BENEFITS OF FLOUR STORAGE AS RELATED TO PROCESS EFFICIENCIES IN MILLING

By

BRENT S. JOHNSON

B.S., Kansas State University, 1982

A THESIS

Submitted in partial fulfillment of the requirements

for the degree

MASTER OF AGRIBUSINESS

Department of Agricultural Economics

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2012

Approved by:

Major Professor
Dr. Bryan Schurle

ABSTRACT

The milling of wheat into white flour is a high volume, low margin business. Flour is a commodity. Competition is fierce. Over the past several years, there have been several mergers and acquisitions leading to fewer, but larger flour mills. The number of companies in the flour milling business has diminished as well. Flour sold in small packages on the grocery store shelf is but a small part of the business these days. Most flour is sold to commercial bakers in large bags or bulk trucks.

The process of milling wheat into white flour consists of numerous variables within an extensive collection of equipment. It is the job of the miller to minimize the negative impact of these variables or at least hold constant as many of these variables as possible while achieving the best efficiency possible. To lessen the effect of these numerous variables on a large extensive system makes for a well running operation. When efficiency is achieved, a flour milling operation can be a profitable venture. A number of the variables that influence efficiency are affected by the amount of flour storage that a flour mill has.

This thesis examines the benefits of flour storage as related to flour process efficiencies in milling. With flour mills operating at large output capacities, it is necessary for a flour mill to have adequate bulk flour storage bins as well as the right amount of warehouse space. Changes from one type flour to another in a flour mill require some time and an abundance of intervention by a skilled operator or miller. Having the proper amount of storage space makes it possible to minimize changes as well as the opportunity to optimize production of each specific flour type that is processed on the mill. To justify

capital project money to invest in the proper amount of storage can be a challenge. Warehouse space and bulk flour storage can be expensive, and it is difficult to quantify how theoretical improvements will increase production and quality in the end product of flour.

Using regression methods, production data obtained from an average sized commercial flour mill was used to estimate the increase in extraction due to a longer length of run allowed by the addition of storage space. By increasing the time a mill stays on a specific wheat mix to a minimum of twenty hours, there is a theoretical increase in extraction of 1.02 percentage points, resulting in wheat savings of over $500,000 per year. This resulting savings on the raw input material showed that capital expenditures on storage can be justified. A positive net present value and good internal rate of return show that the increased efficiency due to longer lengths of run justified the additional expense of the additional storage capacity.

As volatility and the price per bushel of grain continue to increase, having the proper plant infrastructure with regard to storage space is of the utmost importance. Other benefits of storage will be realized as well in the area of flour quality and customer service.

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ACKNOWLEDGMENTS

The author wishes to thank Dr. Bryan Schurle and the MAB Staff for keeping me on task. Additional thanks are due to my previous and current employers for their support of pursuing my degree. Most importantly, thanks to my wife, Vicki, for her help and encouragement in the completing of this endeavor.

CHAPTER I: PROBLEM STATEMENT

Can additional bulk storage and warehouse space at a commercial flour mill be justified by resulting gains in process and quality efficiencies?

1.1 Explanation

There are currently (2011 yr) only 168 wheat flour mills in the United States. This is a departure from the days when many communities had their own flour mill. The capacities of flour mills have grown dramatically while the number of flour mills has declined. Small mills have disappeared or have consolidated into very large companies. In the U.S., 95.4% of the flour milling capacity is produced by the 24 largest milling companies. Even more interesting is that 55% of the U.S. capacity is produced by 3 large companies. ADM Milling Company is 1st with a daily milling capacity of 298,100 CWT/day, (CWT=100lbs). Horizon Milling, LLC is 2nd with a daily capacity of 270,500 CWT/day, and ConAgra Flour Milling Company is 3rd with 251,100 CWT/day. Capacities for companies further down in the rankings decline dramatically. Cereal Food Processors, Inc. is ranked 4th in the U.S. with 100,060 CWT/day. The U.S. domestic flour milling industry produced 414,658,000 CWT (CWT=100lbs) of wheat flour for the 2009 calendar year. This equates to 134.6 lbs per capita per year on the basis of 307.5 million people. Looking at statistics over the last 20 years, production has trended down since the year 2000 when total domestic production was highest for the period at 421,270,000 CWT. Per capita disappearance was highest at 146.8 lbs per capita for the year 1997 (2011 Grain & Milling Annual).

Flour milling is a low margin, high volume business. It is important to produce at a high volume in order to be profitable. Flour mills typically run 24 hours a day, with up to 7 days a week in order to be profitable. Flour mills are sized with high flour capacities. It is typical to produce "millions" of pounds of flour on a daily basis. With high capacities, an extensive processing flow, and a plant with several floors of grinding and sifting equipment, it is important to minimize flour grade changes and wheat mix changes to maximize processing efficiencies.

With economies of scale and the process of separating the wheat kernels' bran from the white flour component inside the kernel, there are a lot of adjustments to be made every time a different type of wheat is introduced in the mill and every time there is a flour grade change. With a continuous process and few production employees, it is a lengthy task to adjust the process to its optimum operating efficiency. Once a new type of wheat or "grist" is introduced to the mill, it could take several hours of adjustments to optimize the quantity and quality of the flour being made. Other parts of the process require an employee's full attention as well when there is a wheat or grade change (a grade change is when a flour with different treatment is made from the same type of wheat). While employees are going through the many steps of making wheat and grade changes, the equipment is not getting adjusted for optimal efficiencies. In many cases, by the time all of the adjustments are made on one type of wheat or grade of flour, it is time to go to the next wheat or grade of flour.

There are other efficiencies to be realized by minimizing wheat and flour grade changes on a flour mill. Prior to the process, the grain elevator has to stage the different wheat mixes for the mill to grind. Several changes require the grain elevator to work longer hours positioning wheat. A savings in labor expenditures would be realized in the grain elevator if there were longer wheat mix runs and minimized flour grade changes on the mill. More bulk storage and warehouse space would be required to accomplish these benefits. More storage would also allow efficiencies in the flour packing department. More bulk flour storage would enable the packing line(s) to pack longer runs of specific flours. This would minimize bag or web (rollstock that bags are formed into) changeovers. Quality checks and paper work would also benefit from fewer changeovers in packing. Additionally, there would be savings on not having to purge the system between different flours. There are other efficiencies that can be found in the warehouse as well.

To minimize wheat and flour grade changes would require additional bulkhouse space and warehouse space at a commercial flour mill located in the Midwest. The current warehouse is very small and requires a lot of changes on the mill and on the packer in order to meet the customers flour grade needs. In many regards, the warehouse is more of a truck and boxcar staging area. Often times, production is taken straight from the packer into a truck trailer or a boxcar. The product does not go to the warehouse. Additional bulk bins or bulkhouse storage for flour storage would not only benefit the milling process by allowing extending runs of wheat mixes and less grade changes, but would allow the packing department to pack out longer runs of specific types of flour. There would be efficiencies by doing this. Packing labor and quality assurance support could be minimized on weekends (often premium time wages) by additional bulkhouse storage. More flour could be packed during the week. Additional warehouse space and bulk flour storage would require capital money, and it is difficult to justify an addition to the warehouse or bulkhouse when the plant is operating at an acceptable level.

