VISIONING THE AGRICULTURE BLOCKCHAIN: THE ROLE AND RISE OF BLOCKCHAIN IN THE COMMERCIAL POULTRY INDUSTRY

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ABSTRACT

VISIONING THE AGRICULTURE BLOCKCHAIN: THE ROLE AND RISE OF BLOCKCHAIN IN THE COMMERCIAL POULTRY INDUSTRY

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Blockchain is an emerging technology that is being explored by technologists and industry leaders as a way to revolutionize the agriculture supply chain. The problem is that human and ecological insights are needed to understand the complexities of how blockchain could fulfill these visions. In this work, I assert how the blockchain's promising vision of traceability, immutabil-ity and distributed properties presents advancements and challenges to rural farming. This work wrestles with the more subtle ways the blockchain technology would be integrated into the existing infrastructure. Through interviews and participatory design workshops, I talked with an expansive set of stakeholders including Amish farmers, contract growers, senior leadership and field super-visors. This research illuminates that commercial poultry farming is such a complex and diffuse system that any overhaul of its core infrastructure will be difficult to "roll back" once blockchain is "rolled out." Through an HCI and sociotechnical system perspective, drawing particular insights from Science and Technology Studies theories of infrastructure and breakdown, this dissertation asserts three main concerns. First, this dissertation uncovers the dominant narratives on the farm around revision and "roll back" of blockchain, connecting to theories of version control from computer science. Second, this work uncovers that a core concern of the poultry supply chain is death and I reveal the socio-technical and material implications for the integration of blockchain. Finally, this dissertation discusses the meaning of "security" for the poultry supply chain in which biosecurity is prioritized over cybersecurity and how blockchain impacts these concerns. Together these findings point to significant implications for designers of blockchain infrastructure and how rural workers will integrate the technology into the supply chain.

This document is dedicated to my family, Julie, Joseph, and Nathan Fennell

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CHAPTER 1

INTRODUCTION

1.1 Visioning the Blockchain

There is an ambition by technology enthusiasts in industry for blockchain technology to be fully integrated in the supply chains of the poultry industry. For the past several years, the International Poultry and Production Expo (IPPE) has offered sessions that envision blockchain technology as transformative for the industry. Titles of sessions were named "How to Prepare for the Blockchain Revolution" or "Preparing for Blockchain in A New Era of Smarter Food Safety". These sessions were loaded with views of techno-utopianism and highlighted the benefits of these solutions for the poultry and agriculture supply chain. However, implementing a blockchain-based supply chain requires a significant change of infrastructure. Researchers have started to show what a new blockchain infrastructure might look like in agriculture [74, 12] with researchers joining blockchain supply chains with complex technologies like Unmanned Aerial Vehicles(UAV) [44], Internet-of-Things (IoT) Devices [24] and Radio Frequency ID (RFID) [83]. While these technologies are exciting, they seem to forget about the Human Computer Interaction (HCI) perspective from individuals who work at these farms.

The problem is that human and ecological insights are needed to understand the complexities of how blockchain could fulfill these visions. The blockchain technology narrative of “turn on the technology and it will fix everything” doesn’t seem to fit. Drawing from the HCI and Science and Technology Studies (STS) literature, I explore the implications of this technology in the rural commercial duck industry. Through an HCI and sociotechnical system perspective, drawing particular insights from Science and Technology Studies theories of infrastructure and breakdown, this dissertation asserts three main concerns. First, this dissertation uncovers the dominant narratives on the farm around revision and “rollback” of blockchain, connecting to theories of version control from computer science. Second, this work uncovers that a core concern of the poultry supply chain is death, an aspect of animal husbandry that has significant implications for the integration of blockchain. Finally, this dissertation discusses the meaning of "security" for the poultry supply chain in which biosecurity is prioritized over cybersecurity and how blockchain impacts these concerns. Together these findings point to significant implications for designers of blockchain infrastructure and how rural workers will integrate the technology into the supply chain.

From a higher-level view, this dissertation is structured in the following way. In this introductory chapter, chapter 1, I introduce the needs of the rural supply chain at a duck farm and report on findings detail their conceptualizing of blockchain. In the next chapter, chapter 2, I explain the rationale and methodology used for this research as well as the structure for the rest of the chapters in the dissertation. Chapter 3 focuses on the beliefs about technology failure and revision that is pervasive throughout the farm. Chapter 4 focuses on the farmers view of death and the strength of relationships on a duck farm. Finally, chapter 5 focuses on how the rural farmers understood vulnerabilities on the farm and how that shapes their perspective on blockchain.

For this chapter, the primary goal is to understand how individuals in the duck industry understand and potentially interact with blockchain technology. It is unclear how the technology would work with the existing infrastructure on a rural commercial farm, how the individuals who would work with it, and what vulnerabilities might arise introducing it into the supply chain. This chapter gives an overview of the technology and how individuals understand the technical components of blockchain.

Specifically, I present a brief explanation of the three properties of blockchain: decentralization, immutability and transparency. Findings show that of the three properties of blockchain, traceability seemed to be the most salient property to the rural commercial farmer. Additionally when it came to the blockchain system itself, participants in this study naturally inferred that the purpose of a system like this is to pull information together. I then explain that when it comes to the perceptions of blockchain, that time could be better served by designers by prioritizing and explaining traceability. The blockchain systems for these rural farmers could focus on how to trace the information throughout the supply chain. Furthermore, a possible design recommendation would be to ensure that the stakeholders are aware of the logically centralized repository and that it could be shared among various stakeholders. Finally, this introductory chapter sets up the following chapters by giving the reader a basic comprehension of how these rural duck farmers understand blockchain technology.

1.2 Supply Chain in the Duck Industry

I chose to study ducks in the poultry industry instead of chickens or other poultry for several reasons. First, commercial duck operations are smaller when compared to the much larger poultry industry. The number of ducks harvested annually are in the range of 31 million [1] compared to 229 million turkeys and 518 million chickens [2]. The lower volume of live animals provides a good place to test out new technologies and makes these firms slightly more flexible to try new technologies. Second, due to the price of duck meat, the profit margins in the duck margin were significantly higher than chicken. This allows the commercial duck farmers more room to explore newer technologies which are often costly. Finally, the field site of Culver Duck farms is a leader in the duck industry and allowed me access to their facilities.

The requirements of a duck farm needing a blockchain system come from a firm's ability to deal with recall. Product recall is a key requirement of USDA poultry guidelines and the Food and Drug Administration (FDA) [3] as other state and local guidelines. Being able to track an item to its source has become an increasing need over the years. For 2020 alone, the FDA issued 521 major product food recalls, an aspect of commercial farming named as having the most transformative potential through the integration of blockchain.[4] A recall can be financially devastating for a company. The FDA has explicit guides for following their mandated recalls [5]. One way agriculture companies try to mitigate recalls is through technology like traceability-focused systems, which are systems

[1] https://www.infarmbureau.org/barntours/duck-poultry.html

[2] https://www.statista.com/topics/6263/poultry-industry-in-the-united-states/

[3] https://www.fda.gov/safety/recalls-market-withdrawals-safety-alerts

[4] For this number, I exported the data made available from the FDA and extrapolated the number of recalls.

[5] https://www.fda.gov/media/71814/download

designed to track inventory. As I will explain in greater detail later, tracking items and linking them together is a unique property of blockchain.

Emphasizing this potential, food security researchers Pearson et al. [94] found that for food traceability, blockchain's ability to be able to track food in a deeply granular way across a supply chain, is a novel addition. However, the authors assert that the blockchain is limited by its lack of data standardization and argue that reorienting blockchain for sharing information would prove difficult. Additionally, the enhancement of the technology would also require changes to the storage infrastructure (large amounts of new data) as well as adding new personnel to analyze the new data. Implementing or changing the supply chain would be challenging for any commercial agriculture firm, but many duck farms are smaller entities, and it's not clear if duck farms are more versatile or would be hampered by implementing a blockchain system. Another perspective from Kamilaris et al.[63] highlighted that many of the proposed solutions and frameworks for blockchain in agriculture and food supply chains are only theoretical and that further work would need to be done in an applied way to investigate the implications of blockchain outside of the "laboratory" settings. For this research, I sought to see if blockchain can help address the challenges of managing the supply chain based on the individual's working with current systems and processes at a commercial duck farming facility. Understanding how blockchain could help or hinder the supply chain was very interesting and finding what HCI design implications might prove helpful to rural farmers felt like a worthy goal.

1.3 The Breadth of Blockchain Research

Blockchain can be easily thought of as a digital ledger, or detailed record of typically financial transactions, that are spread across a network. The technology was born out of the technological innovation of the cryptocurrency, Bitcoin. Blockchain's technological complexity comes from attempting to solve a crucial problem: in an autonomous way, in what way do you order and validate transactions? While there maybe an infinite way to order and validate transactions, the most elegant way was to order them by the time they arrived, down to the millisecond. So, from the Nakamoto whitepaper on Bitcoin [87], transactions are "linked" together primarily through a timestamp (see figure 1.1).

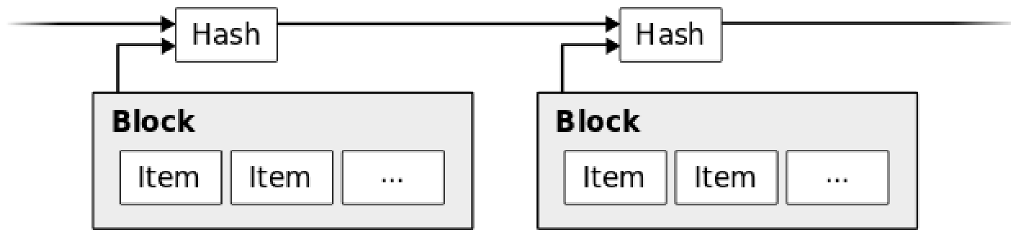

Figure 1.1: In Satoshi Nakamoto's white paper, Items (Transactions) are stored in blocks and then "hashed" to reduce space. Together these blocks are ordered by time and linked together.

This ordering of transactions via timestamp are stored in "blocks" and these "blocks" are artificial units that are simply bundled together with other transactions. A "hash" function takes any value and converts it to a fixed-length string of characters [5]. This fixed length string hash reduces the amount of data that needs to be stored because the transaction is represented in the hash format. Then the blocks are "hashed" and are chained together to form a blockchain. These hashes can be further condensed (See figure 1.2) for more complex and intricate blockchain configurations.

Each and every record is tied together, which makes it useful. Nothing can exist in a blockchain without an origin and a connection to other blocks; hence, the language of "chain".[6] Bitcoin set out to create secure digital money free from a central authority (in this case, banks) that leveraged distributed, rather than centralized. This type of distributed ledger showed that it was possible to have a way to record things that were cryptographically secure and intrinsically linked with each other. Growing alongside the rising popularity of cryptocurrency, blockchain became an interesting general-purpose technology that developers and entrepreneurs found could be useful in other industries, including agriculture. Alongside this popular growth, blockchain became an

[6]The *Crypto* stands for cryptography, which is a branch of mathematics that deals with keeping things secure. The classical Greek root word translation of crytpo (*kryptós*) stands for "secret" or "hidden". With this understanding, it can be thought of as keeping a message hidden or secret from others.

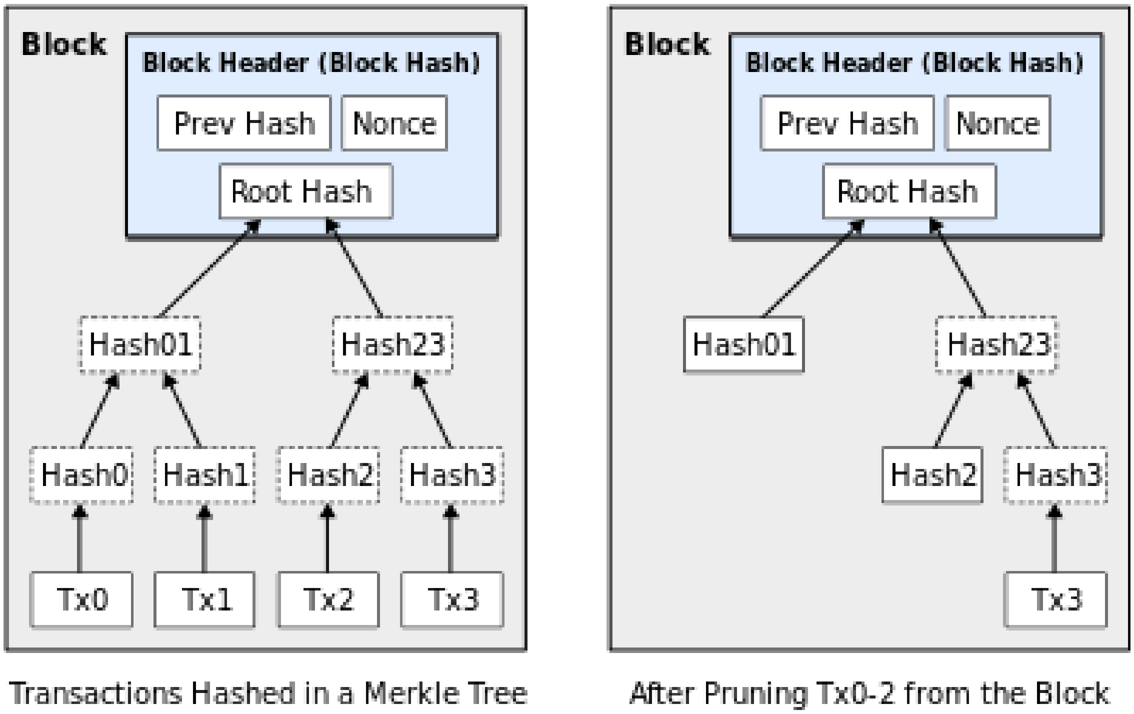

Figure 1.2: Hashes of Hashes. To reduce complexity and the amount of information needed to be stored, hashes are reduced further into hashes. This combination reduces space but shows how complicated the blockchain structure can be.

attractive technology in the agriculture industry, because many items on a farm are in need of tracking, including the animals themselves.

While the potential for blockchain to solve some of the most pressing problems of the supply chain and financially-based industries is well established, less is known about the lived reality of blockchain in practice. This dissertation's core concern is identifying exactly *how* to transform this industry - one which holds rich longstanding traditions including spiritual and intimate knowledges - from a *vision* of the blockchain into a successful *implementation* of the blockchain that integrates its unique culture and material forms. This dissertation illuminates some critical understandings of the lived reality of integrating blockchain into the poultry industry. This research looked across the fields of human and computer interaction, business supply chain, cybersecurity, science and technology studies and rural computing. These disparate bodies of literature speak to the variety of connections researchers are making and show how varied the blockchain technology is being conceptualized. Through this search, additional questions emerged, such as what are the first-order concerns of the different stakeholders of a blockchain solution and what vulnerabilities might arise in the introduction of a supply chain based on blockchain? Ultimately, these questions became the driving force for this research.

1.3.1 HCI and Blockchain

This dissertation is fundamentally informed by the work of HCI scholars Chris Speed and Bettina Nissen who demonstrate the lack of socio-technical understanding that gives nuance to blockchain's promise as a general purpose technology and into one with particular implementations situated in contexts [92, 90, 81, 40] Their work focuses on trying to understand primarily how individuals interact with blockchains via cryptocurrencies. My prior work in this area was focused on how miners (workers who maintain cryptocurrency networks) were incentivized by the perceived value of the cryptocurrencies [43]. This research illuminated the pervasive promise of the blockchain as a general-purpose technology and broad holes in the collective understanding of its implications. From its consensus mechanism to its clever use of Merkle trees, blockchain-based solutions have a lot of properties that could be helpful in the commercial agriculture space. More understanding is needed to understand the sociotechnical consequences of the blockchain.

Blockchain has been positioned as a solution to many problems because of its ability to be decentralized [55, 62], the ledger is immutable and unchanging [76, 108, 74], and the records are transparent to those a part of the network [88, 63, 94]. Examining the properties of blockchain may help in explaining why it might be useful in the commercial agriculture industry. Three important properties of the blockchain are: decentralization, immutability, and transparency.

1. Decentralization - Decentralization can be defined as transferring authority from a central place to many places. This refers to the ledger of transactions being distributed and owned in multiple physical locations in the blockchain. It could also mean being decentralized through multiple independent servers. From this perspective, it is beneficial to have multiple

agents a part of this system so that no one company/agent owns the entire ledger [55]. Unlike Cryptocurrencies, which are public blockchains, these servers would employ a private blockchain which has added benefits that any one agent that accesses the system would have permission to write to the ledger. This distributed model enables trust in each agent in that they may be able to write what they want.

2. Immutability - Immutability is something that can be unchanged or cannot change. Once the transactions are recorded in the blockchain, they are forever a part of the "chain" of transactions and cannot be easily unchanged. The transactions would only be immutable to the extent that the agents managing the blockchain agree that they should be. For example, mistakes would be fixed by creating an additional record that removes or adds as needed. This approach would be similar to a double-entry bookkeeping method [7]. This approach to immutability is dissimilar in theory to cryptocurrencies, but in practice, if a currency ever did run into trouble, e.g. Ethereum DAO fork[8], they can *simply* do a hard fork. This would be no easy task for a public blockchain but a simple execution for a private one.

3. Transparency - Finally, a blockchain system offers Transparency. By definition, it is something that is visible to all or is clear. In the blockchain, this means that the transactions are visible to all that are a part of the blockchain. However, this does not necessarily mean that the processes are transparent. Unlike a cryptocurrency, a private blockchain can withhold much of the information as they decide. An example might be that all supply chain transactions might be completely transparent, but the sales information might be withheld. A completely transparent blockchain has benefits in that auditors can know the provenance of anything within the blockchain. This property is the most appealing part of blockchain to the commercial agriculture industry. In the U.S., the commercial agriculture industry has requirements imposed by the U.S. Department of Agriculture (USDA) due to reasons such as heavy metal contamination, use of chemical fertilizers and pesticides, inferior or improper

[7] https://www.investopedia.com/terms/d/double-entry.asp

[8] https://blog.ethereum.org/2016/07/20/hard-fork-completed/

raw materials and food additives [74]. This makes the provenance or origins of such data not only important to know but also a requirement of law.

Taken together, these three components of blockchain make for a significant argument for adopting this new technology of blockchain infrastructure in the agricultural supply chain. Following this argument, blockchain is not a reinvention of the wheel; it is a progression from earlier systems that have been unified into an integrated system. Current industry solutions have created systems that have existed that offer one or two of these properties. For example, MTech systems [9] a supplier of A.I. based software, offers a comprehensive traceability system used by many major players in the poultry industry. Using the software, suppliers and producers can track the origins of products in its system, yet MTech lacks the decentralized property.

Transparency is often cited as the most helpful property of the blockchain because of its potential to transform the existing agricultural supply chain by raising the visibility of the components within the supply chain. Recall that blockchain has three core properties: decentralization, immutability and transparency. The literature is unclear on how the decentralization and immutability properties of the blockchain affect the supply chain. This dissertation interrogates the potential of the blockchain along with these core properties and emphasizes the human and ecological impacts of its possible integration into the poultry supply chain. I acknowledge that there may be other properties to blockchain that I did not cover or may emerge as a result of this work. As an example, the scalability of a blockchain system has not been explored in the HCI supply chain space, but there has been some work in the cryptocurrency space[15].

1.3.2 Blockchain in Agriculture

In a field like agriculture, which is materially driven, it is hard to tell if any blockchain system will aid in tracking physical things or create new roadblocks to production. Early work has started to show blockchain's potential in this area. An early systematic literature review of blockchain in the agriculture field by Bermeo-Almeida et al.[12] gave a snapshot of the work being constructed

[9] https://mtech-systems.com/

in this space. The researchers explained that blockchain systems were being designed for the purpose of traceability, secure data storage, supply chain and remote monitoring. Outside of this work, blockchain systems in agriculture have been proposed using UAV systems [44], IoT Devices [74, 24] and RFID[83] to develop a better supply chain system. Computer scientists have also explored software development models for farm-to-fork operations using blockchain which would allow customers to trace their product to its origin[9]. Yet within the blockchain literature, there is a sense that blockchain technology is really a superfluous technology in these papers. The aforementioned blockchain systems in these papers are designed with other technologies in mind and it is not solely a blockchain system but complete systems that use blockchain as a transactional back-end system. Whether it's RFID, IoT, or UAV systems, these technologists and researchers are focused on creating workable systems which need to use additional sensor or devices. These important contributions demand an additional understanding of the human and ecological impacts of these technologies.

In the information management field, researchers Behnke and Janssen [11] examined the potential use of blockchain to enable increased traceability of the supply chain in the dairy industry. The researchers found that in order for blockchain to be used successfully, the underlying supply chain would need to be modified and organized around a standard before such a system could be implemented. In a similar research study, researchers Stranieri et al.[106] found that through interviews with individuals in the food retail industry, blockchain systems can improve the management of behavioral uncertainty and increase the supply chain management competency. Taken together, both research groups indicate that blockchain can make improvements to the food supply chain. However, these researchers did not analyze how the individuals using the systems would interact with the blockchain systems in their day-to-day work. This work clearly points to a need for qualitative social scientific insight into these nuanced dynamics.

One remarkably special and unique work in this space is by Xiaowei Wang titled "Blockchain Chicken Farm[110]." The research explores the changing landscape of China's countryside through a series of explorations and interviews. Farmers at the GoGoChickenFarm use a blockchain-based technology in partnership with a tech company Lianmo Technology. The partnership with the technology company using blockchain was less important than the fact that using the technology enabled the farmers to have a reliable market each year. In other words, the coordination costs were lowered by partnering with a firm that used the blockchain technology. While the research also explored the shortcomings of the communist party's authoritarian policies, it placed the perspective as an important voice in the design and collaboration of blockchain technology. Xiaowei Wang described the partnership between the tech company and the local chicken farmers as problematic. Despite the technological improvement, initial orders were great in the first year but no large orders were made in the second year leaving the farmers on their own[110]. Influential to the present dissertation, this research focuses on the farmer's perspective and what challenges farmers might have by using a blockchain system for the supply chain.

Researchers have taken innovative approaches to explore the possibilities of blockchain systems. Khairuddin et al.[66] created a physical blockchain system using clay, paper and other materials to allow individuals to interact with a blockchain system. The researchers allowed individuals to construct their own blockchain system through a participatory design method. The participants the researchers recruited were individuals who were familiar with Bitcoin (a popular cryptocurrency). So it is not immediately clear how individuals who have limited exposure to distributed ledger technologies or cryptocurrencies might understand them. In a different line of research, Nissen et al.[92] explored how blockchain-based technologies could be used to create distributed organizations. In a separate study, they also considered how blockchain-based smart-contracts create geographically based debit and credit zones in a city[90]. For this research, I build upon the work of these researchers by adopting these methods and exploring the rural environment of a duck farm.

1.3.3 HCI and Supply Chain

Before blockchain, HCI researchers were focused on creating supply chain systems that raised transparency of the supply line and logistics[73, 16, 116]. At the MIT Media Laboratory, researchers created a supply chain tool for small businesses in agriculture and other fields to connect via a web tool [16]. The primary goal of the tool was transparency along the supply chain to better enable sustainable business models. Joining a chorus of technologists who promise transparency will improve the supply chain, this research aimed to create a supply chain system that highlighted where products were sourced from by displaying them on a visual map. The authors powerfully detail a caterer who could prove that items on its menu allowed a purchaser to see the origin of its items. Through a series of participatory design sessions, researchers attempted to capture the case studies that would help small businesses use their system to establish a supply chain. In a similar research line, Leshed et al.[72] created a supply chain system that was designed specifically to raise the transparency of fair-trade coffee and Li et al.[73] created a software system that allowed local vendors to track their food supply. These important interventions sought to enable their participants to better track their own inventory and, by doing so, offer better transparency to the consumer. Similarly to these research projects, this dissertation extends the literature by examining the supply chain literature by seeking to understand how the blockchain properties like transparency are understood in the context of a rural farm.

A different view of a supply chain in HCI comes from Mohaddesi et al.[82], who focused on how human decision-making affects the supply chain. Using an agent-based model, they created simulations where they sought to compare their human-like orders vs. non-human-like orders and then compare them to Machine Learning algorithms. Distinct from other supply chain literature, this research focuses on how individuals in the supply chain can affect the outcome. A similar approach to the human-centered research comes from Elissa Redmiles et al.[97], who examined how Facebook users were funding spam. The innovative work of Elissa Redmiles examined how Facebook users were finding spam, positioning spam as a supply chain. In this case the supply chain is not transparent by design. If it was, companies like Facebook could shut down spam as an illegal activity. This work is particularly illuminating because it treats information itself as a type of supply chain.

The power of HCI rests in its insights and interventions into improving interfaces and designs. While researchers have continued to create improvements for the supply chain and novel approaches have examined various types of supply chains, the HCI work in this space is very diverse but focused primarily on the central property of transparency. Adding to the knowledge built through the HCI community in design around blockchain solutions, this dissertation extends and builds on the HCI and supply chain literature by understanding in what conditions a future blockchain system might work in a rural agricultural supply chain. In the next section, I explain the details in which I accomplished this goal.

1.4 Field Site and Background

This dissertation was performed in two phases, first with semi-structured interviews and then followed by a second phase which was composed of design workshops. This research was a qualitative study and was informed by the principles of grounded theory [26]. Through that process, I explored the participant's viewpoints on blockchain. Below I explain my preliminary findings in which the participants focused on the traceability and decentralized nature of the blockchain.

1.4.1 Core Components of Blockchain in the Poultry Industry

Culver Duck Farm served as the field site for this work. They were interested in the use of blockchain to further increase productivity and efficiency at their farm. While I came to this space with an expertise in cybersecurity and privacy, I found that Culver Duck Farm's concerns for network security were far overshadowed by concerns for food security, as detaile in this dissertation. Therefore, this site became a prime case in which to understand when and how cybersecurity would benefit this increasingly digitized environment. Culver also fits well within the USDA's and DHS's critical infrastructure sector for agriculture. Additionally, it is located in Indiana which is the U.S. largest producer of duck[10], and I was able to get access to their facilities. Culver Duck Farm was family-owned for five generations before being bought out in 2015 by Jurgielewicz Farms which runs another duck farm operation in Pennsylvania. Although the farm was family-owned, they have

[10] https://www.in.gov/boah/2715.htm

long been a leader in the commercial duck industry[11]. At one point in their history, they were the largest producer of ducks in the USA. The farm has won numerous awards for food quality in the global food market[12]. This made them an industry leader to try new technologies and among the first to adhere to guidelines imposed on them by the various federal and local government agencies.

For their supply chain, Culver Duck brought on an Enterprise Resource and Planning (ERP) system to help traceability with its live side operations. This tool is helpful but requires a lot of manual entry (see figures F.14, F.17, F.24, in the Appendix for an example of manual forms that later need to be re-entered into an ERP system). Forms later need to be re-entered into an ERP system and additional checks need to be performed in order to ensure accuracy. Additionally, cybersecurity was on the mind of the upper-level management due to a ransomware scam that affected Jurgielewicz Farms. Although the farms operate independently of one another, it was clear that new systems would also need to offer new cybersecurity benefits.

Finally, corporations typically employ an IT work force, albeit small ones, which will presumably be significantly impacted by the introduction of a blockchain system at this scale. Culver Duck Farm employs a rather small IT workforce of 2 individuals to support around 200 employees. It is not clear if a blockchain solution would help or hinder these individuals and how well it would roll out to the hundreds of contractors that maintain its flocks. This research sought to uncover the different organizational, material and technological changes that must be accommodated in order to fulfill the transition to blockchain.

1.4.1.1 Traceability of Blockchain

Since my focus was on technology, it made sense that many of my participants focused on the uses of technology and how they conceive of it in the broader process of animal husbandry and food security. The categories of “Information”, “Process”, “System”, and “Vulnerabilities” were present in all of my interviews and seemed to be the most saturated topics in my study. As I continued my

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[11] https://www.culverduck.com/about-us/history/

[12] https://www.nwitimes.com/lifestyles/food-and-cooking/no-ducking-it/article_855388f4-8033-597d-8f07-1076a2566d73.html

coding, I then began to conduct focused coding. I looked through my codes to see what patterns had begun to emerge as well as which of the codes began to account for the data that I had collected. Naturally, one of the interesting areas to me was the various systems that individuals had to interact with. Comparing and examining the codes in this area showed that I needed to examine the codes in a different way. While I was anticipating conducting an "Axial" coding as suggested by Strauss and Corbin [29], I did not want to limit my view and understanding of how these rural farmers understood the existing systems they interacted with. I instead conducted a focused coding of my subcategories[26] and focused on blockchain as well as what my participants thought about the technology. See Table 1.1

Blockchain Key Codes	
Category	No. of Participants
Traceability of the information	14
Immutable and Unchanging	5
Transparency of the network	4
Distributed network of blockchain	2

Table 1.1: Blockchain Key Codes

Recall that the key properties of the blockchain that I focused on were transparency, immutability and distributed. These components are central to blockchain technology and together represent the foundation to build supply chains in this commercial poultry context. When examining the codes, 14(60%) of the 23 participants commented on the traceability property of blockchain technology. Followed by the Immutable property (21%) and Transparency (17%). Interestingly enough, only two participants in this study mentioned the distributed property of blockchain. Of the three properties that I mentioned, traceability seemed to be the most salient property to the rural commercial farmer. Gathering together these insights, it becomes clear that while the rural farmers were knowledgable of all features of the blockchain, they emphasized the utility of traceability in the poultry industry. P1 stated that:

- P1 - "that it [blockchain] is a more detailed system for traceability and for linking information together, I guess it would be the best way that I think about [it]."

