NET PRESENT VALUE ANALYSIS OF AN AUTOMATED GRAIN AERATION SYSTEM TECHNOLOGY ON STORED CORN

by

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ABSTRACT

The purpose of this thesis is to analyze whether the use of automated aeration systems for reducing moisture in corn during storage provides sufficient net present value for Nebraska corn farmers. The objective is to examine if an automated aeration system provides sufficient energy savings, marketing opportunities and reduced drying costs before corn delivery to an elevator.

On-the-farm corn storage has steadily increased and harvesting corn before the moisture has achieved the desired targets cost farmers in drying charges and shrink. Farmers are interested in whether automated aeration systems can remove enough moisture from grain, without over-drying the bin, without spending a large amount of time determining when to run their grain bin aeration fans.

Data for this project were obtained from four privately owned 60,000 bushel grain bins outfitted with the IntelliAir™ BinManager™ automated aeration system. Moisture samples were taken from each of the trucks hauling grain to the bin and again after removal of the corn after the automated system had ran for 9 months. Energy usage, drying charges, and shrink were calculated for the initial corn moisture averages and the moisture at the time of removal.

Each bin was examined using Net Present Value (NPV) analysis to determine whether the energy savings were enough to offset the initial installation cost and annual expenses of the project. After the NPV was estimated for each of the bins, a sensitivity analysis of how corn price changes and no aeration required would affect the NPV analysis.

Finally, an analysis of the total costs savings of a continuously ran aeration system was compared to the automated aeration system.

The conclusion of the NPV analysis was that adding an automated aeration system would be profitable under most scenarios. More studies are needed to determine the profitability of automated aeration systems in different regions, moisture inputs, and bin sizes.

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ACKNOWLEDGMENTS

The author wishes to dedicate this thesis to his family. If they wouldn’t have pushed and supported me, I would have never been able to complete this program.

CHAPTER I: INTRODUCTION

1.1 Background and Justification

Grain quality can be maintained by controlling physical, chemical and biological factors. Thus, food corn processing and storage facilities are ever-striving to maintain grain quality and reduce spoilage when corn is harvested. Processing facilities are not capable of storing all the grain necessary for stretching inventory from one harvest to another. On-the-farm storage is used to bridge the gap between harvests. Storing corn for nine months has an increased risk of loss to farmers. To control the risk of loss, farmers aerate corn to ensure quality when delivered to the processor. Aerating the corn properly reduces the risk of spoilage but over aerating can reduce the selling price via shrink and excess drying charges.

Aeration techniques used to monitor and reduce the properties of corn are often labor intensive and can result in a reduced selling price. Automated aeration systems present a method to accurately monitor corn quality and control the physical properties of corn to targeted goals via technology. To use these systems, farmers select moisture and temperature set points for a given bin. The automated aeration system determines when the aeration fans are turned on by calculating what ambient temperature and relative humidity conditions outside the bin will achieve the desired grain moisture and temperature within the bin.

1.2 Project Objectives

The purpose of this project is to determine whether the use of automated aeration systems for reducing moisture in corn during storage provides sufficient net present value for Central Nebraska corn farmers to invest. The objective is to provide an economic analysis of whether an automated aeration system can provide profits through marketing opportunities, reduced energy bills, and reduced drying costs before corn delivery to an elevator. A sensitivity analysis will display the conditions needed for profitability to occur.

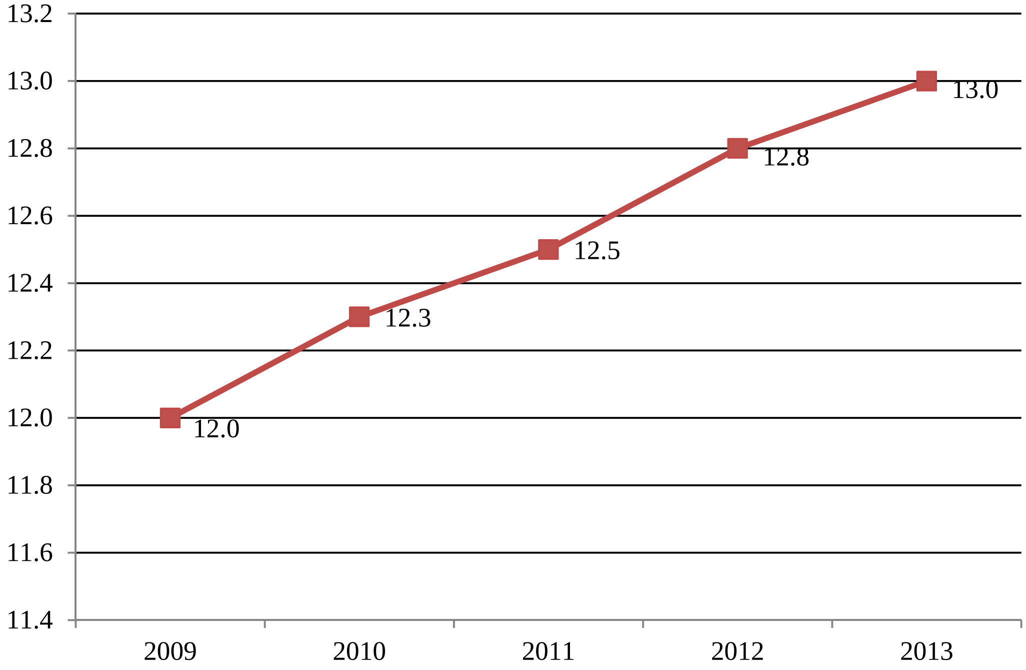
The importance of this analysis lies in the understanding of a new technology and how it could increase farm profits. As farms become larger, farmers often start harvesting corn earlier in the season. Utilizing an automated aeration system allows farmers to harvest corn sooner. The automated aeration system consists of temperature, moisture, and ambient sensors contained in a grain storage bin system. The sensors are linked to a computer system. The computer system turns aeration fans on and off using farmer-defined parameters inputted by farmers. The automated system allows farmers to choose corn holding temperature and desired moisture content. Corn can be dried from 17% moisture to 14% without using natural gas by running aeration fans to reduce shrink and minimize drying charges at delivery. The automated aeration system also allows users to select how long the corn will be held and the desired moisture of corn when delivering it to market. Small amounts of moisture can be added to the grain using the same method of calculating the ambient temperature and relative humidity conditions outside the bin that will achieve the desired grain moisture and temperature within the bin.

CHAPTER II: LITERATURE REVIEW

2.1 On-the-farm Gain Storage

On-the-farm grain storage has increased by 1 billion bushels over the last 5 years (National Agricultural Statistics Service 2009-2013) (Figure 2.1). On-the-farm corn storage allows farmers the flexibility to market their grain at different times during the year and permits farmers to harvest earlier. The aeration of corn is a key component of keeping the stored corn in good condition, so the maximum price can be realized when the corn is eventually sold. Research defines the optimal amount of aeration so that corn taken out of storage will be of high quality and appropriate moisture. Determining when to run aeration fans has been confusing and some farmers resort to running aeration systems continuously to regulate temperature and moisture. A new technology has emerged that automates bin aeration, and is being used to determine the length to run aeration fans. This technology can regulate temperature and moisture of the corn to obtain the maximum value during sale. This literature review will describe how aeration is used to maintain corn in a storage bin, how grain aeration techniques are decided upon, and how the automated aeration system works.

