID chips in order to collect data concerning animal movements, location and general health. This information could be later relayed to a UAV in order to locate and monitor cattle.

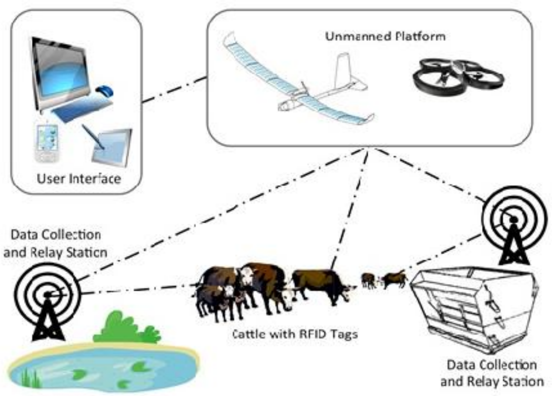

Image courtesy of DII, Inc.

AGRICULTURAL ECONOMICS

In the following set of questions, you will be presented with a set electronic cattle monitoring system components, and asked to select which components would have the greatest influence and would have the least influence on your purchasing decision. Only select **ONE** component as <u>greatest</u> influence and **ONE** component as <u>least</u> influence.

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AGRICULTURAL ECONOMICS

Which of the following electronic cattle monitoring system components would have the greatest influence and would have the least influence on your purchasing decision? (Using your mouse, click and drag only one component to each box).

Items	Greatest Influence	Least Influence
Price		
Pasture GPS collection near feed/water sources		
Unmanned aerial vehicle		
RFID ear tags		

Which of the following electronic cattle monitoring system components would have the greatest influence and would have the least influence on your purchasing decision? (Using your mouse, click and drag only one component to each box).

Items	Greatest Influence	Least Influence
RFID ear tags		
Price		
RFID rumen bolus		
Software package relaying collected data		

Which of the following electronic cattle monitoring system components would have the greatest influence and would have the least influence on your purchasing decision?(Using your mouse, click and drag only one component to each box).

Items	Greatest Influence	Least Influence
Unmanned aerial vehicle		
Pasture GPS collection near feed/water sources		
RFID rumen bolus		
Software package relaying collected data		

<< >>

AGRICULTURAL ECONOMICS

On the next question set, you will be presented with a set of electronic cattle monitoring system characteristics, and you will be asked to select which is the most preferred characteristic and which is the least preferred characteristic. Only select **ONE** component as <u>most</u> preferred and **ONE** component as <u>least</u> preferred.

Characteristics include:
- Live video feed of cattle retrieved using an unmanned aerial vehicle;
- Privacy safeguards preventing others from accessing information about your herd and from flying UAVs over your property;
- Rumen temperature collection using RFID bolus allowing you to have up-to-date health information for each animal;
- GPS location of each animal;
- Notification of altered behavioral patterns of individual animals signaling things from calving to theft;
- Compatibility with leading cattle management software (e.g. CattleMax, Cattleworks, CattlePro);
- Thermal imaging allowing a heat map of the animal to be seen at night or when the cow is located in heavy cover;
- Extended battery life for the unmanned aerial vehicle allowing the UAV to remain in the air for extended periods of time;
- Technologies allowing the unmanned aerial vehicle to also monitor crops.

AGRICULTURAL ECONOMICS

Which is the most preferred characteristic of an electronic monitoring system and which is the least preferred characteristic of an electronic monitoring system? (Using your mouse, click and drag only one characteristic to each box).

Items	Most Preferred Characteristic	Least Preferred Characteristic
Notification of altered behavioral patterns		
Crop monitoring technology		
Extended unmanned aerial vehicle flight time		
Live video feed from unmanned aerial vehicle		
Rumen temperature collection		
Compatibility with cattle management software		

Which is the most preferred characteristic of an electronic monitoring system and which is the least preferred characteristic of an electronic monitoring system? (Using your mouse, click and drag only one characteristic to each box).

Items	Most Preferred Characteristic	Least Preferred Characteristic
Notification of altered behavioral patterns		
Rumen temperature collection		
Thermal imaging		
Privacy safeguards		
GPS animal location monitoring		
Crop monitoring technology		

Which is the most preferred characteristic of an electronic monitoring system and which is the least preferred characteristic of an electronic monitoring system? (Using your mouse, click and drag only one characteristic to each box).

