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# Logistical Costs and Strategies for Wheat Segregation

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**ABSTRACT**

Special segregations that provide unique qualities for end use products are being specified by buyers. As users of wheat become more specific about quality, the number of quality segregations that the logistical pipeline must accommodate increases. The additional cost of increased grain segregations will influence the optimal level of wheat variety segregations marketed in a supply chain.

The primary objective of this research is to develop a model that captures the logistical costs of increased grain segregations in the marketing system. A simulation model was developed to add logistical uncertainty in demand, receipts, rail deliveries, and transit time. Sensitivities were conducted on certain variables to determine their effects on logistical costs.

Logistical costs increase as more segregations are added. In addition, increasing uncertainty into the system raises logistical costs. Pipeline configuration also affects costs as the number of categories/storage bins present at origin may differ from the wheat categories demanded or the number of storage bins present at the export elevator.

**Key Words:** **w**heat, segregations

## HIGHLIGHTS

Special segregations that provide unique qualities for end use products are being specified by buyers. As users of wheat become more specific about quality, the number of quality segregations that the logistical pipeline must accommodate increases. The additional cost of increased grain segregations will influence the optimal level of wheat variety segregations marketed in a supply chain.

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# LOGISTICAL COSTS AND STRATEGIES FOR WHEAT SEGREGATION

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## INTRODUCTION

End-users have become more specific about the quality requirements of traditional commodities. Many specialty grains need to retain their identities in order to capture economic benefits, which is a challenge for the logistical functions of the grain handling system. This research analyzes costs related to increased segregations in the marketing system.

Grain has traditionally been marketed as a bulk product, which is less expensive due to economies of large scale shipping. Segregating grains requires handling and other functions that increase costs. The U.S. grain marketing system has not traditionally been well adapted for segregation or identity preservation. The grain market is not accustomed to preserving absolute purity in lots that look the same (Hurburgh, 1999).

Differentiated categories of commodities have increased the number of products in the grain marketing system. In logistics, product categories are identified as separate stock keeping units, or SKUs. Product differentiation (higher number of SKUs) brings added cost to the logistical system. Variety exacts its price in the logistics channel. For example, when a new item is introduced to a product line, combined inventory levels can rise by 40% or more, even though total demand does not increase (Ballou, 1999). A report in the *McKinsey Quarterly* says that cutting low-volume SKUs can permit companies to reduce costs significantly (Bonnot, Carr, and Reyner, 2000). The SKU problem is emerging in the grain marketing system as buyer specificity increases the number of categories of grain demanded.

The objective of this study is to evaluate the logistical cost of increasing the number of segregations in the grain marketing system. Specific objectives include: 1) to evaluate logistical costs when categories of grain increase, 2) to examine how more storage bins better position an elevator to meet export requirements when specificity increases, and 3) to determine which variables affect the logistical costs of marketing grain when more segregations of grain are added to the logistical pipeline.

## BACKGROUND AND PREVIOUS STUDIES

The functions of identity preservation and increased segregations encompass the majority of some of the recent literature in grain marketing. This section focuses on the logistical issues of increasing grain segregations. The SKU problem is described and testing and sampling issues are discussed.

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## Logistical Strategies

The purpose of logistics is "to get the right goods or services to the right place, at the right time, and in the desired condition, while making the greatest contribution to the firm" (Ballou, 1999, p. 6). Inventory and transportation are important to the grain marketing system. Marketers aim to reduce the costs and risks associated with grain moving through the pipeline by using logistical strategies.

Supply chain management is a set of procedures to efficiently integrate market participants so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time in order to minimize system-wide costs while satisfying service level requirements (Simchi-Levi, Kaminsky, and Simchi-Levi, 2000). Van der Vorst defines an agricultural supply chain as the planning and control of the flow of materials and information from agricultural producers to end-users (Lentz and Akridge, 1997). The supply chain encompasses many logistical components that include transportation, customer service levels, inventory management, information flow, and order processing (Ballou, 1999). Goals of supply chain management are to eliminate uncertainty associated with the movement of goods, to reduce inventories, and to decrease overall system costs. Information technology systems that foster communication provide an important foundation for effective supply chain management and at reducing uncertainties in the pipeline.

## Stock Keeping Unit Problem

A focus of some research is to quantify how additional segregations or products increase costs to the logistical system. Product variety increases the complexity of the logistical network (Ballou, 1999). Complexity rises due to the need for managing and estimating different demand forecasts for each SKU. As categories become more specific, there is increased uncertainty about the demand for each SKU. Uncertainty also exists about substitution that may take place between similar SKUs (Handfield and Nichols, 1999).

The SKU problem has implications for the grain industry. For example, a grain manager may try to keep a wide range of quality segregations in inventory to meet demand requirements. This is because managers want to ensure that grain and grades are on hand to meet upcoming vessel requirements (Bevilacqua, 1999). Product variety due to an increasing number of grains and grades has an impact on effective workspace at an elevator (Bevilacqua, 1999). Collins, Bowland, and Friend (1998) add that effective system capacity is reduced by the increasing diversity of products or SKUs. When demand is more difficult to predict, higher inventory levels must be maintained to ensure the same service level (Simchi-Levi, Kaminsky, and Simchi-Levi, 2000). As the number of SKUs in the supply chain are reduced, inventories decrease due to the consolidation of safety stock.

Transportation costs typically increase when there is more product variety because smaller lots are shipped and economies of scale for shipping are seldom reached. Ballou states that product proliferation increases inventories and decreases shipment sizes and adds that transportation costs can be reduced by shipping in larger quantities that require less handling per unit. Impacts on costs could be two-fold if similar lead-times are maintained, as smaller amounts of products are shipped, which translates into warehouses holding a larger variety of products, which increases both transportation and warehouse costs (Simchi-Levi, Kaminsky, and Simchi-Levi, 2000).

Demurrage is a penalty charge on a shipper for holding transportation conveyances beyond an allotted free time for loading or unloading. Demurrage charges are an important consideration when planning the logistical flow of goods.

Inventories are a method to relieve uncertainty in demand and ingredient quality uncertainty. Holding inventory ties up capital and leads to carrying costs. Carrying costs include space costs for volume usage in a building, capital costs of the invested money tied up in inventory, insurance and taxes, inventory risk due to deterioration, theft, damage, or obsolescence (Ballou, 1999). Although there are benefits to holding inventories, these benefits have an expense associated with them labeled as a carrying cost.

Increased storage costs are incurred in a logistical system that segregates. Identity preservation in grains requires more bin space instead of having everything in one large bin (Rustebakke, 1999). More product variety may also increase carrying costs due to the possibility of non-substitutability between segregations.

A cost with increased product variety is the capital cost of accommodating the storage of segregated product categories. For grains, new storage bins and grain paths may be required to keep the identity of quality categories preserved. Capital improvements may be necessary to keep customers satisfied and to meet purity threshold requirements.

Typically companies seek to reduce their SKUs to lessen logistical complexities, which in turn lowers costs. A method often used to manage SKUs is the 80/20 approach. The 80/20 approach implies that 80% of the sales are generated by 20% of the company's products. The 80/20 method differentiates products into a limited number of categories and then applies a separate inventory control policy to each inventory category (Ballou, 1999). The idea behind the 80/20 rule is that products are not necessarily equally important in terms of sales, profit, market share, or competitiveness so each product should be treated separately. This concept has some bearing on the grain industry as elevators may decide to handle only common quality categories that can be easily sold. This in turn reduces the number of storage bins required and lessens the operating complexity, but also decreases the elevator's ability to satisfy niche market demands.

Postponement is a concept utilized to delay the final production and distribution of a product until demand is known. In essence, products are not shipped in anticipation of demand. Simchi-Levi, Kaminsky, and Simchi-Levi (2000) call postponement 'delayed differentiation' and define it as generic (single) products being shipped as far as possible down the supply chain before variety is added. The advantage of postponement is that customer demand across all products has been aggregated which implies a more accurate demand forecast with a much smaller variability, leading to reduced safety stock (Simchi-Levi, Kaminsky, and Simchi-Levi, 2000).

Postponement is not a possibility in the grain market. Grain is differentiated at its first stage based on quality characteristics such as protein, grade factor, and soon on genetic content. However, when different qualities of grain are combined, they cannot be re-segregated due to the inherent mixing that occurs. To realize the full benefit of a quality segment, segregation needs to occur at the first stages of marketing, which in the case of grains, defeats the benefits of postponement.

**Segregation and Identity Preservation**

Some food processing and beverage companies are implementing segregation programs for grains. The trend towards differentiation and specialization requires segregation or identity preservation to preserve the value that is added by various quality categories. Farmers and elevators represent the first stage of segregation. The farm level is ideal for segregation due to relatively small storage facilities. Many country elevators are not well suited for segregation because they have developed into bulk facilities designed for volume throughput and not for smaller lots of specialized products. In addition, incentives for volume shipping, such as unit and shuttle trains, have greatly influenced the structure of the grain handling industry.

In a system in which only small numbers of segregations are required, elevators consolidate shipments by blending various qualities together. Blending increases elevator margins, because quality is not given away and various qualities of grain are mixed to achieve a given minimum quality standard. Blending also allows for small lots of varying quality to be consolidated into larger lots, which may lead to lower transportation costs. Maltsbarger and Kalaitzandonakes (2000) found that these value added activities are relinquished in an identity preserved supply chain.

There are many possible points where commingling of products occurs. Commingling is referred to as the inadvertent mixing of products that increases the chance of the product losing its unique identity and becoming an undesirable product. Segregation of commodities with minimal mixing is difficult for many existing elevators. Most will be challenged by storage and handling constraints as the number of quality categories required for them to handle increases because most elevator storage configurations are not well adapted to handling small lot sizes. Large storage bins may not be fully utilized if lower volumes of more quality categories or products with unique identities are added to the logistical system. Bullock, Desquilbet, and Nitsi (2000) state that a rise in segregations may exploit problems at elevators and export facilities that are inefficiently located and have too few and too large storage bins, too few separate grain paths per facility, and inefficient types of equipment which are more difficult to clean than would be economically feasible. In addition, increased categories of grains could make shuttle train technology less feasible for elevators since elevators may have more difficulty in accumulating the required quantities to meet the volumes required by this low cost transportation method. Baumel (1999) adds that handling more types of grains reduces elevator capacity and causes problems for efficiently receiving grain at harvest time and reduces effective storage capacity.

