# GRAINS, TRAINS AND AQUA-MOBILES

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**Title**

"GRAINS, TRAINS AND AQUA-MOBILES"

**By**

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

**MASTER OF SCIENCE**

# ABSTRACT

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Grain shippers are constantly faced with making merchandising and logistical decisions while trying to achieve a positive net margin. They have to decide how much grain to sell and when the most opportune time to do so occurs. In addition, decisions regarding how much freight should be acquired and where grain should be shipped need to be addressed. These decisions are met by several sources of risk such as futures spreads, basis levels, transit times, equipment placements, and farmer deliveries.

The primary objective of this thesis was to develop a model to determine both the optimal amount of grain that should be sold in the pipeline and the optimal amount of freight that should be hedged by grain shippers through the use of forward shipping mechanisms. Certificates of Transportation (COTs) offered by the Burlington Northern Santa Fe (BNSF) Railway were used to represent forward shipping mechanisms in this thesis.

A stochastic simulation model of a prototypical grain shipper containing three country elevators and two export facilities was developed. A sensitivity analysis was conducted on merchandising and logistical variables to evaluate different scenarios. The analysis revealed that committing to too many shuttle COTS limited the shipper's flexibility, forced sales to be made in suboptimal periods, and significantly increased the level of demurrage. The type of freight ordering strategy implemented by each elevator ultimately determined the overall sustainability of the firm; shippers need to diversify the

type of freight they commit to because ordering too much long-term freight can result in bad sales decisions, whereas relying only on short-term freight is costly and inefficient. Not being able to quickly adapt to volatile market conditions can result in making bad selling decisions and untimely freight purchases which can hinder the longevity of a firm.

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# CHAPTER 1: INTRODUCTION

## Problem Statement

The grain industry in the United States has been evolving over the past century. The development of a formal futures market in the late 1800s has allowed traders to manage price risk, increase margins, and trade grain more efficiently (Lorton & White, 2006). The U.S. Government entered the grain industry during the Great Depression and continued to influence the marketplace until the late 1970s. It was not until the late 1990s that the industry shifted from a supply market to a demand-driven market. Today, the grain industry is characterized by value added businesses, greater volatility in basis levels and spreads, and a larger emphasis on logistics (Lorton & White, 2006).

Grain shippers act as an intermediary between producers and end-users, moving grain from point A to point B. For example, the agribusiness giant, Cenex Harvest States (CHS), moves more than 1 billion bushels of corn, soybeans, wheat and other grains annually to domestic and export customers in more than 60 different countries (CHS Inc., 2009a).

Grain shippers have the freedom to choose between different modes of transportation such as truck, rail, barge, or ocean vessels. Each mode has its own advantages and disadvantages; shippers make their modal choice based on their own unique situation. These four modes of transportation move grain through what is known as the grain supply chain.

Logistics has been a vital element to the evolution of the grain industry and is thus the key focus of this research. Out of the total U.S. corn production in the 2007/2008 marketing year, 79% stayed in the country for domestic use, 19% was exported to foreign markets, and the remaining 2% was kept on-farm for feed usage (USDA, 2009). Whether corn remains domestic or is used for exports, the product still needs to be transported throughout the supply chain from its origin to destination. In addition, transportation rates ultimately determine a grain merchandiser's net margin. Although the transaction returns from buying and selling grain might be high, transportation costs still need to be accounted for to determine net margins. Thus, grain shippers not only need to know how much of their grain to sell, but also the number of railcars and/or barges to commit to.

The remainder of this chapter briefly examines the grain supply chain and its participants that ultimately dictate the flow of grain. In addition, a brief introduction on merchandising and logistical strategies is included. Chapter 1 also discusses the primary and secondary objectives of the research, the procedures implemented to reach the objectives, and lastly, a brief overview of the remainder of the thesis.

## Grain Supply Chain

Throughout the duration of a growing season, producers make decisions on which crops to plant, the type of pest management practices to utilize and how to market their grain to provide the greatest possible return. Small rural communities and farmers that make up those communities are just the beginning to a massive pipeline, or network of participants that make up the grain supply chain. In its simplest form, a supply chain consists of all the functions enabling the production, delivery, and recycling of materials in an effort to make products and services available to consumers (Wisner, Tan, & Leong, 2008). Thus, key players in the grain supply chain consist of farmers, country elevators, merchandisers, processors, feeders and exporters. Table 1.1 displays each of these key players and their function in the grain supply chain. The end-users, or consumers, are located at the end of this supply chain and ultimately dictate the demand for grain moving through the pipeline. This means that grain grown in rural-America needs to somehow end up on store-shelves, available to consumers in a form that provides them utility. The remedy for moving grain through this pipeline is logistics.