This perspective of linking information together is not new to the farming industry. There is a long history of tracking inventory in the food security literature [61, 62, 63, 94]. Improving the efficiency of tracking in a farming environment can be challenging, and while traceability does help, new systems can be difficult to understand. P17 mentioned that the blockchain traceability:

- P17 - "I mean it, I don't know if it would be... If it would be worth the expense of trying to make a, a blockchain process to help us not run out of shit. . . [laughter] . . . . You know, 'cause it... You, you count it every day, you order it when it's low, there's my two blocks, I chained them together. So I just created a blockchain."

The farmers' focus on traceability and transparency highlighted multiple values of the system that are consequential for any future implementation including accountability, visible power dynamics and auditing, and prioritizing. Whether it is a permissioned or permission-less blockchain is not relevant to the farmers. The same could be said of the distributed network. What does it matter to these individuals that their transactions exist in a distributed fashion? From the rural commercial farmer's perspective, it does not seem to matter much to them. The saliency of technology continues to play a role in how individuals perceive both existing technology as well as future technologies like blockchain. These insights follow a line of thinking from HCI by myself, Rick Wash and Emilee Rader [112] that found what people self-report accurately, in terms of cybersecurity, were arenas where transparency was the key feature. Things like blocking pop-ups were easy for users to remember because systems would give alerts. Similarly, things like Firefox and Windows updates were more difficult to remember because those systems were updated in the background. Blockchain's traceability may be the feature that individuals are able to rationalize because it is salient to them and because it is salient, they talk about it more.

1.4.1.2 Decentralized but Logically Centralized

By understanding blockchain technology, it became clear that individuals interpreted blockchain in ways that I had not anticipated. It seemed that the participants in this study were thinking about blockchain or distributed ledger technologies in a variety of different ways. See Table 1.2

Some participants (26%) understood that the blockchain system could track a lot of data at a very low level, from weather to the vast flock data. This granularity I anticipated to be a bigger component of the research, but it was noticeably absent in the data. Similarly, I also expected that many participants to compare the blockchain technology to their existing technology. While there was some evidence to support that from the coding analysis, only 3 participants out of the

Blockchain Centralized Codes	
Category	No. of Participants
Centralized Information	6
Comparisons to Existing Tech.	3
Granularity and Increased Info.	6

Table 1.2: Blockchain Centralized Codes Breakdown

study commented on it. However, what was more surprising to me was the idea that some of the participants had picked up that blockchain is a source of centralized information.

In Kevin Werbach's book[113] "Blockchain and the Architecture of Trust", the author writes that blockchain allows individual nodes to maintain separate copies of the ledgers but "trusts" that they are all identical. Interestingly, Werbach highlights that despite its decentralized nature, individuals may think about it in a centralized way. Similarly, The farmers on GoGoChicken Farm in China understood that the blockchain tool offered centralized tracking[110]. The individuals in the Chinese market could see where their chicken came from and where it was at any given time. The farm would use a QR code that comes with a vacuum-sealed product that acts as an identifier in the blockchain system. The Chinese farmers' perspective in the story is that he was simply using technology entrusted to him but the author highlights that the farmer's data was sent back to the partnering technology firm. The interaction highlights that the farmer did not possess much knowledge of the blockchain system he was a part of at all.

This study finds that individuals did infact clearly emphasize the power of transparency in the blockchain but, rather confoundingly, otherwise emphasized both centralized and decentralized features as its future vision. According to the data collected, 26% of the participants in the study logically inferred that blockchain acts as a centralized repository. P2 stated:

> "I guess I'm Look[ing] central place to tie in all the data points that are coming in from the plant, and I think for me, just being able to have the answers when you need them."

and P6 said something similar:

> "That everybody puts their notes in one area, señoría put them in there, and then they

> can go back and see what all has he done that day to cause this, or maybe the week before or whatever to cause something to happen."

Participants in this study give the idea that a blockchain system would naturally pull data into one repository. This is interesting because there is no mention of a centralized function in the description I gave of the blockchain system. This fits with Werbach's claim that the blockchain technology is organizationally decentralized but logically centralized[113]. Participants in this study naturally inferred that a system like this aims to pull the information together. I would then argue that the point of decentralization is not something that is generally understood. The issue then comes back to why decentralization is necessary in the first place. Several blockchain papers argue that it comes back to the idea of central vs. decentralized authority [15, 113]. Central authorities can be seen as a central point of failure, whereas if your authority model is decentralized, you can look at any ledger in a blockchain system and "trust" that it is the correct version.

1.4.1.3 Perceptions of Blockchain

What is less known about the poultry industry is how rural farmers identify where blockchain would bolster current practices and enhance their industry more broadly. First, traceability is the most salient feature and makes it the most relevant component to them. HCI and UX researchers could think about designing blockchain systems that highlight the immutability or distributed network properties by outlining them in the display or interface of the blockchain-based system. One could also imagine that time would be better served by prioritizing traceability. The blockchain systems for these rural farmers could focus on tracing the information throughout the supply chain. In the HCI visualization field, Researchers have begun to create blockchain visualization tools to make them user-friendly [67, 53]. While much of the work is focused on visualizing cryptocurrencies, the work would be easily applied to private blockchains or distributed ledger technologies in the rural commercial poultry industry. Existing blockchain systems in commercial agriculture tend to focus on the customer's perspective of food traceability in order to know where their food originated[23, 94]. Yet traceability is larger than tracking the individual product. The blockchain system could be designed to capture the granularity of individual workers, various ingredients used in processing and other relevant units of analysis on the farm.

Second, the fact that blockchain systems are structured in a decentralized manner but are logically inferred by the individuals that use them is not new[113]. Yet, an important implication here is that the individuals in this study make the assumption that the blockchain system is owned by Culver. In Jabbar and Bjorn's work with the shipping industry[55], the blockchain prototype systems they were studying was a private blockchain system shared among various stakeholders in the shipping industry supply chain. In this case, the workshops in this paper were focused primarily on a private blockchain for Culver. It is possible that if the perspective that was shared with the participants was one that the blockchain system would be co-owned by various stakeholders in the duck supply chain, their perspective might have been different. They might not have thought that the data was as centralized as they reported in this study. A possible design recommendation would be to ensure that the stakeholders are aware that the centralized repository could be shared among various stakeholders.

1.5 Conclusion

This introductory chapter sets up the following chapters by giving the reader the motivations for this study and the basic understanding of how these rural duck farmers understand blockchain technology. The participants focus on the traceability properties and logically infer that the technology is centralized. The next chapter, chapter 2 explains the methodology used for this research as well as the preliminary analysis. Chapter 3, focuses on the beliefs about technology failure that is pervasive throughout the farm. Chapter 4 focuses on the farmers view of death and the strength of relationships on a duck farm. Finally, chapter 5 focuses on how the rural farmer's understood vulnerabilities on the farm and how that shapes their perspective on blockchain.

CHAPTER 2

METHODS

2.1 Introduction

For this research, I was interested in understanding how the existing workflows would be affected by introducing a blockchain system through both its human and nonhuman actors at various stages of the agriculture supply chain in the poultry industry. The research in this dissertation was performed in two phases. The first consisted of semi-structured interviews followed by a second phase which was composed of design workshops. Gathering the information from the previous section, the research questions that drives this project can be defined here below:

- RQ1 - With current systems and processes at commercial duck farming facilities, can blockchain help address the challenges of managing the supply chain?
- RQ2 - What are the first order concerns of the different stakeholders of a blockchain solution?
- RQ3 - What vulnerabilities might arise in the introduction of a supply chain based on blockchain?

Taken together, the answers to these questions would illuminate the perceived benefits and implications a blockchain system might bring to tracking many of the items and pieces of information on a farm. Through that exploration, I wanted to see what problems the farmers would emerge from a system they would design and potentially what issues they would be missing. Each individual's perspective may provide important insight into what should be considered and developed in a blockchain supply chain system for the commercial poultry industry.

Data for this project was collected under pandemic conditions. The COVID-19 pandemic also presented a unique test on the existing infrastructure as the system at Culver Duck was under immense strain both from a supply chain perspective and an individual man-power perspective. The conditions also presented an opportunity to explore how the existing system(s) and infrastructure can handle the pressure of a crisis.

2.2 COVID-19 Planning

Restrictions for conducting research were put in place due to the COVID-19 pandemic. As of May 1st, 2020 MSU's Institutional Review Board(IRB) was restricting all in-person research and the only research that was allowed to proceed was research that did not involve direct in-person contact.[1] The entirety of this research was initially outlined to be in person but was transitioned to an online format. Due to COVID, one positive benefit to this research study was that many workers in the poultry industry grew accustomed to virtual meetings because of the pandemic.[2] For the workshops, the goal of creating a physical blockchain through physical modeling was still appealing but needed to be adapted for this study. What resulted was a novel methodological contribution in conducting a participatory design session in an online format. In the workshop sessions, I used a virtual whiteboard technology ExcaliDraw[3] which allowed my participants to interact with a shared whiteboard. Using the creative tool, I created a novel method and contribution to the literature by creating a process that would represent simulated bricks. The process also allows individuals to co-create a blockchain system in a context-independent way. This approach does not have the same benefits of creating/interacting with a physical modeling process but it is useful enough to gain participants' insight.

2.3 Interviews

The first phase of this study consisted of a series of semi-structured interviews performed with employees in different departments over the course of three months. Data from November, 2020 to January, 2021. 23 individuals participated in the interviews and over 35+ hours of interviews were collected. The goal of these interviews was to gather the context and perspectives of individuals.

[1] https://hrpp.msu.edu/COVID-19/index.html

[2] https://www.nytimes.com/2020/05/05/business/pandemic-work-from-home-coronavirus.html

[3] https://excalidraw.com/

Additionally, the data collected in the interviews would also inform the design of a blockchain-based system. The goals of the workshops were to begin by seeking to understand three things: the existing process(es), the current technology, and any regulations. For existing processes, there may be formal processes that are documented and written down while there also may be implicit processes that are not recorded anywhere. Several practice interviews were conducted and the interview protocol was refined each time to eliminate extraneous avenues. See Appendix A for the actual interview protocol used during the study.

This methodological approach is crucial for implementing a blockchain system by understanding what processes are supposed to be captured and what is intentionally left out [55]. Additionally, by identifying ownership of processes, I hoped to better understand the power dynamics in the current infrastructure[72, 59, 57]. Next, by asking participants about the current technology they use, I sought to understand the properties that a traceability or supply chain system might need in order to be a functional system. I also sought to understand any additional technologies that are not explicitly a part of the system that they use. An example might be if a processing line worker used his smart phone to take a picture to remember something that happened while working. Finally, understanding the constraints and compliance issues that individuals face in the poultry supply chain helped me think about how the governance of such systems is helped or hindered by blockchain[55]. Government agencies invoke different methods to ensure compliance, and I found that that this is true in the farming industry[58]. The hierarchy of compliance was interesting to explore in that Federal law supersedes state and local government.

Follow-up interviews were conducted if needed, and artifacts, images and other documents were sent via email to clarify processes or designs. Sessions were recorded to be reviewed and transcribed and information about participants was recorded anonymously so that even the participants' names were immediately recorded under an alias. Due to the nature of work in rural farming, several sessions required a translator present as some of the workers are native Spanish speakers and required a translator. For this research, which is informed by a grounded theory perspective, saturation was achieved when the qualitative analysis began to reveal the same codes through each

	Study Information
N =	23
(Male / Female):	14 Males(61%) & 9 Females(39%)
No. of hours:	35+
No. of Translated Sessions:	4

Table 2.1: Details of Study Population

new piece of data from the interviews[26]. To obtain this sample, I conducted a snowball sampling method and asked managers and administrators to encourage individual workers to participate. I worked with the supervisors and leadership to reach out to individuals who might be interested in being interviewed for my study. One of the upsides of working on a large commercial farm is that Culver was familiar with academics working on and around the farms. My participants were used to working with academic veterinarians, biologists and geneticists. See Table 2.1 for details.

In order to gather different aspects of the effects of a blockchain system at a commercial poultry farm, it was important to speak to all of the different levels of the company. While many of the participants are workers, the farm divides its workers into two categories, Processing Workers and Live Side workers. This represents the two major components of the farm: the live side, where the ducks are "alive," and the processing side, where the ducks are "processed" for consumption. In addition, I conducted interviews with upper management (shown as leadership) as well as mid-level management. Finally, the Contract Grower refers to individuals who grow the flocks for Culver. These individuals are farmers who take on the responsibility of growing ducks either for future breeds or for processing. They are typically contractors and use their land to construct large barns for the many flocks under their care [4]. See Table 2.2 for details.

After completing the interviews, they were sent to transcription services (and translated if necessary). Since I was interested in how the process works at Culver Duck Farms, I wanted the interviews to focus on how a blockchain system might be useful, problematic or both. Questions focused on the costs of implementing current systems and what burdens management, employees, or contractors experienced in the current system? Questions were broken down into 5 sections: process

[4]For a picture of a barn, see figure F.32 in appendix F

	Breakdown of Participants
No. Leadership	2
No. Management	4
No. Processing Workers	6
No. Live Side Workers	6
No. Contractor Grower	5

Table 2.2: Role Breakdown of Participants

questions, challenge questions, granularity questions, first order questions and finally blockchain questions. The breakdown of the interview protocol is as follows:

- Process questions - questions about how individuals use technology and how they carry out their jobs.
- Challenge questions - questions focused on any and all challenges they faced when doing their work.
- Granularity questions - questions focused on things they would like to track in the supply chain.
- First order questions - questions focused on what they were concerned about when doing their work.
- Blockchain questions - questions about their familiarity with blockchain technology. A brief introduction is used but it is largely open-ended.

While this is a high-level overview, please see Appendix A: Semi-Structured Interview Protocol for more details. The goal of the semi-structured interviews was to allow the participants to express their view-points on the job.

2.4 Workshops

For the second part of this study, I conducted multiple design workshops that explored the design of a blockchain-based supply chain solution for commercial poultry. The workshops simulated components of the supply chain process within Culver. The goal was to capture the events from beginning to end with the end goal of creating a new blockchain system. In HCI, one of the common approaches to solving a problem is to develop a technological system, instrument or intervention. While these research contributions are helpful, most of these are one-directional in that the technologist or researcher develops a system by soliciting requirements from users and then delivering the system based on the requirements that were analyzed [85]. In other words, they are designed with minimal input from those they are trying to help. One of the challenges in developing a complex system like a supply chain solution is that while I might have the technical expertise, I do not have the practical field knowledge to know how the system *should* function. While the interviews I've collected could be used to obtain the practical field knowledge and develop subsequent requirements, enabling the participants to design their own system had multiple advantages and follows a rich history of participatory and action research. Methods such as participatory design or open design allow for a two-way communication to co-create a system. In other words, both the individuals who use the system and the technologists designing the system will work together to develop it[90]. For this work, I used the participatory design method described by Michael Muller [85] to conduct workshops in which participants will be instructed to use a virtual whiteboard to develop a blockchain-based system. I am focused on the needs of the rural individuals that live and work in the area.

One constraint I had considered during the development of the workshop was that while I intended to develop a system for a commercial poultry farm, I was not designing a universal system. This approach has many upsides. First, this allows workers who might not otherwise have a voice to offer insight into the design that benefits them and the company. Second, much of the commercial farming in the U.S. occurs largely in rural areas. By approaching the system design in this way, it allowed for greater consideration of the needs of the rural. Finally, I was able to collect information from multiple individuals across the company from contractors working in the farm houses to upper-level management. This holistic approach allowed me to capture shows these diverse individuals think about emergent technology.

Using a design workshop method, HCI researchers Maxwell et al. [81] used physical modeling to allow their participants to better understand how exchanging cryptocurrency works in a way that words alone cannot do.[81]. The researchers constructed a "blockchain" using physical legos and attached stickers with their names affixed to each one to symbolize the cryptocurrency. Next, the researchers had their participants exchange their cryptocurrency for fictional (paper) objects such as wheat, wool, etc. Each time they exchanged hands participants would remove the stickers and hand the cryptocurrency to the new owner. Towards the end of the workshop, the participants would affix the legos and a physical "blockchain" emerged that individuals could easily visualize. I found this approach very helpful because adopting this method allowed me to present blockchain in an accessible way. Participants would describe events in their own processes as events, and as each new event occurred in their existing process, it could be modeled as a block with a corresponding timestamp. Through this type of design workshop, participants constructed drawings of a blockchain system at their duck farm.

For this project, I created a new method for participatory workshops using virtual meeting technology (Zoom/Teams/etc), sharing a virtual whiteboard([5], and adapting physical modeling of a process. This was a necessity because of the covid pandemic and the subsequent inability to do in-person research imposed by the universities' institutional review board. Overall, the workshops were organized into two phases. The first phase of the workshop began by having the participants describe the existing processes in their given field of live side, processing or hatchery. Once the physical processes are established, I would then guide them through the process and instruct them to create the digital blockchain. The participants were instructed any time an event occurs we would have a participant add virtual "block" with their name and timestamp attached to it. As the work proceeded through the supply chain process, we would be building a large transactional event-driven blockchain that represented the supply chain process at the duck farm. I would have the participants go through this process several times in order to account for generalizations and fringe events.

For the second phase of the workshop, I directed participants to offer input in what they would like to change through prompts. Questions focused on the first order concerns, process and processes, vulnerabilities, security and cybersecurity. This approach allows participants to create their own system. This participatory design approach allowed individuals to understand blockchain

[5]https://excalidraw.com/

in a more tactile way that is less technical. The workshops created a space in which they could safely discuss the technology. Observations were used in the analysis to identify design issues and implications.

I organized small workshops with 4-6 individuals in each session [50, 81]. My goal was to conduct a minimum of three workshops and they were all conducted virtually. While I was required to conduct this research virtually, Culver employees were required to come into the office in order to continue processing ducks.

For the participants in the workshop, I was able to have a mixture of individuals from the live side and the processing side in each workshop. Together, I was able to assemble workshops with enough individuals in the room to describe the process of running a duck farm from end to end. From a practical standpoint, I limited the time spent in these workshops to two hours, with about an hour for each side of the workshop.

There were four scheduled workshops, but only three workshops were conducted. Each workshop had 3-4 people in it and were conducted over a period of two weeks. Due to the demand of the poultry industry, January was a busy time for the participants and I was unable to schedule Workshop 3. Participants used the Excalidraw tool, which acted as a virtual whiteboard. Upon arriving at the virtual workshops. The workshops lasted for roughly two hours and were broken down in the following way: See Table2.3

In total, three workshops were conducted and together, they covered the entirety of the Culver supply chain process. W1 and W4 represent the whole of the live side and W3 captures the processing side of the farm. Each has different perspectives on their work area but this also explains how general blockchain technology could be applied across a supply chain. To see the details of the workshop, please see Appendix B - Design Workshop Protocol.

A striking phenomenon in the data was the vast differences in user engagement with the whiteboard during the design workshops. Participants drew arrows, text and blocks using whiteboards (Excalidraw). The goal was simple, draw a simple process first and then draw the coordinating "blocks" that were underneath. Participants would order the blocks themselves, and at the

Workshop Details	
Workshop	Participant Work Area
(W1)	Live side of the farm (excluding hatchery)
(W2)	Live side of the farm - *never conducted*
(W3)	Processing side of the farm.
(W4)	Hatchery workers.
Workshop	No. of Participants
(W1)	4
(W2)	*NA*
(W3)	4
(W4)	3
Workshop Breakdown	Length of section
Introduction	5 mins.
Excalidraw practice	5 mins.
Design Time	50-60 mins.
Group Discussion Time	50-60 mins.

Table 2.3: Breakdown of Participatory Design Workshop

completion of each workshop, they were left with a blockchain system that revealed the types of information that a blockchain system would need. The workshop sessions did not attempt to provide a comprehensive view of blockchain technology or related technologies like cryptocurrencies or distributed ledger technology. The discussions within the workshops allowed the participants to see how much information would be captured and revealed the amount of work completed by each section. After participants adjusted to using the Excalidraw tool, participants largely began to take off and draw out their existing work processes. Often, there would be a discussion about the clarity of the process, or individuals would chime in to make sure a given process was included. Like in-person workshops that use a collaborative space, the virtual whiteboard gave all users access, but there were largely only one or two active users at a time. In W1, several of the participants participated simultaneously but did so by working out the various parts of the process on different parts of the blockchain events.

In contrast, W4 had only one active participant using the whiteboard and the others in the workshop held back to provide input on what should be recorded. Finally, in W3, all of the participants began to immediately draw their perspective areas. Working in harmony to describe and outline their perspective processes. Participants found the workshop largely engaging and it was an exciting activity. The sessions were largely filled with laughter and emotional moments which made the hours spent together pleasant for everyone. In all, the workshops produced 6 different artifacts/diagrams outlining the core areas of the duck farm. The diagrams revealed the following:

Workshop	Processes (Diamond)	Blockchain Events (Blocks)	Identified Agents	Additional Blockchain Events	Additional Agents
W1	10	76	18		
W3	19	63	25	28	28
W4	10	101	14		

Table 2.4: Workshop Details

As we move through table 2.4 we can find some interesting things. First, the process column in the table shows that there were significantly more steps in W3 than on the other sides. Logically this makes sense. To create a finished product, there are simply more steps in order to transform a live duck into the various frozen product lines that Culver offers. One finding that stood out was that there were a lot more events in the W4 when compared to the other workshops. The participants were asked to create the blockchain events for each process, but the specifics on how to do so were left entirely up to them. On the live side (W1 and W4), there are significantly more events that participants felt they should include in this process. One reason for this difference is that the W3 focused more on laying out the processes and reserved less time on the blockchain events. The final two columns only affected W3 because participants in W3 captured other important steps like FDA workers and other biosafety processes that they couldn't describe in detail due to time constraints. For W3, in terms of individuals, the processing side of Culver represents the largest presence of individual workers. It also has a great deal of automation, but even with the automation, there is still a great deal of processing that goes on here. It is possible that W3 did not capture the full details of the blockchain events that are possible here. However, the participants focused on what they thought the system needed first and then thought of other processes as time went on.

The methods in this section describe the overall process for each of the chapters in this dissertation. While each chapter has its unique insights, it is structured in the following way: Chapter 3 focuses on RQ1, Chapter 4 focuses on RQ2 and Chapter 5 focuses on RQ3. Beyond the primary research question in each chapter, there are some additional insights for the other research questions within each chapter.

2.5 Coding

After the first several interviews were completed and after the audio files were transcribed, I began working on coding the files to see what data was coming out and to see if any adjustments needed to be made. Items were coded with the Nvivo software and the transcribed files were broken down and classified. The initial coding was conducted with participants consisting of upper-level management. I quickly noticed that the coding focused on coordination on the farm and the information they were trying to capture was consistent with individuals of their position. As I moved through the coding, I felt more comfortable with the procedure and noticed that my participants were really excited to talk to me about farming and the supply chain. Keeping the interview instrument largely the same, I finished the interviews and quickly sent off the interviews to be transcribed. Throughout the interview process, I continued to compare the notes, memos and initial codes throughout the data collection process. This helped in looking for similarities as well as the differences between the codes as well as the different viewpoints of the data between my participants.

While the data process continued, I would memo after each conversation and interview as well as capture thoughts about the research data I was collecting. Some of the memos include thoughts on how the blockchain system could track individuals, how blockchain could be used to better track the animals and how the thoughts of designing a disconnected blockchain architecture that would better align beliefs about technology with the religious beliefs of Amish farmers. These memos extended my ways of thinking about blockchain technology and proved instrumental in understanding the perspectives in which rural farmers understood the technology, even if not always directly related to my initial research questions. My memos would capture the reflections on what participants said as well as what participants' ideas, questions and thoughts were about farming and blockchain technology. I followed the guidance of Kathy Chamaz [26] and began paying close attention to questions like: What is being said? Who is saying it? What is being omitted? These questions allowed me to gather rich data on the participants and create new thinking on open questions and possible research areas to explore.

Once I received the completed transcripts, I conducted an initial coding. The qualitative approach revealed many different avenues to focus on and the initial coding began to reveal categories and themes within the data sources. The initial set of codes was then examined throughout the study and when data collection had finished. I looked back through the code line-by-line with a fresh perspective adding to the codes and groups of codes. Eventually, the high-level categories started to emerge within my data. See Table 2.5

Coding Categories		
Category	No. of Participants	Coverage
Animal Welfare	14	61%
Beliefs	14	61%
Coordination	21	91%
Economics	3	13%
Emotional Moments	11	48%
Farming	14	61%
Important	7	30%
Information	23	100%
Manager decisions	5	22%
Process	23	100%
Relationship	10	43%
System	23	100%
Vulnerabilities	23	100%
Weather	15	65%

Table 2.5: Breakdown of Coding Analysis

This table gave me an understanding of how my data was looking and what was on the mind of the individuals in the study.

2.6 Conclusion

In this chapter, I explained the methodology for the research project I carried out at Culver duck farms. The research was conducted during the covid-19 pandemic and was conducted virtually at Culver Duck Farm. Breaking the research project into two phases of semi-structured interviews and design workshops allowed me to explore the research questions through the lens of grounded theory. The participants consisted of a variety of individuals from processing workers to senior-level management and resulted in a wide array of insights into the blockchain. The following chapters describe the motivations, details and unique findings of the research questions presented in this chapter.

CHAPTER 3

VERSION CONTROL OF THE FARM: THE VISIONING OF BLOCKCHAIN IN THE COMMERCIAL POULTRY INDUSTRY

3.1 Introduction

Over the past decade, the consumer poultry industry has faced an increased digitalization of its processes and practices. While increased efficiencies act as an incentive toward adopting technology, it is not the sole reason for doing so. Regulations at the state and federal levels add demands for food security which force companies to look for ways of easing the burden of compliance. It is possible that through software technologies like blockchain, the security of the supply chain increases because of its unique traceability properties and cryptographic protocols. However, each time software is added, it adds a new layer to the infrastructure at a commercial farm, and the implications for this are not clear. In order to better understand the technological benefits, commercial farming companies lean on industry leaders and conferences[1] to determine what new technologies are emerging. Once a candidate is identified, it is then integrated into the existing infrastructure. This chapter seeks to understand the implications of integrating blockchain into the existing infrastructure at a major American duck farm, Culver.

Software engineers typically create software through a process called versioning or otherwise known as version control. This allows software developers to add new features and improvements in an iterative way. These enhancements, called "revisions" can also fix existing bugs and errors reported by a software's user base. However, sometimes these updates can introduce errors of their own and developers are forced to revert to a previous code base. This works well for software development and engineering, which is why nearly all commercially developed software employs some type of version control. In this chapter, I explore how poultry farmers employ the language and sentiment of version control to describe the integration and correction of blockchain into

[1]conferences like the International Poultry and Production Expo (IPPE) is an example. https://ippexpo.org/

their supply chain management system. First, I will discuss the forms of revision or "roll back" identified by participants. Second, drawing from an intersection of computer science and science and technology studies on failure and repair, I will discuss version control as an infrastructural phenomenon. Lastly, I describe the implications of version control coming up against a possible “point of no return” in which it would be difficult, too costly or even impossible to remove the blockchain. Through qualitative analysis of interviews and design workshops, these orientations toward versioning arose as key features of a future blockchain system. Version control can be thought of in several ways: *Revise* refers to the belief that implementing a technology, finding the parts that are useful or not useful and organizing around those processes. *Reverting* refers to the belief of going back to a previous revision in which the technology is either present or not present. *Extracting* refers to the idea of removing a technology completely. This does not mean simply going to an earlier version of the product but acting as if the product did not exist at all and removing or extracting the product altogether. Finally, versioning uses the idea of a *revision* which can be defined as simply a previous state or point in time.

In this chapter, I explored the dominant narratives on the farm around revision and “rollback” of blockchain and connected them to theories of version control from computer science. Farmers not only have to live with failure, they believe in versioning technology and that they can always revert to a previous revision or “roll back”. Existing software in the commercial duck industry offers with it proven successes, increased efficiencies, and overall improvements. Yet when the software or technology fails, the farmers take the perspective that things have to continue. The flocks still need to be manage, so the work continues whether the technology is working. While the technology increases the rate at which the farm can operate, simply changing or extracting to a state without the technology might not be possible. Through a series of interviews and workshops at Culver duck farm, I sought to answer: Can blockchain help address the challenges of managing the supply chain at rural commercial farming facilities? The data indicated a lot of uncertainty around the technology, and when it came to designing a blockchain system, there was an awareness that failure was possible but not preventable. Additionally, the increased complexity of a blockchain system coupled with the participant's view of technology failure could lead to catastrophe as new layers are added to the systems. Another insight is that the rural commercial duck farmer believes technology can fail, and there was a rigid belief that the company can always move away from it by extracting the technology. Through the analysis, I present the idea that accommodating the needs of the rural farmers may help in reducing the uncertainty around the technology and possibly change their perspective of technology failure. Additional insights reveal that by taking technological steps forward, there is a sense of a "point of no return" and once a company has crossed this threshold, returning to the way things were becomes problematic and costly. Finally, I present the idea that future work could examine the impacts on rural farmers when the blockchain is implemented.