To further emphasize the importance of a warehouse addition or increasing bulk flour bin capacity at the mill location in this study, it should be noted that such a project would benefit customer service and quality initiatives as well as processing efficiencies. While there are chemical maturing additives that help a flour's baking performance, natural aging of flour is becoming more desirable with some grades of flour. In some cases, customers specify an amount of aging on their flour. In cases of inadequate warehouse or bulk bin space, the distribution chain is relied on to attain the minimum amount of flour aging or maturing. When a customer specifies a period of aging before receiving their flour, shipment by rail is hoped for so the flour can age while in transit. Many European countries use flour storage as a way to mature their flour and avoid the use of chemical baking improvers such as azodicarbimide. Use of this chemical flour maturing agent in the state of California has recently met its demise because of a state proposition. As ideas on the east and west coasts often influence the rest of the U.S., azodicarbimide could see less and less use. Another consequence of inadequate storage space is that it does not allow the temperature of flour to come down after processing and can cause handling and condensation problems when packing or loading out the flour in bulk. The ability to keep product on inventory within a warehouse would also be another customer service benefit that could be realized with a warehouse addition. Quality would be better served with additional flour storage. While analysis of flour specifications has gotten faster over the years, it still takes some time to identify and resolve any deficiencies that may occur while flour is being produced. In a typical flour mill, production rates can be 550 pounds per minute. In the event product is not meeting specifications, it can quickly fill up bulk house storage. With inadequate flour storage, there is a risk of sending out flour that is not within specifications because product is being shipped out soon after it is manufactured. Finally, a number of quality issues with flour are simply blended off with flour that is within specifications. An adequate amount of bin space is required to do this blending, and at the same time there has to be a bin available for the mill production to go to. The blending process cannot be hurried in order to create bin space for mill production. Hastily done flour blending to dilute a quality issue can put quality at risk. Samples taken from production to ensure that product meets specifications are simply “audits” of what eventually finds its way to a flour mill’s customers.

This thesis will determine if additional flour storage creates processing efficiencies. It will do this by analyzing data from a commercial flour mill located in the Midwest. It will analyze the effects that longer wheat runs and resulting gains in temper time have on processing efficiencies. In order to achieve longer wheat runs and temper time, additional flour storage space is needed.

Chapter 2 of this thesis will examine past studies on flour mill processing efficiencies. Chapter 3 will explain the details of the theory from the subject flour mill and how process efficiencies can be determined. Chapter 4 will analyze the data through statistical information, graphical analysis, and regression analysis and determine the economic implications. Chapter 5 will conclude the study.

CHAPTER II: LITERATURE REVIEW

2.1 The Operative Miller and Milling Efficiency

While many good refinements have been made to present day milling equipment, as with the older equipment, many adjustments are required when changing wheat mixes on a flour mill. In an Association of Operative Millers (A.O.M.) Technical Bulletin, The Operative Miller and Milling Efficiency, it is pointed out that "a change in the wheat mix will often require different conditioning of the wheat and different settings of the mill which will affect milling results (Hibbs, 1975)". This relates to the problem statement in chapter 1. Insufficient flour storage requires more frequent wheat mix changes on the mill and will affect milling results.

2.2 Bulk Storage for AOM Workshop 1968

In regards to bulk storage "the general rule for minimum amount of flour storage is three times daily plant capacity" (Hoisington, 1968). This Technical Bulletin explains the "three" rule by saying that packing of flour and loading of flour should be avoided on weekends because of premium time wages. If packing and loading of flour concludes at the end of 1st shift on Friday, there needs to be sufficient bulk storage to hold 2 and 2/3's days of production. The general rule calls for three times with consideration of one third of a day for a safety margin.

2.3 Bulk Flour & Feed, Economics of Bulk Storage

J. W. Speers, General Mills, Inc. puts a high value on adequate bulk flour storage by pointing out that it is a means to control quality. He further states that adequate bulk storage space is needed to accommodate different customer needs. Producing different flours requires considerable manipulation on the mill such as wheat mixes, ingredient addition, stream selection, equipment adjustment. Speers says that short runs make it difficult to assess the quality of a flour. Speers regards efficiency in his paper as well. "Storage can be made to reduce the number of wheat mixes milled which will result in less wheat changes on the mill and more uniform and efficient milling" (Speers, 1955).

2.4 Bulk Flour Storage-The Operator's Viewpoint

This technical bulletin (Atkinson, 1950), begins by stating that having at least a minimum amount of adequate bulk flour storage is the most important factor in milling with respect to the "cost of production" and "flour uniformity". The author further points out that an adequate amount of bulk storage minimizes changes of wheat to make different grades of flour. This minimizes the adjustments needing to be made on the mill and leaves less of a margin for error, thereby making it possible to save on the cost of the wheat used in producing a specific grade of flour. Flour is more uniform as well. To the baker, uniformity is the most important (or at least towards the top of the list) factor with regard to flour quality. Flour is the baker's major ingredient. A flour that is consistent and uniform in its attributes will require minimal changes to a baker's process. With adequate flour storage, packing and warehouse activities can be minimized on the weekends. Labor and supervision on the weekends is usually at an overtime rate as is the staffing of any kind of support in the quality laboratory.

2.5 Bulk Storage for the Flour Mill

In an Association of Operative Millers Bulletin, Don Noyes lists a number of advantages in having adequate bulk flour storage (Noyes, 1963). Mr. Noyes makes the claim that "the packing and loading department functions separately from the mill, therefore delays caused in one will not affect the other." Because of adequate flour storage, the mill can stay on a specific grade of flour for a long period of time. This gives the mill operators time to fine tune the process thereby resulting in efficiencies. As other references have pointed out, adequate bulk flour storage can minimize plant staffing on weekends. This can result in a savings of overtime wages.

2.6 Bulk Storage of Mill Products

Another reference states that bulk storage is necessary in order to store several hours of production and then blend all the production together before packing, so that the customer receives a uniform product. Bulk storage makes it possible to better aerate and "age" flour as opposed to packing it immediately after being milled. The reference claims the biggest advantage of bulk storage is being able to better schedule and staff packing. With enough bulk storage and packing capacity, packing can be limited to only dayshift weekdays. This strategy will avoid paying shift differential and overtime on the weekends. Packing can be accomplished at maximum capacity on a reasonable schedule for labor and supervision. Bulk flour storage of 2 to 3 days capacity is the given recommendation (Lockwood, 1948).

All the literature reviewed recommends adequate flour storage space. The benefit seems to be in uniformity, efficiencies, less in wages, and quality. The references refer to uniformity in the milling process and the packaging part of the operation. Less wheat mix and flour grade changes on the milling process would provide more uniformity in the flour. Many system variables held constant yield better uniformity. While packaging systems are typically smaller and less extensive, minimal flour changes would also bring uniformity to the end product. While the references do not specifically mention the grain elevator operation as a means of uniformity, it is essential to this cause. The grain elevator is where uniformity starts at a flour mill. With typical conveying rates in the thousands of bushels, any small deviation in the grain elevator can turn into a huge problem in the flour mill where flow rates are often around one tenth as large. As mentioned earlier, the entire flour milling process is monitored (and controlled) by samples taken on a frequency to audit the process. Samples taken hourly in the grain elevator represent several hours of milling time on the flour mill.

The above paragraph describes uniformity in ways that it benefits the process. Uniformity and consistency also benefit the baker. If the baker receives a flour shipment from different wheat mixes or production runs, it is probably not as consistent as it would be if it were made from one wheat mix or production run. The baker cites consistency as being the biggest or close to the biggest flour attribute. The baker has minimal adjustments to the process if the flour (his largest ingredient) is consistent and uniform.

The literature review also cites "efficiencies" as a benefit of adequate flour storage. Staying on the same wheat mix or minimizing grade changes, allows the miller to optimally adjust all of the equipment. Sampling is less of a task. When transitioning to a different wheat mix or grade change, there is transitional flour produced (setback). Setback flour is a mixture of the flour that the mill is transitioning from that is mixed with flour that the mill is transitioning to. This flour does not meet specifications. This transitional flour can be dry as a result of the set up time to optimize tempering. As soon as sampling shows that the transitional flour meets grade specifications, flour is diverted from the setback bin to a regular flour storage bin. The transitional flour in the setback bin gets blended at a slow rate (typically 5-10%) back into the flour that is now on grade. Minimizing these transitional changeovers and maximizing the length of specific flour runs avoids the loss of efficiencies due to changeovers. Minimizing the blending in of setback flour can help avoid some quality problems as well.

When there are minimal flour changes, there are fewer adjustments for the packer to make. Sampling is less of a task. Time is saved on “change over procedures”. There is less waste in changeover or “setback” flour. Another efficiency in packing realized with adequate storage space is scheduling labor to avoid overtime. Hoisington explains the “rule of 3” above. With adequate flour storage, you can avoid overtime wages for packing on the weekend.