Identity preservation is a traceable chain of custody that begins with the farmer's choice of seed and continues through the shipping and handling system (Dye, 2000). Identity preservation is an old concept but is increasing in popularity in recent years due to the increase in specialty and genetically modified crops. An increase in identity preservation production is occurring because some consumers are getting more specific about what they want (Anderson, 1999a).

Identity preservation systems have greater costs than the generic commodity system. These are attributed to the strict specifications that must occur. Extra labor and capital are needed to clean equipment and build new structures for the proper preservation of products. If a low tolerance level is set, identity preservation costs increase due to more specific needs and the increased risk of being out of conformance. Identity preservation and certification programs increase logistical costs but also reduce the risk of not meeting quality conformance to strict specifications.

Producers and grain handlers are required to exercise greater care and control to enable the delivery of supplies with high purity when they are needed (Anderson, 1999b). Wilcke (1999) emphasizes that detailed records of planting date, field location and size, seed identity, inputs used, harvest date, crop yield, the storage bin number, crop delivery date, vehicles used, nd the name of the person delivering the crop needs to be recorded; in addition, samples of the crop should be kept until the buyer is satisfied with the quality of the delivered commodity.

Segregation Costs at Country Elevators

Hurburgh (1994) analyzed soybean segregation at an Iowa elevator and estimated the costs of segregating high oil soybeans from regular soybeans. Classification as either high oil or regular soybeans was achieved upon farmer delivery via a test. The test adds two components of cost. These costs include: (1) the actual cost associated with testing the product and (2) a queuing cost. Hurburgh found that the cost of segregating high oil/protein soybeans from regular soybeans is 3.7 ¢/bu.

Lentz and Akridge (1997) examined the costs and benefits of alternative supply chains for soybean segregations. This extension of the country elevator study by Hurburgh includes transportation and marketing expenses.

Krueger et al. (2000) examined the costs associated with receiving an increasing number of grains. A stochastic simulation model was used to quantify segregation costs. Elevator operations become more complex as the number of grain types handled increases. A limiting factor for many elevators is their storage configurations, which are not situated for handling an increased number of low volume grain categories. Quality testing for genetic material is a system bottleneck, which results in a queuing cost. Results show that elevator efficiency has an inverse relationship to the number of grades handled and that costs increase as more segregations are received at a country elevator.

Herrman, Boland, and Heishman (1999), conducted research on segregation at a country elevator. A stochastic simulation model was developed to analyze the effects of segregation. Different elevator configurations were evaluated which vary by number of dump pits, drives, and bucket elevators. The crop was divided into zero (generic commodity), two, and three segregations to estimate the costs of increased segregations. Results from this study vary over the combination of segregations, elevator configuration, and elevator operating efficiency (burden). Results show that the cost of segregating three grades ranges from 1.93 ¢/bu to 6.4 ¢/bu and for two grades the range is from 1.88 ¢/bu to 5.58 ¢/bu.

Maltsbarger and Kalaitzandonakes (2000) examined the costs associated with identity preservation of grains at a country elevator. The major focus was on the loss in revenue due to hidden or opportunity costs such as the inability to grind and blend grains. They also focused on how various elevator asset configurations affect costs. More stringent tolerance levels increase identity preservation costs. A simulation model found that the costs of segregating high oil corn ranged from 16.4 ¢/bu to 36.6 ¢/bu.

Wilson and Dahl (2000) examined the logistical risks of marketing grain in the Canadian system. Past research showed that an increase in grades is a major limiting factor in the efficient movement of grain from the producer (farm) to the port. A component of the research labeled as misgrades was shown to have a large effect on deferring shipments and demurrage costs. Misgrades occur when the grain does not conform to contract specifications. Logistical risks included in the model were uncertainty in vessel arrivals, inventory levels of grain at the port, misgrades that arrive at port, and the railcar unload rate. Other factors that can cause supply disruptions are uncertainty in demand, quality, and performance. The study focused on demurrage costs and examined trade-offs and logistical risks.

Carlson (1998) examined logistical risks associated with marketing homogenous corn between an inland and export terminal. Uncertainties included in the study were yearly supplies of commodities, deliveries into the system, railcar and barge placements, vessel arrivals, and transportation transit times. The focus of the research was on estimating demurrage penalties or expenses. A stochastic simulation model was developed using a scheduling approach.

Reichert and Vachal (2000) studied identity preservation shipments and compared costs of bulk versus container movements. A simple comparison is made of shipping soybeans from Iowa to Japan using alternative modes including container, truck, single railcar, and unit train shipments. Truck transportation is found to be the most expensive at $4.05 per bushel, and unit trains are the least expensive at $1.65 per bushel. The difference in unit train versus container shipment cost is reported to be 33 ¢/bu. McVey (1996) addressed quality in the grain supply chain. He found that elevator handling costs for generic goods range from 10.9 ¢/bu to 12.2 ¢/bu. Incremental handling costs are estimated at 1.42 ¢/bu to 3.13 ¢/bu.

Wheeler (1998) identified variables that are relevant to the higher costs associated with increased grain segregations. He found that the number of segregations impacts grain transportation, handling, and marketing, and that storage capacity, turnover ratios, and logistics are important factors contributing to the costs of segregating grains. The number of wheat segregations received at west coast Canadian ports increased from 81 in 1992 to 112 by 1996. He also reports that only 43 segregations were actually shipped from west coast elevators in 1996. Each additional segregation results in diminishing marginal returns and increasing marginal costs. Askin (1988) found that adding two grades to system receipts increases average operating costs by 5 cents per tonne and average total costs by 13 cents per tonne.

McKeague, Lerohl, and Hawkins (1987) studied the effect that a number of factors, including unloading and grading, weighing, cleaning, storage, and shipping, have on operational efficiency. The number of storage bins is critical to efficient operations and they found that demurrage charges increase when small parcels of grain are introduced into the terminal elevator due to the time required to build up adequate stocks for shipping volumes.

McPhee and Bourget (1995) examined costs associated with an increasing number of grain segregations. Models were formulated to determine the relationship between the number of grains and grades handled to operating costs in the Canadian terminal elevator handling system. A 10% increase in the number of grades handled increased average operating costs by 2.57%.

Wilson and Dahl (2002) examined the costs associated with marketing wheat on an identity preserved basis. A survey found that wheat is being segregated on the basis of grade, protein, and location. Survey respondents noted that the cost of identity preservation may range from 25 ¢/bu to 50 ¢/bu. This study included estimates on identity preservation costs and also pointed out major factors to consider for implementing an identity preservation program. Management and time limitations were listed as important factors to consider for implementing an identity preservation plan. Additional costs to identity preservation systems include testing, time requirements, lot turnover, dispute settlements, and facility modifications.

The major costs included with respect to identity preservation are testing and storage requirements. Another important area of consideration was labeled as quality costs including rejected lots that meet the required specifications and are rejected and also include the opportunity cost of giving away a higher quality of grain; that is, grain that possesses quality traits above those specified. A major conclusion of this research was that increased specificity in strategies has the most impact on the change in shipper costs. As economic costs increase, it increases the incentive for shippers to segregate in order to reduce these economic costs.

Brester, Biere, and Armbrister (1996) examined the costs associated with identity preservation in wheat. A main focus of the research is a principal agent problem where buyers are unable to know immediately if the product delivered conforms to their specified needs. Tests and samples must be conducted to ensure that the product meets their quality requirements. If the product does not conform, it is sold on a scrap market at a lower price. Management costs are considered important due to the complexity that identity preservation presents to administration.

The Economic Research Service (ERS) estimated the cost of segregation for the grain pipeline at 22 ¢/bu to 54 ¢/bu (ERS, 2000). Segregation costs included additional costs of storage, handling, risk management, analysis/testing, and marketing. This estimate was based on a University of Illinois survey on specialty grain handling. The ERS examined a pipeline consisting of a country elevator, sub-terminal, and export elevator. The results show that costs increased at all three points when the number of segregations rose. The cost estimates for segregating Non-GM were 22 ¢/bu for corn and 54 ¢/bu for soybeans.

Table 1 provides a summary for these studies on the estimated costs of segregation.

**Table 1. Segregation/Identity Preservation Costs**

| Researcher | Estimated Cost of Segregation or Identity Preservation | Methodology/Scope of Analysis |
|---|---|---|
| Hurburgh (1994) | 3.7 ¢/bu | Economic Engineering Model |
| Krueger et al. (2000) | $3.04 per truck | Simulation |
| Bullock et al. (2000) | 2.54 ¢/bu | Cleaning and Testing |
| ERS (2000) | 22 to 54 ¢/bu | Survey and Estimations |
| Wilson and Dahl (2002) | 25 to 50 ¢/bu | Survey |
| Askin (1988) | 13 ¢/mt | Econometric |
| Herrman et al. (1999) | 1.88 to 6.47 ¢/bu | Simulation |
| Reichert and Vachal (2000) | 33 ¢/bu | Economic Decision Model |
| Maltsbarger and Kalaitzandonakes (2000) | 16.4 to 36.6 ¢/bu | Simulation |
| Lentz and Akridge (1997) | 6.8 ¢/bu | Simulation Budget Model |

## EMPIRICAL MODEL

The model used in this study is a cost function inclusive of logistical costs. Material requirements planning (MRP) models are flow or systems approach models that are used to pull materials through the logistical pipeline as their need is forecast. Inventory is an integral component of MRP models that accounts for uncertainty in the logistical pipeline. A major component of uncertainty in MRP models is demand. MRP is the method that is most often applied for grain supply chain models. Uncertainties can be introduced into these models which allows one to capture the dynamic flows of grain through the pipeline.