Figure 2.1: On-Farm Grain Storage Capacity in Billions of Bushels



(National Agricultural Statistics Service 2009-2013)

2.2 Defining Aeration

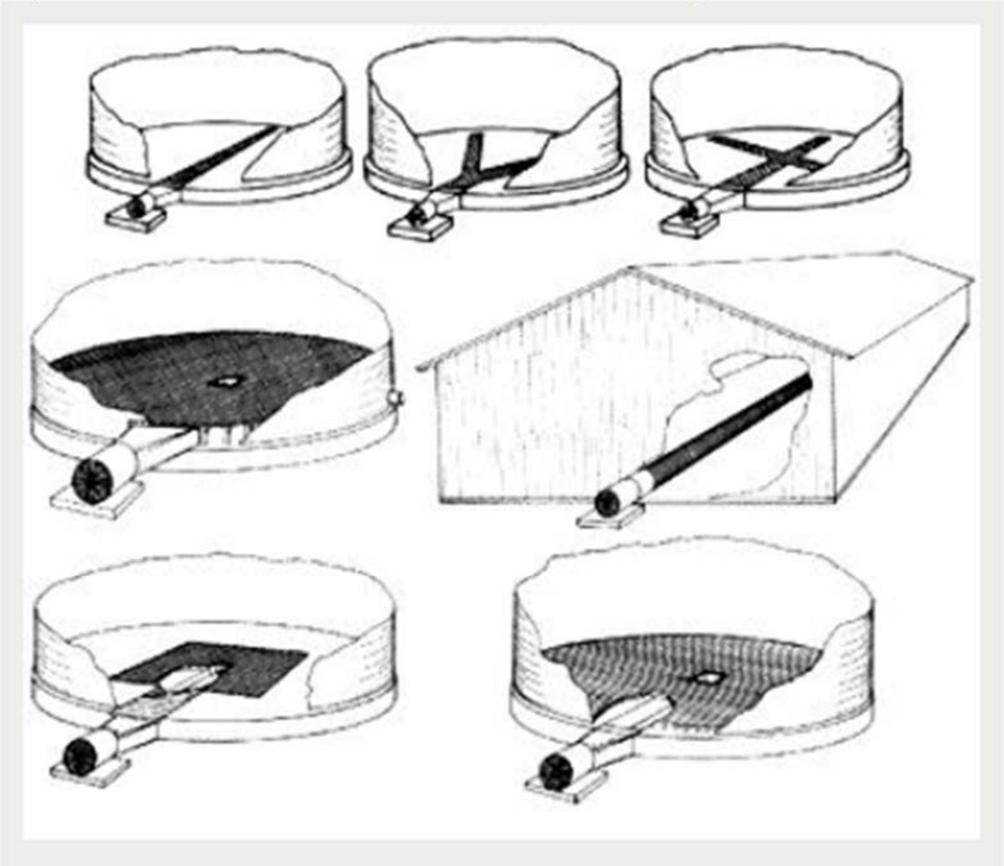
The aeration of grain is described as passing ambient air through a stored grain mass to change the physical (moisture and temperature) properties of the grain. The air to pass through the grain is generated through an axial or centrifugal fan. The air then passes through a series of distribution lines or duct work. From the duct work, the air enters the grain mass through perforated flooring and perforated duct work. Figure 2.2 shows different types of bin/storage floors or plenums. Each type of plenum system allows air to penetrate the grain mass. Aeration fan and ductwork selection is important because different grains have different air resistances. A rule of thumb is if a person’s goal is to dry grain using an aeration system, it is important to have a fan and motor that can generate at least 1-3 cubic feet per minute per bushel of grain (CFM/bu) for proper aeration (Maier, K-State Distance Education Program GEAPS 520 Lecture 6 Fan Selection, Sizing and Operating Strategies 2013). As aeration fans run, ambient air is pushed through the gain mass in levels shown in Figure 2.3. The air front carries the temperature and vapor pressure of ambient air being passed through it. It is important that the grain masses have consistent temperatures during its time in storage. Difference in temperature can cause spoilage.

Other important considerations for grain aeration are the height of the structure, width of the structure, grain consistency, whether the grain has been leveled, and ventilation in the roof of the grain storage structure. A storage structure has to be designed appropriately to correctly aerate the grain inside of it.

2.3 Equilibrium Moisture Content

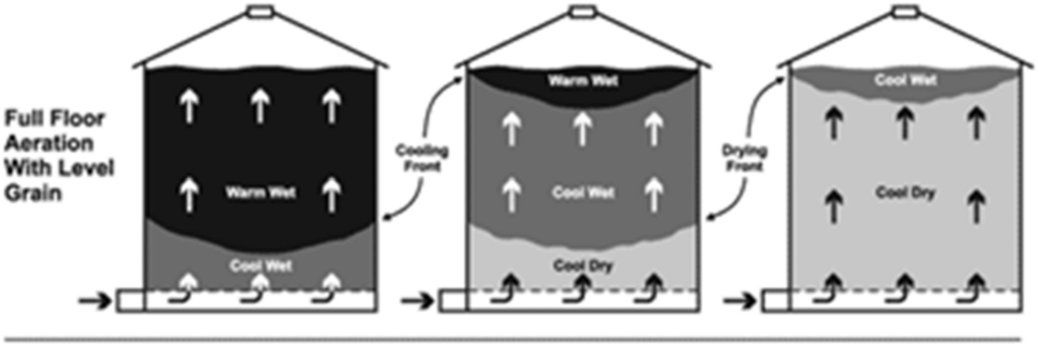
If the system is designed correctly, air passes through the grain mass. Then the temperature and the relative humidity from the ambient air and moisture from the grain react and cause an equilibrium moisture content (EMC) of the grain/corn in storage (Aeration Management). The EMC is described as, “moisture content which the internal vapor pressure of the grain is in the equilibrium with the vapor pressure of the environment” (Maier, K-State Distance Education Program GEAPS 521 Lecture 2 Air and Grain Properties 2013). When aerating, the ambient air can be used to manipulate the moisture content of the grain mass. If the ambient air passing through the grain has less vapor pressure than the grain in the storage bin, prolonged exposure to this air will cause the moisture content of the grain to drop. The reverse is true if the ambient air vapor pressure is higher than that of the grain in storage. Aeration is used to lengthen storage periods through reducing the moisture and temperature of the grain through the EMC process. Proper aeration results in deterring mold, insects, and spoilage, while maintaining grain moisture of a constant rate (Maier, 2013). Improper aeration results in spoiled grain, mold issues, insect problems, and unwanted final moisture content upon removing grain from storage.

Figure 2.2: Plenums and Grain Floor Aeration Designs



(Cloud and Morey n.d.)

Figure 2.3: Grain Aeration Front Movement



(Farms.com 2015)

2.4 Methods of Aeration

Historically, farmers have used multiple methods for aerating grain. One method is manually turning aeration fans on, climbing to the top of the bin and feeling the air coming of the grain. When the air feels cool and doesn’t fog your glasses (less humid), the fans are ready to be turned off. This process can take months of aeration/fan running and depends on the ambient conditions outside the bin, the aeration system design, and fan size. Typically, farmers leave fans on when the daytime temperatures drop and when relative humidity is the lowest. This decreases the temperature and moisture of the grain, but wastes energy and reduces moisture reduction control, due to lack of monitoring capabilities.

Another method that farmers use is a probe system. A probe collects grain samples from multiple points in a grain storage bin. The probe is inserted in the middle of the grain bin and samples are removed and tested to give accurate moisture and temperature of the storage bin. The decisions can then be made to aerate the grain further or not. While this process is accurate, this method takes time and labor to complete. Farmers with a large amount of farm acres find it difficult to allocate the time and effort needed to probe multiple bins. Another issue with this method is that probing is only a point in time and decisions are made from that single observation. Relative humidity and temperatures can change in a matter of hours in the Midwest. Not reacting to these changes quickly can cause adverse grain storage properties.

Some farmers choose to only aerate grain to a predetermined temperature and then don’t aerate the bin afterwards. This method is done by running the fans when the desired temperature is ambient outside of a storage structure. Farmers then insert a temperature probe in the top or bottom of the bin (whichever is the air output). The probe displays if the temperature front has made it through the gain mass. This method of aeration is adequate if the moisture content of grain is at or below the delivery dockage point. If grain moisture is above the dockage point a farmer will lose money due to drying costs and shrink.