Adequate flour storage can benefit the quality of flour. As Speer states above, frequent flour changes make it difficult to assess the quality of the flour and affect the uniformity of the flour.

CHAPTER III: THEORY

3.1 Qualitative Theory

Quality issues are very important when assessing the benefits of flour storage. While there are a number of qualitative reasons to support adequate flour storage, these reasons are difficult to assign a dollar value. Quality problems can result in costs that never appear in the budget. These can be quantified and even used for justification in addressing problems; however, there are probably many more problems that are never fully, if ever accounted for. These are the issues that never get reported to customer service or if they do, the customer "makes do" and/or compromises his process to keep things going. Problems that are never reported can be the most damaging as a company providing goods or services will never fully understand the problem and will not have insight as to how to solve the problem. A customer that has a problem and does not report it may very well take business elsewhere. This further illustrates how difficult it is to assign a value to a qualitative problem.

3.2 Quantitative Theory

While the qualitative problems are well worth mentioning, this paper will focus more upon the quantitative aspects of the benefits of flour storage. The theory behind this subject is that the longer all process variables are held constant, the more efficient the process will be. More specifically, the longer a large commercial continuous process flour mill produces flour from the same type of wheat the more efficient this process will be. There are even further efficiencies to be had from making the same type of flour while on the same type of wheat. There are several different "grades" of flour that are made from the same type or "grist" of wheat. The differences in the flour grades occur by adding different ingredients as well as making some equipment adjustments. Flour grades exist to meet customer's flour requirements. As mentioned previously, "all process variables" must be held constant to realize these efficiencies of volume. This includes specific "lots" of wheat, temperature and humidity, employees on shift, moisture added in tempering, and many other variables. There can be many variables when processing a raw natural commodity such as wheat. This paper will analyze these variables that stay constant for the most part. By using a large amount of data to support the theory of this paper, variability should be minimized. While these things are important, a good portion of the "variables" are repeated every day. Employees change each shift, but the employees are the same each day. Temperature and humidity changes throughout the day, but are somewhat similar changes each day. Temperature and humidity changes throughout the seasons happen slowly and are more subtle.

An adequate amount of scale data of wheat going into the process and flour at the end of the process will be gathered and analyzed to examine the benefits of adequate flour storage. Furthermore, to maximize the length of time a large commercial mill is on a specific wheat mix as well as maximizing the time on a specific flour grade, there has to be adequate flour storage space. Bulk flour storage is used immediately after the wheat is processed into flour. Bins that can hold 100,000 to 200,000 pounds of flour are typical. Flour is accumulated and stored in these bins until it can be packed in bags or loaded into a bulk flour truck trailer or railcar. Having adequate bulk flour bin storage, allows time to ensure that the flour meets its requirements. Bulk storage bins ensure that there are no delays in packing or loading out of flour. It also ensures the continuous process milling operations have space available to store the flour that it is making (Noyes, 1963). Further benefits include allowing the flour to cool before packing or loading. Warm flour can cause flowability problems as well as condensation problems. While there are some added chemical ingredients that help flour mature, natural aging or oxidation are desirable. With adequate bulk flour storage, paying overtime on the weekends can be avoided. Packing and loading employees and quality control employees often make one and one half to double wages when working weekends (Lockwood, 1948).

After bulk storage and the packing of the flour, there needs to be adequate warehouse space. The amount of warehouse space is dependent on a number of variables such as number of SKU's (stock keeping units), loading doors available, loading hours, etc. Adequate warehouse space is important as is bulk flour storage for many of the same reasons. Flour maturing, flour cooling, and having adequate storage space for the weekend are all benefits of having warehouse space.

Building more bulk storage or flour warehouse space requires capital. It is often difficult to justify projects like this without having a lot of supporting evidence. By quantitatively determining the savings or revenue realized with longer wheat mix runs and a minimum of flour grade changes, a net present value and an internal rate of return will be calculated for additional flour storage. This will help determine whether investing capital for additional storage is a viable idea.

Calculating the net present value (NPV) will either result in a positive or negative number. A positive number indicates that the project will be worthwhile, while a negative value indicates that there would be a loss on the project. An internal rate of return (IRR) will provide more insight into the viability of a project surrounding storage of flour (Mansfield, 1999).

CHAPTER IV: METHODS

4.1 Optimization Efficiencies

There are many factors that affect optimization efficiencies in a flour mill. While many factors can be controlled fully or to some degree, there are many factors that cannot be controlled or to very little degree. In some cases, the technology does not exist to dependably control the factor or if the technology does exist, capital costs are too high. Flour milling is typically a low margin business and any capital investments must meet an investment rate of return (IRR) or net present value (NPV) minimum threshold. In the case of IRR, a minimum threshold range would be approximately 8%-15%. There are a number of factors that cannot be fully explained. The behavior of a raw agricultural commodity such as wheat cannot always be accurately predicted. There are other quality factors of wheat that are important to optimization efficiencies. These quality factors are important when procuring wheat for the flour mill to process. A competent grain buyer concerned with the performance of the flour mill that he/she is procuring wheat for will be attentive to these quality factors up to the point where he/she has to pay above the market price for a bushel of wheat. Furthermore, there are crop years where a miller has to compromise his beliefs on wheat quality and simply take nearby wheat that is readily available.

4.2 Flour Extraction Model

A model representing “optimization efficiencies” for extraction % in a flour mill could be represented as: **Extraction %=f(length of run, length of temper, % moisture of temper, type of wheat, quality of wheat, experience of staffing, temperature & humidity, downtime/start-up, maintenance of mill).** A large part of this thesis will be concerned with this model.

To further explain and define the components of the model above:

4.2.1 Extraction %

For the purpose of this thesis, Clean Tempered Wheat Extraction % is the percent of flour extracted from milling wheat that has been conditioned. Conditioned wheat is wheat that has been cleaned of impurities (dust, corn, oats, rocks, chaff, etc.) and then tempered. Tempering is a term that refers to mixing water with dry wheat. Dry wheat typically has a dry wheat moisture of 11-12%. Water is added to get a tempered wheat moisture of approximately 16%. The wheat then rests in a holding bin for a minimum of 6 hours.

4.2.2 Length of Run

This is the length of time that a mix of wheat is continuously milled on the mill. A mix of wheat is a large quantity of wheat that has a specific protein level and a specific variety of wheat or a specific ratio of wheat varieties. The objective of this mix of wheat is to produce a flour for a specific end use. The objective is to have a consistent mix of wheat going to the mill. For the purpose of this paper, *length of run* is a minimum of 11 hours.

4.2.3 Length of Temper

Length of temper is referred to above in sub-section *4.2.1*. Tempering is done prior to milling to help facilitate the removal of the bran which is the outer portion of a kernel of wheat. Tempering makes the bran more resilient to where the bran can be removed in larger pieces as opposed to smaller pieces when grinding bran. Tempering is also done to mellow the interior of the kernel especially on wheat varieties that have a hard kernel characteristic. Part of the milling process involves crushing the interior of the kernel of wheat into flour. Mellowing of the middlings optimizes this part of the process. *Length of temper* is an important part of tempering. Depending on wheat variety, suggested temper times can approach as much as 72 hours. In certain instances, flour mill capacity is increased while temper time is not. This requires that a mill operate at a shorter temper time than optimum. In some cases this could be as low as 6 hours for hard wheats. Soft wheat tempers are typically shorter. Six hours of temper time in the case of soft wheat may be adequate.

4.2.4 Type of Wheat

Winter wheat and spring wheat are the two different distinctions that describe how wheat is grown. Winter wheat is planted in the fall and then harvested in early summer. It lies dormant under the snow during the winter. Hard red winter wheat is the class of wheat that makes up the majority of all wheat harvested in the United States. It has the widest growing range geographically as well. There is a soft red winter wheat that is grown in areas with higher rainfall. Soft red winter wheat has a much softer middling or endosperm. Spring wheat is different from winter wheat in that it is planted in the spring and harvested in late summer or fall. It is grown in the northern United States and Canada and is more limited geographically when compared to winter wheat. Hard red spring wheat is normally higher in protein that hard red winter wheat. The middling or endosperm is normally harder than that of hard red winter. In most crop years, hard red spring wheat is priced at a premium to hard red winter wheat.