MRP methodology is used to model grain movement through a pipeline. Demand at the export elevator is the main component and is forecast from weekly export inspections. Demand is the force that pulls grain through the pipeline from the country elevator to the export elevator. Wheat is pulled through the system from an origination area that includes a number of country elevators. Railcars are ordered for placement due to forecast demand at the export elevator four weeks ahead of the current week. After the railcars arrive at the country elevator, they are loaded with grain and transported to the export elevator. Transit time is defined as the time when grain is loaded and ready to be shipped from the country elevator until the grain is in position to unload at the export terminal.

The export facility is the destination for the grain and is the point of demand. Grain can either be stored if storage capacity allows or loaded onto vessels to meet actual demand requirements. Actual demand at the export elevator is met from grain in storage at the elevator or by the grain that arrived by rail that week.

Demurrage is incurred if equipment is held longer than allowed by the carrier. Demurrage occurs at the country elevator when inadequate grain supplies are present to fill the number of railcars that are ready to load at the country elevator in the week. At the export facility, demurrage charges are applied when the actual export demand cannot be attained by grain on hand.

Substitution of wheat categories is allowed at both the country elevator and export elevator to meet demand requirements. Substitution of higher quality categories of grain into lower quality categories is allowed, but not vice versa. At the export elevator, substitution is only allowed if the cost of doing so is less than the demurrage charge applied.

The mathematical model includes those logistical costs seen as important for capturing the costs of increasing quality categories handled by the pipeline. Costs included in this study are rail tariff rates, interest costs of storage, substitution costs, demurrage costs, and testing costs associated with the adoption of genetically modified wheat. The costs are calculated for 52 weeks using the following equation:

$$TC = \Sigma\,(RC \bullet RC_N + Dem_{CE} \bullet Dem_{RC} + Dem_{EE} \bullet Dem_{REE} + (S_{iCE}+S_{iEE}) \bullet SC + IR \bullet VSku_i)$$

Where:

$TC$ = Total cost of system over 52 weeks,

$RC$ = Railcar tariff rate,

$RC_N$ = Number of railcars loaded at country elevator,

$Dem_{CE}$ = Number of railcars demurrage is applied on at country elevator,

$Dem_{RC}$ = Demurrage charge applied per railcar,

$Dem_{EE}$ = Number of bushels on which demurrage is applied at export elevator,

$Dem_{REE}$ = Export elevator demurrage rate per bushel,

$S_{iEE}$ = Quantity of $SKU_i$ substituted at export elevator,

$S_{iCE}$ = Quantity of $SKU_i$ substituted at country elevator,

$SC$ = Cost or forgone premium of substituting to a lower quality SKU,

$IR$ = Interest, and

$VSku_i$ = Price paid for $SKU_i$ by system participants.

The cost of cleaning for substitution of a high dockage to low dockage SKU is included as a forgone premium cost. In addition, costs of elevation are not included and considered constant. Increasing elevator storage is also not included due to lack of information on the costs of adding more storage capacity as it is required.

## Detailed Description of Model

Flow of grain and how the various logistical costs are calculated is described below.

### Country Elevator

The model reacts to changes in forecast demand at the export elevator. The export elevator draws wheat from a number of country elevators, represented by a scalar in the model. The actual number of elevators in the draw area is unknown so a value is chosen that provides the export elevator with a large enough volume to meet their requirements. Storage space at the country elevator is allocated on a percentage basis determined by throughput. It is assumed that the country elevator has a sufficient number of storage bins for storing all of the quality categories received.

### Railcar Ordering and Transit

Railcars are ordered based on expected demand four weeks ahead of the current week. If the expected demand in four weeks cannot be achieved by grain in house at the export elevator plus the amount scheduled to arrive less the demand previous to the fourth week, railcars are ordered to meet the demand so a shortage does not occur. Railcars are ordered even if there is not sufficient volume at the country elevator to meet the export elevator demand. The export elevator must meet its demand, so it sends out railcars to meet the necessary volume needed. The export elevator also orders to maintain a safety stock equivalent in volume to one week of average demand.

Railcars arrive based on a distribution of placement. Railcars are filled from the SKU that they were ordered for when a sufficient volume of that SKU exists at the country elevator. If the entire volume cannot be met from the desired SKU, the model searches other SKUs of higher quality to fill the remaining volume. A substitution cost equal to the difference in market value between the SKUs is charged to the system when this occurs. If only a partial railcar can be filled, the partial amount is held over until an entire railcar can be loaded. After the railcars are loaded, a distribution allocates the railcar arrival at the export elevator in periods of one to three weeks.

### Export Elevator

As railcars arrive they are allocated to their specific SKU storage or to meet the SKUs' export vessel demand. The identity of each railcar by SKU is known upon its arrival from the country elevator. Higher volume SKUs receive more storage capacity. Grain in house at the export elevator is used to meet weekly demand. If the entire demand for a particular SKU cannot be met from its own volume, the model searches for higher quality SKUs to meet the remaining volume, at a cost. The model does not allow substitution of SKUs at the export elevator if the cost of substitution (the difference in the market values) is greater than the cost of demurrage.

**Detailed Description of Model Parameters and Calculations**

**Demand**

The model evaluates flows of only Hard Red Spring (HRS) wheat. The distributions for demand and forecast demand are included to allow for uncertainty in demand at the export elevator. Normal distributions are assumed for weekly export demand and were derived from the Grain Transportation Report (1996-2000) which provides data on export inspections for all wheat in the Pacific Northwest (PNW). One demand distribution is a forecast of demand that is used for railcar orders and another distribution is used to determine the actual weekly demand at the export elevator. The average and standard deviation for each week is calculated to determine a normal distribution of demand for each week. The forecast and actual demand use the same average and standard deviation but are different distributions. This allows for uncertainty between expected and actual demands and creates a more realistic scenario between what is forecast and what actually occurs.

Of the total wheat weekly inspections at the PNW, 30% is taken to represent the amount of HRS wheat demanded. This was calculated from the Export Grain Inspection System EGIS data (USDA-GIPSA) by evaluating the volume of different classes of wheat exported per year from the PNW.

There are nine export facilities in the PNW with varying storage capacities. The model represents one export facility of average size in the PNW. The average storage size is calculated from Federal Grain Inspection Service (FGIS) data on export facility capacity. This average export facility is taken to represent 11% of the PNW wheat throughput (Figure 1).

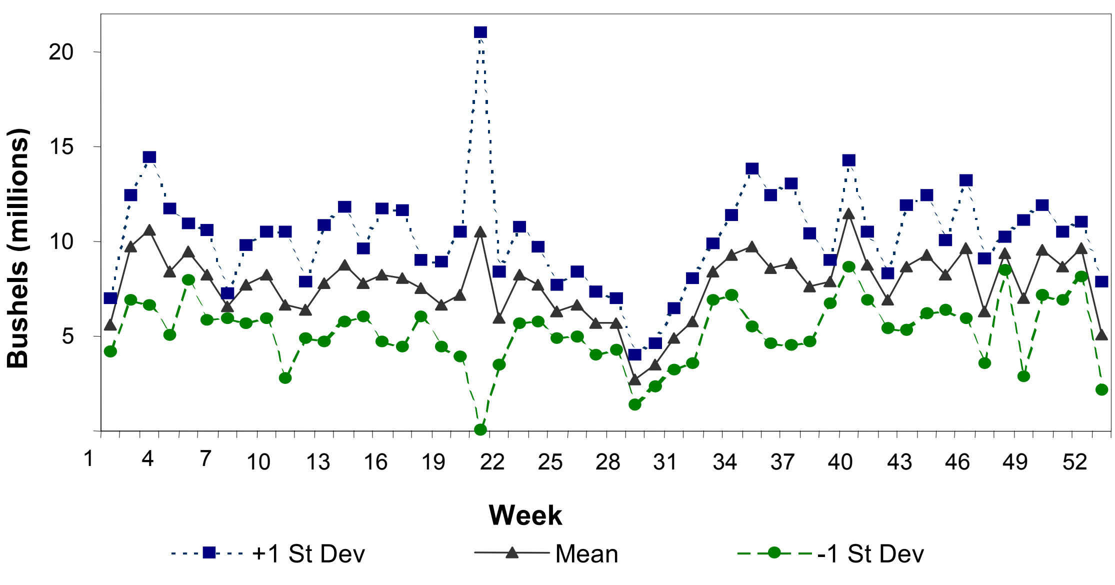


**Figure 1. HRS Demand Distribution at the PNW**

**Receipts**

North Dakota Agricultural Statistics Service (NDASS) data is used to derive a distribution for farmer deliveries. An index of farmer deliveries per month along with the overall wheat deliveries for the year are used to derive deliveries into the system.[1] A normal distribution is used to represent the uncertainty about weekly producer deliveries into the system.