3.2 Literature Review

3.2.1 Rural HCI and Blockchain

Commercial agriculture, which is the process of growing and producing an entire nation's food supply, takes place by and large in rural areas. According to the USDA, only 14.1% of the population of the USA live in what is geographically classified as rural, but these areas account for 87% of food production[2]. However, technology adoption in rural areas vastly different when compared to urban populations [98, 42, 44]. Therefore, rural computing provides a critical perspective in order to understand blockchain and commercial duck farming. Researchers in this space have considered the context in which the technology takes place as well as the impacts these technologies might have on the individuals who live there. Zhang et al.[117] found through contextual interviews that designing for the supply chain was better for their members by integrating a social layer to their supply chain. The researchers examined the artful creation of handmade blankets in rural Malaysia and sought to understand how to help them create their own businesses. The work revealed a blend of physical and digital layers to the design aspects and was able to help these small businesses by showing the benefits of adding a social aspect to the supply chain. Similar research by Jean Hardy

[2]https://www.ers.usda.gov/topics/rural-economy-population/population-migration/

[50], Susan Wyche [49, 51] and Six Silberman [10] have investigated rurality through the lens of HCI and focused on what were the impacts of computing technologies on the individuals who live there. Jean Hardy, in particular, demonstrates that universality is not the dominant or pragmatic approach in most rural computing. Hardy's work on where technology fails [48] speaks to the idea that researchers should consider the vast geographic differences between rural populations when designing software for rural populations. Designing software for rural locations where the internet is sporadic and intermittent might require different software design implications than from other rural towns with stable internet connections.

Critical to this project is understanding the technical capacity of the rural farm and the values of the multiple stakeholders inherent in the system. Important work in HCI concerning blockchain and cryptocurrency has unearthed values in design of these systems. For example, in their work on miners of Bitcoin and their understanding of cryptocurrencies, Irni Khairuddin and Corinna Sas explored the values and trust cryptocurrency users had in Bitcoin. These researchers explored human perceptions of the popular cryptocurrency Bitcoin which is powered by blockchain [65, 103, 64]. The work focused on how participants, miners and users of Bitcoin perceived and used the cryptocurrency. They interviewed and listened to the value propositions of why individuals used and transacted with the cryptocurrency. Influenced greatly by this research focus on values, this dissertation extends this human-centric approach by integrating distinct features of the rural. It was unclear if the participants in this study were from rural or urban environments. While Malaysia does have rural areas, work would need to be explored in those areas to understand how technologies like cryptocurrency and, ultimately, blockchain could be understood by the individuals who would be using them. Relating to this work, as blockchain technologies become more integrated into rural agriculture, there will be an increasing need to understand the technology at the intersection of rurality and agriculture.

I believe this work with blockchain systems needs to consider the individuals who will be interacting with it. While developers can create systems that capture information or replace physical processes with digital processes, understanding that storing, classifying and organizing information has implications for the individuals who use this system. This research seeks to study the impact of blockchain technology on the individuals who work in the commercial poultry industry. Particularly how the implementation of the technology places a point of no return upon its users and that the infrastructure of the firm is changed, for better or worse. [3]

3.2.2 Layers of Farming Infrastructure

"Infrastructure does not grow *de novo*" which is to say that infrastructure does not begin anew. When Star [89] wrote about defining it, she explaint that it is always built upon something. The installed base represents the collection of practices, policies, and social norms layered around the systems at a business or organization. This theory extends through the Science and Technology Studies literature, and it is a useful way of thinking about technology in the Human and Computer Interaction context because it provides a needed complexity in which no system exists in a vacuum. Instead, systems are thought to be built within existing infrastructures, practices, and power dynamics. Examples of the installed base include fiber optics cables following old railroad lines or software replacing physical sheets of paper.

Talking with individuals who work at Culver Duck, you can clearly see remnants from the past: references to old technologies like feeders and water lines, references to the way things used

[3] The study of why individuals do the things they do or behave the way they behave is at the core of many psychological and communication studies. Ajzen's Theory of Planned Behavior and [2] Fishbein's continuation of that work in Theory of Reasoned Action [45] attempt to explain why individuals behave the way they do. Both models take a fundamental look at the behavior and attitudes that affect how individuals behave but not specifically how they use and reject technology. The research in this area is extensive but notable efforts attempt to understand how individuals understand technology itself; it's perceived usefulness and the motivations for using such a system. Fred Davis developed the technology acceptance model (TAM) which builds upon the previous literature by specifically looking at the context of technology [33, 34]. Davis focused on the perceived usefulness, ease of use and the attitude towards using the technology. While there has existed a myriad of research and literature in this space [77], the challenge is that using this model is beneficial for finding out how people use existing technology. Blockchain and distributed ledger technologies (DLTs) are future technologies that are still in their infancy. Asking individuals about their willingness to use a technology that doesn't exist is challenging but a different approach is necessary to do so.

to be, or how much things have changed give an idea of age when it comes to the operation. Founded in 1858, Culver Duck is one of the oldest duck farms in the country and, at one point, was the largest producer of duck in the world. This long tradition of farming duck has largely stayed the same for over a century; recently, with the influx of safety standards and new technology, Culver Duck has experienced a shift in its infrastructure by expanding its installed base to include a reliance on tablets, alert systems and computers. The infrastructure here is built upon years of processes and tacit knowledge, which becomes the base that much of the new technology has been developed. The inertia of the installed base refers to the momentum of the system that is established. When a system is put in place, it carries with it a movement (inertia) that pushes the standards and processes in the direction of supporting the installed base [54, 105]. A closely related idea comes from the economic literature is path dependence. Ruttan[101] states roughly that any technological change is “path dependent” in which previous technologies paved the way for newer related technologies. Similarly, Paul David [32] writes that when it comes to a system’s dynamic processes, the system is limited by its configuration and therefore can only grow in certain directions. While not technological determinism, wherein technology develops without co-construction of culture and ecological elements, the “path” ultimately shapes future changes to a system [68]. Both the theories of path dependence and installed base shape help us understand why firms adopt new technologies.

For example, it was explained to me by one of the flock supervisors, that the pits that ducks get their water on were developed over years of experimenting. See Fig3.1.

The pits contain largely waste below and the ducks get their water through a drip system hanging from above. At some point, the water bowls would get knocked over and the drip system was invented. By placing the drip system over a grated "pit" the water and waste would naturally fall below. Creating an elegant system for keeping barns clean. The pit system alleviates health problems with the ducks by keeping the "pads" of their feet free from infection. Thinking about the pit system as an installed base helps to understand that innovation is already present on the farm and that careful decision-making that occurs on the farm. This infrastructure was developed

Figure 3.1: Image of a grated duck pit, water drip line and heat lamps. This example of technology was developed through experience over a long period of time.

slowly over years of working with animals and represents the base on which newer technologies must conform.

Bowker and Star [18] lay canonical language in considering the installed base as a "bricolage" of information infrastructures. Bricolage gets its definition from the fields of art and literature and can be defined as the construction of a diverse set of available things. The authors define bricolage as an assemblage or a loosely coupled but coherent set of information resources and tools. Thinking about the installed base of technology at a duck farm, one can be presented with a variety of different technologies that are layered upon one another.

Closely related to the idea of bricolage, Karim Jabbar and Pernile Bjorn[56] introduce the idea of blockchain assemblage. The authors explore how the future technology of blockchain consists of both physical artifacts and digital imaginaries. In other words, blockchain assemblages are built upon things that exist as well as future infrastructure that is yet to be built or realized. It is an important concept for this work, as the commercial poultry industry examines the possibility of a blockchain-based supply chain system for their work. An important distinction between bricolage and assemblage is that the bricolage refers to the amalgamation of components at the infrastructure level, whereas a blockchain assemblage seems to be more in reference to the perspective of individuals' view of the relational attributes between the physical artifacts and the imaginary. It is a subtle difference but highlights that as research explores this blockchain space, they do so sometimes with things that are not quite tangible or real. For this work, I will focus on the idea of bricolage and the ingrained information infrastructure.

The forms of versioning described in this chapter push up against the concepts of installed base and bricolage, indicating the deep entanglements that may be difficult or even impossible to revert as infrastructures mature. If the installed base involves practices, policies and social norms, then the blockchain brioclage is the layer in which the technology affects the different aspects of an organization. In this case, the blockchain bricolage becomes entangled with the social practices of farming, the bio-security and food security protocols, as well as the interfaces in which these rural farmers interact. The entanglement aspect of the installed base shows how things cannot be easily disconnected. Additionally, the geographical and supply chain extent of this work is quite large. Adding a complexity of a myriad of different actors, as described in chapter 2, makes the installed base of a commercial poultry organization with layers of complexity all tied together. David Ribes [99] examines large infrastructures by observing what the researcher calls *scalar devices*. This is important because blockchain is designed to grow, and commercial duck farmers deal with large amounts of things like supplies, eggs, feed, etc. Scaling, the installed base and bricolage provide the necessary understanding for any forms of versioning that might exist once a blockchain system is implemented at the duck farm.

3.3 Methods

The research in this chapter was performed in two phases, first with semi-structured interviews and then followed by a second phase which was composed of design workshops. I am interested in understanding how the existing workflows would be affected by an introduction of a blockchain system through both its human and nonhuman actors at various stages of the agriculture supply chain in the poultry industry. Gathering the motivation from the previous sections, the research question that drives this portion of the dissertation can be defined as:

- RQ1 - With current systems and processes at commercial farming facilities, can blockchain help address the challenges of managing the supply chain?

I wanted to explore the perceived benefits that a blockchain system might bring to tracking ducks and what problems could emerge from the system. Each individual's perspective may provide important insight into what should be considered and developed in a blockchain supply chain system for the commercial poultry industry. For this chapter, the categories of codes that I focused on were "system","blockchain", and "failure". Each category gave a unique perspective on the uncertainty around new technology like blockchain and the challenges of living with the technology that may or may not work. Finally, the codes revealed a type of revision rural farmers conceptualized when thinking about future technology.

3.3.1 Uncertainty around Blockchain

From the data, one consistent theme was the "unknown" about blockchain. There seemed to be a lot of uncertainty around the technology. While I defined blockchain in the introduction of this document, the participants largely didn't know what to make of it. Much of the consideration and discussions about the technology were through the managerial and administration of the farm. The table below highlights the codes of how individuals were rationalizing the technology.

When participants begin to think about the blockchain benefits, it seems that they rationalize the technology in the way that they understand it. The data suggest that rural commercial farmers

Gaps in Understanding Codes	
Category	No. of Participants
Not a blockchain benefit	6
Blockchain organizes information	4
Blockchain reduces manual entry	2
Unsure of blockchain tech.	10

Table 3.1: Attributes of Blockchain and Uncertainty from Data

are unsure of the technology and attribute features not necessarily a benefit of the technology. To give an example of a code “Not a blockchain benefit”, P1 stated:

> P1 - “Blockchain may create a more user-friendly interface or cut down on the amount of, I guess, individual information that would have to be entered manually, like it... Like it would be now”

As told by this participant, blockchain as technology might not be a more user-friendly interface nor cut down the amount of manually entered information. So why would the participant ascribe benefits to it? For this, I can only speculate that the blockchain hype train of presentations at the International Poultry and Production Expo [4] and its presence in the media have presented blockchain with an optimistic perspective. While some of it might be well-founded, this type of techno-utopianism is held throughout the technology industry. In a recent presentation by Microsoft researcher Ranveer Chandra[5], he described the use of Microsoft’s application titled Farmbeats, which is an attempt to use AI, IoT and other technologies (including blockchain) to solve the world’s farming problems.[6]. Overall, Farmbeats is presented in a way that shows the limitless potential of technology, but in the presentation, the research did not highlight how farmers could work with and use the technology. They brought with them assumptions of how the technology would be used and perceived. From the data presented in Table 3.1, close to 26% of the participants attributed features that were not direct benefits of blockchain. The common attributes incorrectly attributed by the participants were organizing the information (17%) and reducing

[4]https://ippexpo.org/

[5]https://just-infras.illinois.edu/mar-31-ranveer-chandra/

[6]https://www.microsoft.com/en-us/research/project/farmbeats-iot-agriculture/

manual entry (8%). This data is not surprising because when one thinks about a technology's perceived usefulness, it leads one to have a better attitude towards the technology if we think it will better serve our needs[33, 34].

As evidenced by the 10 of the 23 participants (43%) that were unsure of what blockchain technology is fundamentally, it is critical to consider how to introduce a new system that is outside of the realm of expertise of its main users. Initially the results seemed surprising, but after reevaluating the study, looking through the data and analysis, it made a bit more sense. I asked participants about a technology with which they had little to no familiarity. They would then think about how this technology would impact their work, considering the attributes that I had mentioned like decentralization, transparency and traceability. Understandably, much of the data would be coded as being unsure of blockchain. P3 stated:

> P3 -"So it's just find out into some of the issues that happened, the negative aspect, when you say it can't be erased and that's kind of scary in a sense too, of something... There are some things you don't want to go on. You know what I'm saying? Okay, we're in for legal things, you're supposed to get ready or taxes after seven years, if you keep me around forever... You know what I mean? Even though people don't mean... It just brings up more liability, I would think... You know what I'm saying?"

P3's comments capture the uneasiness of the blockchain's system feature of permanent transactions. The inability to erase transactions can be seen here as a negative, and the participant mentions some of the legal ramifications. From the data, it seems that the participants were unsure about the technology because of the possible negative consequences of using a blockchain-based system. In this case, a future blockchain system for a commercial duck farm here would have to handle accidental entries or mistakes entered into a system.

From the data, there was also a similar line of thinking that features were mentioned that was not captured in the design itself. Recall that the participants in the workshops were asked to outline and create a blockchain system for the various parts of the Culver Duck supply chain. Participant's worked together on a virtual whiteboard to create an outline of the processes and blockchain events at the farm. After participants spent the better part of an hour creating detailed diagrams, they were asked about the blockchain system itself. Surprisingly, individuals here also thought about the risks of technology they understood. Participants in W3 stated:

> W3 -"Well, there'd be some more risk of... 'Cause we use umm, uh... We use the ACH feature to pay our bills and also to receive money from customers. . . . Umm, as far as invoice payment, so I suppose there's a level of security that's needed with the, with the paying bills and receiving, uh receiving..."

In the example, the participant gave an example of a technology they understood: ACH. These workshop participants had spent a great deal of time designing the blockchain processes and yet for clear examples of risk with blockchain, they used other technologies that they understood to explain the risks. Participants in the workshop also had added time to develop and refine their ideas about a blockchain system and still referenced other technologies for clearer examples. The evidence suggests that their observations reflect their views of the capabilities of blockchain and not the technology itself. Since they were thinking about a future system and not one that exists in the real world, they drew their knowledge from their understanding of the installed base. I would hypothesize that if they were interacting with an actual user interface for a blockchain system, the findings might be more focused on how they interact with the system and not its overall capabilities.

In this section, I highlighted the uncertainty around the blockchain technology by showing that participants were associating possible negative consequences with the technology and that their understanding of this new technology was viewed through the lens of the installed base. The existing technological infrastructure shaped their understanding of the technology and how they interact with the technology is shaped by their existing processes and workflows.

3.3.2 Failure and Resilience on the Farm

The previous section specifically illuminates the uncertainty around the possible negative consequences of the blockchain on the farm. Yet when examining technology as situated and contextual, as captured through interviews and participatory design workshops, a different perspective begins to emerge: a perspective of technology failure and resilience. When looking at the technology as a whole, one can begin to get a picture of how blockchain fits into their understanding of technology. P27 states:

> P27 - "I would say, probably the other umm field managers have more issue with this but umm we do have like spots out here where you don't get much reception, like much service and so it's difficult. Like I actually have one barn that I get no service inside of it... Because it's offline. And so I basically have to take a picture, walk out of the barn, and then go back and forth on my little split screen, and try to enter in all the information. Umm I would say also in MTech, umm I wish that we knew more about it, it just... I think that we could utilize it a lot more. Umm, I feel like because it's not user-friendly, we can't get the information out of it that we really need or that we could really utilize. Umm I do feel like we're a little bit limited on some of the items that we collect, like there's I feel like there are some things that if we were to get that information, it would help out as well"

Unpacking this quote, there are a few things here, but of particular importance was the cellular data reception. Working inside a barn reduces the ability to connect to data services and the subsequent process of taking pictures and uploading them to a central server is delayed. This type of process and system failure is challenging because it affects how these farmers can do their work. It is not simply an increase in the wireless or cellular reception; working indoors in some areas in the remote rural country can all but eliminate your cellphone reception. These rural commercial farmers have learned to live with the failures of technologies and try to adapt as best as possible. Another perspective offered by P1 described a successful phishing attack at a different farm and stated:

> "A couple of years ago... Yeah, Pennsylvania did... He did have a... Where they did get hijacked, just crazy to think about... That can happen, so I know. But I guess for me, and this is... Hopefully, it doesn't sound like I'm being overly confident. I guess I get more concerned about technology failure, you know that anything that... Anything else? I don't know what the statistics say, but I guess that's what I get, I get concerned about it, something crashing and all of a sudden you're just dead in the water for however long..."

Here the participant described how they are more concerned with technology not working than a potential cybersecurity breach. This isn't to say that they aren't taking precautions to prevent cyber-attacks; they are more concerned with the existing technology working. Thinking about how the installed base is ingrained with the culture[18, 104] helps us understand this perspective of how cybersecurity breaches are not really the focus of a farm. The care and maintenance of ducks and the existing infrastructure are the focus. For over a century, the processes of farming ducks changed, but it did so slowly over many decades. The pace of change has increased recently as more technology creeps into the field as required by health and safety standards imposed by federal and local regulations.

When it comes to designing a blockchain system, there is an awareness that failure is possible but not preventable. The systems that these poultry farmers interact with a range from large mechanical processing machines to tablets to desktop computers. The variety and the range that these farmers interact with are vast. In order to better understand the implications, I constructed a design structure matrix (DSM) in an attempt to capture the information flow of the systems[20, 21, 41]. This approach to creating systems is the same technique used by NASA in spacecraft mission design[35]. It is an engineering approach to model the information and better enables engineers to create zero fault systems like aircraft carriers and spacecraft. Based on the information collected from interviews and workshops, I created a DSM model for Culver Duck. See Figure3.2

In the diagram, the information arrows in blue show how the system can go down to the next system. It can also go to the right, and inversely, the information can also flow up and to the left of the previous system(s). An *x* on the square means that the information does indeed flow back to the system. As an example, the information from Mtech (A) flows to the James Way (B) system indicated by an *x* and the information is also sent back to Mtech from the system. The dotted line represents subsystems that are in the same work area. Within this diagram there are two: the hatchery subsystems and the processing center subsystem. The first consists of James Way, Nature form, Novatech and Sensephone and the latter consists of PMJ, Bayle, Canopy, Wolf and Manager Plus. Farming technology consists of a collection of devices that exists through-out the farm, such as ammonia meters, humidity sensors and fan controls. These devices are a mix of manual technology, but many could be future Internet-of-Thing (IoT) devices. Many of the technologies served a single purpose and were added over the years as the business grew and expanded. The problem is that with multiple generations of technologies, things like interfaces, UI design and data

Culver Design System Matrix		A	B	C	D	E	F	G	H	I	J	K	L	M
Mtech	A	A	x	x								x	x	
James Way	B	x	B											
NatureForm	C			C										
Novatech	D				D									
Sensephone	E		x	x		E								
PMJ - Processing	F						F							
Bayle - Processing	G							G						
Canopy	H						x	x	H	x				
Wolf	I								x	I	x			
Manager plus	J									x	J			
Farming Technology	K											K		
Excel	L												L	x
Paycom	M												x	M

Figure 3.2: Design System Matrix constructed from interviews and workshops.

output create a multitude of problems.

As an example, consider the challenge of the hatchery subsystem. First, each interface requires a different knowledge set. There are different ways to read the temperatures between the NatureForm and James way Incubation Machines as they are designed differently. Applying an incubation period temperature to one would not be equivalent to the other. An additional monitor can be used to control this, which helps with understanding the variance, but the instrument sensitivity is not perfect (See figure F.23 in the appendix F) Second, both systems have different interfaces, requiring different systems these commercial farmers must learn (See Figure F.16 and F.17 of the different interfaces in the appendix F). Finally, the data they provide are in different formats leading to frequent manual adjustments of the temperature and monitoring. This is problematic in their existing system and developing a designing an automated blockchain system to integrate with that would prove very challenging.

Designing a blockchain system where failure is a natural occurrence and anticipating working in spite of that failure is a process best defined by scholars and technologists who are interested in *resilient* systems. Resilient systems are designed so that they can carry out their intended functions through certain levels of compromise [75, 46]. What is needed to create a resilient system is a human-centered design approach that understands culture, practices and policies that define the full socio-technical system, not just its technological parts. It is not clear if a blockchain system could be designed in a way that users can bypass the system if they view it as failing. Take the conversation I had with the participants in W3:

- Researcher (R): "Yeah, so both the Bell system and the PMJ system have ethernet cords running to the server room. . . . All of that is tied into the internet. So if Bell can link from France, I'm imagining that a hacker would be able to find that information without any firewall?"
- W3 - S1: "Sure"
- W3 - S2: "They could pretty much go in and start changing parameters and settings or... Just to be able to see what we see. Umm, and then uh... On the evisceration side, I mean, we use the PMJ equipment for... That plays a critical role in how we process the birds."
- W3 - S1: "Somebody could go... I guess if somebody got access to PMJ, our PMJ interface, they could go in there and, and make a product selection for something that we don't need..."
- R: "Okay"
- W3 - S1: "And that could be devastating to sales."

In this conversation, users consider the possibility that their systems are accessible to the internet and consider the ramifications if their systems were compromised. In this case, the workshop participants concluded that the failure was possible because of the lack of security measures. This perspective of an inability to prevent technology failure is a commonly held belief among the participants in this study. While systems can be designed to accommodate a variety of different practices, it is challenging to design a system in which the practice is to bypass the entirety of the system if it fails. When it comes to blockchain, the key property of traceability assumes that individuals will be using it. To bypass it would be to conduct items "off-chain" or, in other words, outside the system.

The COVID-19 pandemic also presents a different perspective of failure when it comes to commercial poultry systems. The existing infrastructure and supply chain needs to handle the pressure of a crisis. Resilient properties, which consist of metrics like plan, absorb, recover, and adapt [75], could be incorporated to accommodate both the HCI perspectives of failure as well as negative pressures presented by a global pandemic. Systems were shut off, processing facilities were closed, yet the ducks still needed to be cared for, and things like eggs still needed to be closely monitored before hatching. The COVID-19 pandemic put stress upon the supply chain and if a blockchain system were to be implemented, it would need to be able to account for the perspectives of technology failure as well as the negative pressures in a slowly recovering economy.

3.3.3 Reverting of Technology on the Farm

Participants are unsure of the unintended negative consequences of a future blockchain system and identified many already-existing failures in the current infrastructure that may or may not be amplified by the integration of blockchain. Participants identified reversing, rolling back and removing the blockchain if all or part of it was not working. This section will explore what I call an orientation of versioning as a strategy for resilience in blockchain implementation. These new systems are constructed into this bricolage of diverse tools that allow the rural commercial duck farmer to harvest ducks at a rate that would have been impossible one hundred years before. Yet despite the technology benefits, there is a belief of reverting to a previous version that persists throughout the data. The belief is that we can always extract to earlier times in which we use a non-technological way of tracking ducks. P17 states in conversation with the researcher:

- Researcher(R) - "do you think it [blockchain] would introduce any problems, uh, introducing a system like this?"
- P17 - "No. I don't think so. I mean, 'cause it would be...[Owner]wouldn't let it. . . . [laughter] A, that's the first thing, but no, I mean, 'cause it's, it's not, it's not something that is, is irreversible, you know, it's not something that... I mean, we, we decide to use it, or we would decide to implement it, it's not something that, you know, once you decide, you can't change your mind, right?. . . . And we can always go back to the old-fashioned way."

- R - “Yeah.... Right... And you can always, like... Yeah, go back to the old-fashioned way of uh tracking it, like physically tracking it?”
- P17 - “Right.”
- R - “Interesting...”
- P17 - “So no, I don’t think there’d be any threat.”

The conversation captures the essence of the belief from the participants that we can always shut off the technology and restore the Culver “system” to an earlier revision. There is a sense that not only can technology fail, but when it does indeed fail, the company can always move away from it or revert to a previous revision before the technology was implemented. This example of *versioning* can be thought of as a way to think about a revision. Recall that software engineers typically create software through *versioning* but in this case *versioning* refers to the belief held by the farmers and that technology can be extracted.

P17 described that technology is not irreversible. If it didn’t work, they could always revise and organize the processes around that. This belief is also a shared belief among those at Culver Duck farm. It presents a difficult concept that farmers must wrestle with. This idea of *versioning* here shows that Culver Duck cannot willingly revert to a previous revision. P17 expresses a belief about versioning which explains a desire to *extract* to the time before technology. Schedules are computerized. Forecasts are modeled using spreadsheets and predict when new flocks will arrive, be sold, or be collected for processing. Simply extracting the revision is not an option, yet the versioning belief among the rural farmer persists. Consider the quote from P5:

> P5 - “With our system right now without being able to scale, verify and technically... Let’s say we had our network go down. In theory, we could run our plan without networking, and once you cross the line into full automation, you’re done... When you have an issue like that, if your process completely dependent on networking, which I think is what kind of like cloud, people working with Chromebooks and hoping to not have to have any horsepower in their hands, people are always gonna end up with some local storage. I don’t foresee a world where you could really 100% expect the cloud to take care of you.”

Like this participant, several other participants in this study believe that if the entire network were to go down, the work could continue. While P5 acknowledges that a fully automated system would bring about a permanent change, P5 believes that the current system allows for a way to extract the software to a previous revision which, in this case, means manual processing. Even though the participant qualified the statement with “in theory”, it speaks to the strength of the versioning belief that one can revert to a state without networking is possible. Using the concept of *versioning*, here, P5 states the idea of *extracting* and removing the technology completely. Setting aside the technical complexity of versioning, it is difficult to know if reverting to a previous revision is actually tenable. Regardless, the belief held by the participant still believes it is possible to do so. Version control in software allows developers to go back to previous states of the software. Yet doing so with both physical and technical processes at a farm that has layers of automation might not actually be possible.

One could speculate that the bricolage of technology at Culver is so heavily layered that removing it would also inflict entire changes to the existing processes. The technologies are layered upon one another so well that there is no going back without significant effects on the overall efficiency Culver Duck. From the evidence in this study, farmers at Culver Duck believe that there is a type *versioning* over their existing technology and that one can simply revert to a previous revision. Individuals in this study talked about technology in a way that they would implement or *revise* a technology in order to test its utility. This *versioning* belief would impact the rural farmer if a blockchain system were introduced, as it would require significant changes to the existing infrastructure. This point is obvious. However, a technology like blockchain continues to add layers to the installed base. Making changes, not only as a transactional system, would also require multiple integrations with the existing systems. This sprawling and integrated solution would be difficult to remove. A blockchain system would allow for increased automation and simply shutting it off would prove difficult without a deep understanding of its sociotechnical context. The rural farmers in this study might be against the influx of more technology but the certainty is that more technology will be arriving, not less.

3.4 Discussion

Individuals who work on these farms have expertise in animal husbandry, bio-security, supply chain and other farming-related areas. However, the inner workings of blockchain, like cryptographic protocols or distributed networks, might be beyond their understanding. This is not to say that they have no understanding of technology but that their expertise lies elsewhere. Even the perspective on how they view technology in the future can play a role in their understanding. How a computer scientist can wonder at the Mars rover flying on another planet is similar to how a rural farmer might wonder at the technology of blockchain. These perspectives force us to think of a futurist and techno-utopianism perspective of blockchain and how that might differ for these participants. When it comes to the technology present in our day, the infrastructure that shapes our lives is ingrained into our society and culture. Once the infrastructure is established, it is difficult to remove and carries with it an inertia projecting forward towards a direction that beckons more technology.

Technology seems to be increasing everywhere you look and that is true on the rural commercial farm. The goal of this research was outlined with RQ1, which sought to understand if the current systems and processes at the duck farm could blockchain help in managing the supply chain. To answer this, the interviews and workshops in this study were intentionally constructed in a way that did not confine them to rigid technical definitions but allowed them to explore blockchain in a way that they could understand[81]. Removing the technological constraints has its downsides. One could argue that this closes the possibility of their technical understanding and by extension, bias their perspective of this technology. However, individuals don't have to know the technical complexity to use it as a distributed ledger. Recall that blockchain has embedded cryptography protocols that make it an attractive platform to use because it enables end-to-end encryption. Users of the blockchain system do not have to know that the mathematical complexity of the cryptographic protocol ensures that the transactions are secure from tampering. They only need to know that the protocols are designed in a way that prevents tampering. A similar argument could be made for the use of USD currency. Like many other fiat based currencies, the United States of America's currency takes enormous steps to prevent duplicate money or counterfeit money. The USD currency is designed with counterfeit measuress including microprinting, watermark, raised edges, logo placement, etc[7]. Explaining the technology in an accessible way allows the participants to explore the possibilities of the technology in a way technologists, computer scientists and researchers might not anticipate[96].