Items	Most Preferred Characteristic	Least Preferred Characteristic
Live video feed from unmanned aerial vehicle		
Notification of altered behavioral patterns		
Privacy safeguards		
Extended unmanned aerial vehicle flight time		
GPS animal location monitoring		
Crop monitoring technology		

Which is the most preferred characteristic of an electronic monitoring system and which is the least preferred characteristic of an electronic monitoring system? (Using your mouse, click and drag only one characteristic to each box).

Items	Most Preferred Characteristic	Least Preferred Characteristic
Privacy safeguards		
Rumen temperature collection		
Crop monitoring technology		
Compatibility with cattle management software		
Thermal imaging		
Live video feed from unmanned aerial vehicle		

Which is the most preferred characteristic of an electronic monitoring system and which is the least preferred characteristic of an electronic monitoring system? (Using your mouse, click and drag only one characteristic to each box).

Items	Most Preferred Characteristic	Least Preferred Characteristic
Extended unmanned aerial vehicle flight time		
Compatibility with cattle management software		
Privacy safeguards		
Live video feed from unmanned aerial vehicle		
GPS animal location monitoring		
Thermal imaging		

Which is the most preferred characteristic of an electronic monitoring system and which is the least preferred characteristic of an electronic monitoring system? (Using your mouse, click and drag only one characteristic to each box).

Items	Most Preferred Characteristic	Least Preferred Characteristic
Compatibility with cattle management software		
Extended unmanned aerial vehicle flight time		
Rumen temperature collection		
Thermal imaging		
GPS animal location monitoring		
Notification of altered behavioral patterns		

<< >>

AGRICULTURAL ECONOMICS

In the following section, you will be asked a set of 7 repeated questions regarding your preferences for an electronic monitoring cattle system. Each question will include two unique electronic cattle monitoring systems, consider each system, and select the one you would purchase.

The cattle monitoring systems will be comprised of an unmanned aerial vehicle, a RFID rumen bolus in each cow, and ground data collection stations. All systems will be able to collect temperature and GPS data from the cattle.

Systems vary based on price, information privacy safeguards, compatibility with cattle management software, crop scouting technology, and live video of herd.

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Note: This is set 1 of the Choice Experiment Questions

AGRICULTURAL ECONOMICS

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $8,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Live video of herd
- $3,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
- $3,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
  Crop scouting capabilities
  Live video of herd
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $8,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Crop scouting capabilities
  Live video of herd

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
  Crop scouting capabilities
  Live video of herd
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Crop scouting capabilities
- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Live video of herd
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Compatibility with cattle management software
  Crop scouting capabilities
- $8,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $8,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Compatibility with cattle management software
  Live video of herd

$8,000 electronic monitoring system
$45 bolus per animal
System includes:
Unmanned aerial vehicle
RFID rumen boluses
Ground GPS collection station
Added privacy for herd information
Compatibility with cattle management software
Crop scouting capabilities

I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

$3,000 electronic monitoring system
$45 bolus per animal
System includes:
Unmanned aerial vehicle
RFID rumen boluses
Ground GPS collection station
Compatibility with cattle management software

$8,000 electronic monitoring system
$10 bolus per animal
System includes:
Unmanned aerial vehicle
RFID rumen boluses
Ground GPS collection station
Crop scouting capabilities

I would not purchase either monitoring system

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Note: This is set 2 of the Choice Experiment Questions

AGRICULTURAL ECONOMICS

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Crop scouting capabilities
- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Live video of herd
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
- $8,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Crop scouting capabilities
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $8,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Compatibility with cattle management software
  Live video of herd

- $8,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Compatibility with cattle management software
  Crop scouting capabilities
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Compatibility with cattle management software
  Crop scouting capabilities
- $8,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
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Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

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  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
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  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
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Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
- $3,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
  Crop scouting capabilities
  Live video of herd
- I would not purchase either monitoring system

Of the electronic cattle monitoring systems shown below, which would you choose to purchase?

- $8,000 electronic monitoring system
  $45 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Added privacy for herd information
  Crop scouting capabilities
  Live video of herd
- $3,000 electronic monitoring system
  $10 bolus per animal
  System includes:
  Unmanned aerial vehicle
  RFID rumen boluses
  Ground GPS collection station
  Compatibility with cattle management software
  Crop scouting capabilities
  Live video of herd
- I would not purchase either monitoring system

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AGRICULTURAL ECONOMICS

We would like some background information about you and your operation. This is an important part of our analysis. All responses are confidential. Your answers will not be linked with your name or email address.