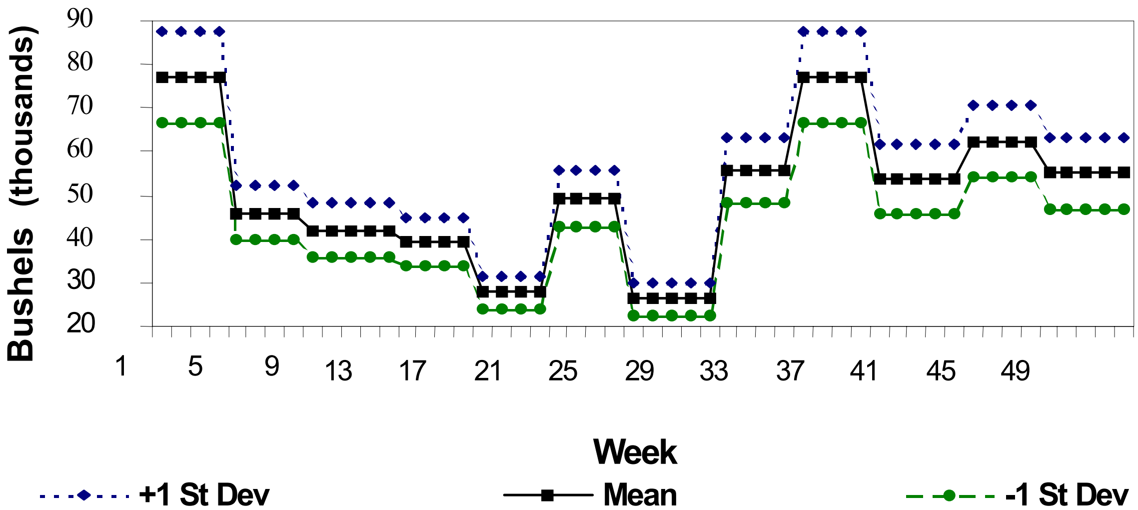


**Figure 2. Receivables Distribution for a Country Elevator**

Figure 2 represents the distribution of receivables at a country elevator. Origination for one country elevator is multiplied by a scalar representing the number of elevators within the drawing area available to the export terminal. An initial value of this scalar for country elevators was chosen to ensure enough supply in the pipeline to meet an average size export facility in the PNW. Sensitivities were conducted to determine the effects of larger and smaller origination capacities.

**Stock Keeping Unit Definitions and Values**

Wheat can be divided into different categories based on its quality characteristics. SKUs are used to define categories of wheat. Export Grain Inspection System data (USDA-GIPSA) for HRS wheat and harvest quality data for North Dakota HRS wheat (Department of Cereal Chemistry and Technology) are used to determine the number and amount of the SKU in the logistical system for the 1999/2000 marketing year. The SKUs are categorized by using grade factor limits, protein, and dockage levels (Tables 2 and 3). SKUs are split further on dockage content. The dockage break value is chosen from evaluating the EGIS and North Dakota crop quality data and from values in Wilson and Dahl (2001). Table 3 provides a definition of the SKUs used in the model.

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[1] Dividing the monthly average by six approximates the standard deviation. The monthly average is converted to a weekly average by dividing the mean by the number of weeks in the month. Deriving a weekly standard deviation from a monthly deviation value is more difficult. First, the variance of the month is divided by the number of weeks in the month. Then the square root of this value is taken to determine the standard deviation for a week.

**Table 2. SKU Breaks**

| Classifying Characteristic | Percentage Break |
|---|---|
| Grade 1, 2, 3, less than 3 – Salvage | Grade factor limits |
| High Protein | Above 14.5% |
| Medium Protein | Between and including 13.7% and 14.5% |
| Low Protein | Below 13.7% |
| High Dockage | Above 0.7% |
| Low Dockage | Below and including 0.7% |

**Table 3. Definition of the SKUs in the Model**

| SKU | Grade | Protein | Dockage | Value | Inbound SKU Country Elevator % | Outbound SKU Export Elevator % |
|---|---|---|---|---|---|---|
| 1 | 1 | High | Low | 3.29 | 7.2 | 0.0 |
| 2 | 1 | High | High | 3.26 | 16.6 | 0.0 |
| 3 | 1 | Low | Low | 3.11 | 7.7 | 0.0 |
| 4 | 1 | Low | High | 3.08 | 9.4 | 0.0 |
| 5 | 1 | Middle | Low | 3.21 | 3.9 | 29.6 |
| 6 | 1 | Middle | High | 3.18 | 12.2 | 2.8 |
| 7 | 2 | High | Low | 3.23 | 0.6 | 3.7 |
| 8 | 2 | High | High | 3.20 | 5.0 | 1.4 |
| 9 | 2 | Low | Low | 3.05 | 0.6 | 6.5 |
| 10 | 2 | Low | High | 3.02 | 4.4 | 1.9 |
| 11 | 2 | Middle | Low | 3.15 | 2.2 | 45.4 |
| 12 | 2 | Middle | High | 3.12 | 7.7 | 8.8 |
| 13 | 3 | High | Low | 3.16 | 0.6 | 0.0 |
| 14 | 3 | High | High | 3.13 | 6.1 | 0.0 |
| 15 | 3 | Low | Low | 2.98 | 0.6 | 0.0 |
| 16 | 3 | Low | High | 2.95 | 1.1 | 0.0 |
| 17 | 3 | Middle | Low | 3.08 | 1.7 | 0.0 |
| 18 | 3 | Middle | High | 3.05 | 5.0 | 0.0 |
| Salvage | | | | 2.71 | 7.7 | 0.0 |

The quantity allocated to each SKU was calculated from EGIS data (USDA-GIPSA) and North Dakota crop quality data (Department of Cereal Chemistry and Technology) and is based on the frequency of the SKU occurring in the data. Figures 3 and 4 show the percentage of time the SKU occurs at the point of receipt into the system and that demanded. There are fewer outbound SKUs at the export elevator than at the point of receipt into the system. The 19 SKUs derived from the data for the origination area at the country elevator are included as separate SKUs regardless of there only being eight SKUs present at the export elevator to capture the substitution costs of not using the country elevator SKU at its best use.

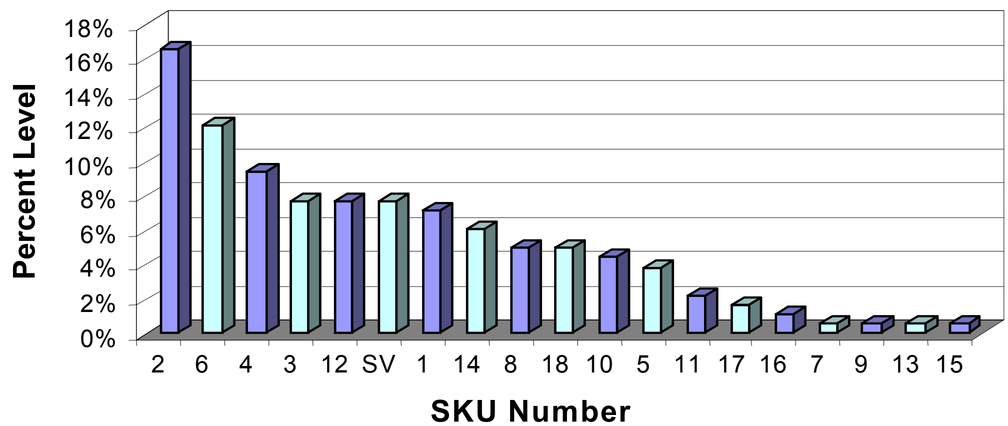


**Figure 3. SKU Percentage at Point of Receipt (Inbound SKUs)**

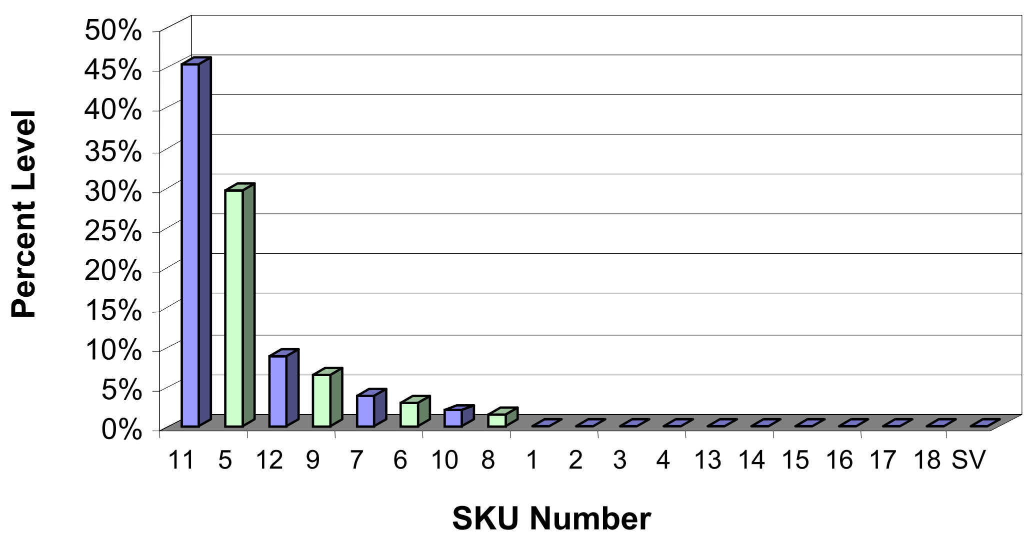


**Figure 4. SKU Percentages at Point of Demand (Outbound SKUs)**

Each SKU has an associated premium or discount associated with it depending on the quality characteristics of the wheat in that category. Market values for the SKUs are calculated from premiums and discounts for the grade factors, protein content, and dockage level. Protein premiums and discounts are applied from values taken from market data. Dockage discounts are taken from a Wilson and Dahl (2001) dockage study, which estimated cleaning costs at 3.3 ¢/bu to bring dockage content to below 0.7%. Substitution between grades with similar protein and dockage values is more difficult to estimate. Discounts are applied to previously graded crop quality samples to obtain a discount value between comparable Grade 1, Grade 2, Grade 3, and lower than Grade 3 SKUs. These calculations are compared to industry estimations and are found to be similar. Each SKU has a unique value due to the composition of its various quality characteristics.

**Substitution**

Substitution of SKUs means that higher quality products can be substituted to meet lower quality product demand, but lower quality products cannot be substituted to meet higher quality demand. Substitution occurs at the country elevator if the railcar loadings cannot be achieved from the specific SKU for which the railcars are ordered. Substitution occurs at the export elevator if the vessel demand for a specific SKU cannot be filled by that SKU and the forgone premium of substitution is less than the demurrage charge. Whenever substitution takes place, a forgone premium is applied to the overall logistical cost function since the substituted product is not optimally used.