3.4.1 Technology Failure and Versioning

Jean Hardy suggests vast geographic differences between rural workers, making them fundamentally unique from many typical internet users[48]. If so, designing a blockchain system may be a unique opportunity for boutique commercial software developers that seek to enter a unique market(s). Accommodating the needs of the rural farmers may help in reducing the uncertainty around the technology and possibly change their perspective of technology failure. However, the complexity of their rural environment, both the different cultures of the individuals who work on the farm and the various personal beliefs about farming, may make a universal system challenging. Recalling Bowker and Star's work[18] on understanding information infrastructures, the existing bricolage of social practices and technological infrastructure act as layers. Blockchain could be designed in a way that potentially minimizes the potential impacts of the shared social belief that technology fails. Yet, it is not just that technology fails but the way in which technology fails. In the rural commercial duck farm, there are complex socio-technical failures that are not just attributable to one point of blame that exist inside complex bricolages.

The complexity of technology points to a need for a rich sociotechnical understanding of the landscape in order to develop more resilience in the inevitable failures that will come from implementing a new blockchain system. Through the data, it became easy to understand why these farmers have adopted the perspective that they can simply revert back to a previous revision of a system where the technology is not implemented. If the technology fails, then the work of caring for, processing and harvesting ducks still needs to continue. When versioning their technology,

[7] https://www.uscurrency.gov/denominations/100

workers continue to use technology and revise technology as needed. Unlike unfinished goods, these animals and the products produced from them are perishable, as explored in the following chapter 4. This means that even at a reduced rate the animals would still need to be processed whether or not the system is there. However, simply moving back to a previous revision is not simply unplugging the blockchain system. Various sensors and IoT devices that point to a blockchain solution would not work. That would mean that the capture of localized weather, humidity, and ammonia would not work and would also need to be collected manually. System efficiency can bring with it a reoriented labor force that would require more technical workers alongside manual laborers. To make a blockchain system resilient, great care would have to be considered in the design, materiality, and redundancy of these systems. A technologist's perspective would be to just add more sensors, but a far better way would be to consider how the system actually gets used and consider the likely failure points and add redundancy in those locations.

Another perspective on the point of versioning again relates to the idea of efficiency. A blockchain system would increase the technological efficiency of the processes. By extension, the automation would allow for increases in line speed, labeling, and even shipping when it comes to the processing of ducks. The increase in efficiency would allow them to increase their supply and inversely customer demand downstream would be allowed to increase. The increase in demand means that the company will become dependent on the increased revenue gained through such a system. Going back to a "manual" process would not be possible without again changing the infrastructure across its multiple interconnected levels of materials, laborers, policies and practices.

Versioning is the orientation these rural commercial farmers have towards technology and designing for it requires a human-centered design for it to work. Reverting to a previous state of no technology is still possible, but this could make for a dangerous combination for a firms success. Consider the scenario in which a blockchain solution is employed; individuals expect it to fail and plan to act as if the technology could be simply shut off. First, this would lead to a lack of adoption of the technology as well as the expectation to not use the system. By starting to use the blockchain system, if they find it cumbersome or difficult to interact with, that might prevent adoption but if they can't do what they need to do, it becomes more complicated. Years of HCI research tell us that they might use the system in an unintended way. For example, the idea of a blockchain system is to allow for greater traceability. However, allowing for changes to blockchain because of an unplanned death of a duck could sacrifice the core benefit of blockchain's traceability. This topic is explored further in chapter 4. Additionally, if they opt to extract the technology and move to a previous revision in which blockchain was no longer present, this also presents a challenge. The existing infrastructure would have changed to support a blockchain system. Data and interfaces would be pointing to the centralized blockchain repository and any interfaces would need to be shut off or risk "throwing" an error. The point here is that just as there would be growing pains in implementing a blockchain system, so too would there be pain in removing the blockchain system. There should be a plan for implementation as well as a plan for the removal of the blockchain system.

Mitigating this problem could be accomplished through a myriad of adoption strategies. First, the blockchain system could be brought in as a parallel system that simply does the job of data aggregation. The system would sit organizationally above the lower technologies and interactions would be one way. In this way, the data integrations would send data without acknowledging the receipt of the data. The blockchain system would collect the various data while establishing data connections between various systems. This would need to be carefully designed and acknowledged that the blockchain is making the system "assumption" that the data is correct. Second, a different strategy could be to tightly integrate a new blockchain system with the existing architecture. In this way, the data systems would communicate in a two-way fashion with the various systems mentioned in figure 3.2. This would mean that any system that wished to connect to this blockchain system would also need to acknowledge that the data was correctly captured. In industry, this is largely accomplished through Application Programming Interface (APIs). For cloud-based architecture, APIs are often conducted through RESTful (More commonly known as REST) architecture which allows for the use of web services. This allows for the easy exchange of information between systems. This approach would have to consider several factors, such as: Would the anticipated gains in productivity outweigh the costs of implementation? Will the IT staff be expanded to support the new infrastructure? If the anticipated gains in productivity do outweigh the added costs, then it would make sense to move forward. However, for both approaches, additional participatory design workshops would help ensure that the blockchain system would work with the existing infrastructure and mitigate any foreseeable problems in terms of using the system. This is particularly important because the findings in this chapter are largely based on how individuals understand technology. Without this consideration, all blockchain systems would run into problems.

3.4.2 Dangers of Techno-utopianism

Taken together, these insights point to a need for combatting the flash and techno-utopian thinking that encircles blockchain and the less flashy realities of failure and revision that pervade the commercial farm. Techno-utopianism is a term that describes the philosophical belief that technology could help bring about a better world. Individuals who subscribe to this belief, generally believe that technology is the solution (techno-solutionism) and that apps, devices, and other technologies can solve the world's problems. No doubt techno-utopianism is prevalent as we constantly see innovations where we hop into strangers' cars like Lyft or Uber or meal delivery services like DoorDash. All are accomplished via technological innovations. In the early days of the internet age, the internet was envisioned as a free market of information and the mantra was "Information should be free!"[109]. While this viewpoint is prevalent in the software development industry, it is not without its problems. Recall the perspective of Microsoft by developing its FarmBeats application. Silicon Valley and software development firms develop for the larger society, but these viewpoints can leave individuals or large groups of people marginalized. This is not to say that these innovations shouldn't exist but that they are not without their costs. When it comes to the belief held by these rural farmers about the failure of technology, these farmers have wanted to use technologies but often are forced to find ways to work around it. Coupled closely with techno-utopianism is the idea that there is also a technological determinism or a belief that technology is the only future. Dickel et al. [36] created an excellent breakdown of the narrative patterns of techno-utopianism. The researchers created a framework of techno-utopianism with two important categories: ontology - how reality is constructed and temporality - how time is constructed.[8] This useful perspective fleshes out the components into tangible ways to consider the impacts of the philosophical belief.

Consider first the ontology of techno-utopianism. It concerns itself with the belief that things like 3D printers, although very limited, can potentially construct homes *en masse* [9] or even develop new organs [10]. The reality that is being constructed in a techno-utopianism framework bases itself in the future, limited only by the imagination and is evidenced by technological innovations not yet realized. From the techno-utopian perspective of blockchain, it is being described as a general-purpose technology to solve problems like being used on a duck farm but the more outlandish claims like solving cancer [11]. Ultimately the ontological perspective can be misleading and overstate its possibilities which it uses as a foundation for its continued operation and maintenance.

Blockchain fundamentally claims to aggregate large amounts of data, making it traceable throughout a supply chain[61, 62, 94]. There is no doubt that the information age has increased the temporality in which we perceive technological innovation. Yet, the evidence presented in this chapter speaks to the belief that techno-utopianism is not present. In fact, it may be that the rural perspective of technology failure speaks to a different worldview altogether. Recall that rural Americans have their own perspectives on technology and a subset of these participants are Amish, bringing with them perspectives informed by their religious beliefs. Jason Wetmore wrote about how the Amish do not ban technology or that they are anti-technology but that they carefully consider which technologies they choose to utilize.[114] My own participants sent me images of generators (See Figure 3.3) and battery arrays (see Figure 3.4) that help power the duck barns.

[8] There is actually a third argument "sociality" but it felt weaker in terms of its effects on individuals

[9] https://www.today.com/home/companies-using-3d-printing-build-houses-half-cost-t217164

[10] https://www.newswise.com/articles/ultra-fast-3d-printing-produces-life-like-organ-models

[11] https://www.labroots.com/trending/cancer/14933/blockchain-cancer-tech-changing-research-treatment

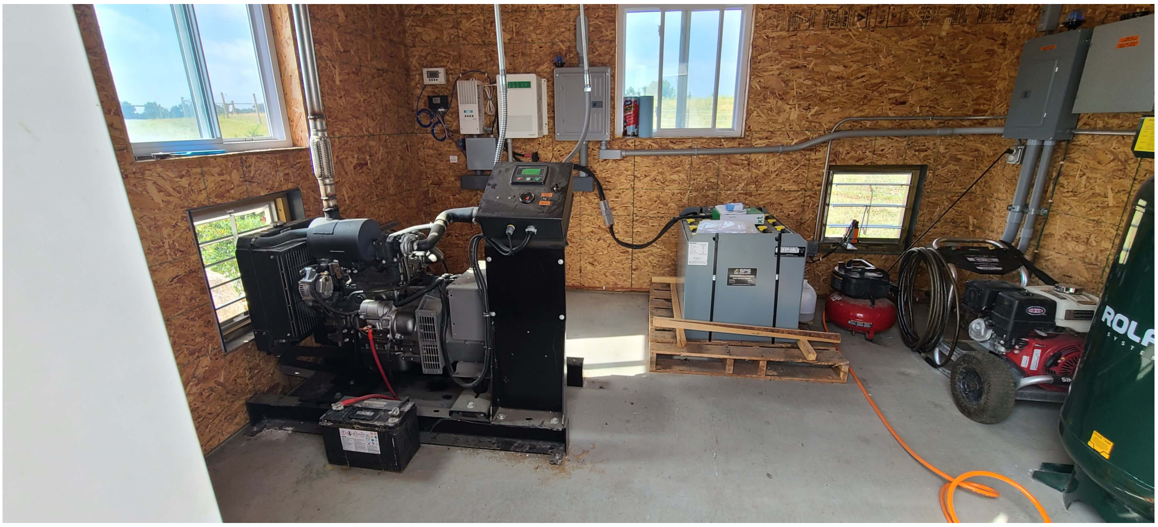

Figure 3.3: Amish Generator that is powered by a fuel source to power the barns lights and fans.

These images help us understand that there is not only a layering of different kinds of technologies that define the bricolage of the commercial duck farm at Culver but also a layering of different cultures whose customs need to be considered part of the infrastructure design. In essence, it is the intersection of worldviews and technology. The software developers design with a techno-utopianism worldview and individuals who live in different cultures operate with different worldviews. Technologists describe technology with all-encompassing benefits, but individuals in these rural areas find that the technology does not always live up to expectations. The prevalent belief is that although the technology directly meets their needs, they continue to work with it, versioning it and creating new revisions that are adjusted to their needs.

3.4.3 Point of No Return

Returning to the idea of infrastructure being ingrained into our society and culture, upgrading the existing technology makes it difficult to revert to a previous revision because of the added layers in the infrastructure. The social and technological is woven throughout the commercial duck farm and the individuals who work there believe that the technology will fail. By taking steps forward with a technology project, there are implications for the technological project and the social and cultural impacts. This leads to a sense of a "point of no return" and once a company has crossed

Figure 3.4: An array of batteries to power lights, fans and other technology at a barn.

this threshold, things seemingly cannot revert to the way things were. The data seems to suggest that the belief in versioning makes them blind to this point of no return on the farm. They continue to believe that they can always revert and revise technology as they always have done, and that belief, in my opinion, is the way to be resilient.

One could argue that any software implementation would require a trial phase. In the waterfall or traditional software development model, a testing and quality assurance phase would potentially identify key problems with the technology before deployment. However, recall that some of the issues these farmers experienced were intermittent internet issues. When developing technologies, most software firms take the approach of trying to address the major issues first. Things like intermittent connectivity issues might be considered a fringe issue and fall down the pecking order.

Despite testing, it is entirely plausible that a significant and costly technology that is faulty could make it all the way to production. In terms of blockchain, a blockchain system being deployed for rural farmers would fundamentally alter the technology landscape. This system would be heavily ingrained with all the various components of a farm and would fundamentally represent a point of no return. Reverting to a previous revision before the implementation of such a system would be costly, impractical and devastating to the commercial farmers.

This concept of the "point of no return" takes on additional challenges when coupled with techno-utopianism. With the rural farmer's belief in returning to a previous revision, this seems to be the exact opposite of techno-utopianism, which offers technology as the solution to a better world. The point of no return could be conceptualized as a threshold between these two beliefs. Experience has taught these rural farmers to adopt the belief of versioning that technology always fails and that revision is possible. While on the other side, techno-utopianism carries the belief that technology is the future and that revision is not necessary.

3.5 Conclusion

As the duck farm continues to change, future work could examine the impacts on the rural farmers when the blockchain is implemented. In this chapter, I revealed how participants are unsure of the unintended negative consequences of a future blockchain system and identified many already-existing failures in the current infrastructure that may or may not be amplified by the integration of blockchain. I explored the orientation of versioning of technology as a strategy for resilience in blockchain implementation.

Commercial duck farming has been around for almost two centuries and was largely accomplished without the technology that we have today. It seems like a reasonable belief to hold on to things continue to operate as always but introducing technologies like blockchain places rural commercial farmers further down the road of increased technology use. Acknowledging technoutopianism in blockchain thinking on the farm provides a need for establishing success metrics that ground its evaluation in its lived experience and not just its promise. That lived experience is the crux of the human-centered design approach asserted by this dissertation.

CHAPTER 4

DUCK, DEATH AND THE BLOCKCHAIN

4.1 Introduction

When it comes to farming animals, sensors and devices are used throughout a farm to help with a variety of different tasks. Devices like ammonia readers and temperature sensors help duck farmers see if the ducks are healthy. These technologies are designed to help ensure the safety of the ducks. One of the challenges of this space is that there is a variety of different modes of death on a farm and it is unclear how these technologies help or hinder those. Any transformative intervention in this space, like a blockchain implementation, will have to take seriously its significant and unique, ever-changing sociomaterial realities.

In Wolf Erlbruch's children's book entitled "Duck, Death and the Tulip," the author describes how a duck is befriended by a character named "Death." Initially scared of Death, the character "Duck" in the story is befriended by Death, and they participate in various activities that range from sitting in a tree to diving. The story centers around pondering the afterlife, and eventually, the story moves towards the end of Duck's life. The character Death gently places Duck in a river with tulip all while carefully caring for Duck's feathers as the duck drifts gently down the river. This book introduces the concept of death in a material and accessible way that children can understand without the added complexities of real-world implications such as religious asceticism.[1]

From the perspective of a rural commercial duck farm worker, the book serves as a great analogy for farmers and the materiality of the animals in their care. In terms of this research, it is fitting that the book examines the relationship between a duck and death. While it might seem harsh comparing farmers with death, the material challenges of raising and ultimately harvesting ducks are the essence of commercial farming. As a technologist, I often think about developing processes

[1]While this book is written in an agnostic way, I do not agree with the philosophical worldview that death is uncertain. From a philosophical worldview, death can be viewed as a certainty yet arguments for the soul/spirit are beyond the context of this paper.

and systems. Yet on a farm, there is a material reality that comes into focus. The assets and artifacts that are a part of this system have physical matter, and are constantly in a state of change. Blockchain systems are typically portrayed as a system that is linear and in order. When juxtaposed with the ecology of a duck farm, things seem like they could break down. On farms, animals get sick, they can die, can get taken off the processing line and then put back on the line out of order. So, these systems seem to be more circuitous and are possibly non-linear pathways that a blockchain system would need to accommodate. This intersection of material, social, and technological worlds needs to be explored. There is a complexity in raising animals that are ultimately meant for slaughter, and with it comes difficult processes that cannot simply be replaced by technology.

For this research, I show how tracking ducks is challenging because of their ephemeral nature and how designing a blockchain system can add to those challenges if complicated material and social practices are not considered. Through a series of interviews and workshops at Culver Duck farm, I sought to understand the first-order concerns of the different stakeholders of a blockchain solution. I found that the ephemeral nature of Duck farming speaks to the material challenges in tracking them. Things like physical mortality reports are useful tools that track ducks, but they speak to complicated processes and procedures. Finally, the complicated death dynamics on a farm could prove challenging for blockchain designs. Accommodating the needs of rural farmers by understanding how their complicated processes around the materiality of the ducks may help in producing a useful blockchain system. Finally, future work could examine the duck supply chain to see the differences and similarities in the perspectives throughout a blockchain-based system.

4.2 Literature Review

Walking through a modern-day commercial duck farm reveals a fascinating efficiency. Many systems highlight the material nature of the farm. Some systems are obvious, like the elegant systems for waste disposal or the water systems that distribute the right amount of water. Yet these systems are more transparent because there is a physical matter to them. Equally important are the digital systems that record the number of eggs in a barn, or the number of deceased ducks on the farm. This type of material info is tracked on a physical sheet of paper to later be entered into a computer system. The question then becomes how to consider the material aspects of the technology on a farm?

Defining materiality is a challenging endeavor because different branches of literature have attempted to add clarity to a subject for their given field. Orlikowski 2007 [93] writes that Organizational Science focus primarily on the material aspects of the technology but not the technology itself. The author claims that the research tends to ignore technology, take it for granted, or treat it as a special case. Orlikowski points out that matter itself is treated as irrelevant. Technologists trust the technology as important but ignore the “matter”. Orlikowski states, “taking a largely functional or instrumental approach that tends to assume un-problematically that technology is largely exogenous, homogeneous, predictable, and stable, performing as intended and designed across time and place. Yes, as critics have pointed out, this perspective defies technology, ignores how technology is bound up with historical and cultural influences, and thus produces technologically deterministic claims about the relationship of technology with organizations.”(p.1435) While not dismissing the value of research in other fields, the author carefully and succinctly explains that the challenge of studying the materiality of technology is to understand that the material world of process, culture and practices have shaped technology. Similarly, research by Edwards [39] – Contested Terrain: the transformation of the workplace in the twentieth century – showed that the pace of the conveyor belt was correlated with the pace at which workers needed to move in order to keep up. At Culver duck farm, it’s easy to see the materiality of things they work with because the animals, they are processing are products they process for their meat. According to the BRCGS food safety standards[2], the line can only move at 60 birds per minute with manual labor. Moving to 75 birds per minute requires the use of a computer and autonomous system. The question remains does it become any less material when technology is involved? The answer I suspect is no but why then do we, as technologist researchers, assume that things move in a frictionless way with technology?

[2] https://www.brcgs.com/our-standards/food-safety/

Extending this argument for materiality, Paul Leonardi [70, 71, 60] suggests that what matters most about an artifact is not what it is made of but rather what it allows people to do. Materiality forces individuals to adhere to policies and procedures. Think of a software policy that has users conduct a social practice, i.e. requiring a physical inventory check. Leonardi states that "researchers should ask when examining practices of use, which features are "material" (significant) for this user and how those features become significant for the type of work she does, for whom she interact with, or for maintaining control." In this case the digital technology is of interest but so is how and what the technology affects. How does this change the work? Or how an individual conducts the work? The effects on work and practices become the research focus that is often missed when it comes to studying the materiality of a given technology.

When it comes to the HCI literature, researchers Dourish and Mazmanian [38] and Rosner [100] explain how the material world shapes the digital and technological world we live in. While some of the HCI material literature focuses on the effects of different types of materials and designing technologies [118], Dourish and Mazmanian eloquently describe that what is interesting is not just the materials but the properties the materials possess. The authors state, "What is of interest to us is not simply the fact that apparently abstract and ineffable digital "stuff" actually takes material form; rather, we want to understand the particular material properties of these forms and their consequences for how people encounter, use and transform them."(p.4) Beyond the physical matter of the technology systems, the digital systems create material outputs, whether they be physical or digital. This line of thinking feels like it borders on the metaphysical realities of our imagination, but the authors point out that beyond the digital "stuff", what they find interesting about materials is the way in which these affect our practices. Leonardi [71] and the HCI literature overlap because they seem to want to study the effects of the technologies on the individuals' practices and work. The theme that seems to be presented is that the effects of the technology alone are worth studying but so are the changes to and by the technology on the culture, the work environment or even government policies.

What becomes important to understand here is that the material, the "what" as Borning et al.[17]

describe, pushes back on any IT. This article focuses on IoT in particular, but encourages the reader to think about the material aspects of the waste generated by technology. Familiar conversations about technological utopianisms and utopian visions are often the guiding principles when it comes to technology design. The authors make a very important statement in that increasing the visibility of the waste is not always desired and the authors liken it to airing virtual laundry. From the text,, "Section 4 notes that in many cases Computer Scientists abstract away the physical manifestations to concentrate on information and computation." The importance of the statement is that there needs to be an acknowledgment of the materiality that results in waste. Just because we get a new IoT device means that we throw away or dispose of the old one, emphasizing the materiality aspect of technology. For this research, while we are not interested in waste generated by technology, the point of considering materiality shows how technology can change processes.

In a duck farm, the goal is to maximize the yield of ducks and reduce waste. However, there may be unknown materiality considerations and the consequences of installing a blockchain-based system for a duck farm will affect the farm in an unknown way. Sensors, devices, technology systems, paper processes, physical checks and other interactions will behave differently when individuals interact with them. This is even more so when the technology is designed to replace human interactions in certain places. Looking at the scope of material literature from the HCI literature [7, 38, 118, 100], Organizational Psychology [70, 71, 19] and management [93, 3], there appear to be widely different perspectives. The focus on materials is treated differently based on the researcher's own field, and while this might be obvious, the material researchers I've included here are interested in more than the direct effects of the materials. They seem to be interested in how digital ineffable "materials" affect the world around us and how the changes by the individual workers are affected.

For this research, I aimed to take a similar approach from the literature. This dissertation explored the material implications of the future use of a blockchain system that does not yet exist. To understand the materiality of a new blockchain system, I needed to explore how the existing system would affect their work and practices at the duck farm. These systems affect the way people interact because they are incorporated into their actions. Placing a processed duck that needs to get vacuum-sealed or sorted into a packaging box requires interaction with a computer system(s). Changing that computer system to a blockchain-based system with its traceability and immutability properties has implications for how duck farmers perform and report their work.

4.3 Findings

The research in this paper continues the exploration of the data collected in Chapter 2. The two phases of the research were broken into semi-structured interviews and followed by the second phase of design workshops. For this chapter, I was interested in understanding what these rural duck farmers considered when it came to developing a blockchain solution for the commercial duck farm. I set out to answer the following research question:

- RQ2 - What are the first order concerns of the different stakeholders of a blockchain solution?

After spending time with participants, one theme began to occur throughout the data: Death is pervasive on a farm. Eggs crack. Weak ducks get culled out. Underweight ducks get downgraded[3]. Yet like in the story “Death, Duck and the Tulip”, the character Death is not an enemy but is something else entirely. Culver Duck farm needs to track death in order to understand the health of the animals in their care. These farmers are compassionate and carry with them strong emotional relationships with the animals. However, death is a part of life on a farm and the purpose is ultimately to harvest the animals. From the data, commercial farmers don’t just view the animals as products; they care for the animals in their charge, which reveals an important social practice that affects how the farmers carry out their work.

4.3.1 Complicated Material and Social Structures

Reviewing the codes in the data revealed an interesting theme about death in terms of words farmers used. Using the analytical software Nvivo, I looked through the data and paid careful

[3] A picture of sorting processed birds by weight can be found in appendix F. See figure F.6 which shows the ducks being dropped into certain bins based on pound ranges

attention to the words participants used. Synonyms of death included "mortality", "Dead-On-Arrival (DOA)", "Dead", and "Cull/culling." See table 4.1.

Death and Related Codes			
Label	No. of Occurrences	No. of Participants	% of Total Participants
Death	3	3	13.0%
Mortality	34	11	47.8%
DOA	3	3	13.0%
Dead	8	6	26.1%
Cull/culling	13	5	21.7%

Table 4.1: How rural commercial duck farmers talk about death is primarily through words like mortality and culling

From the table 4.1, we can see that farmers overwhelmingly referred to death through a more nuanced name, "mortality" with nearly half of the participants referring to death in that way. This was followed closely by "culling" which is the act of removing an animal from the flock. Both of these terms refer to a more humane way of thinking about death. The connotation of the word death has a negative aspect and refers to the killing or end of life of an animal, but mortality refers to a state of being subject to death. In essence, it is a more emotionally disconnected word, but it has a more neutral connotation. One could argue that the word choice allows for an even more callous connection to the animals. Yet the data in this study seem to suggest otherwise. Consider the quote from P3:

> P3 - "Well, the number one is, care of the ducks, do what's right for the ducks. That's number one. Then two is how you treat each other, treat each other with respect, and some people are natural at it, some people are good people, people and other people work well with the Ducks, but not everybody does in those departments, and so it's improving the training for everybody, just to say, and if you're not good at this, we still gotta do it this way, or understand dynamics"

In this statement, P3 stated that the goal of the duck farm is to produce quality ducks. While it might seem obvious, it is an important recognition of why the farm exists, not to just grow ducks but to produce quality ducks. This perspective is commonplace in that they want to care for the ducks, and at the same time, are ultimately dealing with a finished product. This social practice of ethical treatment of the animals that are meant to be consumed presents a socio-material challenge that future technologies may need to be designed around.

Many of these blockchain systems use timestamps as a way to order the transactions, and of the types of orders that exist for a blockchain system, they typically follow a linear path. The point is that a blockchain system is supposed to be able to be this fixed timeline of events. However, what happens if the blockchain system doesn't record the way you want it to? What if an error occurs? As is the case on a farm, what happens when the animals get sick and die? The transactions are linked to each other on a blockchain, and if a transaction is removed, how then does a system accommodate for it. What order does the transaction fit in? These decisions have implications for designing a blockchain system for a commercial duck environment. Duck farming requires individuals to work with death's many forms and not all death is the same. The material structure of duck farming and death presents a challenge that individual farmers have to wrestle with in their every-day lives. Mortality is something that farmers want to keep track of and a blockchain system that tracks the variety of materials on a farm could be a viable solution. However, from a technical standpoint, the number lost prematurely means that there are now few ducks that will end up as a finished product. Farmers are aware of this and therefore are cognizant of mortality. Recording things on a blockchain system may help with the material challenges but to do so in practice may be difficult because of the complication of tracking live animals.

These physical and material structures demand a sociomaterial understanding of the duck farm and any implementation of new sociotechnical solutions. At Culver Duck, many of the contractor barns are managed by a community of Amish individuals. Maintaining a distributed network on a physically distributed infrastructure presents a social barrier for any technological implementation. Consider the quote from P12:

> P12 - "With our belief were our main belief or our main, I don't know if it's called belief, but our main is to be self-sustained... we wanna be dependable on God and not on people, so were that's our main.... So we're just self-sustained people, we don't have electricity off from NIPSCO [Power Company], that's why we create our own energy and our own electricity"

The juxtaposition of the Amish way of living with a blockchain system might be antithetical in beliefs. Blockchain proposes to always be connected and the Amish way is to be disconnected and only dependable on God. How can a blockchain system function in a disconnected way? One possible answer is that the collection of data must be a manual process in that any Information of Things (IoT) system or data collection happening at the farm be collected manually and then rejoined with the rest of the data.

4.3.2 Physical Sheets represent Complicated Processes

Just as Daniela Rosner [100] highlighted in her work how bookbinding required coordination, technical tools and social dynamics to create a book binding process. In a similar way, commercial duck farming also has a complicated ways in which ducks are raised and harvested. Growing ducks and tracking them in a barn requires a list on sheets of paper. For an example of what is tracked in a barn, see figure 4.1 below:

The image describes a manual checklist of items that have to be tracked twice a day, tallied, then recorded on the sheet. On the left-hand side of the figure, farmers are to check the temperatures in the barn, the water, the air, the amount of litter, and feed. For the right-hand side, the farmers are to go through and list the ducks that have been culled and for what reason(s). The list includes: prolapse (a condition where the insides of the animal protrude), swollen leg, lame, ascites (water belly), lethargic or neurological. Several things are happening here. First, things that keep the animals alive are accounted for and second any and all ways of dying are recorded. Consider the quote from P15:

> P15 - "Umm, okay, keeping track of the ducks themselves, I do. Uh, okay, we get our count when they deliver them, we have a count what we start with every day, we keep track of, of any mortality. Any ducks that die or any ducks that we cull out, uh we have to... We keep track of that, like twice a day, I will keep track of that and then record it, so that they can uh keep track of what's happening..."