What is your gender?

- Male
- Female

In what state(s) do you have cattle?

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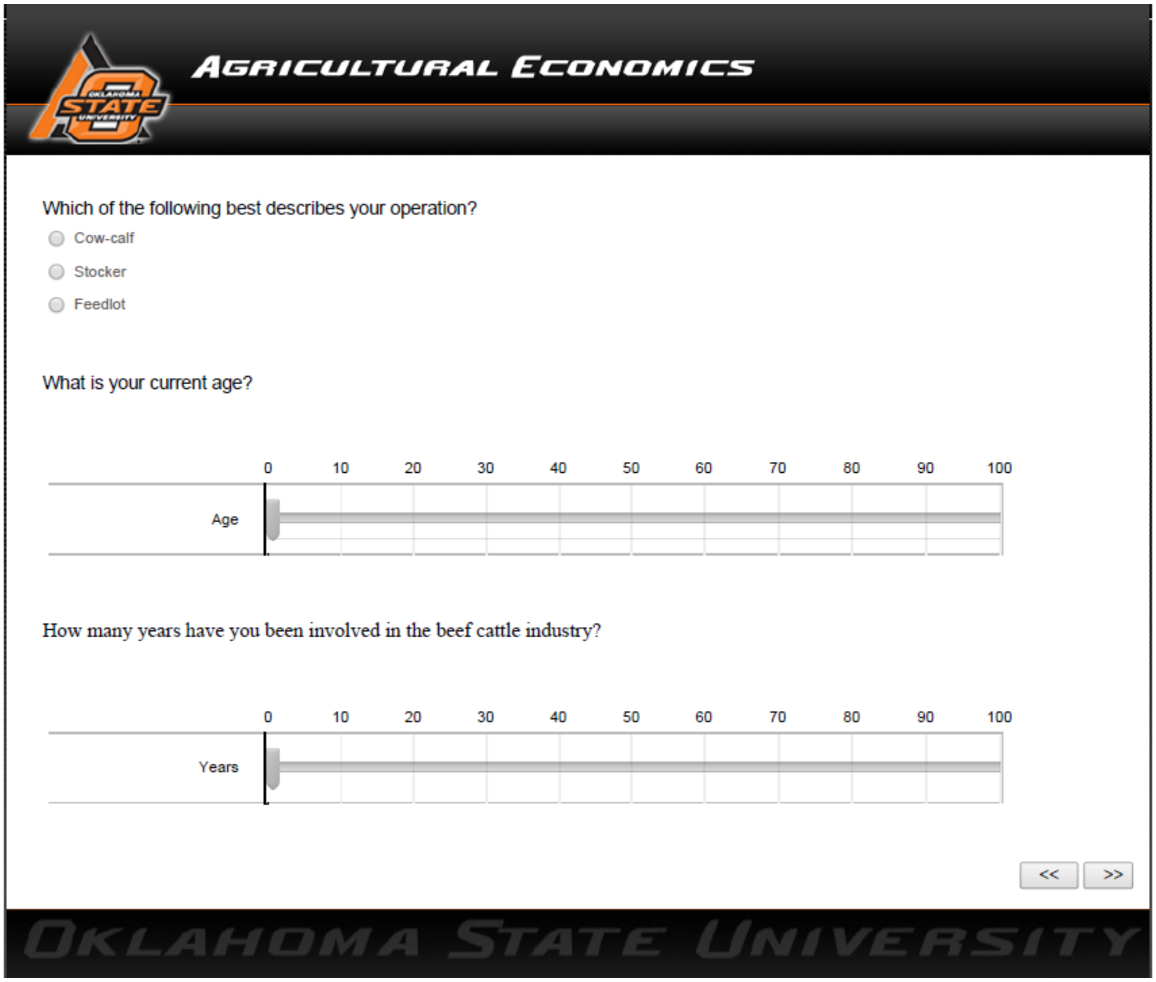

AGRICULTURAL ECONOMICS

Which of the following best describes your operation?

- Cow-calf
- Stocker
- Feedlot

What is your current age?