There are different subclasses of wheat within the above described types of wheat. Within the wheat classes there are many varieties of wheat that have different yielding rates per acre for the farmer and different percent extraction rates for the miller. Different varieties of wheat have different characteristics depending on where they are grown geographically and what the climate of that region might be as well. The logistical channel that wheat follows in the United States makes it difficult to keep wheat varieties identity preserved. There is a lot of co-mingling of different wheat varieties as wheat gets accumulated and stored in the system of grain elevators that we have in the United States. Also, the grain trade in the United States does not promote identity preserved wheat. Wheat is a commodity and is referred to by broad categories. To further explain the importance of type of wheat and its importance to extraction, the level of moisture added in the tempering process and the length of the tempering time (time wheat is allowed to rest after adding moisture) are both important factors when it comes to percent extraction.

4.2.5 Experience of staffing

The experience of staffing in a flour mill is very important with regard to extraction of flour. Flour milling is often described as being an art and not being strictly a science (Ward, Arlin B). There is not a published set of instructions on flour milling. There are too many variables to be considered. There is training of employees by following the more experienced employees around, and there are some written courses and training aids for flour milling. Formalized courses and a degree in Milling Science Management are offered at Kansas State University. The success of a miller begins with a good foundation in education and is further improved upon with years of experience and that individual's own initiative in thoroughly exploring the process of milling. Typically a mill operates 24 hours per day and most of the days of the week. To staff a 24 hour per day operation, there are usually three crews of employees that work eight hour shifts. The different levels of experience on these shifts does have an effect on flour extraction, but using data over a long period of time and having the same employees on shift should minimize the significance of employee experience to the modeling done in this thesis.

4.2.6 Temperature and Humidity

For the purpose of controlling the quality of the flour being milled and the extraction rate, mill environments are typically kept warm and humid. Part of the milling process is the adding of moisture during tempering. As explained above in sub-section *4.2.3 Length of Tempering*

It is important to have moisture present in the mill stocks or grist of the mill during the entire process. The warm and humid environment of the mill helps accomplish this. A cool temperature in the mill does not have the water carrying ability of a warm temperature; therefore, the temperature of a mill is often 80 degrees Fahrenheit or more.

With the changing of the seasons it is often difficult to maintain a consistent mill environment even with sophisticated air handlers that recycle and heat room and/or outside air in a mill. In some regions with cold winters, the mill environment is further complicated by cold wheat entering the process from being stored in an unheated grain elevator.

For the purpose of this thesis, it is hoped that using a large enough set of data will make *Temperature and Humidity* less of a significant factor when considering extraction of flour.

4.2.7 Downtime/Start-up

In a low margin business like flour milling, volume is very important. To make volume, the mill needs to run every available opportunity. Consistent run time makes for a consistent product and consistent mill performance. Having said this, a mill has to shut down on occasion for making necessary repairs, accomplishing sanitation tasks and observing at least some of the holidays. When a mill shuts down, the environment looses humidity and the temperature of the building and equipment goes down below optimum levels. The importance of *Temperature and Humidity* is explained in the above sub-section *4.2.6.*

When starting up after a mill shut down, it takes several hours of operating the mill to optimize mill performance. There are numerous adjustments that the miller has to make on a cold mill. Once the equipment warms up, the miller makes further adjustments. The data set that will be used for this thesis will consider mill start-ups in the model for mill extraction.

4.2.8 Maintenance of Mill

As was earlier explained in sub-section *4.2.7,* downtime and start-ups do have an effect on mill performance. It is for this reason that maintenance on mill equipment is important to the extraction of flour. A good maintenance program will focus on preventative and predicative maintenance. Efforts will focus on inspection of equipment and repair frequencies that will minimize having to shut down the operation because of equipment failure.

A preventive and predictive maintenance program helps in accomplishing repairs on scheduled down days as opposed to making repairs in a break down situation. In the event of a breakdown, repairs are often hurried and incomplete. This can lead to further unscheduled downtime and is certainly not a good practice for optimal mill performance. For purposes of extraction, unscheduled downtime due to maintenance and/or other reasons will be considered in the extraction model.

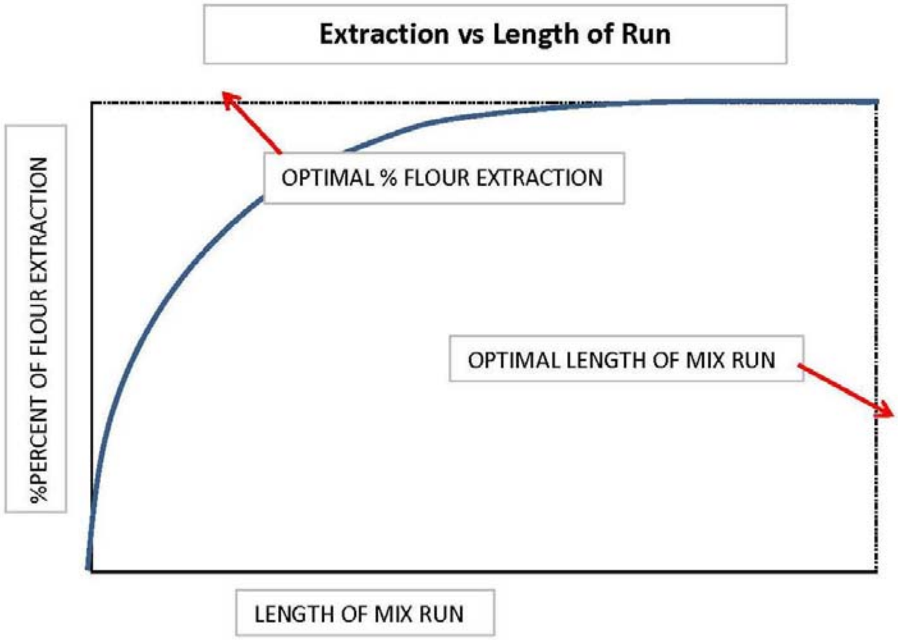
4.3 Key Components of Flour Extraction Model

As was explained in the earlier chapter on **Theory**, the objective of this thesis is to determine if additional bulk flour storage and warehouse space would increase flour extraction. While the flour extraction model considers several variables, the ones that support the objective of this thesis are *length of run and length of temper*. Unless there is supporting data otherwise, the remaining variables in the extraction model will be held constant. To further explain the variables of *length of run and length of temper,* length of temper is dependent on length of run. The equipment that does the tempering only has slightly more capacity than the milling equipment that is grinding up the tempered wheat. It is only possible to gain and keep longer hours of tempered wheat by having longer lengths of run. On shorter lengths of runs, temper time is lost because of time spent changing to a different mix of wheat.

The commercial mill providing the data for the extraction model has varying lengths of mill mix runs as well as varying lengths of temper. While the data set has examples of longer mill mix runs and longer temper times, often times the length of run and length of temper are at minimal levels that are sufficient to meet flour quality requirements. Currently, not a lot of concern is given to length of run and length of temper with regard to flour extraction. The reason for this situation is because of limited bulk flour storage and warehouse space.

The relationship between optimal flour percent extraction and length of mill mix run is shown graphically in figure 4.1. With the horizontal axis being length of mix run and the vertical axis being percent of flour extraction, the optimal length of run for the optimal flour extraction happens when the line on the graph turns horizontal. At this point, extraction will remain constant.

Figure 4.1 Percent Flour Extraction over Length of Mix Run



4.4 Value of Percent Increase of Flour Extraction

In the earlier sub-chapter (4.2), the flour extraction model was explained as a way to determine the significance of several variables that contribute to flour extraction from wheat. If the significance of variables can be quantified, it would then be possible to consider improvements to this variable or factor with the objective of improving extraction. The value of an incremental increase in flour extraction is represented in the following model: \$ of extraction increase=f(% extraction increase, value of flour, value of millfeed). In simple terms, a flour mill produces two different products from wheat. These products are flour and millfeed. While maximum flour production is the objective, what remains of the wheat going through the milling process is called millfeed or feed midds. This material is the bran or outer husk of the wheat kernel as well as any foreign material that has been cleaned from the wheat (for example: corn, oats, chaff, straw, weed seeds, dust). The bran and foreign material is ground for a consistent product and one that does not have any whole seeds in it that could sprout. In determining the value of and increase in extraction, any gain in flour extraction is a loss of millfeed as shown in Table 4.1.

