Analyzing Replacement and Expansion of Grain Storage in Oklahoma

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Abstract

A mixed integer programming model was developed using General Algebraic Modeling System (GAMS) to forecasts grain facility replacement in Oklahoma. The results indicated regionalization in grain storage with fewer but larger capacity structures. The results of sequential replacement overtime indicated that there would be some abandonment of facilities and some shift to larger capacity structures. Producer's transportation cost did not increase with sequential replacement as expected because storage were added in places to the current deficits. The results were not sensitive to crop production, fuel and construction cost and amortization factors. Cost comparison per bushel between configuration after sequential replacement and unrestricted replacement show that transportation cost was $0.04 lower in sequential replacement but total cost was $0.02 higher than unrestricted replacement. The findings of the study are important to grain firms and producers considering replacement of obsolete facilities.

Keywords: Grain Elevators, Transportation Cost, Mixed Integer Programming

1. Introduction

Replacement and upgrading of grain handling infrastructure is an important issue in Oklahoma and other grain producing states. According to the National Agricultural Statistics Service (NASS), there are about 225 off-farm storage infrastructures in Oklahoma with over 225 million bushels storage capacity. The operations of these grain elevators are concentrated mainly on the prime grain producing areas of central and western Oklahoma. Off-farm storage facilities include both country elevators which are smaller in capacities and receive grain by truck directly from farms and terminal elevators which are larger in capacities and receive grain from local elevators. In recent years, as more farmers transport grain in semi-trucks, producers also deliver directly to terminal elevators. A substantial portion of grain handling facilities are beyond their design life and will need to be renovated or replaced in the coming decade. The majority of the storage structures currently in operation are built between 1940's-1960's while some structure dates back to the early 1900’s. The managers of the grain handling firms need information on the regional demand for grain infrastructure as they consider investments at specific locations.

Historically, Oklahoma’s total storage capacity (on-farm and off-farm) has exceeded total grain production (Fig. 3). This is reasonable since producers and grain facility operators want to maintain the ability to handle above average crops. Due to weather patterns, the year-to-year yield variation in Oklahoma is much greater relative to the Corn Belt. Because it is a food crop, wheat is not typically stored on the ground in temporary storage, a common strategy for handling peak yields in feed grains. The number of off-farm storage facilities in Oklahoma has declined over time (340 in 1992 compared to 224 in 2012) while the storage capacity have remained fairly constant (246 million bushels in 1992 compared to 235 million bushels in 2012). This reflects a shift to larger storage structures. Oklahoma’s grain harvested acres have declined since a peak in the early 1990’s as marginal crop land has converted to pasture. However, the crop mix has also been shifting from continuous wheat to rotations with higher yielding summer crops such as corn and grain sorghum. All of these changes in crop mix, crop yields and land use have implications on the capacity and location of needed future infrastructure.

These issues are highlighted by a recent report issued by Co-Bank which examined the need for storage capacity and unloading speed in the Mid-West. The report forecasted the need for an additional 2.3 billion bushels of storage capacity in the 12 Corn Belt States (Kowalski, 2012). The report also indicated, that with the faster rate of harvest there will be demands for newer facilities to have increased grain handling speeds. Because of the shift to summer crops such as corn and soybeans, we can expect some of these effects for increasing demand for storage facilities in Oklahoma and other Southern Plain states. Unlike corn and soybeans, there has been little increase in winter wheat yields over the last 20 years. However, several seed companies are examining the potential of hybrid wheat varieties and the commercialization of that technology could increase demand for storage facilities.

The most logical or “least cost” locations for grain facilities in Oklahoma is also an important issue. At the time that most of Oklahoma’s grain infrastructure was developed producers transported grain in small trucks over unimproved roads. Road infrastructure has improved and most producers now transport grain in semi-trailers or dual axle straight trucks. This has reduced the per bushel transportation cost (in real dollars). Because of the significant economies of size in grain structure construction, there are potentials for structural change as local elevator facilities are consolidated into larger regional hubs. This could increase producers’ cost of transporting grain. However, since over 50% of Oklahoma grain capacity is organized as farmer owned cooperatives, a more regionalized system which minimized the joint cost of grain transportation and grain facility construction might still benefit producers. Research on the optimal number, location and capacity of grain elevators, incorporating information on the trends in grain production would give insights into possible structural changes in the Oklahoma grain storage industry. This information would be useful to both grain facility operators and grain producers.

No previous studies have used plant location optimization model to determine the optimal location, number and capacity of country storage infrastructure in Oklahoma. Baird, 1990 carried out a detail survey of all the existing elevators in Western Oklahoma. The study very well documented details of all the existing storage structures but did not do further economic analysis. A study by Fuller et al. 1981 focused on minimizing transportation cost of export wheat from hard red winter wheat producing regions in Kansas, Oklahoma and Texas. Their study considered feasibility of operating unit trains to sea port locations from selected country elevators converted to sub terminals and feasibility of operating unit trains from inland terminal to sea ports. They did not consider transportation cost from grain producing regions to country elevators to sub-terminals. Tembo, 1988 used a cost minimization model similar to the current study but his study focused on determining the optimal size and capacity of flour milling to meet the excess demand of flour in Oklahoma rather than the optimal capacity and location of grain storage infrastructure.

Plant location and transportation cost models have been used to determine the optimal location and capacity of grain storage structures in other regions. Araji and Walsh, 1969 conducted a study to determine the effect of grain sales densities and truck cost on marketing cost of grain and optimum size and location of grain elevators in Canada. They determine the optimum size and location of grain elevators by solving an equation for average total cost function of plant operation cost and assembly cost. They found that optimum elevator size could be 25-50% less of the size when only economies of size are considered. Ladd and Lifferth, 1975 used a transshipment plant location model to determine the number, size and location of new sub-terminals and expansion of existing country elevators and railway network maximizing net revenue from the grain distribution of corn and soybean in Iowa. They found that with fewer rail lines the total net revenue would increase by 1-2%. Monterosso et al. 1985 used a plant size location problem to determine the optimum location and size of grain storage minimizing transportation cost in Brazil. Unlike most of the previous studies which found that more regionalized structures minimized total costs, they found that smaller units closer to farmers were optimal. Jessup et al. 1998 used Geographic Information System (GIS) and General Algebraic Modeling System (GAMS) to obtain grain transportation optimization model in Eastern Washington State for wheat and barley. Similar to the current study, they used township as their primary source of grain origin but they used only twenty grain production counties. Their shipment of grains are to grain elevators and then to final destination such as feedlots, ocean ports, consumption and export while in our study the shipment of grains are only to country elevators or sub-terminals. Their study found that the transportation cost with barge access are lower and the flow of trucks are on few routes than on several corridors to river ports. Nardi et al. 2007 used GIS and GAMS to develop a methodology that would minimize the transportation and storage costs for soybeans and its by-products in Argentina. Their model would determine optimum routes and modes (truck, rail and barge), production and storage locations, crushing facilities and exporting ports. Their two key finding are that the commodities from lower cost supply chains would ship to the crushing plants and exports ports and that the country elevators without railroad or which are distant from the crushing facility and export ports would have higher shipping and storage costs.

The main objective of this study is to analyze the current grain storage infrastructure in Oklahoma (on farm and commercial) and determine the level and location of additional infrastructure investment under a number of foreseeable scenarios.

Specific objectives include:

- Determine long term trends in grain production at the county or sub-county level.

- Determine existing grain storage capacity at the county and sub-county level along with the age of the facilities.
- Assess excess or deficit grain storage at the county or sub-county level.
- Determine the change in location and size of grain structures that would be projected to occur as the oldest structures are sequentially replaced and the implications on the resulting structure on total transportation and construction costs.
- Compare the size and location of grain storage structures that is projected to occur after older facilities are sequentially replaced with the size and locations that would occur if all structures, regardless of age, were considered for replacement. This objective essentially compares the least cost configuration resulting from sequential replacement with the unconstrained least cost configuration.