Discount and premium values for protein content are taken from a survey made of export grain merchandisers during the fall of 2000 to find the value associated with the SKU level. Values between grades are calculated from current premium/discount values for grade factors and applied to the North Dakota crop quality data to determine an average cost per grade. The grade factor premium and discount values are applied to current classifications of samples already labeled as Grade 1, 2, 3, and less than 3 to find the average value of wheat classified as Grade 1, 2, 3, or less than 3. Industry participants also estimated the discounts between similar SKUs of different grades and the calculated values were comparable. The discounts or forgone premiums in Table 4 are used to determine substitution possibilities.

**Table 4. Discounts or Forgone Premiums**

| Substitution | Forgone Premium |
|---|---|
| | --------¢/bu------- |
| Grade 1 for Grade 2 | 6.0 |
| Grade 2 for Grade 3 | 6.0 |
| Grade 1 for Grade 3 | 13.0 |
| Grade 1 for Salvage | 37.0 |
| Grade 2 for Salvage | 31.0 |
| Grade 3 for Salvage | 25.0 |
| High Protein to Medium Protein | 7.5 |
| High Protein to Low Protein | 18.5 |
| Medium Protein to Low Protein | 10.5 |
| High Dockage to Low Dockage | 3.3 |
| Low Dockage to High Dockage | 3.3 |

**Interest Costs, Storage Capacities, and Shipping Costs**

Average inventory at the country elevator and export elevator for each SKU is used to calculate an inventory cost of holding inventory. Transit inventory per SKU is also included in this calculation to determine the effects that holding inventory has on the entire logistical system. The market value of each SKU is derived to obtain a value of the inventory on hand. An annual interest rate of 7% is applied to determine an interest cost of holding inventory in the pipeline.

Storage capacities are estimated from data (Burlington Northern Santa Fe (BNSF) Grain Elevator Directory for 1999 and the FGIS Export Elevator Directory (2000)) and shown in Table 5. Storage capacity dedicated to wheat is assumed to be 50% of overall storage capacity. Beginning inventory values for each SKU are set at 50% of their individual SKU storage capacities.

**Table 5. Elevator Storage Capacities**

| Elevator Type | Overall Storage Capacity (bushels) | Capacity Dedicated to Wheat (bushels) |
|---|---|---|
| Country Elevator (52-train) | 930,395 | 465,197 |
| Export Elevator | 3,250,000 | 1,625,000 |

Storage capacity for each SKU is calculated on a percentage basis. The throughput of each SKU is calculated to a percent that is multiplied by the overall storage capacity for wheat to determine that SKU's respective storage capacity. Storage is calculated in this manner due to the difficulty in obtaining storage configurations and bin sizes.

Elevators that have the ability to load out a 52-unit train are used to derive the elevator parameters. The base case country elevator has a configuration that is able to accommodate all incoming SKUs, which includes separate bin space for the 19 SKUs. Storage capacity for spring wheat is set at 50% of overall storage capacity for wheat. Beginning inventories for the elevator per SKU are set at 50% of the storage capacity for that SKU.

There are nine export elevators located in the PNW. Capacity is used to determine the throughput or amount of demand for that facility. Through calculations from the FGIS data, the average size export facility is found to account for roughly 11.5% of overall storage capacity. This value is the best estimate of throughput for HRS wheat shipments for a facility from the PNW. Fifty percent of the facility is dedicated to HRS wheat in the model. The export elevator configuration is able to accommodate all SKUs with separate storage. The rail shipping charge is for wheat originating in Jamestown. The tariff charge per car is set at $4,400 per car and railcars are assumed to hold 3,300 bu/car.

Shippers order railcars to transport the grain from the country elevator to the export terminal. Shippers are allowed to specify a want date within a shipping period (Carlson, 1998). The distribution for general tariff car placement is provided by the BNSF railroad. A gamma distribution with parameters (8.38,1.42) is used to incorporate uncertainty to railcar arrivals at the country elevator and is applied to this model (Carlson, 1998).

Transit time is defined as the time between when railcars are loaded and available for shipment at the local elevator until they arrive at the export facility and are available for unloading. Average transit time estimated for rail shipments from North Dakota to the Pacific Northwest is slightly less than two weeks. For this reason, a discrete distribution is introduced to allow for transit time variability of one to three weeks: a 33% chance of the railcar arriving within seven days, a 34% chance of the railcars arriving in week two, and a 33% chance of them arriving after fourteen days.

**Demurrage Calculations**

Demurrage charges are applied at the country elevator when a railcar that has arrived at the origination facility for loading is not filled within the week that it arrived. Demurrage is applied at the export facility when there is not enough grain on hand to meet the weekly demand.

Rail demurrage charges are taken from the BNSF demurrage policy (2000). A value of $50 per car per day is applied. This is the average of the peak season rate of $75 per car per day and the off peak season rate of $25 per car per day. Rail demurrage charges are only applied at the country elevator when cars arrive and the elevator is unable to fill the railcar. The model keeps track of how many weeks a car sits idle and applies a demurrage charge until the car is filled and transported to the export elevator.

Export demurrage charges are calculated on bushels of demand at the export elevator that are not satisfied. Carlson (1998) found that a typical demurrage cost for vessels is $1.40 per metric ton per week or 3.8 ¢/bu per week. This export demurrage charge is applied to all export demand that is not satisfied for each week. The model carries shortages to the next week and adds the amount short from the previous week to the new week's demand.

## Simulation Procedures

Stochastic simulation utilizing *@Risk* simulation software (Palisade Corporation, 2000) was used. The model is developed to cover a 58 week period, allowing six weeks for railcar and barge ordering strategies to initialize and then costs are monitored for the remaining 52 week period, simulating one year of operation for the marketing chain. The model was specified with initial parameters for inventories representing continuing operations. Initial parameters for beginning inventories, capacities, etc. are described below. Models are simulated for 1000 iterations at which time output distributions for total costs over the 52 week period had converged and appropriate stopping criteria were indicated.

## Data

### Data Sources and Behavior

Data sources used in this research are summarized in Table 6.

**Table 6. Data Sources**

| Model Component | Data Source |
|---|---|
| Demand | Grain Transportation Report (1996-2000) |
| Receipts | North Dakota Agricultural Statistics Service (1991-95) |
| SKU Percentages | USDA-GIPSA (2000) and the Department of Cereal Science and Technology at North Dakota State University (1999) |
| General Tariff Placement | Carlson (1998), Burlington Northern Santa Fe |
| Rail Transit Time | Carlson (1998), Burlington Northern Santa Fe |
| Rail Tariff | Burlington Northern Santa Fe |
| Premium/Discounts for SKUs | Export Grain Inspection Service (2000), the Cereal Science Dept at North Dakota State University (1999) and Industry Participants (2000) |
| Country Elevator Statistics | Burlington Northern Santa Fe–Grain Elevator Directory (1999) |
| Export Elevator Statistics | Federal Grain Inspection Service–Directory of Export Elevators (2000) |
| Rail Demurrage Policy | Burlington Northern Santa Fe–Demurrage Table (2000) |
| Export Demurrage Charges | Carlson (1998) |

Stochastic variables included demand at the export terminal and receipts at the country elevator. In addition, uncertainties existed for railcar placement at the country elevator and transit time from the country elevator to the export terminal. Strategy variables in the model include the number of SKUs that can be accommodated at the country elevator and the export elevator. A scalar is introduced to vary the receivable volume for the export elevator pipeline origination area. The forecast for demand is chosen as a strategy and is placed at four weeks (Table 7).

**Table 7. Base Case Variables and Distributions**

| Variable Name | Value |
|---|---|
| Export Demand – Weekly (Actual and Forecasted) | Normal Distribution |
| Country Elevator Receipts – Weekly | Normal Distribution |
| Railcar Placement at Country Elevator | Gamma Distribution (8.38, 1.58) with a mean of 13.24 days and a Standard Deviation of 1.98 days |
| Railcar Transit | Discrete Distribution with a 33% chance of cars Arriving in week one, 34% chance in week two, and 33% chance in week three |
| Railcar Order Placement for Export Delivery | Order railcars for forecast demand four weeks in Advance |
| Distribution of Quality: Origin (SKUs) | Estimated from North Dakota Crop Quality Data – 19 SKUs |
| Distribution of Quality: Export Demand (SKUs) | Estimated from Export Grain Inspection Service Data – 8 SKUs |
| Scalar for Origination Volume | 14 Elevators from which to Originate Wheat |
| Country Elevator Storage Capacity per SKU | SKU Percentage multiplied by Overall Country Elevator Storage Capacity |
| Export Elevator Storage Capacity per SKU | SKU Percentage multiplied by Overall Country Elevator Storage Capacity |
| Beginning Inventories of SKU– Country Elevator | 50% of Country Elevator Storage Capacity for each SKU |
| Beginning Inventories of SKU– Export Elevator | 50% of Export Elevator Storage Capacity for each SKU |
| Acceptance of Lot based on test Accuracy and contamination | Binomial distribution (n,p) where n = number of lots to test and p = probability of accepting the lot |
| Lot Size for Testing | Choose a lot size based on a number of trucks or railcars to perform the genetic test |

It is difficult to portray all factors that are included in a logistical pipeline; however, the most important aspects captured by this model include transit costs, interest cost of storage, demurrage costs, forgone premiums or substitution costs, and testing costs. In addition, distributions are estimated for variables to make the model more realistic in the sense that many factors are not known with certainty. Derivation of a model that is able to keep track of different wheat categories allows for insight into the costs associated with increased grain segregations.

# RESULTS AND SENSITIVITIES

The base case models are designed to represent a typical logistical grain flow. Measures of logistical cost captured in the model include country and export elevator demurrage, interest costs of holding inventory in the system, forgone premiums of substitution at the country and export elevators, and rail tariff costs. Rail tariff costs are a large percentage of the expenses incurred in the grain marketing system (Table 8). Rail tariff costs account for a large percentage of the total logistical costs, representing 91% of the logistical costs.