Table 4.1 Example of relationship between flour and millfeed.

% of Wheat to Mill	Flour % or Extraction	Millfeed %
100%	73%	27%
100%	74%	26%
100%	75%	25%
100%	76%	24%

4.5 Determining Net Present Value for Capital Project Consideration

If the methods previously discussed show that length of mill mix run time increases flour extraction, the value of the increase in extraction may possibly support a capital project to help optimize extraction. Net Present Value (NPV) is a tool used in evaluating whether such a capital project is a wise investment. The NPV is calculated by subtracting the required investment of a proposed capital project from the present value (PV) of the investment. NPV=PV-required investment (Brealey, R.A. and Meyers, S.C., 2000). While a positive net present value would be an acceptable investment, there is often a corporate minimum threshold that has to be met or exceeded in order to be a viable project. One capital project to be considered would be an increase in bulk flour storage or bulk house bins. Having more bulk flour storage would allow longer mix runs on the mill. It would also allow the packing and loading departments to avoid some of the overtime situations encountered when working weekends.

If warehouse space was increased, more bagged and palletized product could be stored which would also allow for longer runs on the mill as well as longer runs on the packer and other associated equipment. This is another example of an efficiency at a flour mill.

A net present value will be determined for both bulk flour bins and additional warehouse space using some industry average costs for construction.

CHAPTER V: RESULTS

5.1 Derivation of Flour Extraction Model

As shown previously in section **4.2,** a model representing optimization efficiencies for extraction % in a flour mill could be represented as: **Extraction %=f(length of run, length of temper, % moisture of temper, type of wheat, quality of wheat, experience of staffing, temperature & humidity, downtime/start-up, maintenance of mill).** All of these variables have been defined previously in this document. They would all appear to positively increase **Extraction%** in a commercial flour mill. In running a regression on the data set of this study, while some of the variables are significant and show a positive correlation to **Extraction%,** a number of the variables do not support an increase in **Extraction%.** The following content will review each variable and describe how it behaved when included as a variable in a regression.

Length of run-throughout the process of running several regressions, length of run always stayed significant ($P<.05$). The sign of the coefficient was always positive as well indicating that longer lengths of run would increase **Extraction%.** This supports the possibility that additional bulk storage and warehouse space at a commercial flour mill might be justified by resulting gains in process and quality efficiencies. The whole premise of this study is that longer runs will increase **Extraction%.** In order to increase the length of run or amount of time that a milling unit is on a specific wheat mix, there needs to be an increase in a combination of bulk flour bin and warehouse storage for flour.

Length of temper-this variable was significant ($P<.05$) on many of the trial regressions, but it did not show a positive coefficient. Leaving it in the equation would lower the **Extraction%.** Practical experience would say that this does not make sense. Trying to run a commercial mill with less than adequate temper time on hard wheat is nearly impossible. There are problems with balancing the loads on equipment and quality issues. The problem with length of temper might be that soft wheat was included in the data set. Soft wheat is an anomaly when compared to the milling of hard wheat. Temper times are very minimal when compared to hard wheat. Tempering is done to toughen the bran and mellow the endosperm. With soft wheat, the endosperm is already soft and mellow. Temper time is minimal simply to toughen the bran and produce a flour with a consistent moisture and other quality attributes. This could be why the coefficient on length of temper was negative.

% moisture of temper-this variable was not used in the regression. % moisture of tempered wheat values were not collected for this study. The particular location of the plant where the data set came from did not routinely monitor these values. % moisture of temper was adjusted up or down depending on the resulting flour moisture at the end of the milling process. With regard to “moistures”, flour and dry wheat moistures were collected as part of the data set. Neither one of these variables were significant when modeled in a regression. While flour moisture and dry wheat moisture is important when calculating a “dirty wheat extraction” (lbs flour/lbs raw wheat), this study only considered clean, tempered wheat (lbs flour/clean tempered wheat). Had this study utilized more flour analysis data, dry wheat and flour moistures might had been more of an influence in the regression.

Downtime-down time hours were tracked for this study, but when used in the regression it was not a significant variable. P-value was greater than 0.05. Downtime should affect extraction. With each downtime event, the mill loses extraction as it is starting back up. When there is a mill start-up, the loading to the mill equipment is not optimum. The grinding and sifting equipment is not running at optimum efficiency for a mill start-up. It is possible that the data set was not large enough to provide accurate results when used in a regression. It should also be noted that the “downtime” data collected was the number of hours the mill was down. This variable would have been better represented as the number of downtime events rather than the total hours.

Start-up-as with the “downtime” variable above, start-up was not a significant variable when it was used in the regression. P-value was well above the 0.05 value required for P to be significant. Again, as with downtime, this does not make sense possibly due to the size of the data set. Start-ups occur after being scheduled down (because of lack of business) on a Sunday, holiday, or after scheduled repairs. As mentioned above, start-ups on a flour mill are not efficient. Start-ups are often where mechanical failures happen.

Maintenance of Mill-data was not collected on maintenance. There was an assumption made that there was an adequate level of maintenance.

Type of wheat-the data set contained several different wheat mixes that could be classified into predominately hard red winter (HRW), hard red spring (HRS), and soft red winter (SRW). When these wheat categories were included in the regression, they were all found to be significant $P<.05$ and they all had positive coefficients which would contribute to an increased extraction.

Quality of wheat-using the Perten SKCS Analyzer, a number of quality variables were gathered for this paper’s data set. This machine does an analysis on individual kernels of wheat and then supplies an average as a result. The variables collected were kernel weight, kernel hardness, kernel diameter, and kernel moisture. When used as a variable in a regression, there was only one variable that was significant and showed a "positive" influence on extraction. Kernel hardness is closely related to "type of wheat" as explained above. Hard red spring wheat is the hardest wheat, then comes hard red winter wheat. Soft red winter wheat is by far the softest of the types. Often in practical experience, the harder the wheat being milled, the higher the extraction. It should also be mentioned that harder wheat also has a higher protein level. Spring wheat can be as high as 15-16% protein while soft red winter wheat can be as low as 7% protein. While extraction is generally higher for harder wheat, ash (analysis of mineral content) specifications of spring wheat flours are generally higher (.54-.60%). On the other end of the spectrum, the ash specification of softer red winter wheat is usually in the range of 0.40-0.47%. With a lower protein content, softer wheats are more "sticky" when milling. There is more starch compared to protein. This stickiness, makes it more challenging to separate the bran from the flour. On harder wheats, there is more protein contained in the endosperm. The protein is more crystalline in its structure and when milled into flour, it sifts away from the bran more efficiently.

Experience of staffing-since milling is a continuous operation, there are normally 3 around the clock shifts to accomplish milling over 6-7 days per week. This variable was not considered in the regression as it was felt that there was little difference in the capability of the different shifts.

Temperature & Humidity-as with experience of staffing above, this data was not collected for this study. It was felt that the temperature and humidity would average out across all shifts using an adequate number of samples. At the particular plant used for this study, a reliable means for controlling temperature and humidity was not available.