The final type of aeration control method is an automated aeration system. This system uses temperature cables sensors within the grain mass, a moisture sensor within the grain mass, sensors to monitor ambient conditions outside of the bin, and can have relative humidity sensors in the head space or plenum of the bin. The system then processes all data points and calculates when the optimum time is to operate the system naturally drying the grain without gas and minimizing shrink and spoilage (OPI-integris Advanced Grain Management 2014).

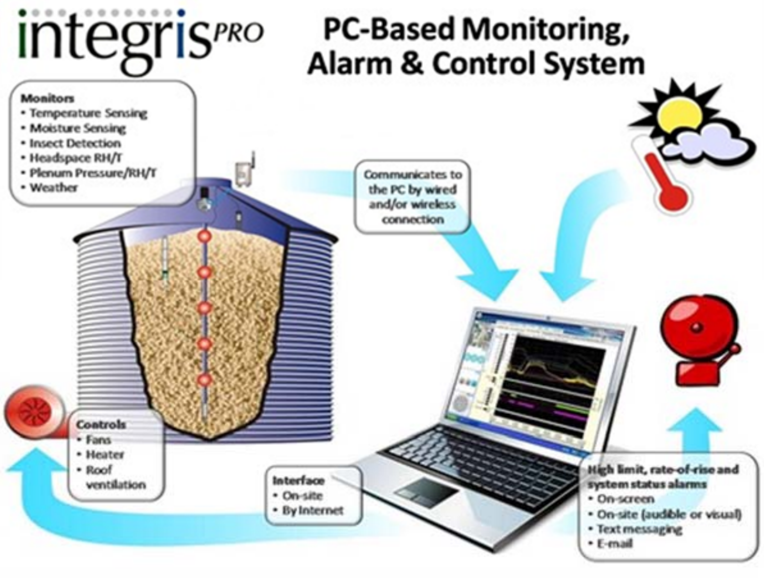
2.5 Automated Grain Aeration System

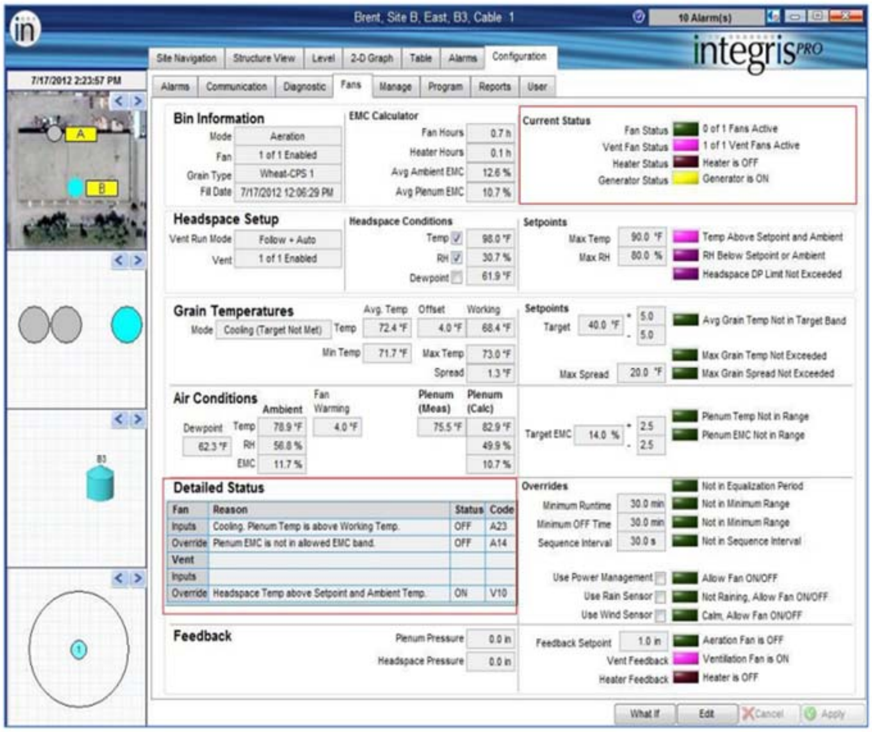
There are two main brands of automated grain aeration systems used in Central Nebraska. The OPI Integris Pro system and the IntelliAir™ BinManager™ use data from ambient air and monitors within a grain mass to make decisions on when to turn aeration fans on/off, alarm farmers if temperatures spike, and record data on a predetermined schedule. Systems can be monitored from the grain site or via radio or cellular signals.

While the OPI IntegrisPro and IntelliAir™ BinManager™ were created to achieve the same results, there are differences between the two. The OPI IntegrisPro system has more computer hardware and software requirements. Figure 2.4 shows the operations screen for the OPI Integris Pro. The dedicated hardware allows OPI IntegrisPro users to examine real-time data from their bin systems. The IntelliAir™ BinManager™ system sends all bin information to a remote cloud server, where any device can access, control, and retrieve data via internet. Figure 2.5 shows the operation screen and basic IntelliAir™ BinManager™ setup. The drawback to sending information to the cloud is the IntelliAir™ BinManager™ systems records readings hourly but only upload to the cloud once daily, at a prescribed time.

The IntelliAir™ BinManager™ system was chosen for the study because it had accessible data through Nebraska Salt and Grain. IntelliAir™ BinManager™ is also serviced and sold at Ag Horizon in Gothenburg, Nebraska. Ag Horizon was able to provide installation and maintenance cost information.

Figure 2.4: Diagram of OPI IntegrisPro Automated Grain Aeration System





Bin Information

Mode Aeration
Fan 1 of 1 Enabled
Grain Type Wheat-CPS 1
Fill Date 7/17/2012 12:06:29 PM

EMC Calculator

Fan Hours 0.7 h
Heater Hours 0.1 h
Avg Ambient EMC 12.6 %
Avg Plenum EMC 10.7 %

Current Status

Fan Status 0 of 1 Fans Active
Vent Fan Status 1 of 1 Vent Fans Active
Heater Status Heater is OFF
Generator Status Generator is ON

Headspace Setup

Vent Run Mode Follow + Auto
Vent 1 of 1 Enabled

Headspace Conditions

Temp ☑ 98.0 °F
RH ☑ 30.7 %
Dewpoint ☐ 61.9 °F

Setpoints

Max Temp 90.0 °F
Max RH 80.0 %
Temp Above Setpoint and Ambient
RH Below Setpoint or Ambient
Headspace DP Limit Not Exceeded

Grain Temperatures

Mode Cooling (Target Not Met)

	Avg. Temp	Offset	Working
Temp	72.4 °F	4.0 °F	68.4 °F

Min Temp 71.7 °F
Max Temp 73.0 °F
Spread 1.3 °F

Setpoints

Target 40.0 °F + 5.0 - 5.0
Max Spread 20.0 °F
Avg Grain Temp Not in Target Band
Max Grain Temp Not Exceeded
Max Grain Spread Not Exceeded

Air Conditions

Dewpoint 62.3 °F

	Ambient	Fan Warming	Plenum (Meas)	Plenum (Calc)
Temp	78.9 °F	4.0 °F	75.5 °F	82.9 °F
RH	56.8 %			49.9 %
EMC	11.7 %			10.7 %

Target EMC 14.0 % + 2.5 - 2.5
Plenum Temp Not in Range
Plenum EMC Not in Range

Detailed Status

Fan	Reason	Status	Code
Inputs	Cooling. Plenum Temp is above Working Temp.	OFF	A23
Override	Plenum EMC is not in allowed EMC band.	OFF	A14
Vent			
Inputs			
Override	Headspace Temp above Setpoint and Ambient Temp.	ON	V10