	0	10	20	30	40	50	60	70	80	90	100
Age											

How many years have you been involved in the beef cattle industry?

	0	10	20	30	40	50	60	70	80	90	100
Years											

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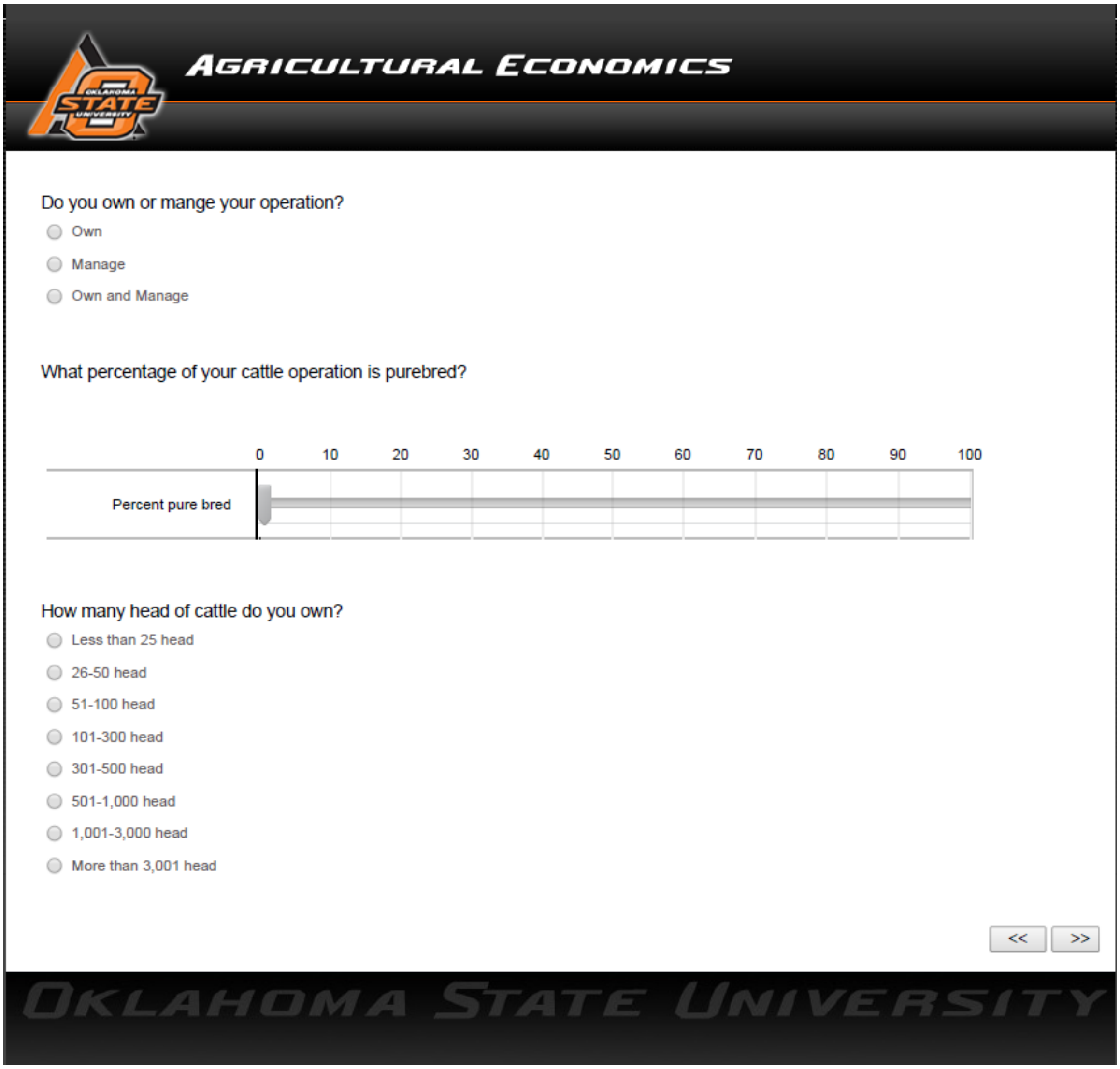
AGRICULTURAL ECONOMICS

Do you own or mange your operation?

- Own
- Manage
- Own and Manage

What percentage of your cattle operation is purebred?