5.2 Explanation of Regression

Several regression equations were estimated using the data analysis regression feature on Microsoft Excel. The one that seems to be the best fit was *extraction percent=f(type of wheat, hardness of wheat, length of run, temper time, down time hours, soft wheat disrupt)*

Table 5.1 Regression Summary

SUMMARY OUTPUT		
Regression Statistics		
Multiple R	0.8660	
R Square	0.7499	
Adjusted R Squar	0.6826	
Standard Error	0.0073	
Observations	34.0000	
	Coefficients	*P-value*
Intercept	0.8053	0.0000
HRW-Hard Red Winter Wht	0.0851	0.0031
HRS-Hard Red Spring Wheat	0.0945	0.0042
Hardness of wht	-0.0018	0.0017
Length of RUN	0.0014	0.0001
TEMPER Time	-0.0018	0.0004
Down TIME HRS.	0.0028	0.5460
DISRUPT=soft w ht run betw een hard w ht runs	0.0106	0.0203

In summary, R square is 0.75 indicating that variables of the sample fit the model equation well. The 3 different classes of wheat included in the data are represented with binary variables. The class of wheat used in the data is represented by a 1 when that class is present. It is represented by 0 when it is not present. Using the 1 when the class of wheat is present simply allows the coefficient to be added into the regression equation. HRW wheat has a coefficient of 0.0851. It is significant with a P value of 0.0031. HRS wheat has coefficient of 0.0945. It is significant with a P value of 0.0042. In cases where

Soft Red Winter (SRW) wheat shows up in the data, there is no coefficient value included in the regression equation. The extraction percent value is 0.0851 higher when HRW is in the equation versus SRW. The extraction percent value is 0.0945 higher when HRS is in the equation versus SRW. Hardness of wheat is another significant variable with a P value of 0.0017. The regression coefficient for the hardness of wheat value is -0.0018 meaning that the extraction decreases slightly the harder the wheat is. Length of run is significant with a P-value of 0.0001. Extraction for length of run will increase by the coefficient of 0.0014 times the length of run factor. Temper time coefficient is significant with a P-value of 0.0004. The temper time coefficient is -0.0018 which means extraction with be reduced with more temper time. Down time hours are not significant as P-value is 0.546. The final variable used in the regression is soft wheat disruption where a small run of soft wheat is milled in the middle of a hard wheat run. This variable is significant with a P-value of 0.0203 and the coefficient of 0.0106. With this variable, extraction will increase by the coefficient whenever there is a soft wheat run that disrupts a hard wheat run.

Table 5.2 Calculated Savings from Length of Run

Example

DATA -all quantities in "per day"!

	Length of Run	Plant Daily CWT Flour Capacity	Clean Wht Extraction AVG.	% Millfeed	Clean Temper Wht Required CWT	Clean Temper Wht Required BUS.	Millfeed Produced CWT	Millfeed Produced TONS	Saved Wheat BUS.	Millfeed Difference TONS
Actual Data	13.1	11300	75.34%	24.66%	14998.98	24998	3698.98	184.95		
Length Run X2	26.2	11300	77.03%	22.97%	14669.16	24449	3369.16	168.46	549.705	16.4911
Min. 20 hr run	20	11300	76.36%	23.64%	14798.65	24664	3498.65	174.93	333.884	10.0165

Savings

	Length of Run	Saved Wheat BUS./day	Saved Wheat BUS. @ 310 days	$ Savings @$10/BUS	Millfeed Difference TONS per day	Millfeed Difference TONS @310 days	Millfeed Difference in $ @ $170/ton	$ Savings Minus Millfd diff. = TTL Savings
Length Run X2	26.2	549.70	170408.54	$1,704,085	16.49	5112.26	$869,084	$835,002
Min. 20 hr run	20	333.88	103504.05	$1,035,041	10.02	3105.12	$527,871	$507,170

5.3 Savings from Length of Run

Table 5.2 provides an example of increasing the length of run period and applying the regression equation. In the spreadsheet of the data, the actual information generated by the formula is shown. On the next line, length of run is multiplied by two. As the average length of run from the data set is 13.1 hours. Doubling it would make the length of run 26.2 hours. Doubling the length of run increases extraction by 1.69 percentage points. For further evaluation of the effect of length of run on extraction, an increase in length of run to an arbitrary period of 20 hours is shown on the next line. This is an increase over the average of the data set by 6.9 hours.

The lower part of Table 5.2 shows significant savings when there are theoretical increases to the length of run. Increasing the length of run by two times, increases extraction by 1.69 percentage points, thereby resulting in savings of 170,409 bushels of wheat. These results are based on a flour mill with a capacity of 11,300 cwt/day, operating for 310 days per year (this is the total capacity of the flour mill where the data set was obtained). As part of the savings calculation, the loss of revenue by reducing the amount of feed made (byproduct of white flour milling) is calculated. In calculating extraction of white flour, when flour extraction increases, feed production decreases (Table 4.1). A reduced feed amount must be taken into account whenever extraction savings are calculated. Savings are substantial with a final calculated savings of $835,002 per year. Similarly, the next line shows an increase in length of run to 20 hours. This increases extraction by 1.02 percentage points. Following the same process for calculating savings as was previously done, savings produced in this example are $507,170.

5.4 Planning for Additional Flour Storage

Often a flour mill will increase capacity without increasing its infrastructure. A capacity increase will lower a plant's manufacturing cost, but not considering infrastructure improvements can negatively affect flour extraction and flour quality. Changing the "mission" of a flour mill can create similar problems. A flour mill can be initially designed to produce one or two types of flour. Business environment can require that a mill that has a minimal number of wheat mixes and flour grades change to a mill that produces many different types of flour. It is best to increase bulk flour bin space and warehouse space (there are many other infrastructure improvements to be considered as well) at the same time mill capacity increases in order to stay at the same level of extraction, flour quality, and service.

As cited earlier, in the technical bulletin, Bulk Flour Storage Space, Lockwood suggests that a mill have 2 to 3 times its capacity in bulk flour storage. In another technical bulletin, Hoisington refers to the “rule of 3” meaning that a flour mill should have bulk flour storage that equals 3 times its daily capacity. The perfect amount of bulk storage is difficult to assess. Having 2 to 3 times daily capacity in bulk flour storage would be desirable to minimize packaging flour on the weekends with overtime wages, but the size and number of bins may be even more important when working towards efficiency optimization. A flour mill is better off having several smaller bins than a few very large bins. A mill can have a large amount of storage, but if it is all half full due to small amounts of several different types of flour, the maximum amount of storage will seldom be realized.

The optimum warehouse space is equally elusive. Every situation has to be looked at individually. Adequate warehouse space at one flour mill may not be adequate at a different plant because of such items as the number of flours produced, package sizes, outside products inventoried, and additional ingredients used at the plant.

5.5 Cost of Construction

As discussed earlier, every situation is different when it comes to optimizing storage space at a flour mill. With this in mind, the estimates that follow below are in quantities that lend themselves to scaling up to fit various storage needs.

Table 5.4 Bulk Flour Bin Estimate

Bulk Flour Bin Estimate			
	materials	labor	
900 cwt steel bin, painted exterior	$19,500	$5,000	
Footing=13'x13' 16" thick concrete pad.	$3,000	$1,500	
Rotary Valve	$1,700	$1,000	
Aspiration	$3,000	$2,500	
Conveying to/fm	$4,000	$4,000	
Ladders/catwalk	$3,000	$1,500	
High level	$500	$1,000	
Bin bottom	$3,000	$1,500	
Electrical	$10,000	$10,000	
Control	$1,000	$5,000	
TOTALS	$48,700	$33,000	$81,700 Grand Total

To further illustrate the purpose of this paper, Table 5.4 illustrates an estimate of capital costs to install individual free-standing steel bins. The bin estimated has a storage capacity of 900 cwt (90,000 lbs) of flour. The bins are fabricated from mild steel with the exterior painted. Materials and labor to install the bin, related structural requirements, and accessories are included for a total cost of $81,700 per individual bin. The estimated price on the bin itself is from a manufacturer, while the accessories and installation costs were estimations derived from past capital projects. It is assumed that the storage bin being discussed would be added to an existing plant’s bulk storage bins. Costs to integrate new storage bins into existing storage will vary with each situation.

Table 5.5 Warehouse addition estimate

Price Estimate for Warehouse Addition-10,000 Sq Ft			
	$/sq. ft	sq. ft. desired	Addition Total
$/sq. ft obtained from Reed Construction Data with input from local contractor	$73.34	10,000	$733,400
Contingency at 15%			$110,010
		TOTAL	$843,410

The other storage option considered would be a warehouse addition of 10,000 square feet to an already existing warehouse. Table 5.5 illustrates an estimate that is based on information from Reed Construction Data with input from a local contractor in the Midwest region. The warehouse addition would use existing plant utilities. Capital money was included for any utility upgrades required.