2. Model

Mixed integer type cost minimization models are frequently used to determine optimal location and size of plants. The current study uses a mixed integer model to minimize total cost of grain transportation from the point of production to the point of storage and construction cost of the storage infrastructures. The grain flow in Oklahoma is generally trucked by producers to country elevators and sub-terminals with some producers delivering directly to terminal elevators. The majority of grain received by country elevators and sub-terminals is trucked to regional demand points such as flour mills and river elevators. Some country elevators are equipped to ship by rail but rail shipments have become much less important. The current study does not consider transportation cost from the country elevator to final demand point because grain is primarily shipped by truck and the outbound transportation cost is not considered to impact the optimal size and location of elevators. Outbound transportation costs are also very difficult to model as shipment distances vary with market opportunities. The focus of our study is only on replacement and expansion of country elevators and sub-terminals. Wheat, Canola, Corn, Grain Sorghum and Soybean are the five crops used in the study. The storage structures considered for replacement are upright concrete and steel. For the purpose of determining useful life and replacement costs, flat structures are grouped under steel structures.

Mathematically, the objective function can be written as:

$$(2.1) \quad Min\ Z = \sum_{i=1}^{2,047} \sum_{j=1}^{210} \sum_{k=1}^{5} TC_{ij}\, Q_{ijk} + \sum_{j=1}^{210} \sum_{s=1}^{13} CC_{js}\, BETA_{js}$$

which is subject to the following constraints:

$$(2.2) \quad \sum_{j=1}^{210} \sum_{k=1}^{5} Q_{ijk} - PRODU_{ik} = 0$$

(Production Constraints)

$$(2.3) \quad \sum_{i=1}^{2,047} \sum_{j=1}^{210} Wheat_{ij} + \sum_{i=1}^{2,047} \sum_{j=1}^{210} Canola_{ij} - \sum_{s=1}^{13} CAP_{js}\, BETA_{js} \leq 0$$

(Winter Capacity Constraints)

$$(2.4) \quad \sum_{i=1}^{2,047} \sum_{j=1}^{210} Corn_{ij} + \sum_{i=1}^{2,047} \sum_{j=1}^{210} Sorgh_{ij} + \sum_{i=1}^{2,047} \sum_{j=1}^{210} Soy_{ij} + 0.5 * \sum_{i=1}^{2,047} \sum_{j=1}^{210} Wheat_{ij} + 0.5 * \sum_{i=1}^{2,047} \sum_{j=1}^{210} Canola_{ij} - \sum_{s=1}^{13} CAP_{js}\, BETA_{js} \leq 0$$

(Summer Capacity Constraints)

$$(2.5) \quad BETA_{js} = 0\ or\ 1,$$

(Binary Constraints)

$$(2.6) \quad Q_{ijk}, Wheat_{ij}, Canola_{ij}, Corn_{ij}, Sorgh_{ij}, Soy_{ij} \geq 0 \text{ for all } i, j, k$$

(Non-negativity Constraints)

The model has primarily two constraints - production and capacity. The production constraints forces the model to ship all the production to the storage structures while the capacity constraints forces the model to ship less than or equal to the capacity of the storage structures. The capacity constraints is separated as winter and summer capacity constraints. Wheat and Canola are winter crops and Corn, Soybean and Grain Sorghum are summer crops. We assume that the winter storage capacity is used only for winter crops. While in summer, we assume half of the winter crops remain in storage and half of the winter receipts have been shipped to the terminal elevators or final demand points. This assumption is consistent with typical grain flows. The binary constraints allows the model to retain or eliminate storage structures and the non-negative constraints forces selected variables to remain positive. The variables used in the objective function and constraints are described in the table below.

Table 1. Description of variables used in the objective function and constraints.

Variables	Description
Z	Total cost of grain transportation and construction cost of storage structure;
Q_{ijk}	Quantity of crop *k* shipped from source *i* to storage structure at location *j*;
$PRODU_{ik}$	Quantity of crop *k* produced at source *i;*
$Wheat_{ij}$	Quantity of wheat shipped from source *i* to storage structure at location *j*;
$Canola_{ij}$	Quantity of canola shipped from source *i* to storage structure at location *j*;
$Corn_{ij}$	Quantity of corn shipped from source *i* to storage structure at location *j*;
$Sorgh_{ij}$	Quantity of grain sorghum shipped from source *i* to storage structure at location *j*;
Soy_{ij}	Quantity of soybean shipped from source *i* to storage structure at location *j*;
TC_{ij}	Transportation cost of crop *k* shipped from source *i* to storage structure at location *j* per bushel per mile;
CC_{js}	Construction cost of storage structure of *s* type (Concrete or Steel) at location *j*;
$BETA_{js}$	Binary variable for building storage structure of *s* type (Concrete or Steel) at location *j*, 1 indicates storage structures which are not eliminated and 0 indicates otherwise;
CAP_{js}	Capacity of storage structure of *s* type (Concrete or Steel) at location *j*;

3. Data

3.1 Grain Elevators

Direct field visits and personal contacts were used to collect grain elevators data which include information on storage capacity by location for each type of structure and their age. The data do not include any on-farm capacities. Estimates of off-farm grain storage capacity were obtained from personal interviews with the grain firms holding federal or state grain warehouse licenses. The data were also obtained from a cooperative insurance company that insures all of the grain cooperatives in Oklahoma. Beside storage capacity, location and age of structures, we also obtained information on the number of dump pits and the speed of handling equipment. However, the grain handling system information was not used in this study.

The collected data covered 477 total storage structures or bins spread in 210 locations (Map 1). Out of the nine crop reporting districts our data did not include storage structures in three eastern crop reporting districts. There were no storage structures in East Central and South East. There were a few structures in North East but their data could not be obtained and was not considered for this study. Grain production in the North East district is very low and we conclude that ignoring few structures from this region does not severely affect our optimal solution. An identification code was given to each elevators such as E1, E2, E3, E4 etc. Available web facility (http://ctrlq.org/maps/address/) was used to convert the physical address of each storage facilities to a precise location by latitude and longitude so they could be mapped and be used to calculate distance matrix.

3.2 Township and Distance Matrix

Grain production was estimated for each township and transportation distances were calculated from each township to all storage structure locations. Townships are geographical areas which are further sub-division of counties. The Oklahoma township shapefile was obtained from the website of “Oklahoma Center for Geospatial Information” at Oklahoma State University. There were 2,047 townships in total. Similar to the elevators each township were given an identification code such as T1, T2, T3, T4 etc. A matrix of distance from each township to each elevator was generated using Quantum Geographic Information System (QGIS) software. The dimension of the distance matrix was 2,047 by 210.

3.3 Grain Production Data

3.3.1 Satellite Imagery Data for Crop Acreage

NASS maintains an online resource of historical satellite imagery data of several crops called the “CropScape - Cropland Data Layer”. This is a web based application for exploring and disseminating geospatial cropland data products throughout the US (Han et al. 2012). We used “CropScape” to obtain raster files (image) of each crops to get acreage for each townships. The raster files were first converted to vector file in ArcGIS and the area of each polygon was calculated. The vector files were then intersected with townships which were then dissolved to get the total acres of crops produced under each township. We used this procedure to obtain the acres of crop produced in each township for each of the five crops in our study.

3.3.2 Grain Production by Townships

County estimates of wheat, canola, corn, soybean and sorghum production (bushels) was obtained from NASS for the 2008 to 2012 time period. The county production was averaged for five years to obtain an overall average of crop production for four crops (wheat, corn, sorghum and soybean). We calculated proportionate acreage by townships in each counties using GIS satellite imagery. The production for each township was then calculated using the proportionate acres of each township and the county average crop production (bushels). Canola production by townships was calculated using the state average (2009-2012) production (pounds) rather than the county average because canola production data was available only by state.