Overrides

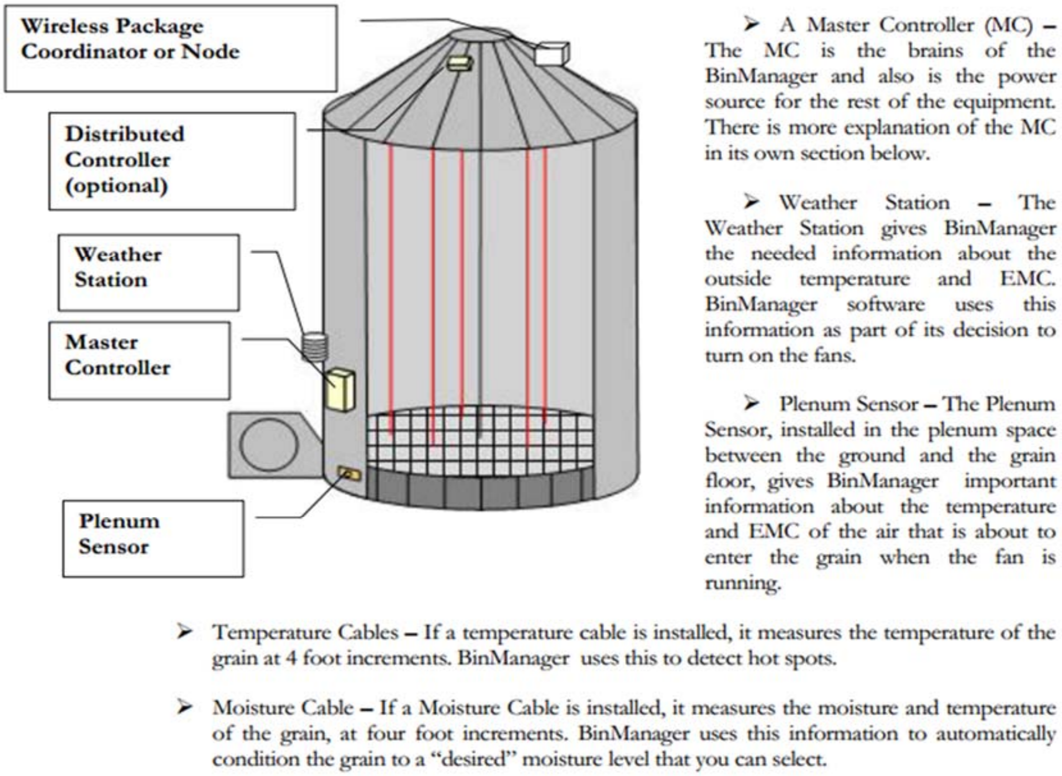
Not in Equalization Period
Minimum Runtime 30.0 min Not in Minimum Range
Minimum OFF Time 30.0 min Not in Minimum Range
Sequence Interval 30.0 s Not in Sequence Interval
Use Power Management ☐ Allow Fan ON/OFF
Use Rain Sensor ☐ Not Raining, Allow Fan ON/OFF
Use Wind Sensor ☐ Calm, Allow Fan ON/OFF

Feedback

Plenum Pressure 0.0 in
Headspace Pressure 0.0 in
Feedback Setpoint 1.0 in Aeration Fan is OFF
Vent Feedback Ventilation Fan is ON
Heater Feedback Heater is OFF

(OPI-Integris Systems 2014)

Figure 2.5: Diagram of IntelliAir™ BinManager™ Automated Grain Aeration System



- A Master Controller (MC) – The MC is the brains of the BinManager and also is the power source for the rest of the equipment. There is more explanation of the MC in its own section below.
- Weather Station – The Weather Station gives BinManager the needed information about the outside temperature and EMC. BinManager software uses this information as part of its decision to turn on the fans.
- Plenum Sensor – The Plenum Sensor, installed in the plenum space between the ground and the grain floor, gives BinManager important information about the temperature and EMC of the air that is about to enter the grain when the fan is running.
- Temperature Cables – If a temperature cable is installed, it measures the temperature of the grain at 4 foot increments. BinManager uses this to detect hot spots.
- Moisture Cable – If a Moisture Cable is installed, it measures the moisture and temperature of the grain, at four foot increments. BinManager uses this information to automatically condition the grain to a "desired" moisture level that you can select.

(IntelliAirBinManager 2011)

CHAPTER III: THEORETICAL MODEL

3.1 Introduction

As farms consolidate and on-the farm storage capacity grows, it is important that farmers use technology to manage corn while in storage. Maintaining the quality of corn in storage is imperative to extend its value until final sale. Over the last few decades, computers and control programs have allowed humans to make complex decisions after inputting parameters into a computer program. Using a computer program to automatically aerate and monitor grain attributes adds value by ensuring grain moisture and temperature are at proper levels for the sale of the grain. The purpose of this study is to estimate the net present value of an investment in an automated grain aeration system. This analysis will help farmers understand the profitability of an investment in an automated aeration system.

3.2 Net Present Value

A central concept of net present value is the time value of money. This concept means a dollar today is worth more than a dollar tomorrow. Therefore, when investing in projects, cash inflows and outflows need to be treated in terms of the time value of money.

To understand how the cash flows are discounted, the assumption of the opportunity cost is important. The opportunity cost is the opportunity given up by an investor making the investment. This opportunity cost is typically a stock or other investment with similar risk characteristics (Investopedia 2014). In the case of a farmer, the investment that they give up could be used for land purchase or payments. In Figure 3.1, the net present value equation is defined. It uses the net cash inflows, the opportunity costs, number of periods, and the initial investment to determine net present value of an investment.

Figure 3.1: Formula for Calculating NPV

$$\boldsymbol{NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o}$$

$\boldsymbol{C_t = net\ cash\ inflow\ during\ the\ period}$

$\boldsymbol{C_o = intial\ investment}$

$\boldsymbol{r = discount\ rate, and}$

$\boldsymbol{t = number\ of\ periods}$
(Investopedia 2014)

3.3 Net Present Value Assumptions

There are assumptions necessary to determine net present value. The first assumption is the cash generated by a project is reinvested to generate a return at a rate that is equal to the discount rate used in present value analysis (OPI-integris Advanced Grain Management 2014). This may not always be the case.

The second assumption is the inflow and outflow of cash other than initial investment occur at the end of each period. To make it simple, outflows and inflows are accounted for at the end of a determined period. Sometimes these cash flows don’t occur at the same time every period in the real world. Cash flows are not always predictable. In the case of aerating grain from higher moisture to target moisture, the energy consumption savings between drying and aerating is the positive cash flow. Predicting what the cash flow without assumptions is not possible because corn moisture is dependent on weather patterns.

CHAPTER IV: METHODS AND RESULTS

4.1 Objective

The objective of this thesis is to analyze whether the energy and shrink savings generated from an automated aeration system used to remove moisture provide a positive net present value compared to reducing the temperature and storing shelled corn after harvest of a higher moisture content in Central Nebraska.

4.2 Bin Dimensions and Aeration System Design

The four bins used for collecting project data each have 60,000 bushel capacities and are located at the same location. They have a diameter of 48 feet and a height, including the cone, of 50 feet. Each storage bin has a full-aeration floor and a 21,000 Cubic Feet per Meter (CFM) centrifugal fan, run by a 20 H.P. motor (GEAPS recommends a 0.05 - 0.25 CFM per bushel for aeration of grain). This system has 0.35 CFM per bushel. All four bins have six IntelliAir™ temperature cables with sensors located every four feet, a single moisture cable with sensors every four feet, an ambient temperature/RH sensor, and a plenum sensor connected to the IntelliAir™ BinManager™ controller.

4.3 Net Present Value Formula

The equation in chapter 3 (Figure 3.1) was used to determine whether the energy savings from using an automated aeration system versus reducing the temperature and storing corn for six months results in a positive net present value.

4.4 Energy Savings Assumptions and Calculations

Energy use was calculated by using data from input bin moistures and output bin moistures. The input moistures in Table 4.1 were used to calculate dryer charges and shrink, of delivering the corn, and holding moisture constant at the time of harvest or later. The output bin moistures in Table 4.2 were used to analyze the energy costs of running an automated aeration system, dryer charges to reach target moisture, and shrink at least 6 months after harvest. The IntelliAir™ BinManager™ was set to a target moisture upper limit of 15% and a lower limit of 14% for each bin. Drying charges were calculated by subtracting the mean moisture from the target moisture of 14 percent, and multiplying by a $0.035 per bushel drying charge, and finally multiplying by the amount of shrunk bushels per corn bin.