The participant explains that keeping track of the ducks is what the sheets do but P15 also states that the purpose is to understand what is happening in the barn or to keep track of the general state

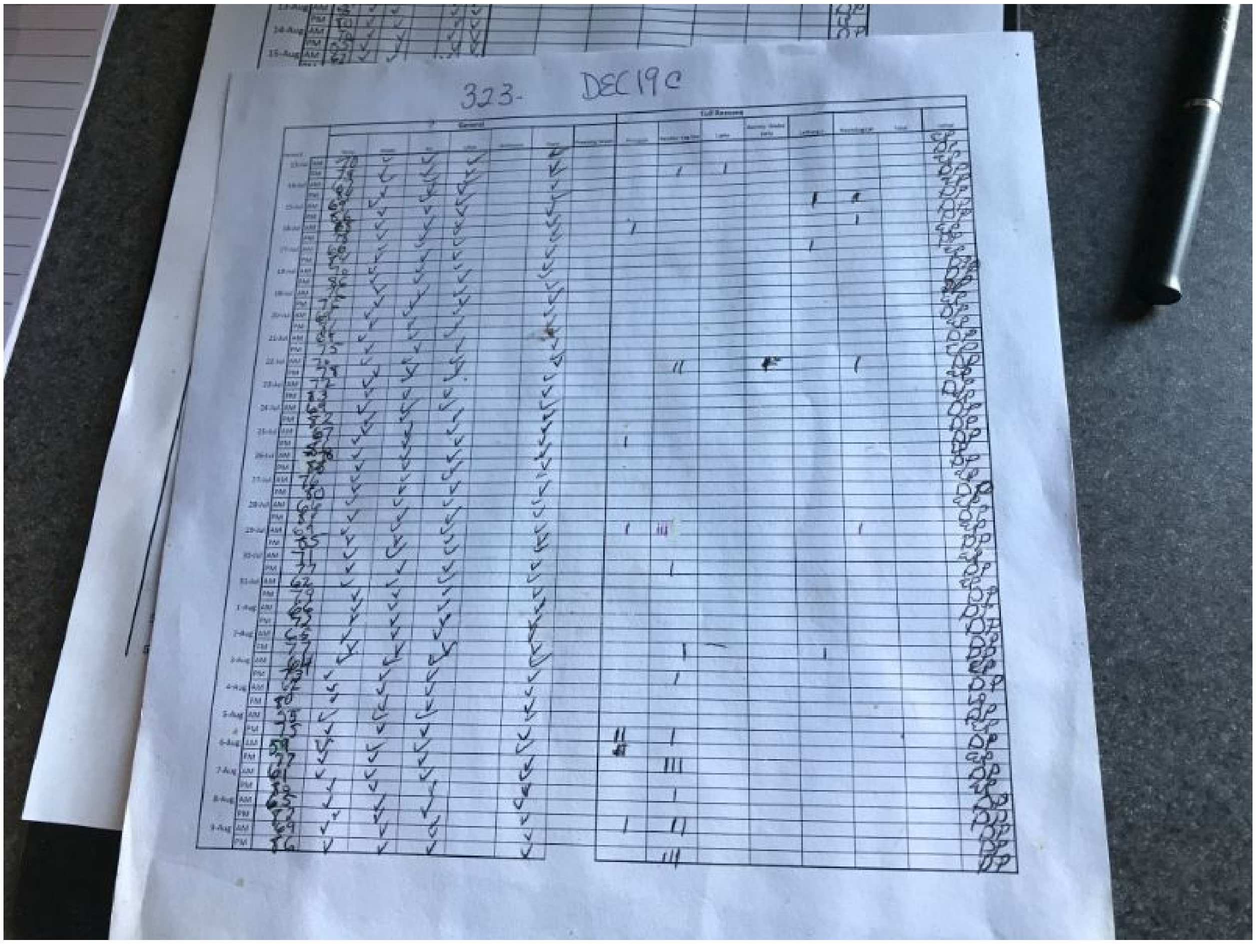

Figure 4.1: Barn Check Sheet.

of the barn. The physical sheets indicate the overall health and well-being of the animals. Take, for example, the count of lethargic. It is possible that a duck that does not move a lot could be tracked through technological tools such as computer vision. Then by applying a deep learning model, the lethargic ducks could be identified and then tallied accordingly in a database. However, a lethargic duck would still need to be culled and removed to protect the health of the flock. This requires an individual to walk into a barn and physically deal with the death of a dying animal that will eventually be culled out. P13 and P23 also say something similar:

- Researcher (R) - "Can you... Can you give me.. an example of something that you have to keep count of?
- P13 - "The feed..."
- P23 - "Mortality."

- P13 - “The mortality, I like to keep... I like to keep track of how much water they drink per day, which we... We have a meter on the line... So yeah, I like to keep track of the heat.”
- P23 - “Mmhmm”
- P13 - “Yeah, we have a... We have a... We have a daily check, a daily chart where we uh... That we fill out. I like to fill it out, well, actually it’s twice a day, sometimes...”

P13 and P23 say things that are equally important: the feed and mortality. Additionally, P13 suggests that the heat in the barn is important but also points back to using a chart. The continual reference of the chart for tracking is helpful in understanding what farmers think about when it comes to raising ducks at a commercial farm. There are a variety of things that they keep track of which can be troublesome if individuals are not able to or neglect to track the animals in their care. Consider the comment by P3 below:

> P3 - “I think the growers, you meaning I’ll probably tell by year how many years the growers have been in, the differences of the way they take care of stuff. I’m sitting in a part and that barn where his barn has automatic curtains. He goes ‘I don’t ever want them.’ Yeah? and he goes ‘except on Sunday, when we go away somewhere or we do something’ he said. ‘It makes me come check my barn, I have to come physically look and see what the conditions are to make the adjustments because so I always know what my ducks are like.’ Okay, good point. So you get a new grower and you put all the bells and whistles on him, well... guess what.. he can send this kid through once or twice a day, and you still somewhat always have a good litter conditions, and as long as they are spread and shavings it looks good... You can definitely tell as a flock supervisor when you walk a block... Yeah, the growers involved in the barn and just by how they walk... When you walk through the ducks react.”

Here the P3 farmer highlights the importance of walking through the barn, which is that the animals react when an individual walks through the barn. The quote highlights the difference in how various farmers take care of things. In this case, the point was to highlight how even with more advanced barns (automatic temperature adjusting curtains), the farmer is incentivized to walk through the barns to visually verify that everything in the barn is functioning as intended. Additionally, P3 emphasizes that the “bells and whistles” aid the farmer, but a child can come through quickly to satisfy the checking of the chart. This emphasizes that the chart implies the practice of walking through the barn and that the health of the animals is dependent on the checking of the ducks. Besides the health aspect of checking on the ducks, this process of walking through the barn occurs regularly because the ducks also lay eggs that have to be collected. These specific practices are not recorded in detail, but the practices' outcomes are tracked via the physical sheets. At face value, each tally or mark on the sheet represents a simple process, yet these examples show how the practice reveals a complicated material structure. These practices ultimately require the individuals to be present in the barn, and when the farmers are not, it can have an effect on the overall health of the flock.

4.3.3 Complicated Death Dynamics for Blockchain

Abductive analysis of the information collected, focused on how the 3 dominant features of the blockchain map to the visions of the participants. The participants spoke about their existing processes and the blockchain "events" that a new system would need to record. From this analysis, I created the table 4.2 below. It shows which blockchain properties were considered as part of their descriptions regarding planned death. Participants commented on the transparent nature of both planned death and things like contagion. This is primarily because things like food safety guidelines require them to have safe practices. However, things like natural death or even sickness seem to be absent from the coding. It is possible that the planned death is how they think our processes "should" perform with a new system. This perspective is similar to that of computer scientists and how they speak about technology as a frictionless technology.

Death on a farm				
Types	Sickness	Contagion	Natural	Planned
Decentralized	??	??	??	X
Immutable	??	??	??	X
Transparent	??	X	??	X

Table 4.2: Codes related to death as they related to the core features of blockchain. Codes are focused primarily on how planned death would work with a blockchain system

What is interesting about this table 4.2 is how it is overlaid with the three blockchain properties. In the planned category, the blockchain properties referenced what should happen on a farm. From the discussions and designs that came out of the workshops, the conversations about the blockchain system focused on how the system should be decentralized and how to track information everywhere across the farm. References were made to how a planned death of an animal would be tracked forever with a blockchain system that speaks to the immutable property. Finally, the transparency of the blockchain system was the focus of the design when it came to the planned death as well as the contagion. While it could be argued that the emphasis was on the planned category of a blockchain system because the overall goal of the workshop exercise was to create a blockchain system, it is interesting that the contagion category was brought to light. This is because the current processes and practices reflected in the minds of the commercial duck farms were concerned about the contagion as it related to seeing how it affected the entire health of the farm.

4.4 Discussion

In this chapter, I sought to understand what the Culver Duck farmers' first order concerns were when it came to designing a blockchain system and identified that the concerns are entrenched in unique material and temporal realities. I have presented data from the study to explain the idea that farmers are concerned with the need to track the mortality of the animals in order to understand the health of their flocks and barns. This perspective forces the farmers to deal with death in all its forms. Culver Duck Farms existing bio-security and food safety policy rules require filling out sheets that track these culls, injured birds and certain health checks. Logically speaking, it would be fair to conclude that the only interests farmers would see in the ducks is that they are the means to an end of obtaining an income. However, the data doesn't support that. Instead, the data gives insight into the complicated socio-material aspects of how farmers in this part of rural America live and work with the ducks.

Another aspect that adds to the socio-technical complexity is that many of the farmers at Culver Duck farms have second jobs. These individuals consider farming as a way to help with a passive income. Farmers with large families help with the daily collection of eggs, and at a farm like infigure

4.2, farmers can collect 3000 plus eggs a day per barn[4]). In addition to the income perspective, Culver Duck has a diverse employee and contractor population. There is a large Hispanic population in the processing facilities at Culver Duck Farms. Many of the line workers are bilingual and live in these rural areas. In contrast, many of the management workers live further away and often have longer commutes to Culver. How this diverse group of stakeholders perceives the duck farm informs their perspective on the design of a complex technology like blockchain. This diversity adds to the complex social and technical layers at the farm and affect how the technology is developed and shaped.

In my initial research of Culver Duck Farms, I learned that the majority of the growers and breeders at Culver are part of the Amish community. Recall, in Chapter 1, Jason Wetmore wrote about the Amish and technology and reported that their technology must reinforce their tradition, culture and religion [114]. One could argue that this also allows for a type of connection to the animals themselves since they are part of creation. When it comes to the idea of death, there may be a conflict of belief in which farmers want to provide for consumption and the ethical treatment of the animals in their care. [5]

Amish farm-houses consist of a great deal of organization and an abundance of what is technology architecture that is disconnected from the rest of the farming infrastructure. However, as they do not have running electricity, one of the USDA requirements requires lights for the animals and heaters during the winter. To comply with the regulations, some of these barns use a somewhat simple array of batteries or solar panels to power lights. Recall that this low-tech solution speaks to the point that Six Silberman was advocating with the research point of the "value of not to design"[10]. Imagining a blockchain solution in this space would require an additional infrastructure of IOT devices and scanners that might require careful consideration. While it might be considered advantageous by corporate management or even the poultry industry, it might not

[4]For a picture of egg collection see figure F.11 in appendix F

[5]In the bible, the book of Genesis speaks to Adam and Eve's responsibility of being caretakers of the garden of Eden(Genesis 2:15). Christians argue that humanity is imbued with a desire to care for the animals and earth.

Figure 4.2: Typical duck growing Amish farmhouse.

be possible for these Amish farms to adopt newer technology based on these beliefs. Recalling Jean Hardy and Susan Wyche's work [49], individuals who live in these rural areas prioritize and perceive technology in ways technologists do not expect. This means that designing for individuals who live in rural areas will require their insight.

4.4.1 Frictionless Technology

The challenge of designing a blockchain solution where many of the farmers live in a disconnected way presents a technological challenge, but the Amish belief systems that support the farm present a social one. The added physical challenges of dealing with the types of death and how a farmer should be present to understand the health of the flock presents another material challenge. The complex bricolage of infrastructure begins to reveal how the social practices, the material needs of the animals, and the general animal husbandry of the animals might affect any technological development. It then becomes easy to see that any technology developed here would not be frictionless and instead would require a great deal of design considerations to work smoothly.

Orlikowski [93] stated that technologists sometimes ignore the “matter” behind the technology. For example, if you think of a duck from egg to duck to processing, the various stages might be easy to record as data. Information is captured and stored in a database or networked system, and in this case, it would be a future blockchain system. However, the evidence presented in this chapter is that social practices need to be considered. Physical sheets of paper represent complicated practices that cannot simply replaced with technology. Even the death of the animals from both the unplanned to planned types of death has different implications addressed by not only Culver but also by regulatory agencies from third parties to federal requirements. The matter of these technologies greatly affects how or in what ways technology should operate. Dourish and Mazmanian [38] and Rosner [100] pointed out that the material world shapes the technology and at Culver duck farms, that continues to be the case. The example from P3 highlights that despite automation, the farmers have a physical impact and relationship with the animals in their care. The material world continues to push back [17] and though the technologies are designed to work flawlessly, the world of farming ducks reveals that it is far from frictionless.

From the workshops (Table 4.2, the data revealed that the blockchain system the farmers designed was focused on the planned death of the animals. This is because the farmers ultimate goal is to produce duck meat as a finished good. Yet from the farmers own practices, the blockchain system must also accommodate the variety of health challenges and various ways the ducks can die. The various physical sheets at Culver Duck Farms showed how complicated a twice daily walk through might be. A lethargic duck or one that appears to be sick due to illness must be recorded in a system but it also means the animal itself needs to be culled out, requiring a physical challenge. Certain health identifiers such as an avian flu might result in the entire flock being culled out because of the risk of spread to neighboring farms. These practices reveal a greater complexity to a blockchain system. This isn’t to say that technology isn’t complicated, but these systems are not frictionless. The variety of death requires different actions and a blockchain system must be able to accommodate more than the planned death of harvesting the ducks.

Finally, the order of the blockchain system requires entries to be entered chronologically. If blockchain "blocks" are tied together in a chronological way, what happens when the duck dies prematurely? The chaining of a duck to a flock in a transactional system must allow flexibility to track ducks who not only are harvested for consumption but also ducks who never make it to harvesting. Any and all ducks that are potentially tagged by a blockchain system will be recorded and left unchanged because of the immutable property of the blockchain. So if a farmer under waters the flock and birds die as a result, the events will be recorded. If the wrong or incorrect feed is given, those events will be recorded. While it seems that this is a good thing in terms of traceability, the system must allow for these mistakes to be recorded. From a UX perspective, warnings or alerts could be generated to inform participants of possible mis-configurations or appropriate action items, but the blockchain system must be able to accommodate the various forms of death.

4.4.2 Design Recommendations

Drawing together the insights from this chapter, I outline some initial design recommendations and new considerations that would benefit the future implementation of the blockchain at Culver Duck Farm. Current metrics track the number of sick or hurting birds which are ultimately culled out if their health does not improve. The main difference I would argue with this HCI centered approach is to consider the socio-material aspects as components of the system. Considering that the individuals here care for the ducks and take pride in that, metrics could be added that speak to the care for the ducks.

First, farmers are required to walk through the barn but the way the interaction is recorded is by writing down on the physical daily check sheet that they walked through the barn. Most RFID blockchain papers [83, 107] focus on tracking the animal at the farm whereas this version would focus on tracking the farmer. RFID sensors could be added to detect if the farmer is walking through the barn. Breaking down a large barn into zones would allow a blockchain system to detect if the individual is actually walking and checking the barns as intended. Depending on the frequency, the barns could simply be checked twice daily. By having blockchain transactions for individuals walking the barn, you could then see how flocks actually respond to their farmer.[6] This could be used to understand flock behavior when correlated with the number of walk-through blockchain transactions. By capturing the individual farmer walking the barns, the blockchain system can capture the practice of walking the barn. This could prove interesting to see empirically the impact of not walking a barn often vs. walking a barn often. This insight into barn walking could then be used for further analysis in the care and maintenance of the ducks and the barns that house them. By understanding how farmers walking through the barn impacts the flocks, farmers could better understand how the direct impact of farmers being present in a barn affects mortality rate, culling and overall health.

Second, ducks that have died are only found by human interactions. When ducks are transported or when a farmer walks through a barn, they can find a deceased duck or a duck that needs to be culled out of the flock. In either scenario, humans are the instrument in which the ducks' mortality is counted, yet existing technologies are not designed with this in mind. In the existing system at Culver, deaths are simply recorded and written down in a sheet to eventually be recorded into a database offsite. While the tracking sheet might capture the "who", it does not guarantee who interacted with or found the duck. It's possible that when a change of staff occurs, some individuals might be better attuned to ducks that need to be culled and a system could help identify this. While implementing a blockchain system does not change recording death directly, it could change the way we look at death. Massimi et al.[79, 80] and Brubaker et al.[22] both examine the impact of the legacy of individuals who have passed on. In a similar way, one could look at death from the perspective of animal husbandry. While the goal of the food security literature aims to give full traceability of its food product[23, 61, 62], the literature ignores the impact of the individual with the technology in this space. Compiling more information on how farmers care for ducks might lead

[6] Walkthroughs happen more often in certain barns. For example, adult female ducks start laying eggs and the barns need to be checked or they will start to rot.

to a better understanding of the interaction between humans and animals. This relationship would be mediated by the blockchain system that would continue to capture key transactional information on mortality, culls and death.

Third, the blockchain system for Culver Duck farm needs to consider the impact of working with the disconnected architecture of the Amish that maintains the barns on their land. These barns constitute a large portion of the commercial duck farm in northern Indiana. The distributed architecture of a blockchain system could work by maintaining separate copies of the entire blockchain. The challenge is that the barns are powered off-grid and are not connected to the internet. This creates an interesting problem space that would require the blockchain to update in batches. The Amish are not opposed to technology directly but believe they cannot be ruled by technology and cannot be connected to any external infrastructure. Small computers could track the blockchain and events at a barn and then periodically could be updated via manual payload updates via USB or removable media. This disconnected architecture would be similar to how NOAA updates its devices at the bottom of the oceans. Periodically these sensors receive updates and send updates when a ship comes by to check on the status. In a similar way, when Farm supervisors come to check on the status of the barns, they could supply the updates directly. From a technological perspective, this may be a non-technological approach to maintaining a blockchain system. However, this approach takes into consideration the socio-material challenges of working with individuals who live and work in these rural areas.

These design recommendations and approaches speak to a different aspect that could be implemented based on the data that was collected. The design recommendations were constructed based on the assessment of the codes and themes that were generated through analysis. There are possibly more ways to think about how to implement design recommendations based on the intersection of rural farmers, ducks, blockchain technology and death. However, these recommendations are the most salient in the data.

4.4.3 Conclusion and Future Work

Only part of the supply chain is captured here as distributors and customers are absent from this study. One reason for this is that they are further removed from the farming process and could have different perspectives. While there is emerging work in this area[106, 11, 102], future work could examine the duck supply chain to see the differences and similarities in the perspectives throughout a blockchain-based system. This work explores the early part of the supply chain but is often overlooked. In a global supply chain, Culver might only act as a single node but this work demonstrates that a commercial duck farm is represented by a plethora of smaller actors. Additionally, it would be interesting to contrast the impact of working in the commercial poultry industry and their views of technology throughout the expanded supply chain. Significant resources would be needed beyond the scope of a single project but the results could prove illuminating.

CHAPTER 5

SECURITY AND VULNERABILITIES ON THE FARM

5.1 Introduction

Security is a central concern of the poultry industry which demands attention to food and safety but my research suggests that any implementation of blockchain must also bring cybersecurity more fully into views on security at large. The Cybersecurity and Infrastructure Security Agency (CISA) defines cybersecurity as “the art of protecting networks, devices and data from unauthorized access or criminal use and the practice of ensuring confidentiality, integrity, and availability of information.”[1]. This definition, although sufficient from a policy standpoint, seems to be agnostic of the individuals who use the system. While I found some issues related to cybersecurity, the larger issue that emerged is the idea of security itself. Security is, by definition, a state of being free from danger or threat[37]. Individuals tend to think about their own perspective on security and do so in terms of dangers and threats in their own context. Contexts with which they are familiar and can comprehend. In the farming context, security is borne out of the need to keep its products safe. An economic perspective allows us to think about security in terms of the financial impact of a supply chain. A food security perspective, lets us think about security in terms of food-borne illnesses or food quality. There are myriad different perspectives on security, and for this research, I wanted to examine the various problems of bio-security/food security and cybersecurity from a level up of security on the farm. Doing so enables a deeper understanding of vulnerabilities, risks and threats to individuals and possible unintended consequences.

For this study, I sought to understand the farmers’ vulnerabilities based on their own jobs at a commercial duck farm. The work was conducted remotely with individual workers from Culver Duck Farm, and I looked to answer what vulnerabilities might arise in the introduction of a supply chain based on blockchain. The data made it clear that the first order concerns determined

[1]https://us-cert.cisa.gov/ncas/tips/ST04-001

what vulnerabilities were most salient to them. What began to emerge is that individuals were designing a blockchain system that fits their perspectives of their given field and the participants revealed a laissez-faire approach to cybersecurity. I then discuss the socio-technical challenges of implementing a blockchain design based on the farmers' perspective. Future design work could focus on making all types of security a greater component in a blockchain system.

5.2 Literature Review

Blockchain has properties that make it an attractive alternative when compared to a traditional centralized database and network solutions. The challenge is that blockchain represents an amalgamation of different technologies that incorporate it into one technology. While this paper does not explore the technology beyond the initial introduction in chapter 1, I will present several security properties that are helpful in understanding the perceived benefits of the technology.

5.2.1 Security and Blockchain

For agriculture, security is often a central contribution to the research. Specifically, security tends to focus on the primary outcome of agriculture: the food itself. Researchers in these areas have explored various ways to use complex technologies like IoT [24], RFID [83], as well as blockchain [31, 24, 63] with the ultimate goal of increasing the safety of the food within the supply chain. The term security can encompass other closely associated concepts, such as risk, threat or vulnerability. These terms can be used in different ways, and I will define them for clarity here in Table 5.1.

Term	Definitions
Security	A state of being free from danger or threat.
Risk	The probability of a negative event occurring times the impact of the event.
Threat	An event that results in compromise or loss.
Vulnerability	Being open to attack or damage.

Table 5.1: Definitions

Risk and threats can be thought of as having the same denotation and are often used interchangeably. However, the difference is that threat can be thought of as what happens in an event and risk can be thought of as the impact of the event. Vulnerability, which can also be referred to as an issue or issues, can refer to the object or thing that is open to attack or damage. In the agriculture industry, many threats that can affect a nation's food supply. A state of security can be achieved when the processes and systems in place mitigate those threats. For example, food contamination is a threat in the agriculture industry and is responsible for over 128,000 hospitalizations annually [14]. To mitigate those threats, researchers in food control and food security dedicate their research to ensuring that well-known vulnerabilities like spoilage are avoided. It does not mean that a state of security is achieved, only that it is better understood in its field. One group of researchers in this space explored food supply chains in the salmon industry[78]. Their work was concerned with vulnerabilities such as lack of hygiene, a wide range of hazards from viruses to heavy metals, and persistent organic populations (POPs) [78]. These food security researchers claim that the vulnerabilities are two-fold. The first group are vulnerabilities that are directed towards the animals and the second group are vulnerabilities that would affect human consumption.

As this dissertation thus far illuminates, the agricultural industry is positioned for increasing investment in and prevalence of technology in more aspects of the farming process. This chapter asserts the need for integrating additional cybersecurity protection in this increasingly mediated environment to match food security with holistic systems security. What seems to be missing is consideration of the vulnerability of the information system which manages the supply chain. Considering the risk that if the information system were compromised, both the animals and the products that are created from the animals would be vulnerable. Relevant to this work, research conducted in the EU, examined the European food system for vulnerabilities but focused on the root causes and origins of the vulnerabilities [84]. They found that among the key drivers for food-based vulnerabilities was an increase in interdependencies. These interdependencies are when different actors depend on each other in order to advance the items within the food supply chain. The interdependencies originate through efforts by the agriculture industry to be more efficient, and they come from a variety of stakeholders from government sectors to private regulators [58, 95, 6].

While the researchers highlighted that the interdependencies are a vulnerability, they also indirectly identified the need to track the changes across a system. From this perspective, a blockchain system may help mitigate the vulnerability of interdependencies by bringing transparency to the system. These perspectives of vulnerabilities in the food security communities speak to the idea that there are different classes of vulnerabilities beyond the technical or supply chain, and each can affect the food supply chain. As a hypothetical example, several vendors for a duck supplier could use different information systems and standards when sharing data in a given supply chain. By sharing a common system, they could remove a data mismatch vulnerability.

Emerging workin cybersecurity around blockchain and its assessment is critical to the thinking inside this dissertation. Michael Mylrea and Sri Nikhil Gupta Gourisetti[47, 86] from the Pacific Northwest National Laboratory have created work that looked to use blockchain technology. They focus on how it can be used with cybersecurity vulnerability assessment tools. While the research focuses on the technical attributes of blockchain and cybersecurity vulnerability assessment tools, it also illuminates how the technology fits into existing frameworks and the implications for policy.

The three properties (decentralization, immutability, transparency), which were described in greater detail in chapter 1, offer potential benefits for an agriculture supply chain. This research aimed to find a deeper understanding of how these features will provide benefit to the industry through the case of Culver Duck Farms. Early research in blockchain has compared traditional systems to blockchain solutions. The traditional centralized server or cloud-based solutions are at risk of being compromised because they lack the depth of defense. This terminology is used to describe adding security measures to many parts of the system. In the case of centralized servers, if a hacker obtains access to a given system they have also likely gained access to the cloud system as well [69]. The risk of a server being compromised in a decentralized system is negligible because the other servers act as a built-in backup [69]. A decentralized blockchain system also has the benefit that the network is cryptographically secure, at not only the storage level but in the transaction and communication aspect as well. No doubt, services like MTech offer encryption, but blockchain offers it as a central property embedded in its design.

While much of this research seems to highlight the positives of blockchain technology, there may be inherent vulnerabilities with the design of these systems. HCI scholars, Cila et al. [27] explored the problem of transparency vs. privacy. The authors examined hypothetical cases in which individuals who cooperate in this system can decide how to reward/recognize each contribution to a blockchain system. Their research showed that the same system that gives rewards could also be used to penalize workers for lower work output. This increased visibility could be problematic in terms of privacy by raising the visibility of things like excused absences. This research resonates with the sociotechnical findings from chapters 4 and 3 of this dissertation that discuss the unintended consequences of blockchain implementation. Another issue with transparency is that by allowing other organizations/contractors to use the same blockchain system, they could become aware of how they are treated when compared to others [25]. An example might be that through the power of negotiation, a commercial farm can achieve a cooperative relationship with a vendor at a significantly discounted cost compared with other vendors. While this type of information might be privileged in a traditional system, the transparent nature of the blockchain system might unintentionally reveal this information.

From this perspective, the design choices become critical in the development of a blockchain system and the choices may reveal additional burdens and costs not anticipated or advertised by a blockchain system. Understanding the sociotechnical challenges may help in knowing how individuals at a commercial duck farm may benefit from blockchain's decentralization, immutability or transparency features.

5.2.2 Security and Agriculture

In this diverse food control and food security literature, researchers primarily focus on the safety of the food, and efforts are made to limit the known risks. Recall that the previous research question I mentioned in chapter 4 was concerned with the first order concerns of individuals and many of the actions that farmers take are in an effort to ensure the safety from known vulnerabilities in the supply chain. This is why many of them were focused on food security-related issues like mortality and the basic husbandry of the animals. When a new system like blockchain is introduced into the existing process, it brings with it its own vulnerabilities, risks and threats. Yet the individuals, in this case, might have no comprehension of the vulnerabilities. This brings to light an important research question that I have defined below.

- RQ3 - What vulnerabilities might arise in the introduction of a supply chain based on blockchain?

Expanding on the previous section, one area that is particularly important to this research is the implications for cybersecurity. Cybersecurity research brings with it its own perspective of risk, threats and vulnerability. However, it is similar to the overall security concerns in that cybersecurity in the agriculture industry is focused on protecting and ensuring the safety of the supply chain[94, 61, 62, 63]. Part of the justification for exploring blockchain as a cybersecurity solution comes from CISA, highlighting common cybersecurity issues such as rogue data in sensor networks or intentional data falsification [14]. This initiative extends from a presidential mandate during the Bush administration known as "Presidential Directive 7" which was meant to identify, categorize and offer protection to critical infrastructure[2] and again under the Obama administration due to repeated cyber intrusion [3]. From this, they identified the Critical Infrastructure sectors: chemical, communication, energy and health care, among others[4]. In total, there are 16 critical infrastructure sectors, and among them are food and agriculture. CISA produces a sector-specific plan for each sector that outlines considerations and issues. For the Food and Agriculture sector[58], the document mentions that the USDA and FDA cybersecurity infrastructure have considered the information control systems (ICS) are critical because it consists of how the information is exchanged and stored with others in the industry[58, 14]. According to this directive, the information control systems (ICS) (to which a blockchain supply chain management solution would

[2] https://www.cisa.gov/homeland-security-presidential-directive-7

[3] https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/executive-order-improving-critical-infrastructure-cybersecurity

[4] https://www.cisa.gov/critical-infrastructure-sectors

be a part) of the Food and Agriculture sector are considered critical components, subject to the Federal Information Security Management Act (FISMA). This designation means that government agencies have an effective information security program [58]. This direction is overseen by the CIO at the USDA but is primarily concerned with government-owned and controlled resources.