3.4 Transportation and Construction Cost

The capacity of a grain semi-trailer is typically slightly under 900 bushels with some variation across commodities. We assume a trucking cost of $5 per loaded mile or $0.0056 per bushel per mile.

Grain storage structures in Oklahoma are usually upright concrete and steel structures. There are some flat steel structures but they are typically only used for overflow due to the higher handling costs. In terms of useful life, we grouped flat structures with steel structures. In terms of replacement costs we only considered construction cost for concrete and steel structures. We assumed that existing steel structures would be replaced with concrete structures and existing round steel and flat steel structures would be replaced with round steel structures. Construction cost estimates were based on discussions with managers of local grain elevators who had recently completed construction projects. The assumed construction cost is $3.0 per bushel for steel structure and $3.3 per bushel for concrete structure. This cost was assumed for a storage facility with a capacity of 100,000 bushels. The construction cost for several other facilities with varying capacities was determined using the exponent method (Dysert, 2003) as below.

$$C = C_n \times \left(\frac{O}{O_n}\right)^m \tag{2.7}$$

where C is the construction cost of facility to be determined with a capacity of O. C_n is the known cost of facility with known output level O_n and m is a scale factor. To determine the construction cost of other facilities with varying capacities we used the known cost of \$3.0 per bushel for steel and \$3.3 per bushel for concrete with the known capacity of 100,000 bushel and 0.7 as the scale factor.

4. Procedure

We first analyzed the location, capacity and age of existing off-farm grain storage structures along with the trends in grain productions in Oklahoma. We then ran series of optimization models written in GAMS to solve the general objective function specified in 2.1. The model was first tested with a few grain structure locations a few crops. An excel solver was set up to solve the objective function with the exact same details as in GAMS and we confirmed that the GAMS and excel solver solutions exactly matched. The full model was then solved on GAMS using crop production data for all five crops by townships, capacity of existing elevators, distance matrix, transportation cost/bushel/mile and construction cost/bushel. We used GAMS/CPLEX solver to solve the optimization problem. Because grain facility managers plan infrastructure to handle above average or “peak” crop years we used 120% of average historical grain volume as baseline case in the model. We performed sensitivity analysis to consider differences in the optimal solution for higher or lower yields

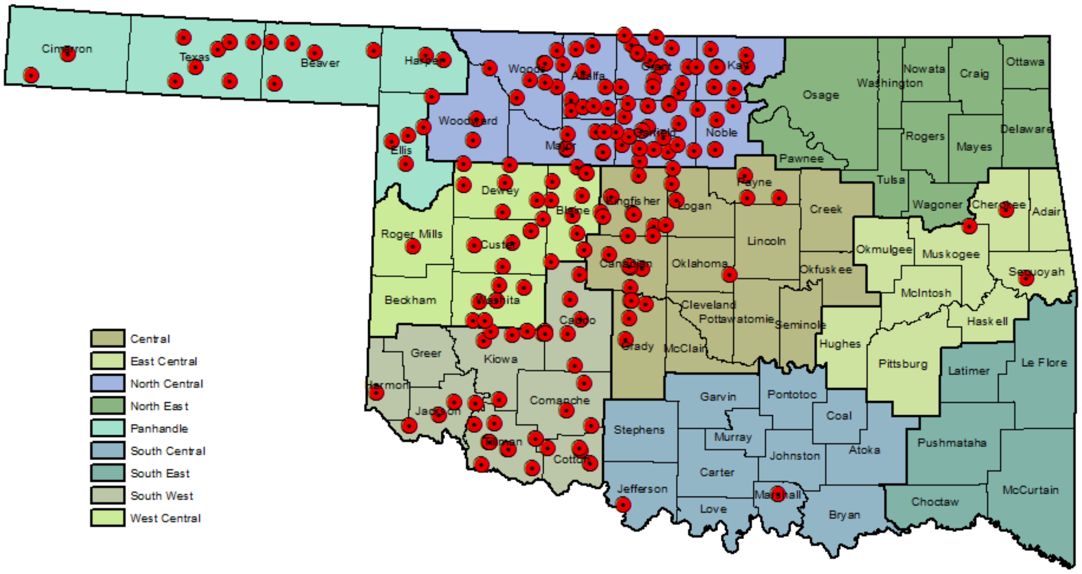
As discussed in the data section, grain transportation cost was estimated at $0.0056/bushel and grain bin construction cost was estimated at $3.00/bushel and $3.30/bushel for steel and concrete structures, respectively, with scale factor adjustment for smaller and larger sizes. Because the model minimized annual costs, an amortization factor representing 6% interest and a 10 year loan was used to convert the total construction costs to an annualized amount. This choice of the interest rate and term was based on conversation with the regional office or Co-Bank, a major lender to grain cooperatives.

Six scenarios were examined. The first scenario, a baseline, determined the least cost system of transporting and storing grain with no construction cost applied to the existing structures. Using age as a basic criteria we created four additional scenarios for sequential replacement as grain structure reached the end of their useful life. Concrete and steel structures were categorized separately for sequential replacement because of differences in their life spans. Generally, concrete structures last more than steel structures. We therefore categorized concrete structures built before 1939, 1949, 1959 and 1969 in Scenarios II, III, IV and V respectively. The steel structures were categorized assuming 30 years life span and steel structures built before 1959, 1969, 1979 and 1989 were categorized in Scenarios II, III, IV and V respectively. In each scenario the grain capacity represented by structures reaching the end of their useful life could be retained only if the model selected a construction activity with the associated construction cost. In each location of an obsolete structure the model could select from the existing capacity or two additional capacities, one with 50% and another with 100% increment over the existing capacity. This way if needed, the model could build up to 250% of existing capacity at any location of an obsolete structure. The model was forced to retain the reconstructed capacity selected in a given scenario in all subsequent scenarios since those structures were now new and not reaching the end of their useful life. A final scenario investigated the least cost structure with no restrictions on the timing of obsolescent. In other words, it imposed a construction cost to retain any of the structures designated as obsolete in the previous scenarios. It therefore reflected the structure that would occur if the grain industry was redesigned to minimize the combined cost of transportation and storage construction without consideration of the remaining useful life of existing structures. In the context of an individual business this is commonly referred to as a "green field approach". The purpose of the scenario was to investigate whether a different industry structure would occur if grain facility managers looked forward in their strategic planning and invested in the compliment of infrastructure that would ultimately be the most cost efficient. It should be noted that the most recently constructed existing grain structures were assumed to be retained in the final scenario so it represents a "near green field" but not "total green field" approach.

5. Results

5.1 Overview of Grain Storage Infrastructures

Grain elevators in Oklahoma are strategically located in prime grain producing areas of the state. Wheat being the major crop, the grain structures are mostly centered in major wheat producing areas. Many of the older storage facilities were built alongside the railway network so that the stored grain could be easily and directly shipped to the terminal elevators or barge for export. Grain elevators in Oklahoma are usually upright concrete and upright and flat steel structures. Most of the flat steel storage structures were built during the period of time when the USDA Commodity Credit Corporation (CCC) program provided storage payments for grain held for producers. Flat storage is slightly cheaper to construct on a per bushel basis relative to round steel bins but has much higher handling costs. Many flat grain storage structures have been converted from grain storage to other warehouse uses. However, our data only reflects the flat storages which are still included in the facilities grain license. There are slightly more steel structures than concrete in terms of both the number of facilities and total capacities (Table 2).