**Table 8. Base Case Costs**

| Category of Cost | Total Cost ($000's) | ¢/bu |
|---|---|---|
| Demurrage: | | |
| Country Elevator Demurrage | 79 | 0.58 |
| Export Elevator Demurrage | 37 | 0.27 |
| Forgone Premiums: | | |
| Forgone Premiums at Country Elevator | 621 | 4.51 |
| Forgone Premiums at Export Elevator | 1 | 0.01 |
| Interest Costs of Inventory | 1,254 | 9.10 |
| Rail Tariff Charges | 18,847 | 136.76 |
| TOTAL | 20,848 | 151.30 |

Excluding rail shipping costs, interest cost is the largest cost to the logistical system. This is followed by forgone premiums at the country elevator and demurrage expenses. Forgone premiums are charged to the system when a SKU is substituted and not utilized by the system in its best use. Whenever a substitution of a higher quality SKU occurs, the difference in market value between those SKUs is charged to the system in the form of a forgone premium. Forgone premiums are higher at the country elevator due to railcar arrivals ordered to meet only SKUs present at the export elevator. The large number of inbound SKUs is thus consolidated to the number of export SKUs.

## Sensitivity on Stochastic Variables

### Export Demand

The percentage or volume of each SKU demand is not known with certainty so a sensitivity analysis was performed to determine the effect on logistical costs when this uncertainty increased. A scalar is introduced to the model to vary the standard deviation of export demand. The scalar is applied to both the forecast demand used for railcar orders and to the distribution representing actual demand.

The results indicate that as volatility in export demand increases, costs in almost all categories increase (Table 9 and Figure 5). Export elevator demurrage, export elevator forgone premiums, forgone premiums at the country elevator, and rail tariff charges increase when more volatility is introduced to the demand components of the model. The amount of demand satisfied rises as well due to the possibility of higher export demand. Average logistical costs are higher at every incremental rise in the scalar value, which increases demand volatility.

**Table 9. Cost Comparison with an Increase in Demand Volatility**

| | Base Case | Standard Deviation of Demand Scalar | | |
|---|---|---|---|---|
| Scalar | 1.0 | 1.1 | 1.2 | 1.3 |
| | | ---------------------- ¢/bu | --------------------- | |
| Country Elevator Demurrage | 0.58 | 0.57 | 0.56 | 0.57 |
| Export Elevator Demurrage | 0.27 | 0.31 | 0.35 | 0.40 |
| Country Elevator Forgone Premiums | 4.51 | 4.56 | 4.61 | 4.67 |
| Export Elevator Forgone Premiums | 0.01 | 0.01 | 0.01 | 0.01 |
| Interest | 9.10 | 9.09 | 9.07 | 9.05 |
| Rail Tariff Charges | 136.76 | 137.14 | 137.57 | 137.98 |

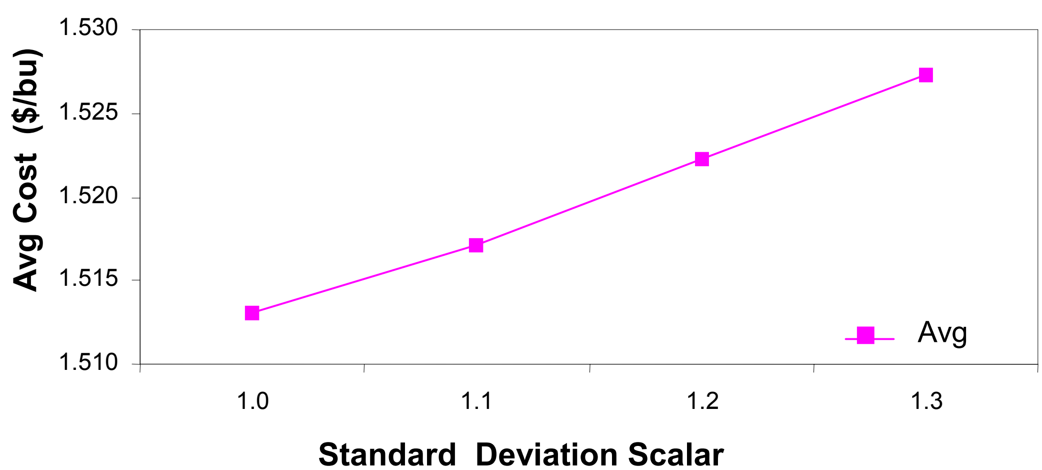


**Figure 5. Logistical Costs for Increased Demand Volatility**

A large increase in export demurrage costs occurs due to the risk of not knowing the volume demanded for each SKU. Export elevator forgone premiums rise due to more substitution being required to cover the more volatile demand. Forgone premiums at the country elevator increase due to increased substitution to meet the more volatile demand forecasts. Finally, the amount of demand satisfied rises because of the standard deviation scalar effect of increasing export demand.

Figure 6 shows the probability representation on the distribution of costs and export volume shipped. As volatility increases, costs rise.

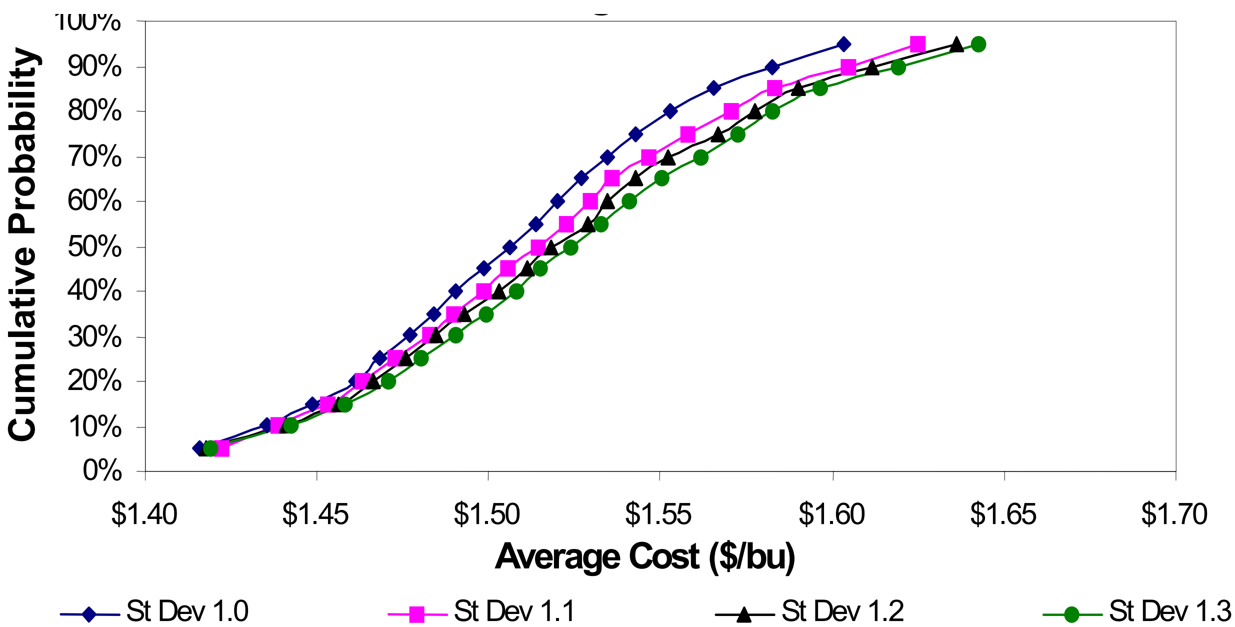


**Figure 6. Distribution of Average Costs as Export Volatility Increases**

## Sensitivities on Strategic Variables

Sensitivities are performed to determine how logistical costs change when a shipper alters strategic decisions. Strategic variables on which sensitivities are performed include the number of SKUs handled at the export facility and the number of incoming SKUs or storage bin space at the country elevator.

### Outbound Stock Keeping Units at the Export Elevator

In the base case, eight categories of wheat are used that are based on the break points for grade, protein, and dockage. The throughput found for these categories is combined and expanded into different numbers of quality categories to determine what happens when there are more or less SKUs present in the marketing channel.

In lowering the number of SKUs, dockage is removed so the splits are based on only grade factors and protein. This reduces the number of outbound SKUs to four. The number of SKUs is further reduced to the two highest SKU percentages. The two most frequent SKUs account for over 75% of the grain exported in the base case. The SKU categories are grouped by Grade 1 and Grade 2. In expanding the number of SKUs, Grade 1 SKUs are proliferated by percentages that have evolved for Grade 2. In the base case, 30% of the overall SKU total is distributed between two SKU classes of Grade 1, and 70% of the overall SKU total is distributed between all six SKU classes of Grade 2. To expand the number of SKUs in Grade 1, the percentage totals for each class of Grade 2 are applied to the corresponding SKU in Grade 1 so that the overall percentage of Grade 1 is present in all six SKUs instead of the two Grade 1 base case SKUs. This expansion assumes that Grade 1 categories develop in a similar manner in which Grade 2 categories have evolved.

As the number of outbound SKUs increases from the base case, the logistical costs rise. Of the sensitivities included, the lowest cost occurs with four outbound SKUs. As the number of SKUs decreases to four SKUs from the base case value of eight, average costs decrease by 1.71 ¢/bu. Increasing to 12 SKUs from the base case increases the average logistical cost by only 0.07 ¢/bu. Decreasing the number of SKUs from four to two SKUs increases logistical costs by 5.88 ¢/bu (Figure 7). The cost increase of moving from four to more SKUs is due to higher country elevator demurrage charges, interest costs, forgone premiums at the country and export elevators, and rail charges.