Electricity costs were collected from IntelliAir™ BinManager™ system. The system records total number of fan hours for each bin. To find the amount of energy consumed by the aeration system the 20 HP fan motors were converted to kilowatt and multiplied by the number of hours used. The kilowatt hours were multiplied by Nebraska Public Power Department electricity utility cost of $0.10 kW/hr. Table 4.3 shows drying charges for the grain moisture sample placed in the bin at the time of 2013 harvest. Table 4.4 shows drying and aerations costs when the corn was removed from bin September 2014.

4.5 Shrink and Drying Charge Calculations.

Shrink is the calculated percentage of water loss from an amount of grain after aeration or drying. If grain moistures are higher than contracted amounts, grain purchasers deduct the percentage of water weight and handling fees that will be removed during drying. For this thesis, the corn will be deducted by 1.4% per point of moisture above 14%, during delivery. If a grower delivers below the targeted grain moisture because the grain is too dry, they lose money due to reduced water weight. It is therefore important for growers to not over dry or under dry corn.

The target moisture for the corn was 14 percent. Shrink was calculated subtracting the mean moisture from the target and then multiplying by 1.4 (elevator shrink for handling grain). Finally, one is subtracted from that amount and multiplied by 60,000 bushel. Shrink is shown in both Tables 4.3 and 4.4. Below is an example of how the shrink loss, dryer charges, and aeration costs were calculated for bin 1.

Figure 4.1: Formulas for Calculating Shrink Loss, Dryer Charges and Aeration Costs

$\boldsymbol{Bin\ 1\ Input\ \ Corn\ Moisture\ Shrink\ Loss\ Calculations} =$

$\big[[Bin\ 1\ Input\ Mean\ Moisture\ 16.47\% -$

$Moisture\ Target\ 14\%]\ \text{x Elevator Shrink Constant 1.4}\big]*$

[Bin 1 Total Initial Bushels 60,000]

$\boldsymbol{Bin\ 1\ Output\ Corn\ Moisture\ Shrink\ Loss\ Calculation} = \Bigg[\Big[100 -$

$\left[\frac{100-Bin\ 1\ Input\ Moisutre\ Mean\ 16.47}{100-Bin\ 1\ Output\ Moisutre\ Mean\ 14.95}\right] * 100\Big] +$

$\Big[\big[\textit{Bin 1 Output Mean Moisture 14.95\%-Moisture Target 14\%}\big]\ \textit{x Elevator Shrink Constant 1.4}\Big]\Bigg]$

*[Bin 1 Total Initial Bushels 60,000]

Bin 1 Input Corn Dryer Charges=[Bin 1 Input Mean Moisture 16.47%-Moisture Target 14%]

$.035 Dryer Charge[Total Bushels 60,000-Bin 1 Input Corn Shrink Loss 2,075 Bushels]

Bin 1 Output Corn Dryer Charges=[Bin 1 Output Mean Moisture 14.95%-Moisture Target 14%]

$.035 Dryer Charge[Total Bushels 60,000-Bin 1 Output Corn Shrink Loss 1,856 Bushels]

Bin 1 Output Corn Aeration Costs=[Bin 1 Aeration Fan Hours 500]*

[20H.P. Aeration Fan Motor*0.735 kW per HP]* $0.10 per kW Hour

Table 4.1: Input Corn Moisture Statistics Harvest October 2013

	Moisture % Bin 1	Moisture % Bin 2	Moisture % Bin 3	Moisture % Bin 4
Total Bushels	60,000	60,000	60,000	60,000
Mean	16.47	16.43	16.35	16.16
Maximum	18.0	18.0	18.0	17.9
Minimum	14.5	13.4	13.8	13.7
Range	3.5	4.6	4.2	4.2
Standard Deviation	1.28	1.20	1.20	1.44

Table 4.2: Output Corn Moisture Statistics September 2014

	Moisture % Bin 1	Moisture % Bin 2	Moisture % Bin 3	Moisture % Bin 4
Mean	14.95	14.42	14.57	14.04
Maximum	15.70	15.30	15.5	14.9
Minimum	14.10	13.70	14.1	13.5
Range	1.60	1.60	1.4	1.4
Standard Deviation	0.39	0.46	0.32	0.28
Aeration Fan Hours	500	420	610	300
Moisture Removed	1.52	2.01	1.78	2.12

Table 4.3: Input Corn Moisture Drying Charges and Shrink per Bin

	Drying Charges $	Shrink Loss (bu)
Bin 1	$5,007	2,075
Bin 2	$4,929	2,042
Bin 3	$4,772	1,974
Bin 4	$4,398	1,815
Total	$19,108	7,906

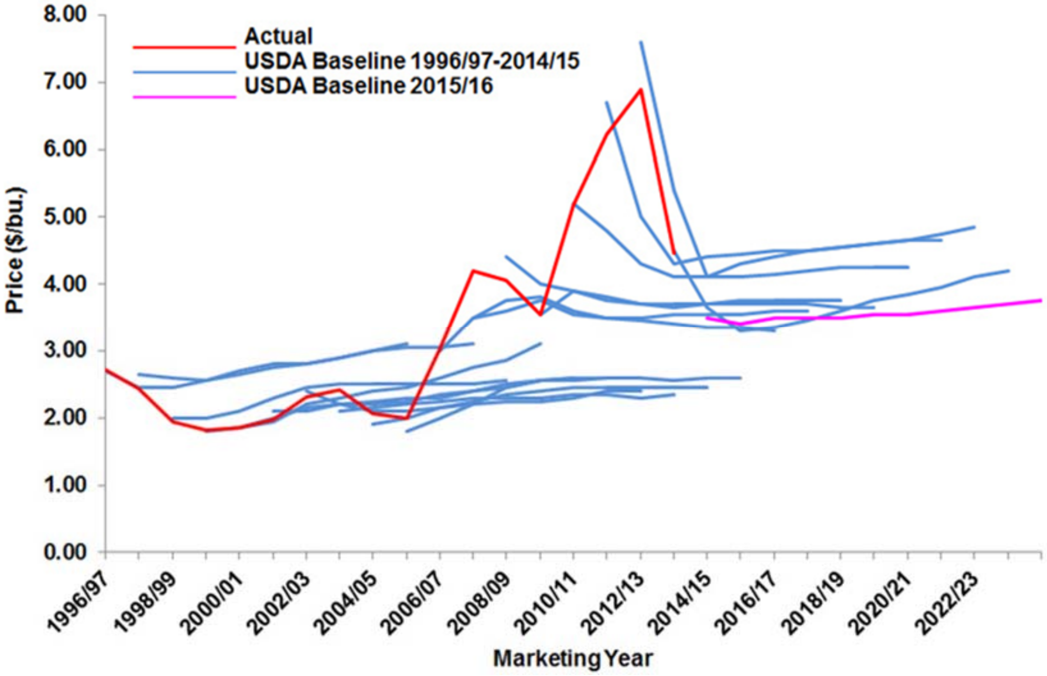
Table 4.4 Output Corn Moisture Drying Charges, Aeration Costs, and Shrink per Bin

	Drying Charges	Aeration Costs	Shrink Loss Bu
Bin 1	$1,968	$736	1,856
Bin 2	$876	$618	1,754
Bin 3	$1,187	$897	1,719
Bin 4	$83	$441	1,513
Total	$4,116	$2,692	6,841

4.5 Corn Price Assumptions

Table 4.5 shows corn price assumption from 2014 to 2024. Years 1 through 4 assumptions are based upon corn future quotes from the CME Group (CME Group 2015). Figure 4.1 was used to determine corn cash price for years 5 through 10. Blue lines on the Figure 4.1 represent forecasted pricing by the USDA in 10 year increments. Each of the 10 year forecasts tend to stay in a steady-state meaning, they tend to follow a semi-flat linear line. The exception to these forecast are periods of large supply/demand causing price variations (Irwin and Good 2014). The magenta line represents the 10 year corn price forecast from 2014/2015 to 2024/2025. A flat price of $4.30 was used for years 5 through 10 in the NPV model.