	0	10	20	30	40	50	60	70	80	90	100
Percent pure bred											

How many head of cattle do you own?

- Less than 25 head
- 26-50 head
- 51-100 head
- 101-300 head
- 301-500 head
- 501-1,000 head
- 1,001-3,000 head
- More than 3,001 head

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AGRICULTURAL ECONOMICS

How many times a year do you sell cattle?

- 1 time per year
- 2 times per year
- 3 times per year
- 4 times per year
- 5 or more times per year

What is the highest level of education you completed?

- Some grade school
- Some high school
- High school diploma or G.E.D equivalent
- Some college
- Bachelors
- Masters
- Ph.D.
- D.V.M.
- M.D., D.O., or D.D.

What is your approximate before tax income?

- Less than $20,000
- $20,000 to $39,000
- $40,000 to $59,000
- $60,000 to $79,000
- $80,000 to $99,000
- $100,000 to $199,000
- $200,000 or more

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

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Appendix 5: Best-Worst Components Questions SAS Code

```
dm 'log; clear; output; clear; ';
ods html close; /* close previous */
ods html; /* open new */
options ls=100 ps=55 pageno=1 nodate;
proc plan seed=22175 ordered;
factors x1=6/noprint;
output out=full;

proc optex data=full
coding=orth seed=22675;
class x1;
model x1;
blocks structure=(3)4;
output out=design1;

proc print data=design1;

proc freq data=design1;
table x1;
quit;
```

Appendix 6: Best-Worst Components Questions SAS Output

The SAS System

The OPTEX Procedure

Class Level Information

Class	Levels	Values
x1	6	1 2 3 4 5 6

The SAS System

The OPTEX Procedure

Design Number	Treatment D-Efficiency	Treatment A-Efficiency	Block Design D-Efficiency
1	89.1301	88.2353	99.0335
2	89.1301	88.2353	99.0335
3	89.1301	88.2353	99.0335
4	89.1301	88.2353	99.0335
5	89.1301	88.2353	99.0335

Design Number	Treatment D-Efficiency	Treatment A-Efficiency	Block Design D-Efficiency
6	89.1301	88.2353	99.0335
7	89.1301	88.2353	99.0335
8	89.1301	88.2353	99.0335
9	89.1301	88.2353	99.0335
10	89.1301	88.2353	99.0335

The SAS System

Obs	BLOCK	x1
1	1	1
2	1	5
3	1	2
4	1	6
5	2	5
6	2	4
7	2	3
8	2	1
9	3	3
10	3	4
11	3	2
12	3	6

The SAS System

The FREQ Procedure

x1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	2	16.67	2	16.67
2	2	16.67	4	33.33
3	2	16.67	6	50.00
4	2	16.67	8	66.67
5	2	16.67	10	83.33
6	2	16.67	12	100.00

Appendix 7: Best-Worst Characteristics Questions SAS Code

```
dm 'log; clear; output; clear; ';
ods html close; /* close previous */
ods html; /* open new */
options ls=100 ps=55 pageno=1 nodate;
proc plan seed=55675 ordered;
factors x1=9/noprint;
output out=full;

proc optex data=full
coding=orth seed=55675;
class x1;
model x1;
blocks structure=(6)6;
output out=design1;

proc print data=design1;

proc freq data=design1;
table x1;
quit;
```

Appendix 8: Best-Worst Characteristics Questions SAS Output

The SAS System

The OPTEX Procedure

Class Level Information

Class	Levels	Values
x1	9	1 2 3 4 5 6 7 8 9

The SAS System

The OPTEX Procedure

Design Number	Treatment D-Efficiency	Treatment A-Efficiency	Block Design D-Efficiency
1	93.5414	93.3333	99.7775
2	93.5414	93.3333	99.7775
3	93.5414	93.3333	99.7775
4	93.5414	93.3333	99.7775
5	93.5414	93.3333	99.7775
6	93.5414	93.3333	99.7775
7	93.5414	93.3333	99.7775
8	93.5414	93.3333	99.7775
9	93.5414	93.3333	99.7775
10	93.5414	93.3333	99.7775