Grain logistics consists of all the different modes and processes of shipping products through the supply chain. The three primary modes used by grain shippers for transporting grain to domestic or export markets are rail, truck, and barge (Koo, Tolliver, & Bitzan, 1993). The optimal mode chosen is that which offers the lowest cost; this depends on the distance from the origin to the destination. Chapter 2 will discuss the tradeoffs among these primary modes of transportation.

The process of moving grain through the pipeline begins as soon as the grain has left the field. "Trucks are the first means of transportation, carrying grain to country elevators, near-by mills, and processing plants, to other farms for feeding purposes, and also to more distant places to persons engaged in these kinds of businesses" (Schonberg, 1956, p. 114). Typically, once grain has been trucked to a country elevator or some other initial node in the pipeline, it is then loaded onto railcars for transporting long distances to feeders, processors, or exporters.

Grain can also be trucked to river elevators. These grain terminals are strategically constructed along major rivers that utilize barge transportation (Schonberg, 1956). For

**Table 1.1. Key players in the grain supply chain**

| Market Player | Player Function |
|---|---|
| Farmers | Grow/raise grain and sell it either forward or on the spot, and thus, eventually deliver it to country elevators, processors, or feeders. |
| Country Elevators | Procure grain from farmers and then decide to either store as inventory or sell and ship it directly to any of the other nodes listed below. |
| Merchandisers[1] | Purchase grain from their own elevator networks and other independent elevators and then turn around and sell it to other merchandisers or any of the other nodes listed below. |
| Processors | Purchase grain directly from farmers or from country elevators and merchandisers. They then blend and process grain to produce a value-added product. |
| Feeders | Purchase grain directly from farmers or from country elevators and merchandisers in an effort to produce feed for various types of livestock. |
| Exporters | Purchase grain primarily from merchandisers, but also from some country elevators and then sell it overseas to international markets. |

example, the CHS grain terminal in Savage, MN is strategically located along the Minnesota River and is used as a transfer facility equipped with enough track capacity to accommodate shuttle trains and enough storage capacity (560,000bu) to accommodate local area producers (Gergen, 2010). This facility was constructed in 1982 to unload railcars and trucks for loading barges that mainly run down to the U.S. Gulf for export. Since its opening in 1982, roughly 1.5 billion bushels of grain has passed through this facility (Gergen, 2010).

Even though barge transportation is useful for transporting large quantities of grain, this mode of transportation is limited to rivers and other major bodies of water. Thus, the use of barge transportation is constrained by the fact that shippers not only must have a

[1] Large grain companies that operate their own elevator-network and ship grain either domestically or internationally are considered merchandisers in this study.

facility equipped for loading barges, but they must also be located along a major water-route that accesses a favorable destination (Murphy & Wood, 2008).

Since grain shippers are constrained in where they can ship by utilizing barges, the use of railcars, more specifically, shuttle Certificates of Transportation (shuttle COTs) have become more widespread in the grain industry throughout the 21st century. For example, in the past couple of years there has been an increase in the number of direct railcar wheat shipments to ports, taking volume away from barges (Wilson, 2009). A shuttle COT is a long-term forward shipping mechanism offered by the Burlington Northern Santa Fe Railway (BNSF). In short, a shuttle COT can be defined as a 110-car unit train of dedicated, high capacity equipment and locomotives that make a consecutive number of trips among different origin/destination pairs (BNSF Railway Company, 2006). Other Class I railroads have also created long-term forward guarantees similar to the shuttle COTs offered by the BNSF. Chapter 2 includes a detailed description of shuttle COTs and their importance in shipping grain.

In summary, a supply chain is a means for products to reach their customers (Wisner, Tan, & Leong, 2008). Several service providers such as trucking, rail, barge, and vessel companies play a key role in the eventual delivery of value-added products to end-consumers. Effectively managing a supply chain involves integrating key business processes regarding the flow of materials from origination to final consumption (Wisner, Tan, & Leong, 2008). The concept of supply chain management, as it applies to grain shipping, is known as managing the pipeline. It encompasses all functions regarding the origination of grain at the producer level to selling grain domestically or internationally (Wilson, Carlson, & Dahl, 2004). Because grain shippers, or merchandisers play such a pivotal role in the flow of grain through a supply chain, they are the area of emphasis in this research.

**Merchandisers**

The act of merchandising is defined as "the process grain businesses go through to effectively manage the purchase and sale or use of grain as it occurs in their normal course of operations" (Lorton & White, 2006, p. 3). Thus, merchandising is a means of buying grain from an initial node in the pipeline (e.g. producers, country elevators), waiting for a favorable move in the basis, and selling it to one of the latter nodes in the pipeline such as processors or exporters. Large grain firms that buy from country elevators and other grain companies are considered merchandisers in this study. Because merchandisers use logistics to transport grain from its origination to its terminal market, they are also considered grain shippers; the two terms will be used interchangeably throughout the remainder of this thesis.