Each sector-specific plan offers unique insights into the concerns about potential vulnerabilities in cybersecurity, yet they are structured differently. While they address cybersecurity risks, some seem to be well understood in certain sectors while others are less clear. The common theme is that they all recognize that there are cybersecurity risks and that they need to be managed. However, they vary in terms of the details they include. For example, in the communication sector [28] they list the data integrity and confidentiality as specific risks and list employing the NIST cybersecurity framework [5]. Similarly, the Energy sector [52] also lists cybersecurity as a key component, but it is far more detailed in its approach. They list an integrated cybersecurity vision statement and have more details about their information infrastructure and the development of cybersecurity solutions specific to their industry. While each critical infrastructure sector has different needs and considerations, some areas seem to be more mature in thier cybersecurity infrastructure plans. I suspect this to be the result of continual cyber-attacks and raised transparency of the potential vulnerabilities[6]. When it comes to commercial duck farms, there is already evidence that the critical infrastructure in the poultry industry is under-prepared. JBS, a Brazilian-based chicken producer, was the target of a ransomware attack [7]. The attack revealed weaknesses in the critical infrastructure of the meat supplier operations, and instead of planned remediation, JBS felt it had no choice but to pay the ransom of $11 million to the hacker group. Similarly, Iowa-based agriculture supply firm New Cooperative Inc was hit by ransomware which stole 1,000 GB of its data, including

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[5]https://www.nist.gov/system/files/documents/cyberframework/cybersecurity-framework-021214.pdf

[6]Iranian hackers have been password spraying the energy grid https://www.wired.com/story/iran-apt33-us-electric-grid/

[7]https://www.cnbc.com/2021/06/09/jbs-paid-11-million-in-response-to-ransomware-attack-.html

its proprietary soil technology [8]. The company attempted to negotiate a release of its data, citing it was apart of the critical infrastructure, but it is unknown if the company paid the demands.

Many big agriculture farms lack a sophisticated cybersecurity team and rely solely on vendors to meet the company's needs. With the exception of major players in the agriculture industry, which have substantially larger infrastructures, my understanding is that the infrastructure of the U.S. farming network is critically vulnerable to cyber attacks.[9] This assessment is founded on the understanding that commercial farms consist of an army of smaller cooperative farms that act as contractors to the larger farms. In the case of the poultry industry, a flock is grown individually at hundreds of smaller farms and then brought to a large commercial farm for processing. If the infrastructure lacks sophistication at the higher levels, then one can only assume that at the smaller farms, it is non-existent. By understanding the vulnerabilities that individuals are aware of, I can better understand the threats and risks to a blockchain-based supply chain in a rural commercial poultry farm.

5.3 Findings

This chapter concerns data collected during the design workshops and focuses on issues of security and, in particular, cybersecurity. The two phases of the research were broken into semi-structured interviews and followed by the second phase of design workshops. For this chapter, I am interested in understanding what vulnerabilities are on the minds of these rural commercial duck farmers. For this chapter, I focused on the data collected during the workshops. Recall that in the workshops, there were three separate workshops with different focuses for each one (See Table 2.3 and 2.4). W1 focused on the live side, W3 focused on the processing side and W4 focused on the hatchery. These workshops allowed the participants to express their viewpoints on what a blockchain system should look like from their perspectives.

[8] https://www.wsj.com/articles/iowa-grain-cooperative-hit-by-cyberattack-linked-to-ransomware-group-11632172945

[9] The amount of evidence supporting this continues to grow.

5.3.1 Vulnerabilities on the Mind

When reviewing the data from the workshops, it became clear that there were some interesting perspectives in terms of what was on the farmers' minds. The data revealed the various first order concerns and vulnerabilities the participants were focused on in the workshops. Individuals at these three workshops were asked to design a blockchain system based on their current occupation and understanding of their current jobs. The three workshops could be broken down in the following way (See Table 5.2):

Workshops	Concern
W1	Animal welfare items, cull individual ducks, No. of DOAs, Feed Restriction, pre-placement health checks, basic husbandry
W3	Processing items, finished product, packing, weighing, Biosecurity
W4	Critical points, inspection points, disinfecting procedures, temperature, humidity, clean room and sanitation

Table 5.2: Concerns by the participants during the workshop

W1 was focused primarily on things that would make the animals vulnerable (See Figure 5.1). W1 participants designed a system that would work for the live processing side at Culver duck farm. They focused on the live system in two places: Breeder barns and grower barns. The outside areas they connected to were the hatchery systems and the processing plant. While there are daily feeds of eggs that go to and from the hatchery, it is largely focused on the development of the ducks. P22 stated the following about the hatchery's role:

> P22 - "...the eggs come in right for the hatchery, so the hatchery can hatch them right, so the the ducklings that go out into the grow-out field are the best quality, you know, and will grow for that person, the best [ducks]"

It is logical that their first order concerns were about the animal welfare of the ducks. Things like where the ducks are going, making sure the pre-placement checks were performed and overall basic husbandry of the animals. Even weighing 50 ducks weekly lets field supervisors know an

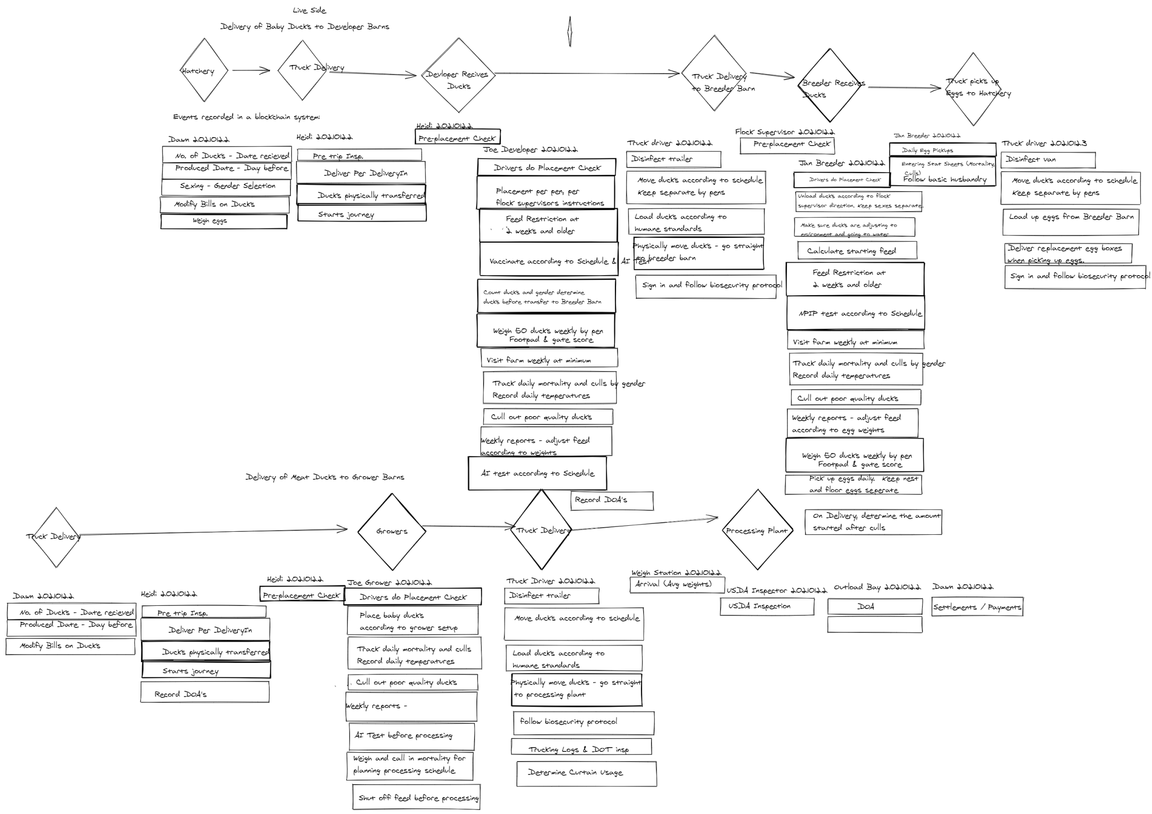


Figure 5.1: Workshop output designed by the participants in W1.

estimation of how the ducks are doing. Frequent adjustments are necessary, but it also speaks to the resilience of the animals. Participants at the farm would compare ducks to chickens as a way of explaining how their work was different from the norm. Apparently, by comparison, chickens require more automation because they need their barns adjusted by tenths of a degree, whereas ducks appear to be more resilient.

For W3, the participants were from the processing plant and therefore were much more focused on outlying the processes (See figure 5.2). Their goal was to transform the animals into a finished product. This is no easy task and also explains that after the intro, the participants immediately took off and just started working on the board. They immediately started drawing all the critical process points and for the most part engaged in silence. My own observations showed that they really wanted to show the complexity of running a processing facility in the poultry industry.

For this workshop, the vulnerabilities seemed to be centered around the processes. Here the

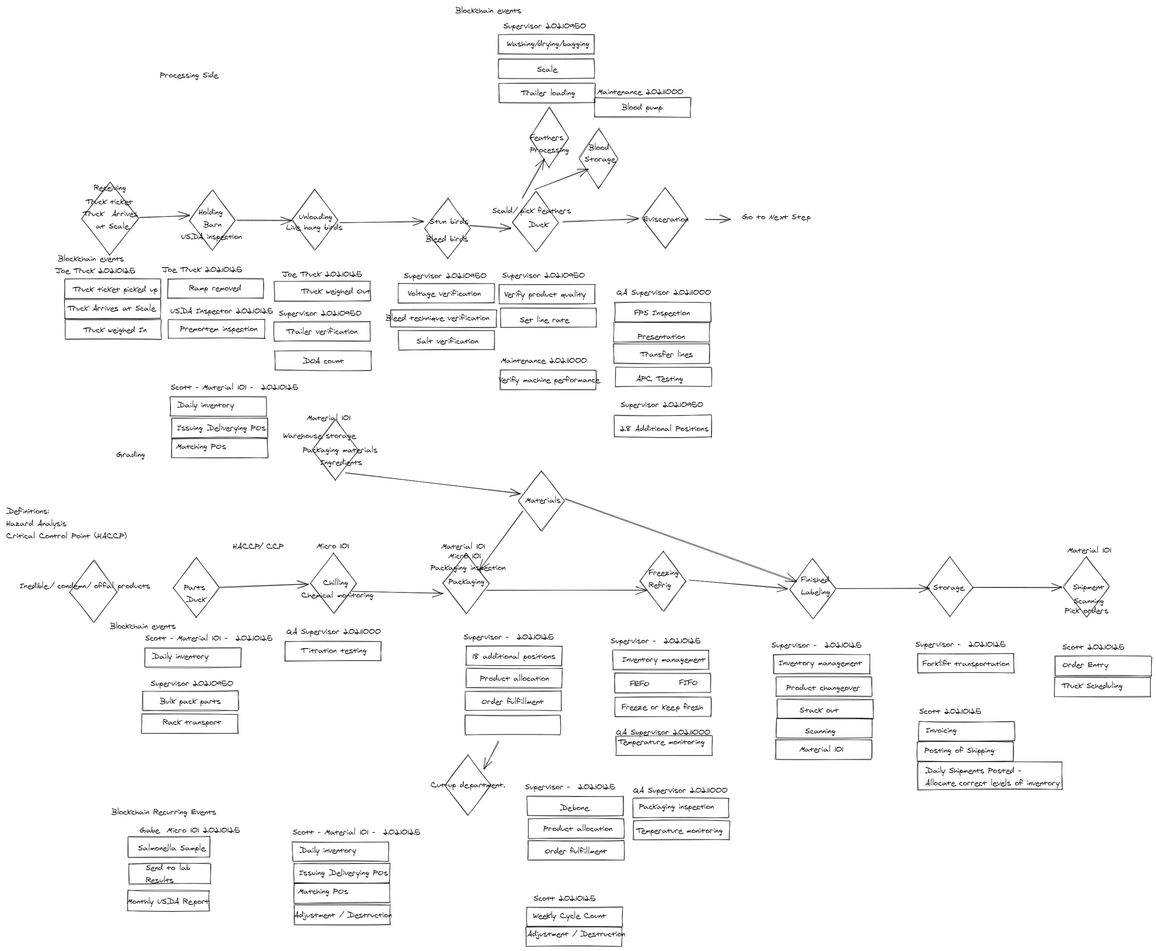


Figure 5.2: Workshop output designed by the participants in W3.

animal is processed and turned into various products for consumption. Threats to the safety of the products could involve things like bacteria growth which could cause problems if they were consumed. If certain tables/surfaces were not checked regularly there was a potential that it could cause issues to the meat and ultimately make the food unsafe. The processes at these facilities were designed to keep the food product safe and to reduce the number of vulnerabilities that are common in the poultry industry. W3 participants had a diverse set of roles which meant that they were focused on a number of physical processes as well. The processing plant handles the shipment and distribution of not just products but of live birds as well. This means that compared to the other workshops, this has a high number of top-level processes (See Table 2.4 for more info).

For W4, the participants consisted of those who worked at the hatchery. In this part of the supply chain the hatchery is on the live side and acts as a unique place in which its entire operation occurs indoors. For obvious reasons, the hatchery acts as a critical point in which ducks are "hatched" and sent to grow for breeding or to be processed.[10] It is a vital area to any poultry operation as its incubators act as the only feasible way to grow ducks at scale. The participants described the hatchery as a growth medium for the existing infrastructure. The commercial farm cannot get larger without increasing capacity at the hatchery. This is because only so many ducks can be hatched and processed at any given moment and thus operates as a maximum threshold for the entire duck operation. The participants at W4 described that because of the different jobs and processes present in the hatchery, they have to carry out various roles.

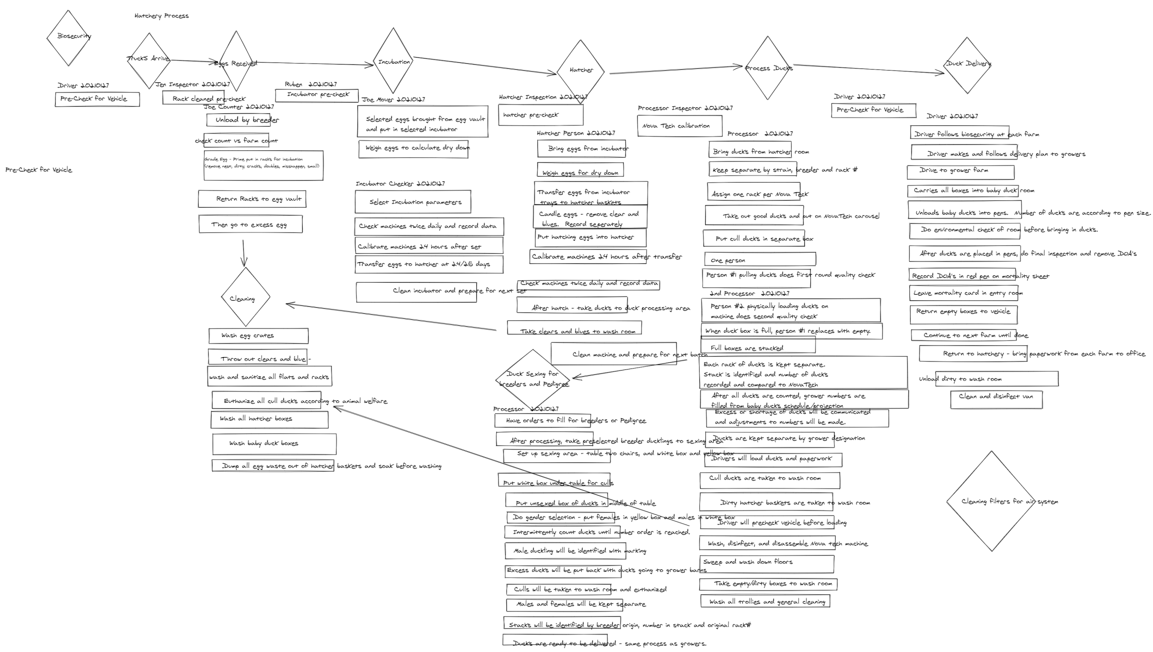


Figure 5.3: Workshop output designed by the participants in W4.

In this workshop, the vulnerabilities the individuals was concerned with was temperature, humidity and biosecurity. Humidity and temperature are important in the incubators (where the ducks grow in eggs) because it regulates the rate at which ducklings are able to grow and hatch. This is common in the poultry industry to regulate as doing so controls the date at which ducks

[10]For pictures of the hatchery, See appendix F. Figure F.15 shows eggs in an incubator. Figure F.21 shows recently hatched ducks. Finally figure F.22 shows the ducks ready to head out to the farm to grow.

will hatch. As you might imagine, baby ducks like certain temperatures. Too cold and the ducks never develop. Too hot and the ducks begin to literally cook. Humidity plays a factor in terms of bacteria. The additional biosecurity concerns relate to clean rooms and sanitation. The hatchery itself is a secure area which means workers wear clean suits, protective boots and eye-ware to ensure no external threat is brought in to the facility. While Table 5.2 showed that participants were concerned about biosecurity, the blockchain events detailed in the workshop show that they were more concerned with inspections and disinfecting. While this might fall under biosecurity, the steps in the blockchains were defined by the participants. They created separate steps for inspections and disinfecting as they felt a blockchain system should capture those components.

Looking at all of the workshop data together, some patterns began to emerge. First, W1 was focused primarily on the animals. This feels obvious because the W1 participants dealt with the live side of the animals. It's not that W3 and W4 did not care about the animals but in their work areas, the animals are largely inanimate. Second, W3 and W4 were focused primarily on the processes and adhering to the processes. This is because adherence to the processes helps ensure the safety of the animals but also the safety of the food itself. For W3, the animals are humanely processed in a painless fashion, but the animals are processed into various food products, so the focus is adherence to process both for biosecurity reasons as well as human worker guidelines. Similarly, for W4, participants wanted to stick to the many processes they have in place so that they could produce quality ducks. The main theme that began to emerge is that individuals were designing a blockchain system that fits the first order concerns of their given field. W1 participants have to focus on the animals that are alive, healthy, and need to stay that way. Tracking them is a primary first order concern. In contrast, individuals that work on the processing side (W3) and hatchery side (W4) have to work with products that don't necessarily move and stay in one place. Therefore, the interactions with the animals will be different and the system that the participants designed in these workshops reflected those changes.

5.3.2 Laissez-faire of Cybersecurity

When looking at the data presented in the study, there is an acknowledgment of failure points that speak to resilience in existing systems, not future ones. If individuals did not mention cybersecurity, I asked them where security was in the workshop's design (See Appendix B under interviews in the second half of the workshop). When conducting the analysis of cybersecurity, individuals thought that cybersecurity is largely the responsibility of the IT department. Data from the workshop revealed:

- W1[Researcher] - "I noticed there isn't a lot of cyber security in here, and I know because we're thinking about process and blockchains, and can you tell me about where in the system we do have security and what that means?"
- W1[participant] - "It all falls on our IT. [laughter]"

While initially met with laughter, it speaks to the mentality that cybersecurity problems are the role of IT professionals. However, at Culver, the IT staff is limited to one professional and one additional software support staff who manages the live side ERP system. Technical support is contracted out to various vendors, depending on the applications. So while it seems that the support might exist, it does not appear as robust as the commonly held belief by the rural commercial farmers. Similarly, another participant in the same workshop stated:

> W1 - "I said it goes back to IT. We don't have control over that. We can tell them if we're having issues with some with something and then they work on it or try to get whatever is fixed and um... Yeah. Right, guys? I don't... We don't have control over that... We just tell them when we have issues and then they just work on it and try to fix..."

Many of the participants in this study exhibited a sort of laissez-faire type of mentality when it came to security. By allowing the IT staff to take its own course, things will get resolved and fixed eventually. Combining this understanding with rural farmers' perspective of technology failure in chapter 3, it becomes clear that the participants aren't necessarily interested in cybersecurity, nor are they disinterested. It is simply a state of being that technology now plays a role in farming. Yet, this perspective does not mean these individuals are not knowledgeable in cybersecurity. Consider the quotes from the participants below:

> W3: "Somebody could go... I guess if somebody got access to PMJ, our PMJ interface, they could go in there and, and make a product selection for something that we don't need... And that could be devastating to sales."

In this quote, the W3 participant was describing one of the processing line machines which holds the ducks as they are being processed. The participant is actually describing a networking threat in which a malicious actor gained access to a critical system. While not describing the details in which the threat would be enacted, it speaks to the general understanding that the PMJ system is crucial and should be considered something worth protecting through cybersecurity practices and protocols. This general understanding of cybersecurity is ubiquitous and is presented throughout the data. Another example involves another cybersecurity problem:

> W3: "So I think this open email from outsiders is... Is a risk, because it could be impersonating somebody of importance here at the plant and not knowing any different, you might respond."

This W3 participant was referring to a phishing attack in which a link is used to gain root access to a machine or user's credentials. This again speaks to the general understanding of cybersecurity. While the workshop participant did not elaborate on details, it's possible that some of the cybersecurity best practices are common knowledge now, and the participant was reflecting on what they knew. Regardless of the reasoning for mentioning phishing, it again speaks to the general cybersecurity knowledge of rural commercial farmers. They are not completely devoid of cybersecurity knowledge; it is perhaps just limited or, as this research has demonstrated, it is not a first order concern. This is understandable as their primary job, and what they have expertise in, is the production of ducks. Expecting them to be experts in cybersecurity is not the goal; protecting them from cybersecurity attacks, vulnerabilities and threats is the goal. There is a balance in security that needs to be achieved. In one sense, training users is costly, and it's not clear if doing so actually results in a more secure environment.

Conversely, taking humans out of the loop is inadvisable as they are a vital part of the information infrastructure. Adams and Sasse [1] write that users are not the enemy and that having sufficient security is having policies and practices that people adhere to. They write that some policies and user interfaces are too challenging or difficult for users, and as a result, users actively try to circumvent the technology. Considering that these individuals know some things about cybersecurity suggests that they have listened to or acquired useful knowledge. The success of implementing a blockchain needs to understand their laissez-faire perspective of technology and security. Understanding these worldviews could help in mitigating the security threat of mismanagement and mis-configuration.

5.4 Discussion

The design workshops clearly underlined multiple classes of vulnerabilities that must be addressed in any future rollout of the blockchain at the duck farm. One, in particular, is the intersection of security policies and the HCI understanding by individuals on those policies. Participants in this study seemed to have a good grasp of the policies that they are required to adhere to, but this might expose them to unknown cybersecurity vulnerabilities. Another closely related area is the potential area of vulnerabilities when it comes to their first order concerns. How the first order concerns shape their priorities and how they understand these vulnerabilities is important when it comes to introducing a blockchain solution.

5.4.1 Potential Cybersecurity Challenges with Blockchain Technology

For this section, I will expand on the vulnerabilities highlighted by the participants in this dissertation. Recall that the three properties of the blockchain are decentralization, immutability, and transparency. Each has technical properties, which make them attractive properties for cybersecurity, but they also carry socio-technical challenges that may introduce unintended vulnerabilities.

5.4.1.1 Decentralization

In chapter 4, table 4.2, the participants designed the blockchain focusing on the planned death components as they related to the three properties. When approaching the same information through the lens of cybersecurity, the perspective begins to take a different shape. Due to the organization of Culver Duck Farm, the farm is naturally decentralized, with farms scattered across northern Indiana. However, because many of the farmers are a part of the Amish community, there is a self-imposed technological barrier. This barrier is vulnerable to a man in the middle type of attacks. This technical attack could be accomplished by inserting false or malicious transactions into the distributed network. Since many of the farms are distributed geographically, this method could be accomplished by allowing a blockchain network to accept bulk transactions. In a private blockchain, bulk transactions where a farm is updated to the network could be a common activity and, therefore, difficult to thwart a malicious actor uploading incorrect or malicious bulk transactions. This hypothetical argument is justified because of the socio-technical requirements of working with the Amish community. However, the geographically distributed architecture at Culver Duck has an advantage because it has segments of the farm that are disconnected. In the NotPetya attack that affected Maersk Shipping in 2018 [11], a domain controller had become disabled because of a blackout and it unintentionally became a backup of sorts for the entire Maersk network. In the same way, these disconnected architecture blockchain nodes become back ups of the entire network by maintaining copies of the entire network of transactions.

Another challenge for this distributed blockchain network is that there are multiple sources of truth at any given point. Kevin Werbach [113] cites that "a blockchain system replaces trust in individuals or institutions with trust across a system as a whole." While copies of the blockchain exist in the distributed network, which server does one trust? In theory, you could trust them all, but in practice, that might prove challenging. At Culver Duck Farm, the system would be vulnerable to multiple copies existing at different times. In theory, they would share transactions up to a certain

[11] https://www.wired.com/story/notpetya-cyberattack-ukraine-russia-code-crashed-the-world/

point. Differences would exist across the disconnected nodes and although there may exist overlap in transactions it may prove difficult to verify without a central repository. Regulatory requirements by the FDA might find such a system challenging to approve though this is speculative.

5.4.1.2 Immutable

Continuing with the previous example, the immutable property is clear in that the blockchain is unchangeable and that once added, it cannot be undone. For a variety of different reasons, this is impractical because mistakes can happen both from individuals and systems. This could be classified as a technical vulnerability, but there is also a socio-technical component to this vulnerability as well. Considering the first order concerns of the individuals who work there and their first order concerns primarily on food safety, it is likely that technical mistakes could occur. This view-point is again supported by the Laissez-faire approach to cybersecurity. IBM food trust [12] attempts to mitigate this vulnerability by allowing its private blockchain to add transactions that effectively neutralize previous transactions. This is akin to cost accounting with positive and negative variances. If Culver were to adopt this approach, the mistakes would not be erased but effectively neutralized with a record to offset the mistake. This means though that as the system begins to scale, any and all records that are deemed mistakes are not forgotten but are permanent transactions in the blockchain system.

5.4.1.3 Transparent

Of the three properties of blockchain, transparent seems to offer the most benefit to a blockchain-based system for Culver Duck. By understanding that all the transactions are transparent to individuals who hold permissions to view them, the socio-technical vulnerability is that who is given permission to see the transparent system? In a public blockchain, anyone can view the network; however, in a private blockchain system, the roles are determined by the stakeholders. In the case of the Culver Duck Farms, the individual farmers who partner with Culver have a challenge

[12] https://www.ibm.com/blockchain/solutions/food-trust

in that they don't use computers within their households. This system would need to accommodate them by allowing them some reporting or feedback in which they can see how their flocks/barns are recorded in a blockchain system.

Another possible socio-technical vulnerability is deciding how much of the blockchain system will be transparent. When implementing a blockchain, Culver Duck can choose whom to partner with when it comes to growing or producing ducks. Having a transparent system could reveal pricing info to other farmers and disrupt buying power for Culver Duck since many contracts are negotiated. Culver could choose to make the supply chain system exclude financial pricing and maintain that separately in order to protect information from its partners. Either way, choosing how transparent a system is represents a socio-technical vulnerability that would need to be carefully considered before being implemented.

5.4.2 Policy USDA Requirements and Cybersecurity Policy

There are mechanisms in place established by the federal government in which all of the food requirements require commercial farms to be compliant and for the US it is the United States Department of Agriculture (USDA). The USDA defines an area that demands an inspection in a poultry supply chain as a Critical Control Point (CCP) [13]. These CCPs represent places in which contamination could enter the food supply. They are concerned with things like toxins or possible contamination points. These CCPs can be looking for hidden growths (bacteria) or visible things such as deformities.

When it comes to information on the supply chain, the CCPs are monitored daily by either a physical USDA person or a worker stationed at a CCP. This information is obtained and stored on spreadsheets at Culver and eventually entered into a rudimentary relational database. The USDA requires all records to be reviewed on a weekly basis. One of the downsides of increasing the production line is that this also increases the data in the information stream. This added benefit of

[13] See USDA document for more info https://www.fsis.usda.gov/sites/default/files/media_file/2021-03/HACCP-Model-NPIS-Poultry-Slaughter.pdf

having more information is also what makes it vulnerable in terms of cybersecurity. Recall that CISA identified the information control systems (ICS) as critical components. These USDA records are stored on servers and are apart of these information systems and streams. The participants in these workshops identified the CCPs as inspection points and biosecurity points in the workshop. However, these are all part of compliance with USDA standards but cybersecurity problems are not part of their concerns and therefore are superfluous requirements. One possible threat to the system could be that the data recorded is changed or altered in some way. This could potentially impact the processing plant at Culver Duck by shutting it down if the number of inspection points reported is too high with infections or bacteria growth. Although hypothetical, the complication of information would force Culver Duck to go through a manual process of confirming actual counts via manual counts written on physical sheets. A blockchain-based solution could potentially mitigate this problem due to its tamper-resistant nature, as well as its cryptographic protocols which innately protect the records. However, it does not guarantee that it would work because in a private blockchain records can be removed as easily as in any other relational database.

What is surprising is that the data from this study seems to indicate that there are potential issues in the existing structure. While this research will not report specific problems with cybersecurity, common issues of cybersecurity are present at this farm. This finding echo's CISA's viewpoint that commercial agriculture, a critical sector, is significantly at risk of compromise. A blockchain based supply chain offers promise and potentially can mitigate problems but only if it first meets the compliance requirements followed closely by the user requirements.