Figure 4.2: USDA 10-Year Baseline Price Forecasts for Corn and Actual Marketing Year Average Prices 1996/97 – 2024/25



(Irwin and Good 2014)

Table 4.5 10 Year Corn Price Assumptions

Year	Corn Price
2014	$4.05
2015	$3.99
2017	$4.43
2018	$3.50
2019	$3.50
2020	$3.50
2021	$3.50
2022	$3.60
2023	$3.75
2024	$4.00

(CME Group 2015) (Irwin and Good 2014)

4.6 IntelliAir™ BinManager™ Online Subscription and Service

The IntelliAir™ BinManager™ system has an annual subscription of $20 dollars a month per bin equaling $240 dollars per bin. The subscription provides data tracking, grain out of condition alarms, and the ability to change grain moisture/temperature targets through the internet daily. All data is stored in the IntelliAir™ Cloud. There are no annual maintenance costs for the system.

4.7 Depreciation Schedule

The depreciation schedule for the system is based on a 7-year recovery Modified Accelerated Cost Recovery System (MACRS) for equipment. Salvage value for the equipment is $0. Table 4.6 shows the schedule in its entirety. The $55,000 investment includes materials for each of the four storage systems including temperature cables, a moisture cable, plenum temperature sensor, master controller, weather station, and wireless transmitter. Labor to install electrical wiring and cable was also included in the initial investment. The $55,000 is divided by four to calculate each the NPV's for the 60,000 bushel storage bins.

4.8 Marginal Tax Rate

A marginal tax rate of 34.84% was used which combines the state of Nebraska and Federal tax rates (the state of Nebraska tax bracket was 6.84% and the Federal bracket was 28%).

4.9 Opportunity Costs

The opportunity cost used for this project was 9%. The 9% was used because that is the opportunity costs used by my company to justify investments. The opportunity costs for the majority of farmers is the opportunity to invest and purchase land.

4.10 Net Present Value Calculations

Each bin has separate net present value calculations. Table 4.1 shows inputs of corn moisture statistics during corn harvest for the corn storage bins. Table 4.2 shows the storage bin corn moisture statistics and how much moisture was removed compared to the input moistures.

Data were collected from trucks during delivery and removal of corn via a probe sampler. The cash inflow calculations represent the total amount of savings calculated by finding the difference between shrink and energy gains from Tables 4.3 and 4.4. The savings of the system were calculated based upon the difference of not using the aeration system (Table 4.3) and using the aeration system (Table 4.4)

Corn cash prices for shrink calculations are based upon the futures markets and the USDA 10-year baseline price forecasts for corn shown in Figure 4.1. The prices used for the life of the project are shown in Table 4.5. Tables 4.7 through 4.10 are set up accordingly; the initial investment for each bin is inputted in year zero. The only cash outflow per year is the $20 a month wireless fee to upload data into the cloud. Cash inflow per year is calculated by inputting the difference between running the automated aeration system and not running the aeration system, assuming moisture inputs were similar to the data (based on Tables 4.3 and 4.4). Taxes were calculated by subtracting cash inflow from cash outflow, and depreciation then multiplied by the marginal tax rate. Operating cashflow after tax is calculated by subtracting cash inflow from cash outflow and tax. Discounted cashflow is calculated using the NPV equation. Each of the bins shows a positive NPV.

The project provides sufficient savings, compared to the opportunity cost of 9%. Surprisingly, each NPV table has a different value. Bin 1 (Table 4.7) has the lowest NPV. This can be explained by an increased amount of wet corn in the bin, causing higher drying charges, energy costs, and shrunk pounds. What is peculiar is that bin 1 (Table 4.7) has the highest initial mean moisture, but has smallest amount of moisture reduction reducing drying charges and making it the largest NPV value. Table 4.10 shows that bin 4 was the most profitable. This can be explained due to it having the lowest initial mean moisture and greatest moisture removal of all the systems. All bins have NPV calculations greater than zero meaning that the investment was profitable for each bin.

4.11 Cash Inflow Calculation

Cash inflows were calculated by finding the difference between the input drying costs and shrink associated with the price of corn in that year, and the output drying costs, aeration costs, and shrink associated with the price of corn in that year. Below is an example of the 2014 cash inflow calculations for bin 1 in figure 4.3.

Figure 4.3: Formula for Calculating NPV Cash Inflow

$$\begin{aligned}
&\mathbf{2014\ Cash\ Inflow\ Calculations\ for\ Bin\ 1}\\
&= [\text{Input Corn Shrink Loss } 1{,}856 \text{ Bushels} - \text{ Output Corn Shrink Loss } 2{,}075 \text{ Bushels}]\\
&* \text{ 2014 Corn Price Assumption } \$4.05\\
&+ [\text{Input Dryer Charge } \$5{,}008 - [\text{Output Corn Dryer Charge } \$1{,}856\\
&+ \text{Aeration Costs } \$736]]
\end{aligned}$$

Table 4.6 Depreciation
Initial Investment: $55,000

Year	Tax Depreciation Percentage	Dollar Amount
1	14.29%	$7,860
2	24.49%	$13,470
3	17.49%	$9,620
4	12.49%	$6,870
5	8.93%	$4,912
6	8.92%	$4,906
7	8.93%	$4,912
8	4.46%	$2,453
Total	100%	$55,000

Table 4.7 Corn Bin 1 Net Present Value Calculations and Cash Flow

	Initial Investment	Cash Outflow	Cash Inflow	Taxes	Operating Cash Flow After Tax	Net CF	DCF	Cumm. DCF
0	$13,750	$240		-$84	-$156	-$13,906	-$13,906	-$13,750
1		$240	$3,226	$356	$2,630	$2,630	$2,413	-$11,337
2		$240	$3,212	-$138	$3,110	$3,110	$2,618	-$8,720
3		$240	$3,309	$231	$2,837	$2,837	$2,191	-$6,528
4		$240	$3,105	$400	$2,465	$2,465	$1,746	-$4,782
5		$240	$3,105	$570	$2,295	$2,295	$1,491	-$3,291
6		$240	$3,105	$571	$2,294	$2,294	$1,368	-$1,923
7		$240	$3,105	$570	$2,295	$2,295	$1,255	-$667
8		$240	$3,127	$792	$2,095	$2,095	$1,051	$384
9		$240	$3,160	$1,017	$1,903	$1,903	$876	$1,260
10		$240	$3,215	$1,036	$1,938	$1,938	$819	$2,079
						NPV	**$1,922**	

Table 4.8 Corn Bin 2 Net Present Value Calculations and Cash Flow

	Initial Investment	Cash Outflow	Cash Inflow	Taxes	Operating Cash Flow After Tax	Net CF	DCF	Cumm. DCF
0	$13,750	$240		-$84	-$156	-$13,906	-$13,906	-$13,750
1		$240	$4,623	$842	$3,540	$3,540	$3,248	-$10,502
2		$240	$4,606	$348	$4,018	$4,018	$3,382	-$7,120
3		$240	$4,732	$727	$3,765	$3,765	$2,907	-$4,213
4		$240	$4,464	$873	$3,351	$3,351	$2,374	-$1,839
5		$240	$4,464	$1,044	$3,180	$3,180	$2,067	$228
6		$240	$4,464	$1,044	$3,180	$3,180	$1,896	$2,124
7		$240	$4,464	$1,044	$3,180	$3,180	$1,740	$3,864
8		$240	$4,493	$1,268	$2,985	$2,985	$1,498	$5,362
9		$240	$4,536	$1,497	$2,800	$2,800	$1,289	$6,651
10		$240	$4,608	$1,522	$2,846	$2,846	$1,202	$7,853
						NPV	**$7,697**	