Map 1. Grain Elevators in Oklahoma

The regional distribution of grain elevators show that North Central and South West occupy majority of the storage structures while there are very few storage structures in the eastern part of the state. In terms of the capacity, North Central alone has about 40% of the total storage capacity followed by Central, Panhandle, South West and West Central each having about 10-15% of the total storage capacity. North Central alone has more than half of the total storage capacity in concrete structure and about 40% of the total storage capacity in steel structure. In terms of Counties, Garfield County (North Central) has the highest storage capacity of 21.7%, followed by Texas County (Panhandle) with 8.23%, Grant County (N Central) with 6.21 % and all other counties having less than 5% of the total storage capacity.

Table 2. Number and capacity of structures by type and crop reporting districts.

Crop Reporting District	Concrete Structure		Steel[1] Structure		Total	
	No.	Capacity (Bu)	No.	Capacity (Bu)	No.	Capacity (Bu)
Central	23	6,824,000	32	8,137,307	55	14,961,307
East Central	0	-	3	2,313,572	3	2,313,572
North Central	127	38,307,783	73	28,247,205	200	66,554,988
Panhandle	17	8,715,540	32	9,025,507	49	17,741,047
South Central	0	-	2	360,000	2	360,000
South West	26	6,517,089	78	16,801,127	104	23,318,216
West Central	32	8,902,516	32	10,315,961	64	19,218,477
Total	225	69,266,928	252	75,200,679	477	144,467,607

[1] Flat structures are grouped under steel structures.

Table 3 classifies storage structures by their age. The table show that a large number and capacity of storage structures were built between 1940 and 1989. The majority of the concrete structures (about 56%) were built between 1950 and 1959 after which the construction of new concrete structures sharply declined. The majority of steel structures (about 40%) were built between 1980 and 1989 but unlike the concrete structures there was no sharp decline in addition of new steel structures. A few structures still in operation date back as far as 1900's. There has been investment in new structures during the last 10 years and during the last three years, with the majority of those structures being round steel bins.

Table 3. Number and capacity of structure by type and years.

Year	Concrete Structure		Steel[2] Structure		Total	
	No.	Capacity (Bu)	No.	Capacity (Bu)	No.	Capacity (Bu)
1900-1909	2	266,244	8	1,706,450	10	1,972,694
1920-1929	1	77,210	0	-	1	77,210
1930-1939	16	1,915,874	3	193,417	19	2,109,291
1940-1949	58	14,678,439	6	1,002,733	64	15,681,172
1950-1959	108	39,318,944	21	3,934,947	129	43,253,891
1960-1969	19	6,679,658	25	3,938,328	44	10,617,986
1970-1979	3	858,588	54	5,413,523	57	16,272,111
1980-1989	8	2,089,945	69	30,577,344	77	32,667,289
1990-1999	1	24,000	22	5,160,016	23	5,184,016
2000-2009	3	1,170,026	28	6,458,300	31	7,628,326
2010-2013	6	2,188,000	16	6,815,621	22	9,003,621
Total	225	69,266,928	252	75,200,679	477	144,467,607

[2] Flat structures are grouped under steel structures.

5.2 Overview of Grain Production

The time series of grain production in Oklahoma do not show a consistent trend (Fig. 1). The range of grain production show a minimum of 93 million bushels to a maximum of 257 million bushels with a five year average of 118 million bushels. Wheat is the major crop in the state with majority share of about 78% of the total crop production. The other major crops after wheat are corn and sorghum which share about 18% of the total crop production. Canola and Soybean share about 3% and 1% of the total crop production.

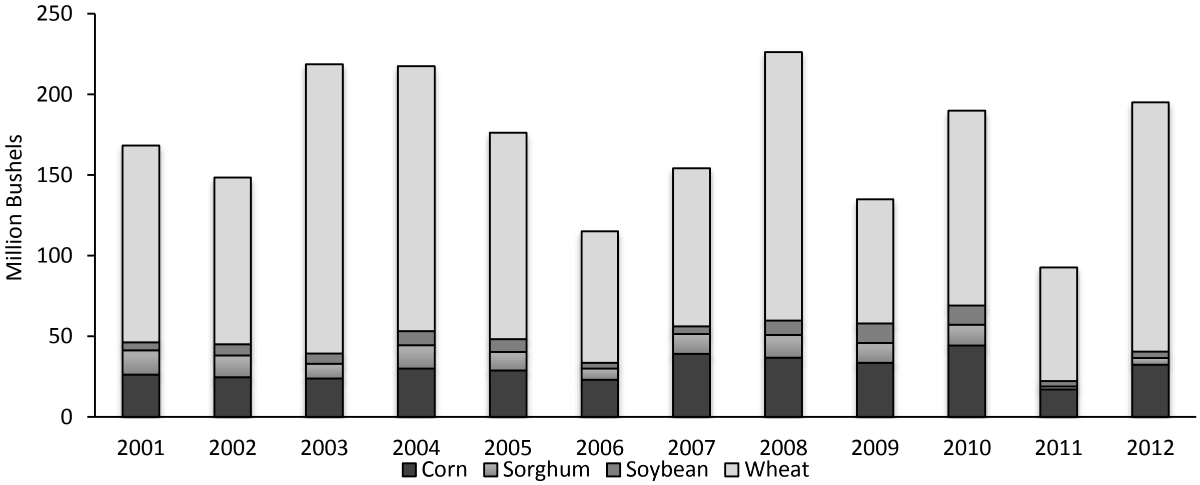


Fig. 1. Historical Grain Production in Oklahoma.

The production of canola however is in rapid rise. In 2009, canola production was 962,000 bushels which almost doubled to 1.7 million bushels in 2010 and 2011 and it again doubled to 3.2 million bushels in 2012 (Fig. 2).

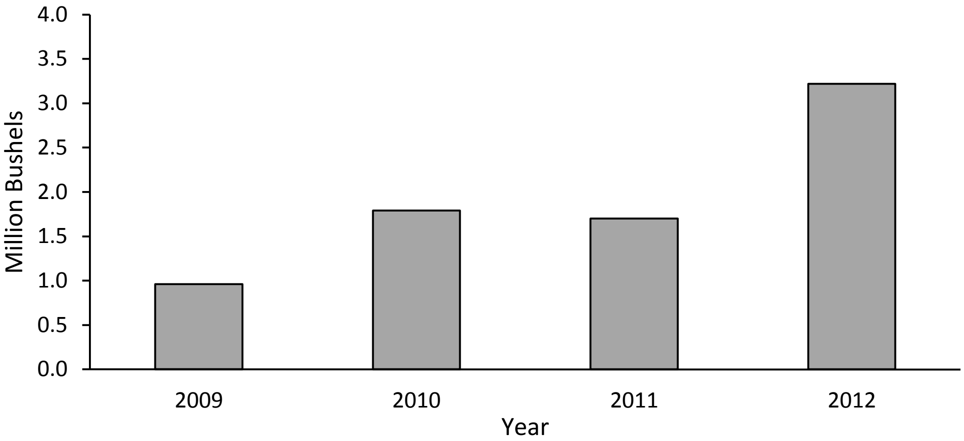


Fig. 2. Time Series of Canola Produciton

The on-farm and off-farm capacity data collected from NASS show that historically Oklahoma has never been deficit in storage capacities (Fig. 3). The off-farm capacity have almost been consistent at about 235 million bushels and on-farm capacity is consistent at 75 million bushels after 2003. Based on our personal contacts with grain facility managers, the NASS data appears to overstate actual grain storage capacity. As discussed previously, there was at one time a large amount of flat storage in Oklahoma due to incentives from the CCC grain storage program. Much of that capacity is not used for grain storage but may still be reflected on the NASS data. There are also several large terminal elevators in Enid, Oklahoma with combined storage capacity over 40 million bushels that have not been in use for many years. Prior to the mid 1970's rail road commonly offered a "transit billing privilege" that allowed grain to be shipped and stored at terminal elevators in route to eventual shipment to export facilities at the same cost as direct shipment to export (Warman, 1994). This created an economic rationale to stage grain at inland terminals such as Enid, Oklahoma. When the transit billing privilege was eliminated the demand for terminal storage decreased. However, the abandoned terminal capacity is still reflected on the NASS storage data. Similar issues impact on-farm capacity. Many producers constructed flat grain warehouses or quonset structures when CCC storage payments and subsidized loans for on-farm grain storage were available. Oklahoma is a high risk storage environment due to temperature and insect pressure. Because of this, most producers shifted to commercial grain storage. Unfortunately, there are no reliable estimates on the amount of grain actually stored on farm. For the purpose of our study we did not consider on-farm grain storage.