The SAS System

Obs	BLOCK	x1
1	1	8
2	1	6
3	1	2
4	1	1
5	1	4
6	1	7

Obs	BLOCK	x1
7	2	5
8	2	9
9	2	8
10	2	3
11	2	1
12	2	6
13	3	5
14	3	3
15	3	7
16	3	2
17	3	4
18	3	9
19	4	6
20	4	8
21	4	3
22	4	7
23	4	4
24	4	5
25	5	2
26	5	3
27	5	9
28	5	6
29	5	7
30	5	1
31	6	1
32	6	5
33	6	2
34	6	8
35	6	4

Obs	BLOCK	x1
36	6	9

The SAS System

The FREQ Procedure

x1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	4	11.11	4	11.11
2	4	11.11	8	22.22
3	4	11.11	12	33.33
4	4	11.11	16	44.44
5	4	11.11	20	55.56
6	4	11.11	24	66.67
7	4	11.11	28	77.78
8	4	11.11	32	88.89
9	4	11.11	36	100.00

Appendix 9: Choice Experiment Question SAS Code

```
dm 'log; clear; output; clear; ';
ods html close; /* close previous */
ods html; /* open new */
options ls=100 ps=55 pageno=1 nodate;
proc plan seed=5556 ordered;
factors x1=2 x2=2 x3=2 x4=2 x5=2 x6=2 x7=2 x8=2 x9=2 x10=2 x11=2 x12=2
x13=2/ noprint;
output out=full;

proc optex data=full
coding=orthcan seed=5556;
title 'UAV Attributes';
class x1-x13;
model x1-x13;
generate n=14 method=m_federov;
output out=design2;
proc print data=design2;
quit;
```

Appendix 10: Choice Experiment Question SAS Output

UAV Attributes

The OPTEX Procedure

Class Level Information

Class	Levels	Values
x1	2	1 2
x2	2	1 2
x3	2	1 2
x4	2	1 2
x5	2	1 2
x6	2	1 2
x7	2	1 2
x8	2	1 2
x9	2	1 2
x10	2	1 2
x11	2	1 2
x12	2	1 2
x13	2	1 2

UAV Attributes

The OPTEX Procedure

Design Number	D-Efficiency	A-Efficiency	G-Efficiency	Average Prediction Standard Error
1	95.7246	92.8571	93.0949	1.0377
2	93.7526	87.6712	78.4465	1.0680
3	93.3317	87.2404	74.6203	1.0706
4	92.2032	85.7143	74.5356	1.0801
5	92.2032	85.7143	74.5356	1.0801
6	92.2032	84.6660	75.0992	1.0868

Design Number	D-Efficiency	A-Efficiency	G-Efficiency	Average Prediction Standard Error
7	91.4875	83.1392	69.8518	1.0967
8	91.4534	83.6066	72.5102	1.0937
9	91.4534	83.6066	72.5102	1.0937
10	90.8258	82.3729	72.6202	1.1018

UAV Attributes

Obs	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13
1	2	2	2	1	2	2	2	1	2	2	1	2	2
2	2	2	1	2	1	2	2	2	1	1	1	2	2
3	2	2	1	1	2	1	1	2	2	1	2	2	1
4	2	2	1	1	1	2	1	1	1	2	2	1	2
5	2	1	2	2	2	1	2	1	1	1	2	1	1
6	2	1	2	1	1	2	1	2	2	1	1	1	2
7	2	1	1	2	1	1	1	1	2	2	1	2	1
8	1	2	2	2	1	2	1	1	2	1	2	2	1
9	1	2	2	1	1	1	2	2	1	2	1	1	1
10	1	2	1	2	2	1	1	1	2	1	1	1	2
11	1	1	2	2	2	1	1	2	1	2	2	2	2
12	1	1	1	2	2	2	2	2	2	2	2	1	1
13	1	1	1	1	2	2	1	1	1	1	1	2	1
14	1	1	1	1	1	1	2	1	2	1	2	2	2

VITA

Lori Dawn Allmon

Candidate for the Degree of

Master of Science

Thesis: WILL CATTLE PRODUCERS BE WILLING TO ADOPT ELECTRONIC CATTLE MONITORING SYSTEMS?

Major Field: Agricultural Economics

Biographical:

Education:

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08/11-08/12	Marketing and Communications Assistant, OSU College of Human Sciences
05/09-08/09; 05/10-08/10; and 05/11-08/11	Intern; Stock Horse News Editor's Assistant, Pro Management, Inc.

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