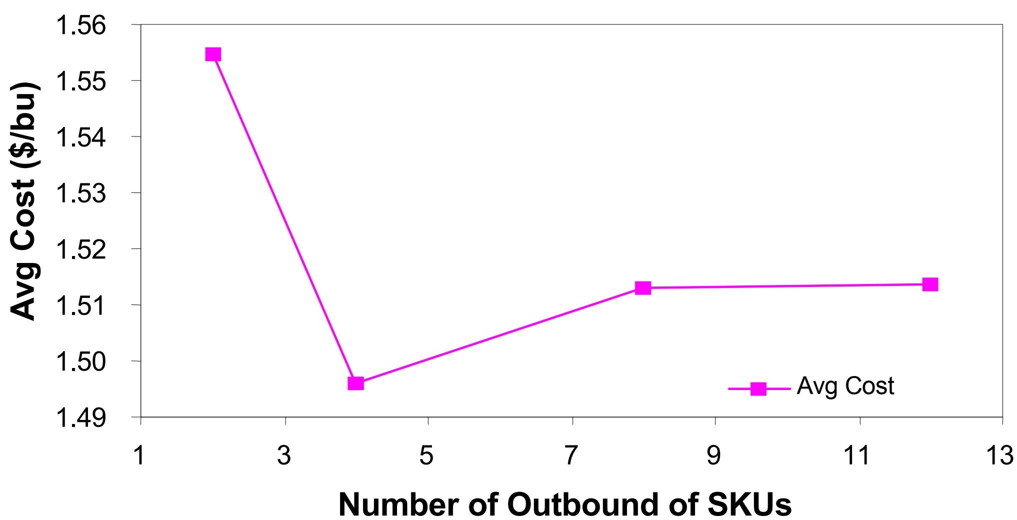


**Figure 7. Outbound SKU Effect on Logistical Costs**

Country elevator demurrage charges increase due to increases in higher quality Grade 1 SKUs for which there are fewer substitution possibilities. Interest costs increase due to more wheat in the system with a higher market value and an increase in average inventory holdings for the system. With more SKUs in the system, inventory at the export elevator increases due to a need for more safety stock for the additional SKUs. Forgone premiums increase at the country elevator due to increased substitution to meet this higher level of safety stock at the export elevator. Forgone premiums increase at the export elevator because higher quality SKUs are now present in the system, which can be substituted for the lower quality SKUs. Tariff costs increase due to more wheat being shipped to the export elevator to maintain the increase in safety stock inventory. Demurrage expenses at the export elevator decrease which means that more safety stock is on hand and more substitution is possible with the higher number of SKUs present. The increased substitution to decrease demurrage occurs and is shown by the increase in forgone premiums at the export elevator as more SKUs enter the system.

Costs increase with more outbound SKUs (Figure 8). Logistical costs increase due mostly to an increase in demurrage at the country elevator and export elevator. The low cost strategy is to export four SKU categories (Table 10). This is due to the removal of the dockage specification and the cleaning cost. The highest percentage of incoming wheat SKUs at the point of origin is high dockage SKUs that require cleaning. Eliminating the dockage specification also eliminates the opportunity cost of substituting low dockage wheat for high dockage demand at the export elevator, which leads to a lower logistical cost. Most logistical costs increase as outbound SKUs increase, but forgone premiums at the country elevator decrease.

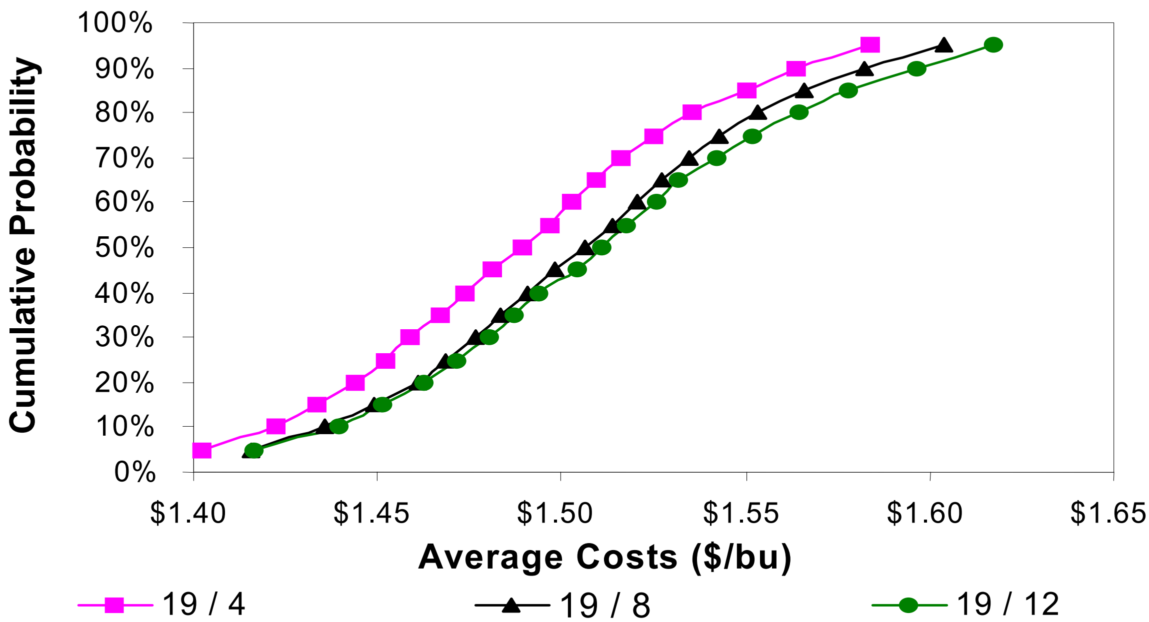


**Figure 8. Distribution of Average Costs with an Increase in Outbound SKUs**

**Table 10. Logistical Costs for Outbound SKU Comparison**

| Category/Elevator | 2 Outbound SKUs | 4 Outbound SKUs | 8 Outbound SKUs | 12 Outbound SKUs | Change in Value (2 to 12) |
|---|---|---|---|---|---|
| | ---------- | ---------- | ¢/bu | ---------- | ---------- |
| Interest Cost | 8.85 | 9.12 | 9.10 | 9.32 | 0.47 |
| Demurrage: | | | | | |
| Country Elevator | 2.20 | 0.56 | 0.58 | 0.58 | -1.61 |
| Export Elevator | 0.31 | 0.29 | 0.27 | 0.26 | -0.06 |
| Forgone Premiums: | | | | | |
| Country Elevator | 7.26 | 3.06 | 4.51 | 4.01 | -3.26 |
| Export Elevator | -- | -- | 0.01 | 0.01 | 0.01 |
| Total Costs | 155.48 | 149.60 | 151.30 | 151.37 | -4.10 |

*(From 4 to 12 SKUs)

**Inbound SKUs – Number of Bins at Country Elevator**

In the base case, the elevator handles all 19 SKUs. In this section, the costs of not being able to accommodate all SKUs is explored by grouping SKUs first by dockage, so that quality categories are not separated by this characteristic. This reduces the number of inbound SKUs from 19 to ten. There are three SKUs for each grade factor based on protein content and one additional salvage SKU. In the final sensitivity, the number of bins or inbound SKUs is reduced to four with a separation only on grade factors with the incoming SKUs grouped into a middle protein category.

The number of bins or inbound SKUs has a large impact on the logistical costs of the system. As the number of bins is reduced, average logistical costs rise. When decreasing from 19 to ten SKUs or bins the average logistical cost rises 0.85 cents. As a further reduction in the number of bins is introduced to the model, a move from 19 to four bins, costs rise significantly (Figure 9). The average cost increase of moving from 19 to four bins is 31.6 ¢/bu.

The reason for the increase in costs is due to demurrage charges. Export elevator demurrage costs increase when there is a reduction in the number of inbound SKUs. Because the country elevator is less able to meet the specific export elevator demands. Railcars are ordered to meet the forecasted demand, but end up waiting at the country elevator until a SKU can be substituted for them. Forgone premiums at both the country and export elevators rise when the number of bins or incoming SKUs is decreased by dockage. This increases cleaning costs and may also have an effect on timing due to cleaning capacity at the elevator, which is not captured by the model. As the number of bins is decreased further to generic grades, a middle protein bin for each grade is modeled. Demurrage costs increase sharply due to the inability to meet any high protein demand at the export elevator, which decreases vessel loadings or satisfied export demand.

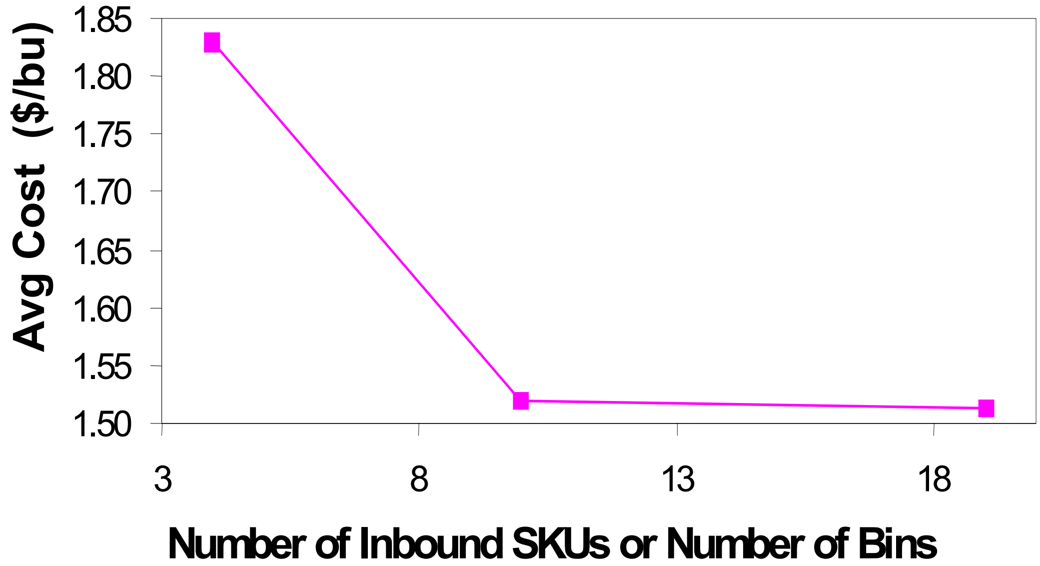


**Figure 9. Effect of Number of Country Elevator Bins or Inbound SKUs**

### Stock Keeping Units: Inbound and Outbound Combinations

In the previous sensitivities, one component is held constant to determine the SKU effect on either the demand or the origination side of the pipeline. In this section, results are shown that allow for all combinations of inbound and outbound SKUs.