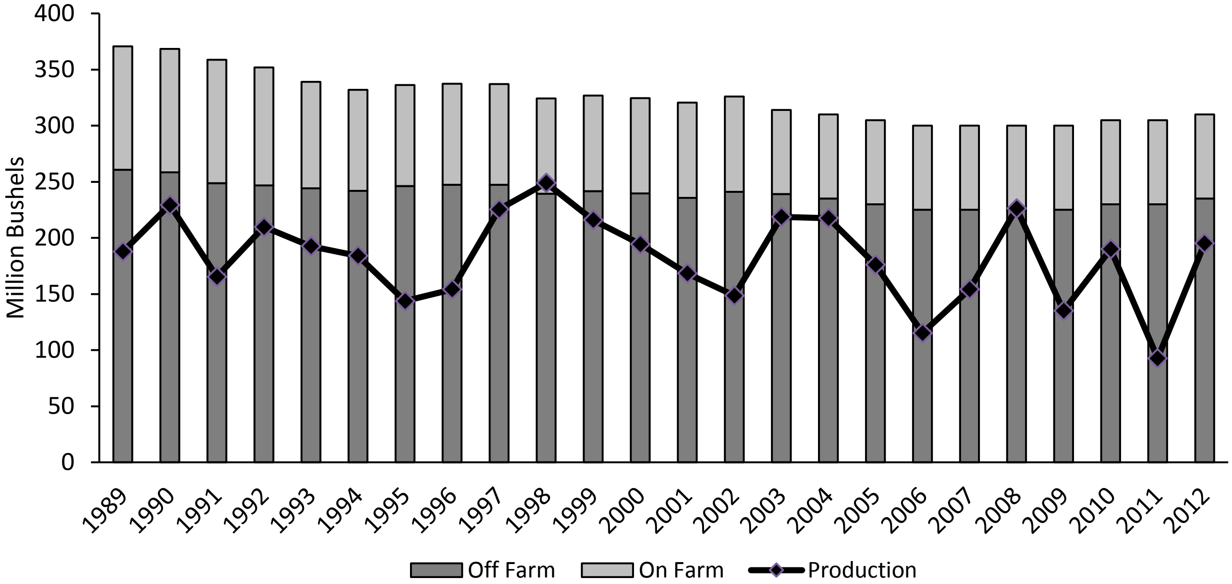


Fig. 3. Historical grain production versus grain storage capacity.

5.2.1 Shift in Grain Production

We analyzed wheat production by county from 1981 to 2008. Unlike the mid-west Corn Belt where corn yields have maintained a consistent growth trend line, no definite or consistent trend of wheat production was found in any counties. There was no regional shift in production between minor wheat production to major wheat producing counties or vice-versa. The only discernible trends in production were in the minor wheat producing regions in Oklahoma such as East Central, North East, South Central and South East which had a declining trend. Similar analysis with corn (1981-2012) show an increasing trend of corn production in counties like Beaver (Panhandle region) Garfield, Grant, Kay (North Central Region), and McCurtain, Muskogee, Ottawa, (Northeast Region) but the production in these counties was less than 2 million bushels per year. There was a significant and consistent rise of corn production in Texas County with 2 million bushels in 1981 to 15 million bushels in 2012. There was a similar increasing trend of corn production in Cimarron County (also in the Panhandle Region) until 1999 when production reached 8 million bushels but corn production declined after that time period. In the Oklahoma Panhandle most of the crop production is irrigated out of the Ogallala aquifer and it accounts for the majority of Oklahoma corn production with an average production of more than 15 million bushels. While accounting for a much smaller portion of total corn production, corn yields are increasing in most of the other crop reporting districts in the state. There was negligible corn production in West Central.

The analysis with grain sorghum show that Cimarron and Texas Counties in the Panhandle District are the major producers of grain sorghum. Both counties however show a declining trend in sorghum production, likely due to a shift from grain sorghum to corn. Cimarron County had 6 million bushels of sorghum production in 1981 which sharply decline to less than a million bushels in 2012. Likewise Texas County had about 8 million bushels of sorghum production in 1981 which also declined to less than a million bushels in 2012. Beaver County (in the Panhandle district), and Grant and Kay counties (in the North Central District) have sorghum production of about 1 million bushels but they also have a slightly declining trend. Alfalfa and Garfield (in the North Central District) are the only two counties to have an upward trend of sorghum production but their production which is about 1 million bushels is very low compared to Cimarron and Texas Counties in the Panhandle Region. The yield trends with Soybeans show that Wagoner, Sequoyah, Ottawa, Muskogee, McCurtain, Le Flore and Kay Counties (all in the North Central and North East Regions) are the major soybean producers. Some counties show declining trend in production while others show increasing trend. Counties such as Alfalfa, Grant, Kay and Washington show increasing trend while counties such as Le Flore, McCurtain and Rogers show a declining trend. The productions by region show that soybean production is concentrated in North East. A trend analysis show an increasing trend of production in North Central and a decreasing trend in South East.

Canola production data by county was not available rather a short time series of state production was available. The trend show a very rapid rise of canola production in Oklahoma. The production was almost four times more in 2012 than the production in 2009.

5.3 Sequential Replacement of Older Structures

Table 4 show the number of structures replaced and retained in sequential replacement of older structures. In scenario 1, there were no construction costs imposed on any structures and the model retained and calculated the transportation costs to the 477 existing grain structures. This provided an approximation of the transportation cost currently incurred by Oklahoma grain producers. In subsequent scenarios, structures older than the specified age were considered obsolete and construction costs were imposed if that capacity or additional capacity was selected at the location. Fifty seven structures were considered obsolete in the first scenario. The cumulative number of structures considered obsolete in each scenario is shown in Table 4. In general, the model rebuilt capacity at most but not all obsolete locations and at times did so by increasing capacity. Out of the 57 locations with obsolete storage in Scenario 2, the model rebuilt capacity at 50 of those locations. By Scenario 5 the total number of structures was reduced from 477 to 293 but total capacity increased from 162.5 million bushels to 170.8 million bushels (Table 5).

Table 4. Number of structures replaced and retained in subsequent scenarios.

Scenarios	Number of Structures Replaced			Number of Structures Retained		
	Obsolete structures	Additional structure options provided	Total	Structures replaced	Structures not obsolete	Total
Scenario II	57	114	171	50	420	470
Scenario III	140	280	420	85	337	422
Scenario IV	302	604	906	163	175	338
Scenario V	390	780	1,170	206	87	293

Note: There are 477 total storage structures with 144,467,607 bushels capacity.

The regional distribution of number and capacities of structures retained show that majority of structure locations which were eliminated were in the North Central and Central regions while additional capacity was added in South Central and Panhandle Regions. In part, this results reflects the excess capacity in terminal elevators near Enid Oklahoma (North Central Region) due to changes in CCC storage programs and rail rate structures. The shortage of capacity in the Panhandle reflects increased corn acreage and yields.