CHAPTER VI: CONCLUSIONS

6.1 Determining Level of Capital Investment

This chapter looks at the financial aspects of adding additional storage capacity and the increased extraction percentage due to the longer length of run that is allowed with the greater storage capacity.

Table 6.1 Worksheet showing capital investment levels for storage

	10,000 Square Foot Warehouse Addition (each)=			$843,410		
		Additional 900 cwt bins(each)=		$81,700		
				# of bins or whse additions	$/bin or whse addition	Total Investment
Rate	6.00%		10,000 SF Warehouse Addition	2	$843,410	$1,686,820
			900 CWT bins	4	$81,700	$326,800
			TOTAL $'s			$2,013,620

Table 6.1 shows the total cost required to add 20,000 SF of warehouse space and 4 additional bins. The capital expenditure of these additions would be $2,013,620. The pricing estimate of the bulk flour storage bins and the warehouse addition was based on 1 bin and a 10,000 SF warehouse addition. The number of bins and warehouse additions were scaled up to a level estimated to help extraction by longer runs on the mill and at the same time to be a viable capital project.

As discussed earlier in this paper, the amount of warehouse space and flour bulk bin storage can vary depending on a flour mill's type of business. The size of a warehouse addition would be dependent on a plant's total capacity or output. The square footage of addition considered would also be dependent upon how many different products or SKU's (stock keeping units) the plant made. If the warehouse inventories outside products in addition to its own products, adequate accommodations need to be made. In the case of adding bulk flour bins, the number of bins and the bin capacity need to be carefully considered. As with warehouse space, number of flour types and variations need to be considered. Are flour ingredients added prior to bulk storage or are they added prior to packaging and/or loadout? The amount of bulk business versus packaging is important. The number of days and shifts available is a factor to be considered when adding bulk flour bins. The rate of the packing line(s) and/or bulk system(s) needs to be considered.

Table 6.2 Internal Rate of Return (IRR) and Net Present Values (NPV)

2X (times) Length of Run Increase

Year	TOTAL INVESTMENT	1	2	3	4	5	6	7	8	9	10
Benefit	-$2,013,620	$835,002	$835,002	$835,002	$835,002	$835,002	$835,002	$835,002	$835,002	$835,002	$835,002
					NPV	$6,145,687		NPV-Initial Investment=			$4,132,067
					IRR	40%					

Minimum 20 hour Length of Run

Year	TOTAL INVESTMENT	1	2	3	4	5	6	7	8	9	10
Benefit	-$2,013,620	$507,170	$507,170	$507,170	$507,170	$507,170	$507,170	$507,170	$507,170	$507,170	$507,170
					NPV	$3,732,815		NPV-Initial Investment=			$1,719,195
					IRR	22%					

Table 6.2 shows the internal rate of return (IRR) and the net present value (NPV) for the additional storage space under two situations. The first situation is that length of run is doubled from what is the current average. The regression equation was used to estimate the extraction rate, an increase of 1.69%. The second situation was to theoretically extend the run to 20 hours with an estimated increase in extraction percentage of 1.02%. The value of the increased extraction was projected over 10 years. When this cost is analyzed in the 2 times the average length of run scenario, the net present value (NPV) is $4,132,067. Internal rate of return (IRR) would be 40% for this particular example (Table 6.2).

When the extraction rate increase of 1.02% is used with the "minimum 20 hour length of run" scenario, the Net present value (NPV) is $1,719,195 with a period of 10 years. Internal rate of return (IRR) would be 22% (Table 6.2).

A discount rate of 6% was used for determining the net present value (Table 6.1). This was a conservative estimate based on the current rate of borrowing $2MM. Discount rate includes the cost of borrowing money with consideration for risk and inflation added in.

6.2 Resulting Benefits

Financial analysis shows the benefits of increased flour extraction results in a positive net present value for the two different scenarios. The positive NPV indicates that both of these situations would be good investments. A company would have to compare this investment opportunity to other opportunities to determine whether to proceed with the investment. Further analysis of the increased flour storage scenarios would be required to understand the tax benefits with depreciation and the tax implications with any additional profits realized. The examples illustrated in this paper are all on a pre-tax basis. It should also be noted that changes in the cost of wheat and feed may change the results of wheat savings shown in this paper. While the examples in this paper were based on wheat being saved, it would be interesting to do further analysis on milling the same amount of wheat and determine the additional revenue and sales margins realized. There could also be a competitive advantage in pricing flour against the competition because of lower material input costs. It could make the difference in acquiring new customers at the expense of other flour milling companies.

While there is a trend to work towards "lean manufacturing", adequate flour storage space should not be underestimated. As shown in this paper, there are financial implications with flour extraction. Additionally, there are quality benefits and customer service advantages. Flour performs better with aging because of the oxidation process. The color becomes whiter and the flour bakes better. Ingredients such as azodicarbamide and benzoyl peroxide are used to chemically whiten and mature flour. With adequate storage space, flour ages to where these chemical ingredients can be minimized or eliminated. Longer flour runs produce flour that is more consistent. This is important to the baker. Having a supply of flour in inventory makes sense from a customer service aspect too. Lead times for flour orders could be minimal so customer orders could be filled promptly. While this study does not consider the details of staffing, regular hours, and overtime hours, it should be mentioned that additional flour storage will be of benefit to labor costs in a flour mill. Labor hours and staffing will be less in the grain elevator by not having to stage as many wheat mixes for the mill every day. There would be some subtle reductions of labor in the milling process as well. Labor hours in packaging would definitely benefit by less packing on the weekends. This may benefit the staffing of Quality Assurance tasks as well.

There is a potential negative benefit when considering adding additional flour storage at a mill. There will be an increase in working capital inventory because of the additional flour in storage. While the positive benefits would appear to outweigh this potential negative benefit, an analysis should be conducted to determine the net effect.

In summary, based on the analysis, it appears that adding bulk storage has considerable economic advantages based on increased lengths of run of the mill and on meeting the needs of customers. It is a challenge to quantify the benefits of increasing storage at a flour mill, but by gathering the right production data and applying financial methods, a compelling justification for capital funds can be made.