5.4.3 First Order Concerns and Usable Security

One way to think about how first order concerns make them vulnerable is to consider how the security research has approached and understood this problem. There has been a myriad of security research on systems, but in the early 90s, user-centered security research began to emerge[4, 30, 120]. Ross Anderson [4] was studying the retail banking system because they were the largest implementation of applied cryptography. When he surveyed individuals who worked at these banks, they found that the threat model[14] was wrong in that the attacks were not caused by technical attacks but by misconfiguration and implementation of how the cryptographic tools were applied. Similarly, in a classic cybersecurity paper, Alma Whitten and J.D. Tygar [115] explored why users could not use an encryption system for email (PGP 5.0). The researchers concluded that the technology was not designed in a way that could be usable.

Mary Ellen Zurko and Richard T. Simon [120] wrote an early paper on how security should be designed with the perspective of the user in mind and that mechanisms that are confusing to the user will result in misuse. Mary Ellen Zurko's future research affirms and extends this argument by asserting the grand challenge of a user-centered approach to computer security[119]. These early research papers identified that user problems exist, but it is surprising how user problems continue to exist. Understanding what individuals are concerned about when using technology gives insight into how to protect individuals. One way to mitigate the development is to understand the user mental model [111, 8, 13], which attempts to understand the cognitive understanding of security in the minds of the users. In this research, the goal was to understand what users' first order concerns were, and while I could use it to construct a mental model of security around blockchain, that was outside the scope of this research. However, by understanding what individuals are concerned about, I can begin to understand how they think about system design through the participatory design approach. The data shows that the vulnerabilities that the farmers brought up are based on their own jobs. However, when taking the idea of food security, bio security and cybersecurity, there is a sense that they are resilient in some areas but vulnerable in others. Food security is concerned with keeping the overall product safe for consumption. Bio-security is focused on staying within compliance with policy and government mandates, whereas cybersecurity is focused on ensuring the safety of the information system. While commercial farms have grown immensely in food security and bio-security, cybersecurity is an area that requires improvement. Recall that they were

[14] A threat model are how cybersecurity scholars and practitioners refer to something you are trying to mitigate. A good definition is a structured representation of all the information that affects the security of an application or system. For example, for phishing, a threat model would consider all of the ways a phishing attack can be successful and what barriers need to be in place to prevent its impact.

aware of phishing attacks and network vulnerabilities. It is not that they have no expertise in these areas, just limited expertise.

5.5 Conclusion

This dissertation sought to understand from a broad level what vulnerabilities individuals understood. The data in this study showed that first order concerns of the rural duck farmers could potentially make them vulnerable to a man in the middle cybersecurity attack because of the distributed infrastructure that blockchain would have to accommodate. This chapter presented how blockchain may offer cybersecurity and compliance benefits and also discussed how their first order concerns are not necessarily on cybersecurity. They have adopted a type of lassiez-faire approach to cybersecurity which would have implications for designing a future blockchain system. Future design work could focus on making security a greater component in a blockchain system.

CHAPTER 6

CONCLUSION

6.1 Overview of Dissertation Research

This dissertation sought to understand the problem of the complexities of how blockchain could fulfill visions of revolutionizing the agriculture supply chain. The blockchain technology narrative of "turn on the technology and it will fix everything" doesn't fit at a rural duck farm.

In chapter 1, the primary goal was to understand how individuals in the duck industry understood and would potentially interact with blockchain technology. Chapter 1 gave an overview of the technology and how individuals understood the technical components of blockchain. Specifically, I presented a brief explanation of the three properties of blockchain: decentralization, immutability and transparency. The preliminary findings revealed that of the three properties of blockchain, traceability seemed to be the most salient property to the rural commercial farmer. Additionally when it came to the blockchain system itself, participants in this study naturally inferred that the purpose of a system like this is to pull information together. I then explained that when it comes to the perceptions of blockchain that time could be better served by designers by prioritizing and explaining traceability. The blockchain systems for these rural farmers could focus on how to trace the information throughout the supply chain. Furthermore, I explained that a possible design recommendation would be to ensure that the stakeholders are aware of the logically centralized repository and that it could be shared among various stakeholders. In chapter 2, I defined my qualitative approach to capturing a sociotechnical understanding that would lead to specific findings and pragmatic recommendations.

In chapter 3, I explored the dominant narratives on the farm around revision and "rollback" of blockchain, connecting to theories of version control from computer science. Farmers not only have to live with failure, they believe in versioning technology and that they can always revert to a previous revision or "roll back". Existing software in the commercial duck industry offer with it proven successes, increased efficiencies, and overall improvements. Yet when the software or technology fails, the farmers take the perspective that things have to continue. The flocks still need to be managed and so the work continues whether the technology is working or not. While the technology increases the rate of which the farm can operate, simply changing or extracting to a state without the technology might not be possible. Through a series of interviews and workshops at Culver duck farm, I sought to answer can blockchain help address the challenges of managing the supply chain at rural commercial farming facilities? The data seems to indicate that there seemed to be a lot of uncertainty around the technology and when it comes to designing a blockchain system, there is an awareness that failure is possible but not preventable. Additionally, the increased complexity of a blockchain system coupled with the participants view of technology failure, could lead to catastrophe as new layers are added to the systems.

Another insight is that the rural commercial duck farmer seems to indicate that not only can technology fail, when it does indeed fail, there is a rigid belief that the company can always move away from it or revert to a previous revision before the technology was implemented. Through the analysis, I present the idea that accommodating the needs of the rural farmers may help in reducing the uncertainty around the technology and possibly change their perspective of technology failure. Additional insights reveal that by taking technological steps forward, there is a sense of point of no return and once a company has crossed this threshold, things seemingly cannot revert to the way things were. Finally, I present the idea that future work could examine the impacts on the rural farmers when the blockchain is implemented.

In chapter 4, I uncovered that a core concern of the poultry supply chain is death and how these beliefs have socio-material implications for blockchain. My findings show that these farmers need to track death in order to understand the health of the animals in their care but there are material aspects to their practices that shape how they interact with both the animals and technology. The combination of a dynamic workforce, whose beliefs may affect how any technology is used, could dramatically affect the use of a blockchain. It would require a fundamentally different type of disconnected blockchain architecture and does not appear to exist anywhere today. I explain how the designs of a blockchain based system must consider the socio-material concerns of the farmers who work with them and that death requires individuals to be present in any future blockchain design. Finally, future work could examine the duck supply chain to see the differences and similarities in the perspectives throughout a blockchain based system.

For chapter 5, I sought to understand the vulnerabilities that farmers are aware of based on their own jobs at a commercial duck farm. I looked to answer what security vulnerabilities might arise in the introduction of a supply chain based on blockchain. The data made it clear that the first order concerns determined what vulnerabilities the participants in the workshops were most salient to them. What began to emerge is that individuals were designing a blockchain system that fits their first order concerns of their given field and that the farmers adopted a lassize-faire approach to cybersecurity. When taking these viewpoints and practices and comparing them to the technical properties of blockchain, socio-vulnerabilities became apparent. The challenge of decentralization of blockchain with the disconnected farming architecture presents a unique vulnerability for blockchain designs.

6.2 Concluding Thoughts

From a high level perspective, this work explored how a complicated, distributed, and networked technology could be ingrained into a rural commercial duck farm. I set out to understand how blockchain's key properties would affect the farmers from a technical perspective but the answers that surprised me were the socio-material processes that emerged as important considerations by the farmers. I learned that the farmers approach on how they do their work was shaped through many years of socio-technical infrastructure at the farm. This lens into the world of a commercial duck farmer shows how the existing physical systems like the egg incubator machines or the physical sheets used to track ducks, creates complicated processes that influences their understanding of what it means to be a duck farmer. The technology that they use must fit into this perspective or it will be discarded. The version control perspective in chapter 3 and the laisezz-faire understanding to cybersecurity in chapter 5 were both shaped by the existing farming and social infrastructure. These lessons I learned make a contribution to the literature of Materiality [70, 71] and HCI [38, 100] by giving another perspective on how the materiality of the technology is shapes individuals.

Another contribution this works makes is with the participatory design workshops. The workshops were a fun and collaborative process where my participants were able to create a blockchain system full of events and processes informed from their own perspectives. Analysis showed how the technical and social practices that were important to them were reflected in their design. This adds to the HCI literature led by Nissen [90, 91] who explored the uses of blockchain and cryptocurrencies and its potential uses. This research could be used to prototype and build the blockchain system designed by the farmers that could potentially change the way they duck farming is done in that part of the world. The experience of remotely conducting research and working with a large Amish community changed my perspective on how to look at technology and even how to run workshops. Add the layer that these workshops were conducted during the COVID-19 pandemic, it became a far more complicated activity than I ever thought possible. Yet the implications for using collaborative whiteboards via Excalidraw was an important substitution in place of in-person workshops.

Taken together these chapters represent a concentration of the data and analysis from my time at Culver Duck Farm. There are other issues that could be explored that came up through the course of working with the rural farmers but these chapters represent the issues that were the most relevant to the impact that blockchain technology might have on the supply chain. One important consideration worth noting is that the scope of this supply chain was limited to the farming operation at Culver Duck. A future blockchain supply chain study that expands beyond Culver Duck would be beneficial to determine if the findings extend beyond the duck farm. Specifically, further down stream in the supply chain, agents like the distribution companies that Culver partners with or some of the larger customers could provide further human and ecological insights. The findings in chapter 3, speaks to a type of version control but what is unknown is the extent that the findings extend to other rural areas or if it is limited to just to Culver Duck Farm. While this direction might take it out of the scope of studying blockchain in rural areas, a future study would help understand if other rural companies like the distributors would be affected in a similar way. Further, studying individuals who are further removed from the “death” component, established in chapter 4, would be interesting if the care for the product remains and what implications might be relevant for those individuals. Finally, cybersecurity is achieved through a balance of cost vs risk which is something I would have like to explored more in chapter 5. Early conversations with Culver Duck revealed that insurance companies have assessed the cost of cybersecurity compromise but no data was made available for this study. A policy analysis compared with the proposed design work by the Culver employees of the blockchain based supply chain could prove illuminating to policy researchers as well as HCI security researchers.

APPENDICES

APPENDIX A

INTERVIEW PROTOCOL

A.1 Semi-Structured Interview Protocol

This protocol seeks to answer the following research questions:

- RQ1 - With current systems and processes at commercial farming facilities, can blockchain help address the challenges of managing the supply chain?
- RQ2 - What are the first order concerns of the different stakeholders of a blockchain solution?

A.1.1 Participants

The day before the workshop, an email reminder will go out to the participants who are to be interviewed reminding them of their interview. If any of the participants are not native English speakers and need a translator, there should be a translator available to us.

- Order of events:
- Send out an email to participants that the CEO of Culver gives me informing them that there is an ongoing study that they would be helpful participating in.
- If they agree to participate, two things happen:
  - Send them the consent form and ask them to sign via DocuSign and it needs to be completed prior to the interview.
  - Send them an email through the Culver scheduling tool. This allows us to setup the zoom information and a time for us to meet

A.1.2 Questions

- After discussing consent form and notification of recording - start by explaining the research project briefly and discussing introductions. Encourage participants that none of the information being collected will be used against them and that the data will be anonymized before publication.

- "Hi and thank you so much for agreeing to be interviewed as part of this study. Thank you for filling out the consent form."
  - Verify if they have agreed to be recorded or not on their consent form.
  - Check what they have agreed too and what they have not agreed too.
  - Start recording if they have agreed to be recorded.
- Introduction
  - "So a little bit about me and this project. I am a PhD student in the department of Media and Information and this work is for my dissertation research. I am really interested in emerging technologies in the supply chain of the poultry industry and I am especially interested in technologies like blockchain for solving the problems. I am interested in being here at Culver because of some of the discussions they have had about blockchain. To give you an example of what blockchain is, the easiest way I can describe it is to think of it as a notebook. This notebook is able to track your work. Anyone can read this notebook and once you record something on it you are unable to change it. What is really neat is that this notebook can exist in multiple places at the same time. This is essentially what blockchain is and it turns out these kinds of properties are useful for any kind of supply chain, including the poultry industry.

    So what I am interested in talking with you today is what are your problems and how is it possible that the blockchain can fix it. So what I want to do is to start with you right now with your process and practices and what you do day to day. This helps me understand where it can even fit. So, we will start off simply with Job description and background questions"
- Job Description and background questions
  - Could you please tell me what you do for Culver?
  - How long have you been at Culver?

  - How long have you been in farming?

- Process questions - "For the next set of questions, I am going to ask you about the various processes and jobs that you do here at [Culver]."

  - I know your job title and I have a bio of what you do. Could you describe for me what your day was like yesterday?
  - Possible deep dive questions
    * Did you have to open an app for that?
    * What does that mean when you do this?
    * Do you have an idea of why you have to do this?
  - In our day to day jobs we often interact with technology throughout our day and sometimes without recognizing it. It might be a Computer or touch screen or even a Tablet or some type of device. It could also be something as low tech as the water drip system or something as simple as scissors. I am really interested in the technology at your position[s], app interfaces and machines you interact with. [Based on the technologies described,] Could you describe for me how you use that technology?
  - Possible deep dive questions
    * What does this technology do?
    * Why do you use it?

- Challenge questions - "For the next set of questions, I am going to ask you about the challenges you face doing your work here [at Culver]."

  - What are some of the challenges you face when doing your job?
    * If they cannot think of anything] If you cannot think of anything that is okay. Sometimes it can be mundane as I don't have this tool so I have to do my work a different way or it could be a that we have to process things quickly so I don't have the time to look at this. Etc. Anything come to mind?

  - Possible deep dive questions
    * When you encounter this how do you deal with it?
    * How often would you say this happens?
    * What kind of impact does [the challenge] have on your work?

- Granularity Questions - "For this next set of questions, I am going to ask you about details about the supply chain."
  - There are somethings that our current system or systems can track but there are things that it cannot track. It might be something as simple as wasted parts or something that you already track like labels.
  - Can you give me an example of something that you have to keep a count of?
  - Or something that you need to keep track of?
  - If you could track something, no matter how large or small it is, what would you want to track

- First order questions - "For this next set of questions, we are going to focus on your own considerations when it comes to doing your work."
  - – "Everyone is different and has different viewpoints of the job that they do. I'd like to talk about what it is you think about your job?"
    * What do you care about when it comes to your job?
    * When it comes to your work, what do you think is important for your job and why do you think it is important?
    * Are there any issues [vulnerabilities] that you need to be mindful of?
    * (If Senior) What would you want a trainee to pay attention too?
    * Can you give me an example of something that you missed and the consequences that were associated with that? (I don't really like this question but I want to ask it)

- Blockchain questions – “Okay so I have a really good sense of what you do now.. I’m curious of what you know about blockchain? Do you know anything about blockchain?”
- if they know
  - I’m curious about your thoughts on how it could improve your work. I’m interested in what you know about blockchain and this possibility of a blockchain being part of your workplace in the future.
  - Follow up questions:
    - how you think a blockchain system might affect your work?
    - Do you think the problems today are the same that you had before as a solution?
    - Do you think it would introduce any problems?
- if they don’t know
  - Somewhat technical introduction – “Going back to my short introduction at the beginning. Blockchain is now being thought of as a general-purpose technology which can be used to track all kinds of work. What a blockchain can do is that it can track things that we wouldn’t have considered tracking before and it can track events at a very low level of granularity. With a system like this you can see where things have been contaminated, where something has shipped too, and even who has changed what.”
  - “With that explained, I’m curious about your thoughts on how it could improve your work. I’m interested in what you know about blockchain and this possibility of a blockchain being part of your workplace in the future?”
  - Follow up questions
    - how you think a blockchain system might affect your work?
    - Do you think the problems today could be fixed with a solution like this?
    - Do you think it would introduce any problems?

- Conclusion - "Thank you for all of that info you have shared with me. I feel that I have a better sense of what you do. I like to ask one final question which is now that you have a sense of the things that I am interested in, do you have anything you would like to add?"
- Closing statement - "In closing I like to share what all of this means. Here is where I am in the process, I am at the very beginning of this research. Over the next few months I will be collecting interviews, and eventually conducting workshops. I anticipate that I will be contacting you again and this work will contribute to a dissertation on emergent technologies, particularly blockchain, in the poultry industry. I also hope to publish this research within the next year. If you have any other questions or if you think there is something interesting for me to know feel free to email me. It can also be things about this research like when do I plan on publishing this. Here is my email."

APPENDIX B

WORKSHOP PROTOCOL

B.1 Workshop Protocol

- Introduction
  - "Greetings - Hi everyone thank you for joining me for this session. I want to start by telling you that these meetings will be recorded, and the drawings and various writings will be captured. However, all the data will be anonymized and won't be identifiable prior to publication."
- Introduce the goal of the workshop
  - "Today's workshop is an attempt capture the entire supply chain process for Culver duck farms. You are here because you work in the supply chain and we are trying to better understand what a blockchain system would look like in the commercial poultry industry.
  - Blockchain, briefly explained, is a digital ledger that is distributed across a network. That is it in a nutshell. It has some unique properties such as it is distributed, immutable and is transparent. Distributed in that the transactions are stored across a variety of servers who are a part of the network. Immutable in that all the transactions that are recorded become permanent parts of the network. Transparent in that anyone who joins the network can see the provenance of an item.
  - With that being said, our goal today is to explore the idea that if you could track anything at Culver what would we want to track and how that would affect the system. Remember, the system we are discussing today does not exist. We, together, will be designing one.
  - Roughly what is going to happen is that the session is broken into two different parts. The first part will be about 60 minutes or so exploring the current process. We will go through from start to finish adding transactions along the way which we will block up. The second part, which will be about 60 minutes or so, I will start to ask a series of questions about the flow and what is interesting for the group to focus on."

- Ground Rules

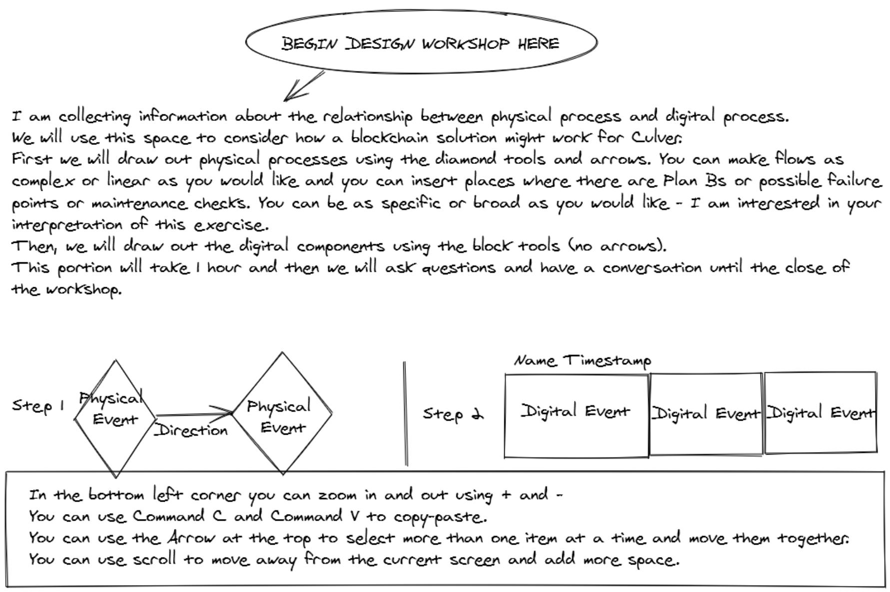
  - Today we are meeting virtually, and we will be using a virtual whiteboard to create artifacts such as drawings and statements that will help us understand this system.
  - Please do not speak to others what we discuss here in this room. This is for two reasons. The system that we design here is more of a proof of concept and thus some ideas will be great and others not so great. We don't know which ones are which yet so please do not discuss. Also, we are likely going to be holding multiple iterations of this workshop and you are likely to know someone else who will be participating later. Research necessitates quote unquote objectivity, and while true objectivity is never possible, it may bias people's participation in the workshop.
  - Be respectful of others. We are going to be here for a while and while we are a small group, differences of opinion are bound to happen. Some of us have a lot of experience in farming and others have just started. The important part is that we all feel included and our voices can be heard here.

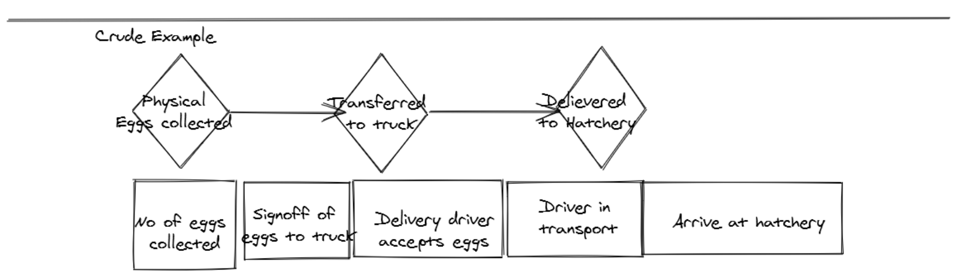
- Definitions

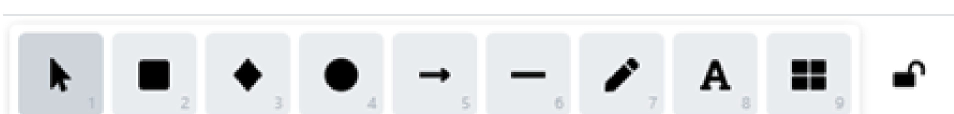
  - Supply chain - Supply chain is a system that delivers goods and services to customer. In agriculture this is the sequences of processes involved in the production and delivery of a commodity.
  - Blockchain - is a digital ledger that is distributed across a network. That is it in a nutshell. It has some unique properties such as it is distributed, immutable and is transparent. Distributed in that the transactions are stored across a variety of servers who are a part of the network. Immutable in that all of the transactions that are recorded become permanent parts of the network. Transparent in that anyone who joins the network can see the provenance of an item.
  - Security - Simply stated is a state of being free from danger or threat

- Vulnerability - Being open to attack or damage
- Threat - An event that results in compromise or loss
- Risk - The possibility of a negative even occurring times the impact of the event.

• Pre-activity - Introduction to excalidraw and warm up

- For this activity we will be using excalidraw. `https://excalidraw.com/` it is a collaborative tool that allows us to work on a virtual whiteboard together.
- 

- Next we show them the crude example
- 

- Here are the tools we will be going over
- 

  * The first is the arrow tool, this allows you to pick and choose objects

    * The next is the diamond tool, we will use it to describe an event, For this workshop, we will be using it to describe a specific area or station. We will use it to describe the physical processes.
    * The next is the square tool. This will represent a block or event. We will stack these besides one another to get an idea of how the blockchain events will work. For each block in the system we will put a name on it and timestamp as a way to place a "block" in the system. In a blockchain system these events will stack and give us a tangible way to understand how the system is working.
    * Next we will all try at creating a system. To start, we will pick an event that happens in the area we know. Ducks being delivered to a place for example would be an event. Lets try to model that now.

- Main Activity
  - Current Live side instructions
    * I would direct the participants to describe how a duck goes down each side. We would then use the whiteboard to create a transaction and begin to start adding blocks to the blockchain. Each participant would sign their block as it moved from each stage. As an example, we know that eggs get picked up from the barns and delivered to the hatchery. We would have
    * a participant in the workshop sign the transaction that it was delivered and another participant sign that the eggs were received. The exercise will produce a document of transactions which will ultimately represent a "block chain".
  - Current Processing Side -
    * Will go through the supply chain steps of the processing side of the house. We would go through a similar activity and then construct transactions that are driven by events.

- Blockchain System - Primary Activity
  * Now that we have covered both sides. Let us design our own system. Using the idea that we want to track all event driven transactions. Let us start using the whiteboard to create the system. Let us start with the processing side first, ducks arrive, and we will begin by capturing that information. As an example, when the truck arrives, we would draw a block on the google doc and then sign that block with the person recording it. We would then move on through the system. Does that make sense?

- Break 5-10 mins
- Second Half - Interviews
  - For the second part of the workshop, the participants will offer input in what they would like to change through interview prompts. This approach informed by participatory design and would allow individuals to understand blockchain in a less technical way. This is also focused on what individuals think is the first order concerns. They will answer and design this system based on what is important to them.
  - PART II Questions
    Can you reflect a little bit on the process you just outlined? Why did you select what you did?
    What was the most difficult aspect to document here?
    I noticed there isn't a lot of cybersecurity in here. Can you tell me a little bit about where you have security?
    Where are the points of failure here? How do you ensure quality control?
    FINAL Q: Is there anything here that is missing or that you would like to discuss before we close the workshop?
  - Conclusion - Thank people for participating in the workshop.

APPENDIX C

CONSENT FORM

C.1 Blockchain and the Poultry Industry

Principal Investigator:

- Stephanie Steinhardt, Assistant Professor, Department of Media and Information, Michigan State University
- Chris Fennell, PhD Candidate, Department of Media and Information, Michigan State University

You are invited to be a part of a research study titled "Blockchain and the Poultry Industry" The primary goal is to understand of how new large-scale technologies are envisioned and planned in the supply chain, in order to identify possibilities for creating more stable and sustainable future blockchain infrastructures.

We are asking you to participate because of your involvement with Culver Duck farm and your role with the company.

If you agree to be part of the research study, you may be asked to participate in an interview, either by phone or in person. Interview topics will include questions about your own professional background and prior work, current professional activities and practices, use of information technologies or resources, and patterns of interaction with other colleagues. We may contact you again during the next few weeks with additional questions and/or for one or more follow-up interviews. Each interview should take around one hour. Additionally, we may also contact you about participating in a virtual design workshop. This workshop will be with other individuals and will be a longer session of approximately two hours. You may also choose to participate in some parts of the study (e.g. interview) and not others (e.g. design workshop). You may choose to leave the study at any time without any negative consequence.

To ensure that our conversations are recorded accurately, we would like to make an audio recording of the interview. To give other study team members a sense of your work practices and environment, we may also ask permission to make photographs of your workplace. Before we make any recording at a specific time/place, you will be asked whether it is okay to do so. You may decline to be photographed or audio recorded and still participate in other parts of the study.

Within our study team, your real name will be used in our notes and multimedia records. However, when study results are released outside of the study team, we will remove identifying information from the data by using pseudonyms and omitting or aggregating data about relationships, gender, work location, etc.

The researchers plan to keep all study data, including our notes and all photographs/screenshots and audio recordings, along with identifying information, indefinitely in a secure, password-protected online repository for future research. Individual team members may also keep data on secure, password-protected computers.

There are occasional reasons why people other than the researchers may need to see information you provided. This includes organizations responsible for making sure the research is done safely and properly, such as Michigan State Universities' Institutional Review Board.

While you may not receive a direct benefit from participating in this research, your contributions may inform the development of large-scale network science projects both at Michigan State University and Culver Duck farm. You will be compensated through Culver Duck by participating with this study during normal work hours.

If you have questions about this research, please contact Prof. Stephanie Steinhardt, Department of Media and Information, Michigan State University, 404 Wilson Rd, East Lansing, MI 48824, email ssteinh@msu.edu or Chris Fennell, Department of Media and Information, Michigan

State University, 404 Wilson Rd, East Lansing, MI 48824, email cfennell@msu.edu

If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at 517-355-2180 or access their website at http://hrpp.msu.edu

By signing this document, you are agreeing to be part of the study. Participating in this research is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time. You do not need to provide a reason for your decision. If you choose to withdraw from the study, you may request that all data associated with you be erased. You will be given a copy of this document for your records and one copy will be kept permanently with the study records. Before you sign, please be sure that any questions you have about the study have been answered and that you understand what you are being asked to do. You may contact the researcher if you think of a question later.

I agree to participate in the study

Name	Signature	Date

______ *I agree to be audio-recorded as part of the study.*
Initials

______ *I agree to be photographed as part of the study.*
Initials

______ *I agree to be contacted again in future about this study.*
Initials

APPENDIX D

RECRUITMENT LETTER

D.1 Recuritment Letter

Hi,

My name is Chris Fennell and I am a researcher with Michigan State University working with Culver Duck on a research project. I am reaching out to you because [contact person/manager] informed me that you might be a good person to talk to about the existing processes here. Your expertise [in a given field/department/area/] will be helpful as I seek insight in how Culver Duck Farms operates it supply chain. My work is particularly focused on how a technology called blockchain can be used in the poultry supply chain. If you are interested, please reply to this email and I will send you further instructions which include a consent form via an electronic service DocuSign and a schedule to sign up for appointments.

Thank you for your time.

Best regards,

Chris Fennell

APPENDIX E

DUCK FARM FIELD GLOSSARY

Items presented here are items I wrote down that I didn't understand in order to have context in which the farmers referred to. Not all definitions are recorded here but only ones that I felt required a definition as I explored this space.