Table 4.9 Corn Bin 3 Net Present Value Calculations and Cash Flow

	Initial Investment	Cash Outflow	Cash Inflow	Taxes	Operating Cash Flow After Tax	Net CF	DCF	Cumm. DCF
0	$13,750	$240		-$84	-$156	-$13,906	-$13,906	-$13,750
1		$240	$3,745	$537	$2,969	$2,969	$2,724	-$11,026
2		$240	$3,730	$43	$3,447	$3,447	$2,902	-$8,125
3		$240	$3,842	$417	$3,185	$3,185	$2,460	-$5,665
4		$240	$3,605	$574	$2,791	$2,791	$1,977	-$3,688
5		$240	$3,605	$745	$2,621	$2,621	$1,703	-$1,985
6		$240	$3,605	$745	$2,620	$2,620	$1,562	-$422
7		$240	$3,605	$745	$2,621	$2,621	$1,434	$1,011
8		$240	$3,631	$968	$2,423	$2,423	$1,216	$2,227
9		$240	$3,669	$1,195	$2,234	$2,234	$1,029	$3,256
10		$240	$3,733	$1,217	$2,276	$2,276	$961	$4,217
						NPV	**$4,061**	

Table 4.10 Corn Bin 4 Net Present Value Calculations and Cash Flow

	Initial Investment	Cash Outflow	Cash Inflow	Taxes	Operating Cash Flow After Tax	Net CF	DCF	Cumm. DCF
0	$13,750	$240		-$84	-$156	-$13,906	-$13,906	-$13,750
1		$240	$5,101	$1,009	$3,852	$3,852	$3,534	-$10,216
2		$240	$5,083	$514	$4,329	$4,329	$3,643	-$6,573
3		$240	$5,216	$896	$4,080	$4,080	$3,150	-$3,423
4		$240	$4,934	$1,037	$3,657	$3,657	$2,591	-$832
5		$240	$4,934	$1,208	$3,487	$3,487	$2,266	$1,434
6		$240	$4,934	$1,208	$3,486	$3,486	$2,079	$3,513
7		$240	$4,934	$1,208	$3,487	$3,487	$1,907	$5,420
8		$240	$4,965	$1,432	$3,292	$3,292	$1,652	$7,072
9		$240	$5,010	$1,662	$3,108	$3,108	$1,431	$8,504
10		$240	$5,086	$1,688	$3,157	$3,157	$1,334	$9,837
						NPV	**$9,681**	

4.11 Soft Savings

Along with the NPV analysis for each bin there are soft cost savings. The IntelliAir™ BinManager™ system monitors the temperature and moisture of the grain within the bin. The farmer doesn’t need to travel to the bin site and check the bins. Therefore, there are saving of fuel and labor. Also, if there are increases in temperature of the bin, such as a hotspot, the system alarms the farmer. If the farmer didn’t receive the alarm, they would run the chance of spoiling the entire bin. The automated aeration system gives farmers peace of mind that their grain is of good quality. If an issue is identified, the farmer can empty the bin and salvage the grain before it is spoiled.

CHAPTER V: SENSITIVITY ANALYSIS

5.1 Sensitivity Analysis Objective

The NPV analysis in the previous chapter is presented with forecast data. The objective of this chapter is to provide sensitivity analyses to show the effects of changing certain variables on the NPV analysis for each bin. The three variables I changed are corn prices, moisture percentage of the corn, and the costs difference between continuous and automatic fan operation.

5.2 Sensitivity Analysis Increase/Decrease in Demand

The USDA has forecasted corn prices from 2014 to 2024 in Figure 4.1. The magenta line shows a positive weak trend for that period of time. During the 2011 corn growing season, global demand for corn grew because of drought in the United States. Likewise, after 2011 corn prices decreased. Table 5.1 represents how the NPV analysis would affect each bin each if the price average increased $1.00. Table 5.1 shows that each bin would have a positive NPV values even if average prices were $2.00 per bushel during a 10-year average. Positive NPV’s at $2.00 per bushel corn makes the investment profitable and valuable even when farm prices are low.

Table 5.1 NPV Sensitivity Analysis of Increase/Decrease in Price of Corn

	$ per Bushel of Corn				
	$2.00	$3.00	$4.00	$5.00	$6.00
Bin 1	$262	$1,178	$2,093	$3,009	$3,924
Bin 2	$5,511	$6,716	$7,922	$9,127	$10,333
Bin 3	$2,127	$3,193	$4,260	$5,326	$6,393
Bin 4	$7,387	$8,652	$9,917	$11,182	$12,447

5.2 Sensitivity Analysis of No Aeration Drying

Since data is not available for energy use for corn input moistures above or below the data collected, I chose to show a sensitivity analysis representing a model with 1 to 5 years of no aeration drying. I chose alternating years starting with 2015. Table 5.2 shows that the NPV values are negative and positive values in each of the five years analyzed. The only bin with a negative NPV in the first year was bin 1. This can be explained because bin 1 had the lowest NPV value during the initial analysis. The sum NPV stays positive until the third year without need of aeration. When there are 5 years of no aeration drying, all bins have a negative NPV. Looking at the Gothenburg Frito Lay Corn Facilities historical data, there has only been 1 year out of the last 10 where corn hasn't needed drying during harvest. Therefore it would be logical to assume that the automated aeration system would be a profitable investment in our region.

Table 5.2 NPV Sensitivity Analysis of No Aeration Drying

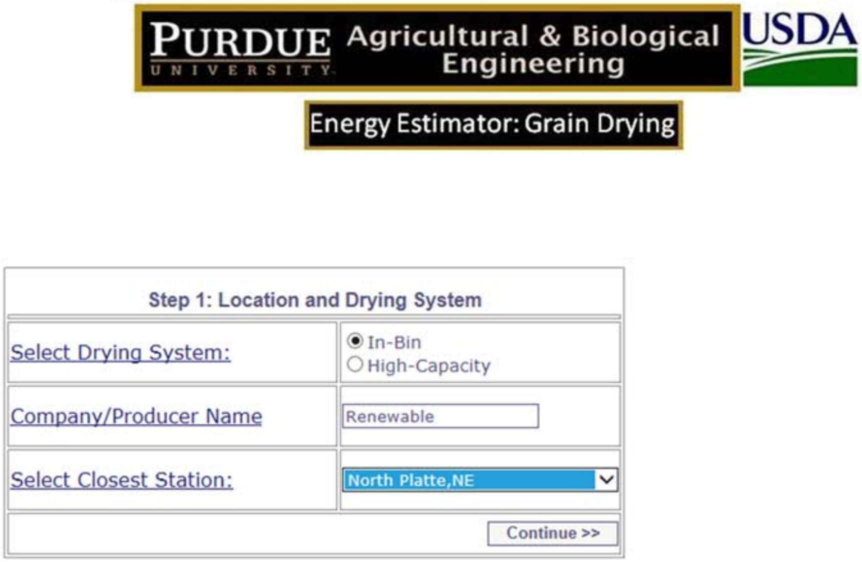
	Years With No Aeration				
	1 Year	2 Years	3 Years	4 Years	5 Years
Bin 1	-$6	-$1,671	-$2,986	-$4,092	-$5,041
Bin 2	$4,933	$2,552	$662	-$930	-$2,291
Bin 3	$1,822	-$112	-$1,638	-$2,923	-$4,024
Bin 4	$6,632	$4,007	$1,918	$159	-$1,344

5.3 Continuous Aeration versus Automated Aeration System Sensitivity Analysis

Running aeration fans continuously for a determined period of time is another option to remove moisture from corn compared to the automated aeration system. For this analysis, I used the Purdue University's Energy Estimator for Grain Drying. This energy estimator can be used to evaluate energy use for different heat sources including; electric heat, natural gas, and continuous aeration grain drying. The grain drying tool was developed by Purdue University, Agricultural & Biological Engineering Department through a USDA-NRCS Conservation Innovation Grant (CIG)