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APPENDIX A: WORKSHEET USING REGRESSION EQUATION

				Intercept	DATA	coefficient	DATA	coefficient	DATA	coefficient	DATA	coefficient	DATA	coefficient	DATA	coefficient	DATA	coefficient	DATA	Results of	Results of	Results of
DATE	Wheat		SAMPLE		Wheat Mix	Wheat Mix	Wheat Mix	Wheat Mix	SKCS	SKCS	# HOUR	# HOUR	HRS OF	HRS OF	DOWN	DOWN	O MIX	O MIX	CTW	Regression	Increasing	Minimum of
	Mix		NUMBER		HRW	HRW	HRS	HRS	Hardness	Hardness	RUN	RUN	TEMPER	TEMPER	TIME HRS.	TIME HRS.	DISRUPT	DISRUPT	EXT. %	Equation	Length of Run X2	20 hr runs
13-May	EH	6AM	1	0.805348	0	0.0850827	1	0.0945093	82.07	-0.0017895	13.5	0.0013808	23.6	-0.0018327	0	0.0028119	0	0.0106014	0.760822838	0.72833746	0.746978219	0.766315
14-May	H	9PM	2	0.805348	0	0.0850827	1	0.094509346	78.37	-0.0017895	11.5	0.001380797	11	-0.0018327	0	0.0028119	0	0.010601	0.757268578	0.755334733	0.771213899	0.767072
14-May	E	6:45AM	3	0.805348	0	0.0850827	1	0.094509346	82.75	-0.0017895	6.5	0.001380797	9.7	-0.0018327	0	0.0028119	0	0.010601	0.75	0.742975272	0.751950452	0.761616
14-May	E6	6:45AM	3	0.805348	0	0.0850827	1	0.094509346	82.75	-0.0017895	24.16	0.001380797	9.7	-0.0018327	0	0.0028119	0	0.010601	0.772664426	0.767360146	0.800720201	0.767360
15-May	E	7:10AM	4	0.805348	0	0.0850827	1	0.094509346	80.595	-0.0017895	12	0.001380797	11.8	-0.0018327	0	0.0028119	0	0.010601	0.747924362	0.750577357	0.767146921	0.761624
19-May	J	10:30AM	5	0.805348	1	0.0850827	0	0.094509346	71.55	-0.0017895	25	0.001380797	12.3	-0.0018327	0	0.0028119	0	0.010601	0.778314372	0.774370721	0.808890645	0.774371
20-May	H	9AM	6	0.805348	0	0.0850827	1	0.094509346	78.18	-0.0017895	11	0.001380797	10	-0.0018327	0	0.0028119	0	0.010601	0.760130333	0.756817031	0.772005798	0.769244
20-May	E	10:30PM	7	0.805348	0	0.0850827	1	0.094509346	78.87	-0.0017895	15.5	0.001380797	12	-0.0018327	0	0.0028119	0	0.010601	0.746076772	0.758130482	0.779532836	0.764344
21-May	H	1PM	8	0.805348	0	0.0850827	1	0.094509346	80.09	-0.0017895	14	0.001380797	12	-0.0018327	0	0.0028119	1	0.010601	0.768207523	0.764477552	0.78380871	0.772762
22-May	J	4AM	10	0.805348	1	0.0850827	0	0.094509346	73.72	-0.0017895	11	0.001380797	9.5	-0.0018327	0	0.0028119	0	0.010601	0.755192854	0.756287904	0.77147667	0.768715
22-May	E6	12:30AM	11	0.805348	0	0.0850827	1	0.094509346	79.36	-0.0017895	20	0.001380797	10.4	-0.0018327	0	0.0028119	0	0.010601	0.770075504	0.766399526	0.794015465	0.766400
27-May	E	12:30AM	11	0.805348	0	0.0850827	1	0.094509346	79.36	-0.0017895	9.5	0.001380797	10	-0.0018327	0	0.0028119	0	0.010601	0.748116254	0.752634235	0.765751806	0.767133
27-May	A	4:30PM	12	0.805348	1	0.0850827	0	0.094509346	75.445	-0.0017895	11	0.001380797	10.7	-0.0018327	0	0.0028119	0	0.010601	0.752265855	0.751001798	0.766190565	0.763429
27-May	E	2:30AM	13	0.805348	0	0.0850827	1	0.094509346	80.345	-0.0017895	11	0.001380797	10.2	-0.0018327	0	0.0028119	0	0.010601	0.746266364	0.752576241	0.767765008	0.765003
28-May	J	12:35PM	14	0.805348	1	0.0850827	0	0.094509346	74.01	-0.0017895	7.75	0.001380797	9.1	-0.0018327	0	0.0028119	1	0.010601	0.768902548	0.762615884	0.773317061	0.779531
29-May	J	1:35PM	14	0.805348	1	0.0850827	0	0.094509346	74.01	-0.0017895	12.25	0.001380797	10.7	-0.0018327	0	0.0028119	1	0.010601	0.756676323	0.765897162	0.782811925	0.776598
31-May	J	11PM	17	0.805348	1	0.0850827	0	0.094509346	67.305	-0.0017895	21	0.001380797	14.7	-0.0018327	0	0.0028119	0	0.010601	0.767722846	0.772045466	0.801042203	0.772045
2-Jun	J	6:45PM	17	0.805348	1	0.0850827	0	0.094509346	67.305	-0.0017895	10.75	0.001380797	19.25	-0.0018327	0	0.0028119	1	0.010601	0.760543572	0.760154992	0.774998559	0.772927
4-Jun	E	9PM	21	0.805348	0	0.0850827	1	0.094509346	87.065	-0.0017895	11	0.001380797	15	-0.0018327	0	0.0028119	0	0.010601	0.728339513	0.731753926	0.746942693	0.744181
4-Jun	H	4:30AM	22	0.805348	0	0.0850827	1	0.094509346	76.855	-0.0017895	6.83	0.001380797	15	-0.0018327	0	0.0028119	1	0.010601	0.758082368	0.754868168	0.764299012	0.773053
4-Jun	H	4:30AM	22	0.805348	0	0.0850827	1	0.094509346	76.855	-0.0017895	6.83	0.001380797	15	-0.0018327	0	0.0028119	1	0.010601	0.747714036	0.754868168	0.764299012	0.773053
6-Jun	E	10:30AM	24	0.805348	0	0.0850827	1	0.094509346	85.425	-0.0017895	12.25	0.001380797	15.7	-0.0018327	1.5	0.0028119	0	0.010601	0.73131368	0.739349663	0.756264426	0.750051
6-Jun	E6	10:30AM	24	0.805348	0	0.0850827	1	0.094509346	85.425	-0.0017895	18.5	0.001380797	15.7	-0.0018327	0	0.0028119	0	0.010601	0.731206253	0.743761787	0.769306531	0.745833
7-Jun	E	2:45AM	25	0.805348	0	0.0850827	1	0.094509346	84.62	-0.0017895	11.5	0.001380797	14.9	-0.0018327	0	0.0028119	0	0.010601	0.746891474	0.737002903	0.752882069	0.748740
9-Jun	J	8:30PM	26	0.805348	1	0.0850827	0	0.094509346	69.52	-0.0017895	11	0.001380797	22.83	-0.0018327	0	0.0028119	1	0.010601	0.752730983	0.749975425	0.765164192	0.762403
10-Jun	E	4:15PM	27	0.805348	0	0.0850827	1	0.094509346	85.15	-0.0017895	12	0.001380797	15.7	-0.0018327	0.5	0.0028119	0	0.010601	0.735767576	0.736684669	0.753254233	0.747731
10-Jun	EH	3AM	28	0.805348	0	0.0850827	1	0.094509346	79.675	-0.0017895	11	0.001380797	16	-0.0018327	0.75	0.0028119	0	0.010601	0.744378938	0.745254512	0.760443279	0.757682
11-Jun	E	3PM	29	0.805348	0	0.0850827	1	0.094509346	82.075	-0.0017895	10	0.001380797	17	-0.0018327	1	0.0028119	0	0.010601	0.748449768	0.738449217	0.752257187	0.752257
11-Jun	E6	3PM	29	0.805348	0	0.0850827	1	0.094509346	82.075	-0.0017895	26.5	0.001380797	18.8	-0.0018327	0.25	0.0028119	0	0.010601	0.762743443	0.755824591	0.792415711	0.755825
14-Jun	E	5:30PM	31	0.805348	0	0.0850827	1	0.094509346	82.16	-0.0017895	27.5	0.001380797	16	-0.0018327	1	0.0028119	0	0.010601	0.735909106	0.76429375	0.802265667	0.764294
14-Jun	E6	5:30PM	31	0.805348	0	0.0850827	1	0.094509346	82.16	-0.0017895	13	0.001380797	16	-0.0018327	0.25	0.0028119	0	0.010601	0.764878771	0.742163265	0.760113626	0.751829
15-Jun	E	5:30PM	31	0.805348	0	0.0850827	1	0.094509346	82.16	-0.0017895	3.5	0.001380797	16	-0.0018327	0	0.0028119	0	0.010601	0.749259058	0.728342717	0.733175507	0.751126
17-Jun	J	12:15PM	32	0.805348	1	0.0850827	0	0.094509346	68.92	-0.0017895	9.75	0.001380797	14.9	-0.0018327	0	0.0028119	0	0.010601	0.748725321	0.753254931	0.766717702	0.767408
18-Jun	O	7:30AM	33	0.805348	0	0.0850827	0	0.094509346	23.625	-0.0017895	7	0.001380797	5.9	-0.0018327	0	0.0028119	0	0.010601	0.76151381	0.761924305	0.771589884	0.779875
Averages									77.05441		13.105		13.7		0.15				75.34%	75.22%	77.03%	76.36%
MIN									23.62500		3.50000		5.9		0.00				72.83%	72.83%	73.32%	74.42%
MAX									87.06500		27.50000		23.6		1.50				77.83%	77.44%	80.89%	77.99%