Table 5. Number and capacities of structures retained in subsequent scenarios.

Crop Reporting Districts	Number of Structures Retained					Capacity Retained (Million Bushels)				
	Existing Structures	Scenario II	Scenario III	Scenario IV	Scenario V	Existing Capacity	Scenario II	Scenario III	Scenario IV	Scenario V
Central	55	49	42	32	24	15.0	14.2	12.1	12.6	12.9
N Central	200	176	133	86	70	66.6	63.2	56.7	55.0	53.6
S Central	2	4	4	4	4	0.4	1.4	1.4	1.4	1.4
W Central	64	66	60	48	44	19.2	21.3	21.3	22.6	23.3
E Central	3	3	3	5	4	2.3	2.3	2.3	10.4	10.4
Panhandle	49	57	70	65	62	17.7	19.8	38.0	38.4	38.4
S West	104	115	110	98	85	23.3	29.0	30.6	30.4	30.9
Total	477	470	422	338	293	144.5	151.3	162.5	170.9	170.8

Table 12 and 13 in Appendix B show similar results by county. Capacities were eliminated in most of the counties in North Central and counties like Kingfisher and Canadian in Central regions. There were significant increase in the number of structures in Texas County in the

Panhandle Region and Tillman County in the South West Region. The trend in changes in storage capacity followed the same pattern. Tables 6 show the effect of sequential replacement of older infrastructure on transportation and construction costs. The transportation cost is a function of distance travelled, quantity of grain shipped and cost per bushel per mile. A prior, we anticipated that transportation costs would increase as larger structures were constructed in pursuit of scale economies. However, contrary to our expectations, transportation costs declined even though there were fewer structures in the subsequent scenarios. In the existing structure of elevators, there is insufficient capacity in some locations. The cost of transporting the excess grain to other locations was reflected in the base scenario. In the subsequent scenarios, there were fewer total structures but capacity was increased in previously deficit storage space locations.

Table 6. Transportation and construction cost with sequential replacement of older infrastructures.

Crop	Transportation Cost (Million Dollars)					Annualized Construction Cost (Million Dollars)			
Reporting Districts	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V	Scenario II	Scenario III	Scenario IV	Scenario V
Central	5.4	3.7	3.5	1.1	1.2	1.9	4.5	11.0	15.8
N Central	17.0	13.1	8.4	4.0	3.4	5.2	17.5	52.3	64.2
S Central	0.1	0.8	0.9	0.7	0.7	0.4	0.0	0.0	0.0
W Central	11.4	10.4	1.4	1.5	1.5	1.7	3.6	14.3	16.4
E Central	0.8	0.8	0.8	3.8	3.9	0.0	0.0	1.7	0.0
Panhandle	3.9	4.6	5.2	4.3	4.0	1.1	6.4	5.8	9.2
S West	6.7	6.4	4.0	2.5	2.4	3.6	3.3	12.5	18.6
Total	45.5	39.8	24.2	17.8	17.1	14.0	35.3	97.5	124.3

Table 7 show excess winter and summer capacity with sequential replacement of older storage infrastructures. In the baseline case (Scenario 1) the existing storage capacity was slightly higher than the assumed grain flow (120% of average yields). The winter storage capacity was the closest to crop demand with only 2.5 million bushels of excess capacity. Since the model had to incur construction cost to retain or increase capacity at obsolete storage locations we had no a prior expectations as to whether total storage capacity would increase or remain near the level of crop production. Total storage capacity increased in all of the four subsequent scenarios indicating that the transportation cost savings from increasing capacity at some locations offset the construction cost for increasing capacity. In the last scenario, where all of the existing structures except the very newest structures had the opportunity to be replaced, winter excess storage capacity increased to 29 million bushels, a more than tenfold increase over the baseline scenario representing the existing structure.

Table 7. Excess capacities with sequential replacement of older infrastructures.

Crop Reporting Districts	Existing Capacity (Mil Bu)	Excess Capacities (Mil Bu)									
		Scenario I		Scenario II		Scenario III		Scenario IV		Scenario V	
		Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Central	15.0	0	1.4	0	1.8	0	0.9	0.2	3.4	0	3.3
E Central	2.3	0.2	0	0.3	0	0.2	0	7.6	0	7.7	0
N Central	66.6	1.1	7.8	6.1	9.9	0	10.7	0.2	14.0	0	13.2
Panhandle	17.7	1.2	0	2.9	0	20.3	0	21.1	0.5	21.3	0.6
S Central	0.4	0	0	0	0	0	0	0	0	0	0
S West	23.3	0	4.0	0	7.5	0	10.9	0	12.4	0	12.8
W Central	19.2	0	0.6	0	1.4	0	9.3	0	9.8	0	10.2
Total	144.5	2.5	13.8	9.3	20.6	20.5	31.7	29.1	40.1	29.0	40.2

The excess capacity is calculated by subtracting the retained capacity with the total quantity of grains shipped in that region.

5.5 Unrestricted Replacement of Older Structures

The last case examined represented a near “Greenfield” scenario where almost all of the existing structures were considered eligible for replacement. This scenario investigated what would happen to the grain storage industry structure if the grain industry looked forward and implemented the least cost structure even though some facilities would be replaced prior to the end of their useful life. In this scenario, not only was their no restriction on sequentially replacing the oldest structures first, but the model also had no restrictions on the amount of capacity that could be added at a location. In order to examine the sensitivity to grain production, a second case with a 25% increase in grain yield was also examined in this unrestricted model. Table 8 provides a comparison of the existing grain industry structure and the cost minimizing structure under the near “green field” approach. The number of structure/locations decreased from the current level of 477 to 81 as the model selected fewer locations with higher capacity structures. Most of the structures selected were above 1.5 million bushels capacity. Increasing the grain yield by 25% resulted in a structure of 103 locations, still much more regionalized than the current industry structure, with the same pattern of fewer but larger regionalized locations. With base production, the solution represented a 9.1% increase in capacity relative to the existing industry structure and with 25% increase in assumed grain production the model solution represented a 40.7% increase over the existing capacity.

Table 8. Number of structures by type and capacity – existing and different scenarios.

Capacity (Bu)	Existing Structures			Base Production	25% Increase in Base Production
	Concrete	Steel	Total		
3,000-100,000	39	63	102		
100,001-200,000	63	54	117		
200,001-300,000	62	63	125		
300,001-400,000	28	25	53		
400,001-500,000	9	14	23		
500,001-600,000	8	11	19		
600,001-700,000	2	6	8	2	1
700,001-800,000	1	5	6		
800,001-900,000	3	1	4	1	
900,001-1,000,000	2	3	5		
1000,001-1,500,000	3	2	5	1	3
>1,500,000	5	5	10	77	99
Total	225	252	477	81	103

Table 9 summarizes the regional impacts of the near “green field” scenario. Not surprisingly there would be regional losers and winners if the industry was reconstructed to minimize total system costs. With base production, the Central and North Central regions loses capacity while the South Central and East Central would see significant increase. The same pattern is evident even if the assumed grain flow increased by 25%. While there is a general trend toward increased capacity the largest increases remain in the South Central and East Central Regions.

Table 9. Capacity retained (Million Bushels) with no limit on structure size.