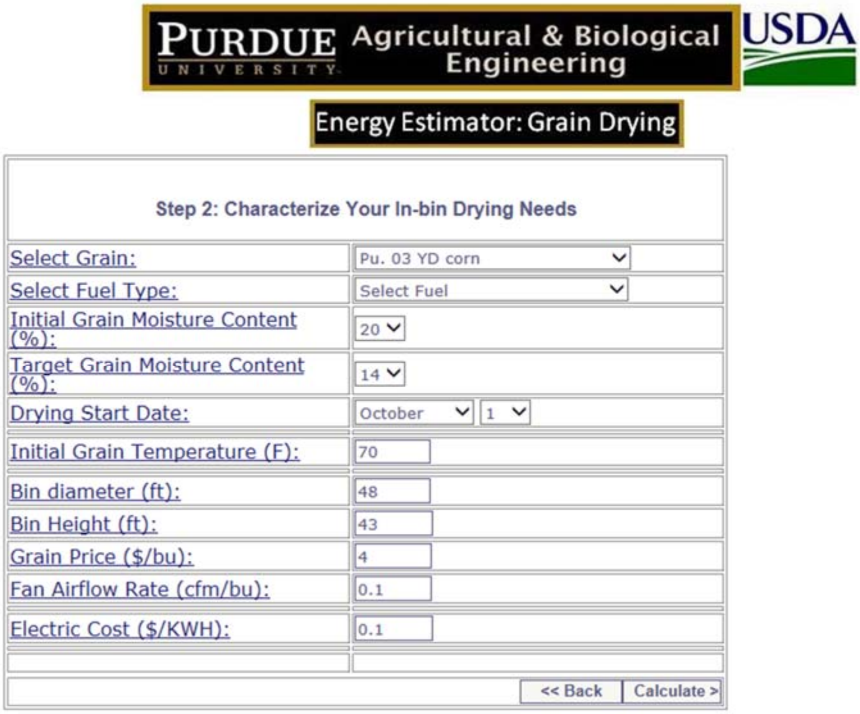
(Purdue University Agricultural & Biological Engineering Department, USDA n.d.). The energy estimator allows a user to input characteristics to analyze grain drying energy costs under the entered conditions (Figure 5.1). An important feature this tool has is the ability to use historical weather conditions to predict the effects of aeration on a grain mass and energy usage. For my analysis, I chose to study the effects of initial moisture percentage versus cubic feet per meter (CFM) per bushel. Table 5.3 shows predicted yellow corn moisture percentages after 92 days of continuous (except for the 1 CFM per bushel row total days were approximately 30). Table 5.4 shows the anticipated energy costs of operating an aeration system with the initial moisture inputs and CFM per bushel for a 60,000 bushel storage bin. Inputs held constant for the analysis are shown in Figure 5.1. To calculate aeration costs savings, the initial input grain moistures and output grain moistures from Table 5.3 were used to calculate dryer charges and shrink loss described in Figures 4.1 and 4.3 holding the price of corn constant at $4.05. Table 5.5 shows the predicted costs savings of running aeration fans continuously. While there are savings from 0.1 to 0.30 CFM per bushel at most initial moisture, the savings decreased as the initial moistures decreased. It is harder to remove moisture from corn as it gets closer to the target moisture of 14%. If the continuous aeration estimates and automated system data are compared at the initial moisture content of 16% and 0.35 CFM per bushel, the automated system produces more savings than the continuous aeration estimate.

Figure 5.1: Energy Estimator's Input Examples



Step 1: Location and Drying System

Select Drying System:	● In-Bin ○ High-Capacity
Company/Producer Name	Renewable
Select Closest Station:	North Platte,NE



Step 2: Characterize Your In-bin Drying Needs

Select Grain:	Pu. 03 YD corn
Select Fuel Type:	Select Fuel
Initial Grain Moisture Content (%):	20
Target Grain Moisture Content (%):	14
Drying Start Date:	October 1
Initial Grain Temperature (F):	70
Bin diameter (ft):	48
Bin Height (ft):	43
Grain Price ($/bu):	4
Fan Airflow Rate (cfm/bu):	0.1
Electric Cost ($/KWH):	0.1

Table 5.3: The Effects of CFM per Bushel on Initial Grain Moisture After 92 Days of Continuous Aeration Fan Operation

		Initial Grain Moisture				
		20%	19%	18%	17%	16%
CFM per Bu	0.10	18.6%	17.7%	16.8%	16.1%	15.3%
	0.15	18.4%	17.5%	16.7%	16.0%	15.3%
	0.20	17.9%	17.2%	16.5%	15.8%	15.2%
	0.25	17.5%	16.8%	16.2%	15.7%	15.2%
	0.30	17.1%	16.4%	16.0%	15.5%	15.1%
	0.35	16.6%	16.0%	15.7%	15.4%	15.1%
	0.50	15.3%	15.1%	15.1%	15.0%	15.1%
	0.75	14.0%	14.0%	14.3%	12.7%	12.3%
	1.00	11.9%	11.7%	11.5%	11.6%	11.0%

Table 5.4: The Cost of Energy per Bushel at Different CFM per Bushel and Initial Grain Moisture After 92 Days of Continuous Aeration Fan Operation

		Initial Grain Moisture				
		20%	19%	18%	17%	16%
CFM per Bu	0.10	0.004	0.004	0.004	0.004	0.004
	0.15	0.010	0.010	0.010	0.010	0.010
	0.20	0.020	0.020	0.020	0.020	0.020
	0.25	0.030	0.030	0.030	0.030	0.030
	0.30	0.050	0.050	0.050	0.040	0.040
	0.35	0.070	0.070	0.070	0.060	0.060
	0.50	0.160	0.160	0.150	0.150	0.140
	0.75	0.330	0.340	0.420	0.170	0.140
	1.00	0.340	0.310	0.280	0.250	0.230

Table 5.5: Drying, Aeration Costs, and Shrink Loss Savings at Different CFM per Bushel and Initial Grain Moisture After 92 Days of Continuous Aeration Fan Operation

		Initial Grain Moisture				
		20%	19%	18%	17%	16%
CFM per Bu	0.10	$3,272	$2,981	$2,632	$2,196	$1,699
	0.15	$3,313	$3,280	$2,758	$2,095	$1,286
	0.20	$3,990	$3,465	$2,773	$1,806	$791
	0.25	$4,391	$3,750	$2,787	$1,672	$374
	0.30	$4,316	$3,537	$2,099	$1,590	$10
	0.35	$4,366	$3,374	$1,718	$700	-$1,112
	0.50	$2,111	$222	-$1,497	-$3,846	-$6,092
	0.75	-$4,800	-$7,753	-$15,939	-$6,060	-$5,990
	1.00	-$10,763	-$11,889	-$12,881	-$13,628	-$11,318

CHAPTER V: SUMMARY AND CONCLUSION

6.1 Summary of Results

Each of the NPV analyses performed on the corn bins using the automated aeration system exhibited positive NPV values. The first sensitivity analysis used to determine how fluctuations in corn prices would affect estimated NPV values determined NPV would continue to be positive at low corn prices and increase as corn prices increased. To conclude, the final sensitivity analysis displayed how the NPV analysis would be affected if the corn didn't need to be dried using the automated aeration system from one to five years. The results showed that all bins maintained positive NPV's for the first two years. Years three, four, and five resulted in mixed positive and negative NPV's for the four bins.

6.2 Recommendation

Based upon the NPV of the grain bins and the sensitivity analysis, corn growers should consider installing an automated aeration system. There are some uncertainties with regards to the profitability of using the aeration system at different moistures, but historical data and under most scenarios suggest that this would be a valuable investment.

The risks associated with this project are increased chance of corn spoiling, uncertainty of weather patterns, or failure of the automated aeration system company. In the past decades, many technology companies have consolidated or failed because the sector is changing rapidly and businesses find it hard to keep up with hardware and software changes. Microsoft purchased FoxPro (a data base company) and after purchase, FoxPro was dismantled and the software was no longer supported.

6.3 Future Study

Future studies could focus on how much energy an automated aeration system would save using an array of different moistures, locations, and bin sizes. This would help justify the installation of automated aeration systems for different sized operations in different regions.

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