The grain shipper modeled in this study is a prototypical grain company with rail, barge, and ocean shipping capabilities; and it operates its own elevator network in the Upper Midwest. This type of grain shipper was selected for this research in an effort to model the largest grain companies that currently exist in the industry. These large grain companies play an important role in facilitating the flow of grain from its origination at the producer level to the final consumer. The largest in the world today include Cargill, CHS, Bunge, and Archer Daniels Midland (ADM). They are all involved in some form of origination, adding value to the commodity, and then shipping and exporting large quantities of grain. Contemporary firms are also becoming more vertically integrated with goal of cutting costs and reducing risk through vertical linkages (Wilson & Dahl, 1999).

Within the past 20 years, the amount of risk a grain shipper faces has become very significant. This is due to changes in farmer production practices and merchandising techniques, forward freight mechanisms, and access to international markets. This significant amount of risk has resulted in a need for grain shippers to strategize the way they conduct business.

## Need for Strategy

Grain shippers need to be able to effectively manage their logistical position reports by utilizing the right amount of forward railroad mechanisms and the optimal number of barges. In addition, grain shippers must be able to sell the optimal quantity of grain to maximize net margins. In an effort to find the optimal amount of grain to sell and the optimal amount of freight to acquire, grain shippers encounter sources of risk that impact their decision-making. Volatile market conditions and penalties imposed on shipping grain create a need for strategy, or a plan to follow that would help the firm succeed. Strategy is so important to an organization that it ultimately determines its success or failure. Thus, a shipper's strategic decisions concerning logistics and merchandising are essential to the survival of the firm in a competitive environment.

The following sections introduce both merchandising and logistical strategies that grain shippers can utilize to provide them with the greatest possible return. Chapter 2 will describe both sources of strategy in greater detail.

### Merchandising Strategies

The most common type of hedge for merchandisers is the "storage hedge." This involves taking a long cash/short futures position. Merchandisers hedge their grain by taking a position in the futures market; this process allows them to eliminate price risk.

However, basis risk is still present and additional hedging strategies and techniques are discussed in Chapter 2 to demonstrate how to mitigate basis risk. Basis values are very important for determining net margins. Merchandisers use basis levels to make their buying and selling decisions and regard the price of grain as being irrelevant (Lorton & White, 2006).

In addition to hedging and basis values, storing grain as inventory is a very important aspect of merchandising. Storing grain is an alternative to shipping and merchandisers can use storage when market conditions are unfavorable. In addition, storage acts as a buffer against sources of risk in the supply chain. Chapter 3 discusses the importance of inventory in greater deal and introduces the theory behind supply chain models.

**Logistical Strategies**

When shipping grain, many forms of risk are present in the grain supply chain. Sources of risk range from grain delivery patterns of farmers, shipping demand, and the timing of modal arrivals to tariff rate changes, railcar premiums, and changing basis levels. When a storage hedge is undertaken, a short freight position is established (Wilson, Priewe, & Dahl, 1998). Merchandisers with a short freight position face the risk of rising freight prices similar to a short futures position being adversely affected by rising grain prices.

In order to manage these sources of risk, grain shippers can utilize the forward shipping mechanisms that Class I railroads have to offer. According to Wilson, Priewe and Dahl (1998), too many long-term guarantees can remove flexibility because of the long duration of commitment associated with them. However, too many short-term guarantees increases the level of risk even though they allow merchandisers to more accurately target months with favorable prices. Thus, a mix of long-term and short-term guarantees, as well as general tariff railcars is optimal.

Table 1.2 provides a brief description of the shipping mechanisms currently offered by the BNSF Railway.

**Table 1.2. BNSF Railway mechanisms**

| Rail Mechanism | Description |
|---|---|
| **General Tariff** | Shippers order cars on the spot market for delivery within 30 days of the order date. Cars are allocated via a random selection process and shippers pay the general tariff rate. |
| **24-car Certificate of Transportation** | Short-term guarantee in which shippers can acquire cars for up to 6 months in advance via an auction and shippers pay either a premium or discount to general tariff for guaranteed cars and service. |
| **Shuttle Certificate of Transportation** | Long-term guarantee in which shippers can acquire cars for either 1 or 2 years forward via an auction and shippers pay either a premium or discount to general tariff for guaranteed cars and service. |

## Objectives

The primary objective of this research is to develop a model to determine both the optimal amount of grain that should be sold in the pipeline and the optimal amount of freight that should be hedged by grain shippers through the use of forward shipping mechanisms. Taken together, these two primary objectives were created in order to maximize net margin. Specific objectives were:

1. Define key strategic and uncertain variables facing a grain shipper.
2. Develop a stochastic simulation model of a prototypical grain exporting firm.
3. Evaluate the effects on output after changing key decision variables.