The low cost combination occurs when dockage is removed so that there are ten inbound SKUs and four outbound SKUs. The combination that results in the highest logistical costs is with four inbound and twelve outbound SKUs. Increasing SKUs at export while having only four inbound SKUs is the highest cost combination (Table 11 and Figure 10).

As the number of inbound SKUs increases, the change in cost between a higher number of outbound SKUs diminishes. This is due to the country elevator's ability to keep its specificity and match its specific SKUs with the increased categories of export specific SKUs. When there are only four inbound SKUs, it is much more difficult to meet the specificity of the higher number of outbound SKUs. Figure 10 is a representation of the logistical costs.

**Table 11. Combination of Inbound and Outbound SKU Costs**

| Inbound SKUs | Outbound SKUs | Logistical Cost | Change in Cost |
|---|---|---|---|
| | ------------------------------¢/bu--------------------------- | | |
| 4 | 4 | 179.14 | -- |
| 4 | 8 | 182.90 | 3.76 |
| 4 | 12 | 201.24 | 18.34 |
| 10 | 4 | 149.15 | -- |
| 10 | 8 | 152.15 | 3.01 |
| 10 | 12 | 152.36 | 0.21 |
| 19 | 4 | 149.60 | -- |
| 19 | 8 | 151.30 | 1.71 |
| 19 | 12 | 151.37 | 0.07 |

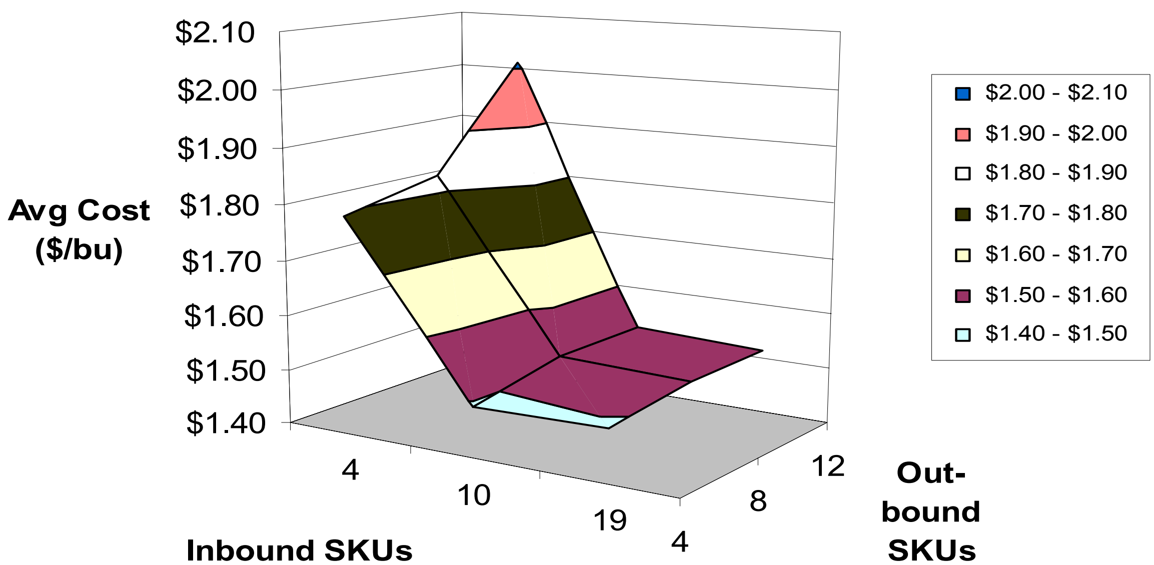


**Figure 10. Inbound and Outbound SKU Combinations**

The logistical costs rise as the number of export elevator SKUs increases and the number of country elevator SKUs decreases. When there are a low number of SKUs at the country elevator, there are large demurrage costs due to the inability to meet high protein demand at the export elevator. As the number of SKUs increases at the country elevator, overall demurrage expenses decrease. Substitution costs at the export elevator are the highest when there are more export SKUs and when a lower number of inbound SKUs exist in the system. Less demand is satisfied when there are a low number of inbound SKUs.

This sensitivity provides insight into storage limitations and different elevator configurations. Inbound SKUs are representative of the number of storage bins available at the country elevator. Export SKUs represent the specificity of products desired and the number of export elevator storage bins.

Logistical costs increase as the number of outbound SKUs increases regardless of the incoming number of SKUs. In moving from four to 12 outbound SKUs with four inbound SKUs, costs increase 18 ¢/bu, whereas moving from four to 12 outbound SKUs with 19 inbound SKUs increases logistical costs by only 0.0007 ¢/bu. The large increase in costs that occurs when only four inbound SKUs are present is due to high demurrage costs and forgone premiums of substitution. Fewer inbound SKUs translates into an inability to meet the demand of more specific SKU categories. With more outbound SKUs, the rise in logistical costs is due to higher forgone premiums at the export elevator due to an increased possibility to substitute to meet vessel loadings, an increase in interest costs, and an increase in country elevator demurrage.

Logistical costs could be lowered if two criteria were met. These include: 1) identical storage bin configurations at the country elevator and export elevator to decrease capital costs and 2) adequate volumes of each SKU demanded at the export elevator would need to be present at the origination area to avoid shortages or demurrage charges. Less substitution would occur from a diminished number of storage bins or quality categories at the country elevator as storage configurations become identical. If adequate volumes are present no substitution is needed, which would decrease substitution costs. For example, the combination of four inbound and four outbound SKUs does not result in the lowest logistical cost. In this configuration, inbound SKUs consisted of grade one, grade two, grade three, and a salvage SKU with medium protein levels and high dockage content, whereas the four outbound SKUs consisted of grades one and two with high protein and middle protein levels with high dockage content. In essence, the inbound and outbound SKUs were not evenly matched even though storage bin configurations were identical. Since SKU volumes were not properly matched, high demurrage charges resulted. If SKUs were produced in the same manner in which they are demanded, capital costs and substitution costs would be reduced.

## SUMMARY

Logistical costs in the agricultural grain marketing system are important due to their large impact on profitability. Logistical costs include tariff rates (transportation costs), demurrage at the export elevator (vessel demurrage), demurrage at the country elevator (railcar demurrage), interest costs of holding inventory, and forgone premiums or the cost of substituting high quality wheat into a lower quality category to meet demand requirements at the country elevator and export elevator.

The objective of this research was to evaluate the logistical cost of increasing categories of grain. A model is constructed using a materials requirement planning approach that allows for various segregations of wheat to be transported from local elevators to export ports for loading on vessels for shipment. The research examines some of the logistical costs of shipping wheat from country elevators to an export elevator located in the Pacific Northwest.

This schedule pulls grain through the system based on a demand forecast for each category or SKU of wheat. The forecast is an estimate of demand four weeks in the future. The model evaluates the amount of the SKU required to meet the forecasted demand and railcars are ordered for the country elevator to fill the demand if the demand cannot be filled from current inventories. A substitution calculation is included to allow for one-way substitution of higher quality wheat to lower quality categories of wheat. Each time substitution occurs, a forgone premium is charged, which is the cost of not using the SKU in its best use. Market values for each segregation are calculated to determine this forgone premium and to apply an interest cost of having inventory in the system. In the MRP model, whenever the demand at the export elevator or the railcars at the country elevator cannot be filled, a demurrage penalty is applied, similar to a shortage cost.

There are several important areas of uncertainty impacting grain market logistics. Demand is uncertain and forecast accuracy has a large impact on logistical costs. Farmer deliveries are also uncertain. Another source of uncertainty includes transit time for railcars. Distributions are used for the placement of railcars at the country elevators and for the transit time to the export elevator.

Various sensitivities are performed to determine how those factors affect logistical costs. Model sensitivities include the number of outbound SKUs or export elevator (demand) categories, inbound SKU categories or country elevator storage bin configurations, and increased demand volatility. The volatility of demand is also evaluated by the introduction of scalar to the standard deviation of export demand. Logistical costs increase as the volatility in demand rises. Results indicate that as the export demand volatility increases, export elevator demurrage and forgone premiums at the country and export elevators also rise.

The model allows for segregations of different wheat categories and calculates an average logistical cost of marketing these categories within a common pipeline. Logistical costs increase as more categories are added at export. Moving from 4 to 8 outbound SKUs increased logistical costs, as did moving from 8 to 12 outbound SKUs. The cost increases of more outbound SKUs are partially offset by reductions in forgone premiums. Country elevator demurrage costs

increase for each incremental rise in outbound SKUs. Increasing SKUs causes interest costs of holding inventory to rise. Forgone premiums decrease as the number of outbound SKUs increase due to inbound and outbound SKUs being better matched with similar characteristics. There are more inbound SKUs than outbound SKUs, so each increase in outbound SKUs matches an inbound SKU already in existence.

Logistical costs also increase when the number of inbound SKUs decreases. This represents an inability to separate different categories of wheat due to storage bin constraints. As the number of inbound SKUs decreases, the country elevator is less able to meet the specificity of demand at the point of export, which increases costs. Reducing to four inbound SKUs increases country elevator demurrage charges significantly due to the inability to meet the high protein SKUs demanded by the export elevator. Demurrage costs also increase at the export elevator for each reduction of inbound SKUs. Reducing inbound SKUs increases forgone premiums at both the country and export elevator.

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