Crop Reporting Districts	Existing Capacity (Million Bushels)	Base Production		25% Increase in Base Production	
		Capacity Retained	%Capacity Gain/Loss	Capacity Retained	%Capacity Gain/Loss
Central	15.0	14.0	-6.4%	18.0	20.3%
N Central	66.6	46.0	-30.9%	60.0	-9.8%
S Central	0.4	2.6	622.2%	2.7	650.0%
W Central	19.2	22.0	14.5%	28.0	45.7%
E Central	2.3	10.0	332.2%	12.0	418.7%
Panhandle	17.7	39.0	119.8%	44.5	150.8%
S West	23.3	24.0	2.9%	38.0	63.0%
Total	144.5	157.6	9.1%	203.2	40.7%

5.6 Comparisons with Sequential and Unrestricted Replacement

We compared the industry configuration after sequential replacement of older bins with the unrestricted or “near green field” case of replacing bins without restrictions on age and with capacity unconstrained (Table 10). In order to compare system cost we calculated the total construction cost of sequential replacement and also included a construction costs for the most recently constructed elevators which were not included in the sequential scenarios. The selected 293 structures from sequential replacement were re-run with construction cost given to all 293 structures. The model retained 276 structures with 169.8 million bushels capacity. The results from this run was compared with the results from the unconstrained replacement which had 81 retained structures with 157.6 million bushels capacity. Not only was the industry in the “green field” case much more regionalized than the existing industry structure, it was much more regionalized that the structure that would occur if structures were sequentially replaced on an "oldest first" basis. As a means of visualizing this result we could consider a grain elevator firm with an elevator in the eastern and western area of its trade territory. If it considered the replacement of the oldest elevator, for example the western elevator, while maintaining the eastern elevator without a construction cost, it might conclude to replace the capacity at the western location. If it looked ahead and considered the fact that both structures would eventually need replacing it might decide to eliminate one location and increase capacity at the other. In the unrestricted or "green field" scenario transportation cost was higher relative to the sequentially replaced structure but total system costs (transportation plus construction) was lower.

Table 10. Cost comparisons with configuration after sequential replacement and capacity unconstrained.

Crop Reporting Districts	Configuration after sequential replacement (Million Bushels)			Unconstrained replacement (Million Bushels)		
	Transportation Cost	Construction Cost	Total	Transportation Cost	Construction Cost	Total
Central	1.15	3.16	4.31	1.43	2.39	3.83
N Central	3.46	11.53	14.99	4.20	7.87	12.07
S Central	0.65	0.39	1.04	1.56	0.49	2.05
W Central	1.51	5.74	7.26	2.56	3.76	6.32
E Central	3.92	1.50	5.42	6.79	1.71	8.50
Panhandle	4.37	8.81	13.18	7.76	6.78	14.53
S West	2.34	8.46	10.80	2.19	4.10	6.30
Total	17.41	39.60	57.01	26.50	27.10	53.61
Cost Per Bushel	0.086	0.196	0.283	0.131	0.134	0.266

Note: The construction cost is an annualized cost.

In terms of regional impact, there was more regional shifts in storage capacity with sequential replacement relative to the unrestricted structure. More structures and capacities were concentrated in North Central, Panhandle, South West and West Central while in unconstrained replacement there was more uniform distribution of capacities in relation to the quantity of crop produced. Few but large capacities structures were built in the unconstrained replacement while in sequential replacement large number of small sized structures were built. The total cost per bushel from both scenarios reflects the need to regionalize large capacity grain storage structures.

Table 11. No. of structure and retained capacity comparisons with configuration after sequential replacement and capacity unconstrained.

Crop Reporting Districts	Base Production (Bushels)	Configuration after sequential replacement		Unconstrained replacement	
		No. of Structures	Retained Capacity (Bushels)	No. of Structures	Retained Capacity (Bushels)
Central	19,029,198	22	12,761,050	7	14,000,000
N Central	63,595,369	69	53,587,050	23	46,000,000
S Central	2,857,169	4	1,410,000	2	2,600,000
W Central	24,295,660	41	23,,204,960	11	22,000,000
E Central	3,539,925	3	10,350,000	5	10,000,000
Panhandle	45,845,940	56	37,948,480	21	39,000,000
S West	32,345,194	81	30,599,920	12	24,000,000
N East	7,432,103				
S East	2,693,009				
Total	201,633,567	276	169,861,460	81	157,600,000

5.7 Sensitivity Analysis

In addition to the previously described sensitivity analysis on the grain production assumptions we conducted sensitivity analysis on fuel cost, construction cost and amortization rates. Fuel and construction cost were changed by 25% and 50% of the base price and amortization factor of 10% and 12% representing longer term loans were used. We did not observe any significant changes to our previous results due to the change in fuel cost, construction cost and amortization factors.

6. Summary and Conclusion

Replacement and expansion of grain handling infrastructure is a critical issue in Oklahoma and other grain producing states. In many regions, a large portion of the infrastructure is nearing its design life and will need to be renovated or replaced in the coming decade. Changes in crop mix, crop yields and land use impacts the size and location of needed future infrastructure and could create a partial reconfiguration of the size and location of grain handling facilities. The managers of grain handling firms in Oklahoma need information on the regional demand for grain infrastructure as they consider investments at specific locations. This paper attempts to analyze current grain storage infrastructure in Oklahoma and determine the level and location of additional infrastructure investment under a number of foreseeable scenarios. The results of the analysis are relevant to agribusiness managers and producers across the Southern Plains.

A mixed integer type plant location model was developed using General Algebraic Modeling System (GAMS). Five crops (wheat, canola, corn, soybean and sorghum) were considered in the study. Satellite imagery data of crop production was processed using ArcGIS to obtain crop production by townships in Oklahoma. Direct field visits and personal contacts were used to determine the location, capacity, age and type of existing grain storage facilities. Because over 90% of the grain produced in Oklahoma are stored in commercial facilities, on-farm storage was not considered.

The model minimized total cost of grain transportation (from the point of production at the township level) to the existing elevator locations and construction cost of storage structures. Several scenarios were created to sequentially replace older structures. The results of sequential replacement overtime indicated that there would be some abandonment of facilities and some shift to larger structures as fewer but large capacity structures were retained. The model eliminated 39% of the structures by the last scenario of sequential replacement where we had replaced all concrete structures built before 1969 and steel structures built before 1989. Surprisingly, producer’s transportation cost did not increase as structures were sequentially replaced because storage capacity was added in locations which were currently storage deficit. The transportation cost decreased by 57% in the final replacement scenario which resulted in 293 total structures as compared to the initial scenario which represented the current industry of 477 structures. Total storage capacity increased after sequential replacement implying that additional construction is cost effective as it reduced transportation costs from locations which are currently storage deficit. The industry structure resulted from the sequential replacement of structures was compared to a near “green field” scenario in which all but the most recently built structures were simultaneously considered for replacement. This unrestricted model also had no limits on storage capacity at each location with 12 concrete and 12 steel structure size options and the possibility of up to 3 same size structures at each elevator location. The unrestricted or near “green field” model resulted in a much more regionalized industry structure with much fewer locations and large capacity structures. The “green field” scenario resulted in higher transportation costs but a lower combined cost of construction and transportation relative to structure resulting from sequentially replacing older structures. This suggests that the grain industry structure would be more regionalized if decision makers looked ahead and planned for the replacement of all of their older infrastructure. This would have implications for producers who would likely incur higher transportation costs. We performed sensitivity analysis on grain volume, construction cost, transportation cost and the amortization factor and concluded that the results were fairly robust to those assumptions.

The results of the study highlights the magnitude of the investment that must occur and suggest some trend towards regionalization. Grain industry decision makers are likely to replace bins sequentially on an “oldest first” basis due to capital constraints. If this is the case, the degree of regionalization will be limited. The infrastructure replacement will likely benefit producers since transportation costs will be reduced by adding capacity in locations which are currently storage deficit.