- All fall - Basically - inedible product - the name for internal organs - variety meats - entrails - butchered animals
- Silage - bi product once you bacteria is done with the product - eaten and gassed what they can - the bi-product - add nutrients the ground for soil - can take that and put it on crops and keeps soil fertile
- HOFO - Head on, feet on - Buddhist/chinese style
- Western style - Head off, feet off, neck off
- Biosecurity - the safety and handling of the animals also used synonymously with animal welfare
- AI - Avian Influenza
- Vaccinations - Vaccines given to animals to prevent a given disease
- DOA - Dead on Arrival - With living things, transferring live animals can be challenging and an important metric they are required to track as well as knowing what happened when the ducks die.
- Modify Bills - Ducks on a farm have their bills very slightly modified so that they can better get the water drip systems that they have employed
- Husbandry - the care, cultivation and breeding of crops and animals
- Sexing - Gender selection for identifying correct placements of animals. Grower barns have a placement of 5 to 1 female to male ratio.

- HAACP - Hazard Analysis Critical Control Point - A requirement by BRC which sought to standardize food safety standards across the supply chain
- BRC/BRCGS - Food safety standards that are above the regulatory compliance. Companies in food safety self select to participate in order to ensure food quality.
- USDA - United States Department of Agriculture - the governing body that regulates the duck industry and the safety of food at the duck plant. They have numerous inspection points at the processing facility that they are governed by.

APPENDIX F

IMAGES COLLECTED BY PARTICIPANTS

Images were sent to me by the participants to better explain their roles, jobs, occupations or clarifying certain points they were trying to make. I have added a collection of images here that help explain certain cases or simply giving a better idea of what they do.

Figure F.1: Loading bay for processing ducks.

Figure F.2: Processing of the ducks.

Figure F.3: Processing Ducks in the wax bath. Removes particulates.

Figure F.4: Capturing blood from ducks to sell as high grade protein feed.

Figure F.5: USDA worker inspecting duck quality on the line.

Figure F.6: Sorting the processed ducks into weight sizes for packaging and storage.

Figure F.7: Cold storage freezer for ducks ready to head out waiting for shipping info.

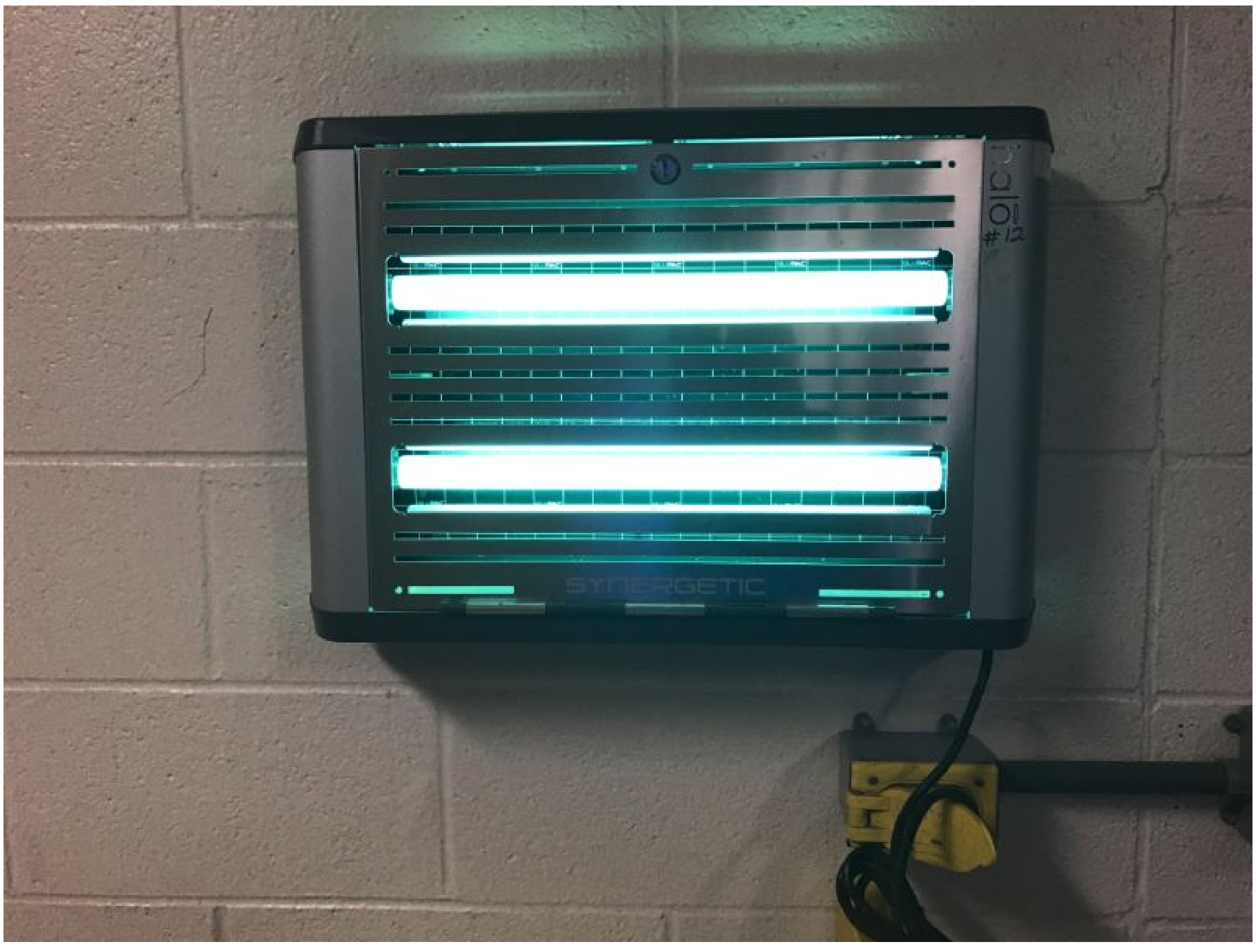


Figure F.8: Industrial bug zapper.

Figure F.9: Shipping gun scanner for fulfillment in shipping.

Figure F.10: Nice view of the Culver duck farm buildings.

Figure F.11: Racks of eggs fresh from the farm.

Figure F.12: Egg rack sorted.

Figure F.13: Egg rack sorted further.

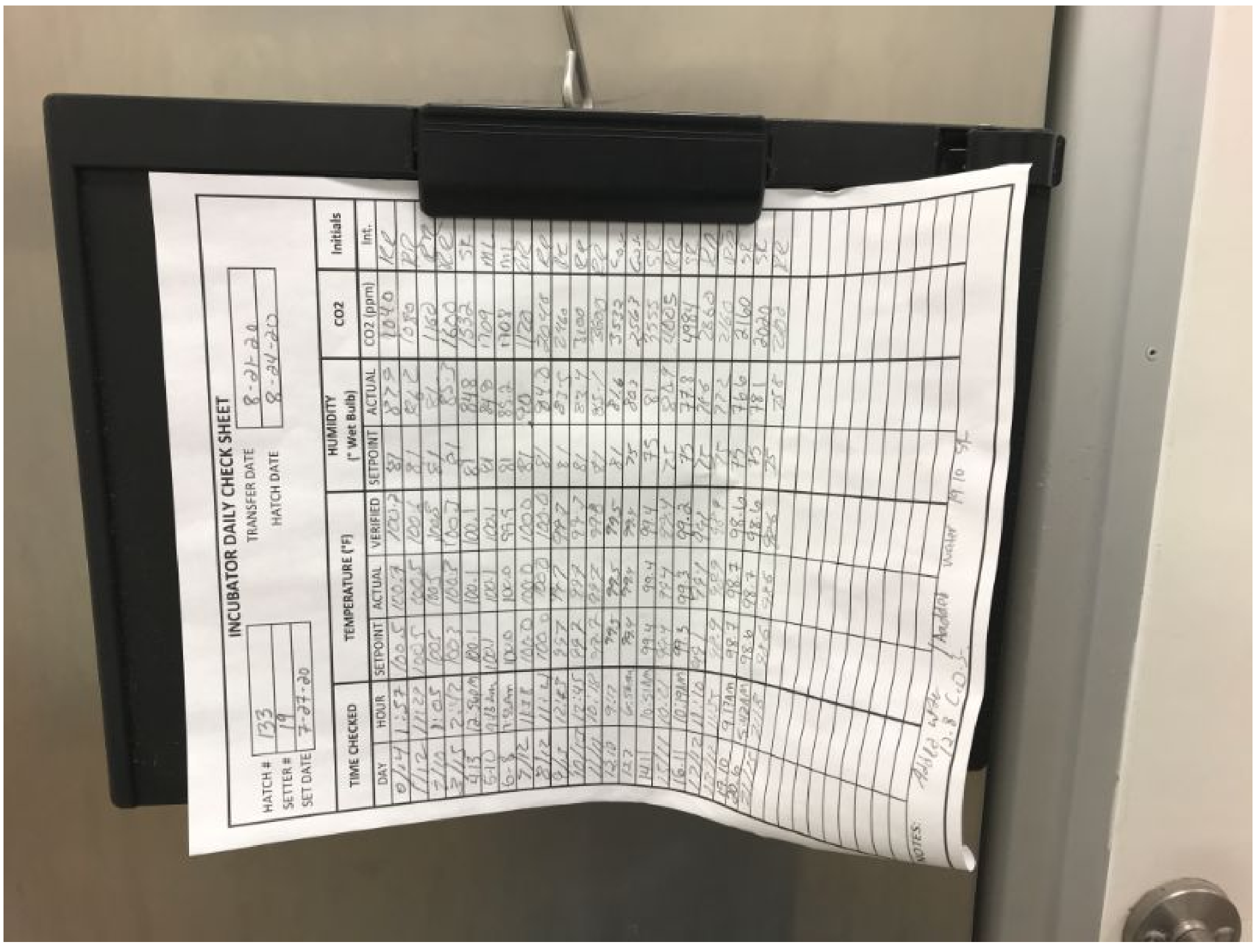


Figure F.14: Sheet that records egg counts in the daily incubator.

Figure F.15: Incubating Eggs.

Figure F.16: Incubation Monitor.

Figure F.17: Incubation monitor with chart.

Figure F.18: This process is called candeling in which they shine a light to see if the eggs are fertilized, not fertilized or rotten.

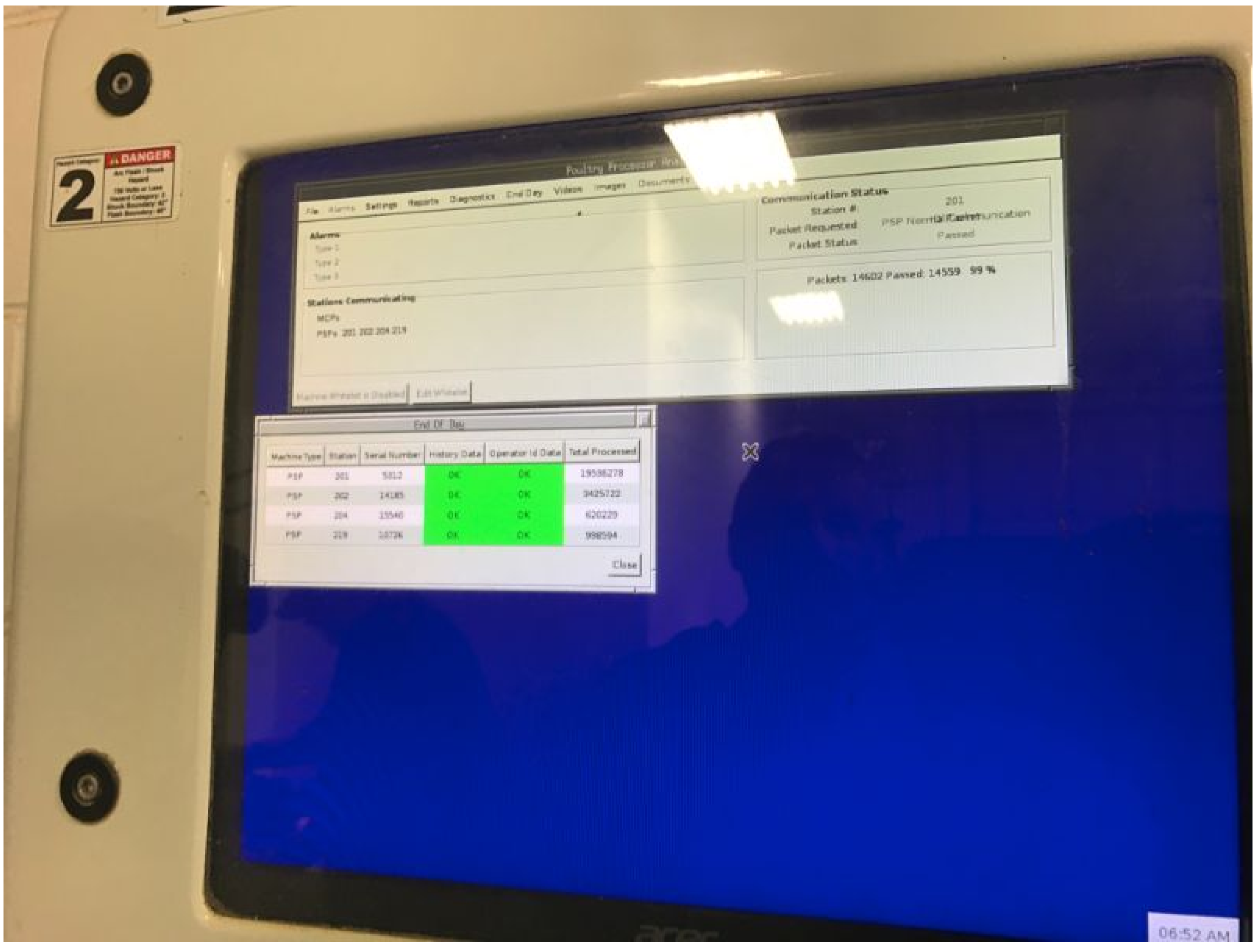


Figure F.19: Control interface for bill modification machine.

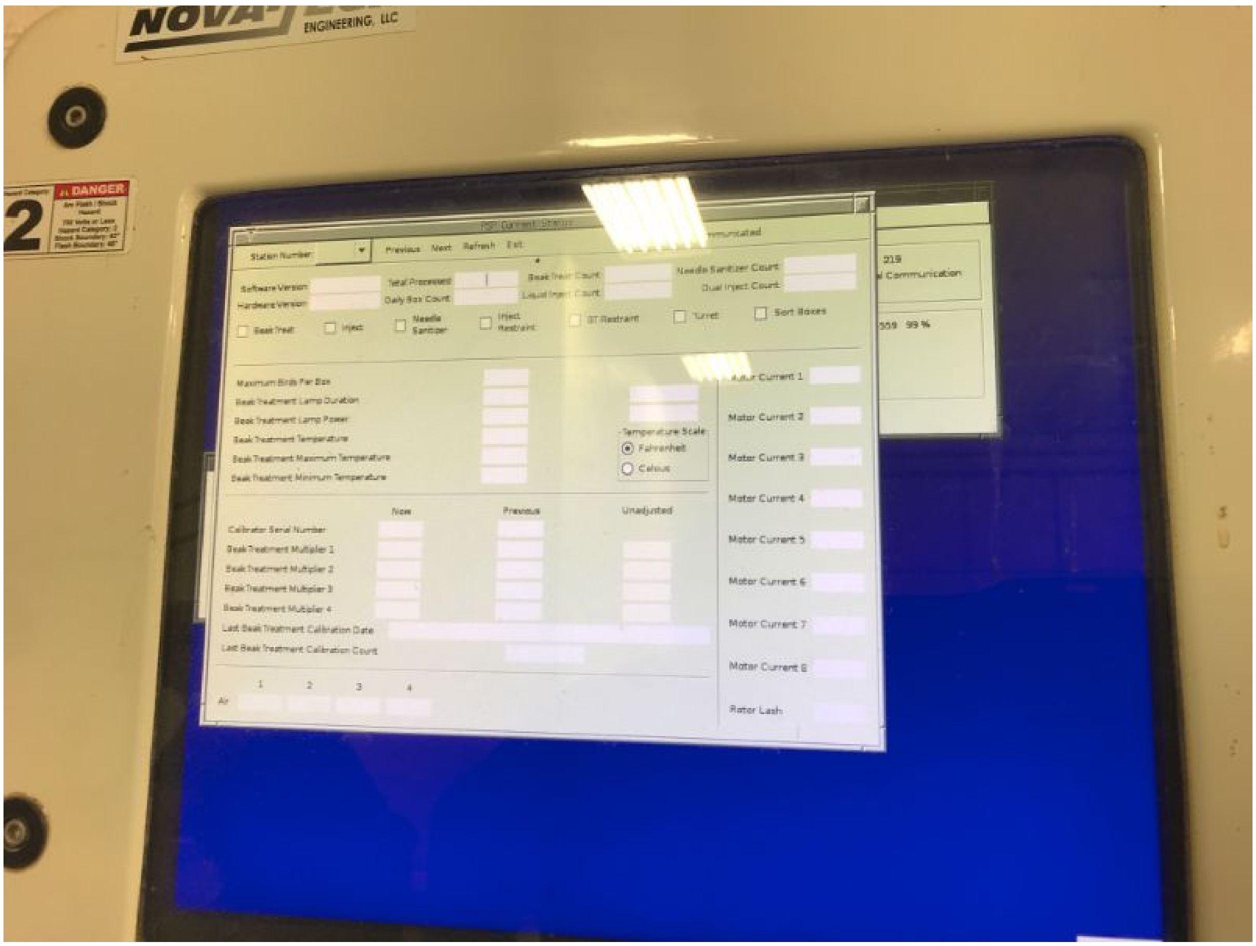


Figure F.20: Second screen of bill modification machine.

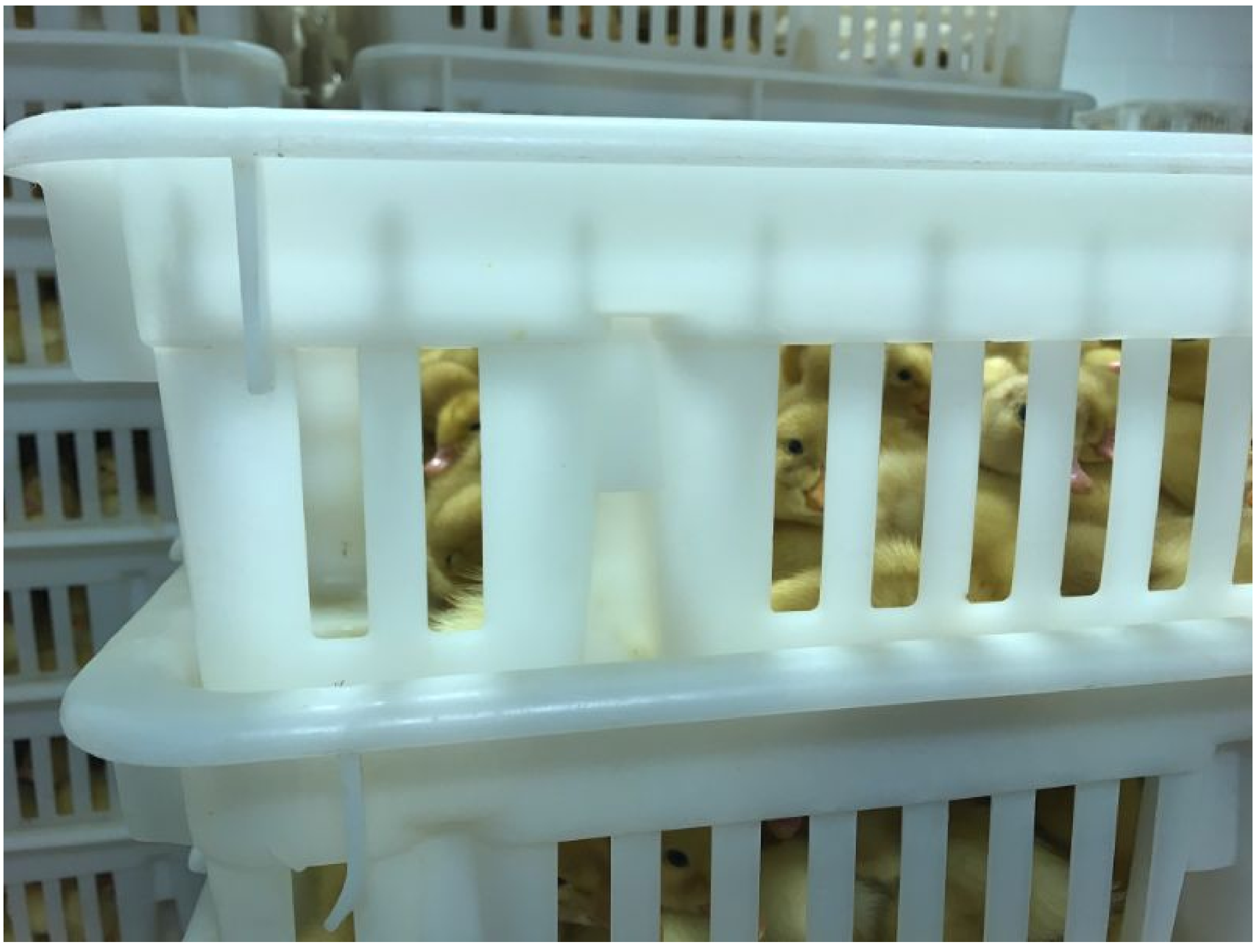


Figure F.21: Baby ducks.

Figure F.22: Baby ducks stacked in containers ready for safe transport to barns.

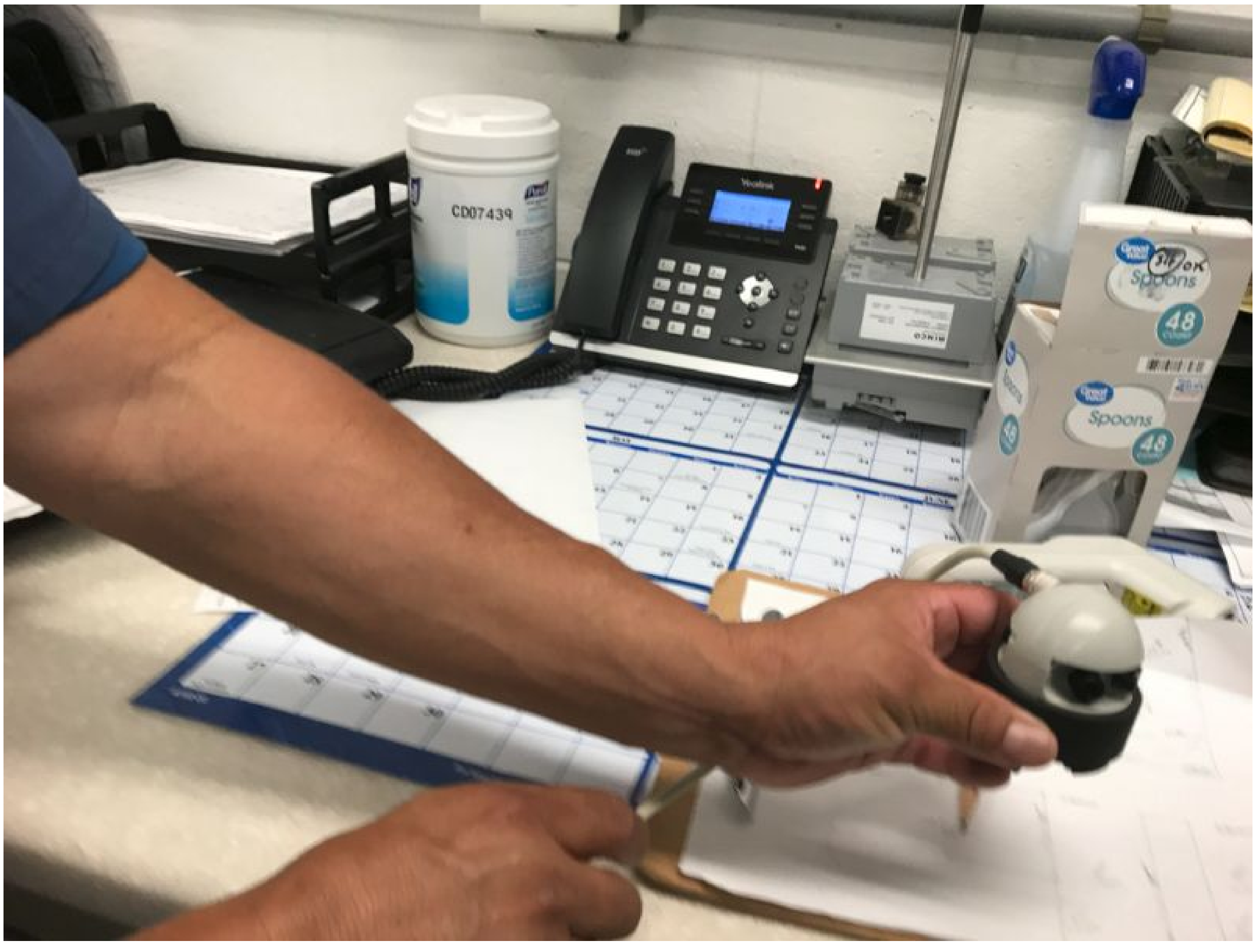


Figure F.23: Egg monitor that goes in the incubation machine to give temperature and humidity readout in a specific section of the incubation machine.

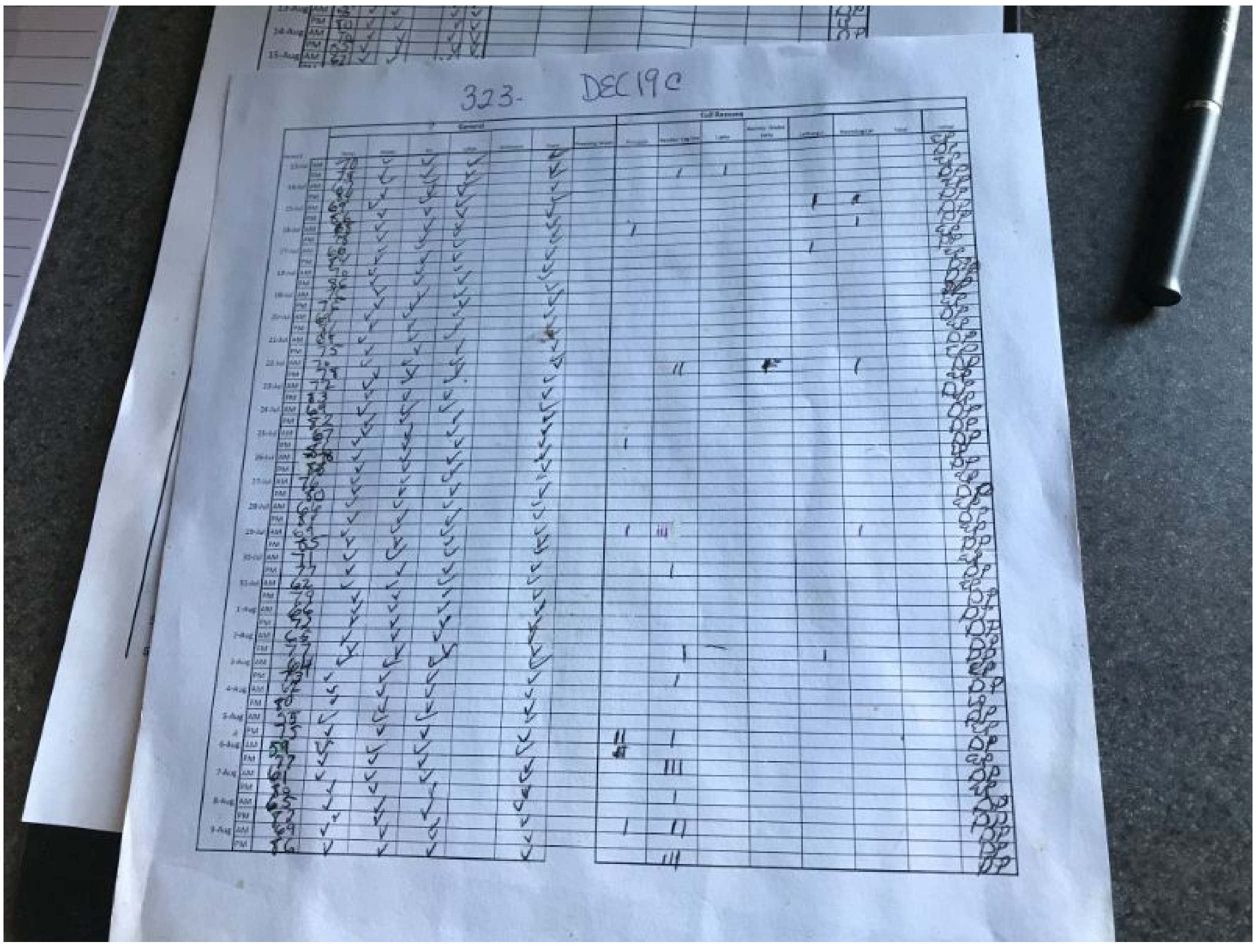


Figure F.24: Barn check sheet for contract growers to monitor and enter.

Figure F.25: Picture of a barn power source at a contract grower barn.

Figure F.26: Barn walkthrough showing feeding system.

Figure F.27: Duck barn floor sample. These can very but the dryer the floor the better the health for the duck.

Figure F.28: Image of larger ducks at the farm.

Figure F.29: Barn being retrofitted to new standards.

Figure F.30: Organized Baby duck feeders.

Figure F.31: Barn check list.

Figure F.32: Baby ducks at a barn.

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