The industry structures created by market place competition and firm capital constraints do not always end up in achieving the lowest cost. The “green field” scenario that we examined investigated the structure that would minimize the total cost of construction and transportation without restrictions on replacing the oldest structures first. The resulting industry structure would have significantly lower total costs but would involve much more regionalization and higher transportation cost for the producer. While it is not plausible to assume that the grain industry would plan for the simultaneous reconstruction of its total capacity, the results do suggest that decision makers might want to implement a long term planning process. If grain managers considered both obsolete structures and soon to be obsolete structures as they determine capacity and location decisions they might find more opportunities for regionalization. Regardless of whether grain storage becomes more regionalized, it is clear that Oklahoma will need a large amount of investment to replace storage structures that have passed their design life. The replacement of all of the concrete structure built before 1939 and steel structures built before 1959 (the very oldest structures) will require 140 million dollars’ worth of investment. The replacement of all the concrete structure built before 1969 and steel structures built before 1989 (all structures nearing the end of their useful life) will require an investment of around 1,240 million dollars. This study did not consider grain handling speed and unloading time. Infrastructure re-investment with or without regionalization, would likely result in higher grain handling speeds which would likely reduce the producers’ waiting time during harvest. This represents another cost factor not quantified in this study. While the current study is focused only on Oklahoma, the methods and procedures are equally applicable across the grain belt.

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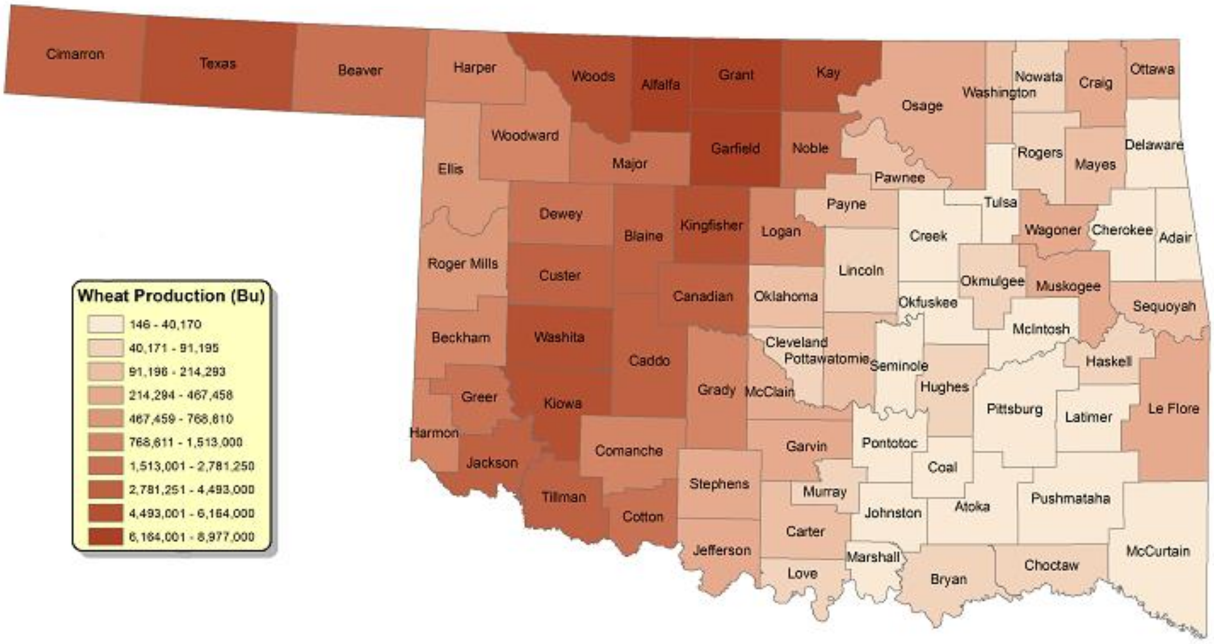
Appendix A – Map



Map 2. Five Years (2008-2012) Average Wheat Production in Oklahoma

Appendix B – Tables

Table 12. No. of structures retained with sequential replacement of older structures by counties.

Crop Reporting Districts	Counties	Existing Number of Structures	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Central	Canadian	14		13	10	8	5
	Grady	8		8	8	8	7
	Kingfisher	21		19	17	12	8
	Logan	7		6	5	1	1
	Oklahoma	1		1	1	2	2
	Payne	4		2	1	1	1
E Central	Cherokee	1		1	1	1	0
	Muskogee	1		1	1	3	3
	Sequoyah	1		1	1	1	1
N Central	Alfalfa	28		24	18	9	8
	Garfield	61		50	42	24	10
	Grant	34		31	20	13	12
	Kay	23		21	17	18	17
	Major	16		13	10	7	7
	Noble	9		9	7	4	5
	Woods	24		23	15	9	9
	Woodward	5		5	4	2	2
Panhandle	Beaver	13		15	15	13	12
	Cimarron	5		5	7	8	10
	Ellis	5		7	7	4	3
	Harper	5		5	4	4	4
	Texas	21		25	37	36	33
S Central	Jefferson	1		3	3	3	3
	Marshall	1		1	1	1	1
S West	Caddo	27		27	26	16	12
	Comanche	8		8	6	4	2
	Cotton	9		11	11	8	8
	Harmon	2		4	3	3	3
	Jackson	13		12	11	14	11
	Kiowa	17		16	16	17	17
	Tillman	28		37	37	36	32
W Central	Blaine	18		18	15	6	5
	Custer	16		17	16	13	11
	Dewey	11		10	7	5	3
	Roger Mills	1		1	1	1	1
	Washita	18		20	21	23	24

Table 13. Capacities retained with sequential replacement of older structures by counties.

Crop Reporting Districts	Counties	Existing Number of Structures	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Central	Canadian	4.24		4.16	2.59	4.01	3.23
	Grady	2.11		2.11	2.11	2.11	2.63
	Kingfisher	6.43		5.87	5.50	4.33	4.87
	Logan	1.17		1.09	1.05	0.62	0.62
	Oklahoma	0.23		0.23	0.23	0.56	0.56
	Payne	0.79		0.74	0.68	1.01	1.01
E Central	Cherokee	0.01		0.01	0.01	0.01	0.00
	Muskogee	2.30		2.30	2.30	10.35	10.35
	Sequoyah	0.01		0.01	0.01	0.01	0.01
N Central	Alfalfa	6.02		5.66	4.76	4.63	4.59
	Garfield	31.38		30.38	29.56	22.51	17.78
	Grant	8.97		8.12	6.29	6.84	6.64
	Kay	6.17		5.77	5.58	7.67	7.35
	Major	3.42		2.79	1.66	2.84	3.66
	Noble	2.68		2.68	2.35	2.47	4.96
	Woods	6.31		6.23	4.96	6.82	7.35
	Woodward	1.62		1.62	1.54	1.27	1.27
Panhandle	Beaver	2.33		2.46	2.64	2.73	2.73
	Cimarron	0.88		0.88	2.26	3.18	3.65
	Ellis	1.53		2.80	2.80	1.94	1.69
	Harper	1.12		1.12	0.92	0.95	1.21
	Texas	11.89		12.58	29.38	29.58	29.07
S Central	Jefferson	0.30		1.35	1.35	1.35	1.35
	Marshall	0.06		0.06	0.06	0.06	0.06
S West	Caddo	7.18		7.18	7.08	4.95	5.53
	Comanche	1.72		1.72	1.59	1.32	1.19
	Cotton	1.60		2.19	2.19	2.40	2.40
	Harmon	0.10		0.31	0.27	0.27	0.27
	Jackson	2.96		2.93	2.90	4.32	3.98
	Kiowa	3.68		3.65	4.24	5.80	6.72
	Tillman	6.08		11.01	12.32	11.38	10.79
W Central	Blaine	7.34		8.04	7.44	6.79	6.62
	Custer	5.36		6.60	6.52	7.47	7.61
	Dewey	2.47		2.41	2.21	1.75	1.87
	Roger Mills	0.11		0.11	0.11	0.11	0.11
	Washita	3.93		4.17	5.06	6.49	7.12