4. Interpret the results and assess the implications for grain shippers.

## Procedures

To reach the primary and secondary objectives listed above, a stochastic simulation model was developed to determine the optimal amount of freight acquired by a grain shipper and the optimal quantity of grain to be sold in an effort to maximize net margin. After stating the problem and defining a prototypical grain shipper, logistical and merchandising strategies were introduced to combat risk associated with buying, selling, and shipping grain. A literature review was conducted to analyze the tradeoffs of the primary transportation modes for shipping grain. In addition, a review of the rail industry, both pre-and-post deregulation is provided. The literature review also encompassed a discussion on the forward shipping mechanisms offered by Class I railroads and alternative supply chain methodologies. Finally, a detailed outline of strategies available to grain shippers was examined. Important data pertaining to the random variables associated with risk in merchandising and logistical decisions was identified. Using this data, a prototypical grain shipper was modeled using a "push" inventory system. The model was developed in a Microsoft Excel spreadsheet using @Risk stochastic simulation software to simulate a typical grain shipping environment. These results were then used to determine both the optimal amount of freight to acquire and the optimal quantity of grain the shipper should plan tc sell in the pipeline.

## Organization

Chapter 2 of this thesis examines the different modes of transportation in the grain industry and how they have evolved to a point of offering forward freight mechanisms to shippers. A literature review of supply chain theory and the models it encompasses were discussed in Chapter 3. Chapter 4 includes a description of the empirical model and stochastic simulation procedure, provides an explanation of random variables, and presents the data sources used in the model. Chapter 5 presents the results of the model and a sensitivity analysis on key variables. Finally, Chapter 6 provides a summary of the research with implications for grain shippers.

# CHAPTER 2. EVOLUTION OF THE GRAIN INDUSTRY

## Introduction

Over time, the grain industry in the US has passed through several different phases dating back to the late 1800s up until the beginning of the 21st century. The industry has seen changes ranging from the invention of futures markets and country elevators to an increased emphasis on international trade and deregulation of the rail industry. For example, in 1881 the Minneapolis Grain Exchange (MGEX), formally known as the Minneapolis Chamber of Commerce, was established to provide a formal cash and futures market for grain grown in the Upper Midwest (Kenney, 2006). During this same time period, several country elevators sprouted up along rail lines to provide farmers with local cash markets and by the 1960s, unit trains began to encourage point-to-point shipping. Unit trains allowed for more efficient grain movements and they helped foster the development of the export system in the US because increases in grain exports created a demand for shipping to export facilities.

Crops mature at different times of the year around the US and once harvested, some grain is allocated for export while the rest is used for domestic use. Thus, the demand for transport services differs across different geographic regions depending on the types of crops grown in the area (Bitzan, Vachal, VanWechel, & Vinje, 2003). Whether a crop is grown for export, domestic use, or is carried-over into the following year, it requires logistics to move it throughout the pipeline. The following section discusses the increased importance put on logistics in the years following World War II leading up to the present day grain industry.

**The Grain Industry Following WWII**

In the decades after World War II, the grain industry has been characterized by an increased emphasis on exports in the 70s, government intervention and significant grain surpluses in the 80s, and a trend of consolidation among firms in the 90s. All of these stages have shaped the grain industry into what it is today. However, no time period was more important than the 70s because an increase in export volumes jump-started the need for greater capacity within the logistics system and it placed a greater emphasis on grain transportation.

During the 1970s, one of the prominent features of the grain industry was that several countries began expanding their imports and because of this world trade grew dramatically (Wilson & Dahl, 1999). The US sold a total of roughly 82 million tons of grain to Russia by 1975 (Morgan, 1979). As a result, U.S. agricultural exports generated about $21.3 billion and grain prices were at their highest since 1917. However, a growing world demand for exports, a lack of government-held reserves, and the entry of large sporadic customers into world grain markets caused the 70s to be a period of increasing instability (Wilson & Dahl, 1999).

Because of the huge jump in export volumes, the logistics system within the grain supply chain had to increase capacity to accommodate the overwhelming flow of grain. Therefore, in 1980 the passage of the Staggers Rail Act (SRA) called for deregulation of the rail industry. The SRA will be discussed in detail later in this chapter, but it basically allowed more competition in the industry among rail firms and it gave them more freedom to set rates and design car allocation mechanisms.

Overall, the industry in the past 15 years has evolved to become more efficient in terms of basic market functions and transactions, logistics, and international trade. Large grain companies have either acquired or merged with the smaller firms in an effort to exploit vertical coordination within the industry (Wilson & Dahl, 1999). This trend in acquisitions and joint ventures has caused the number of country elevators to dramatically decrease: the number of elevators in Montana decreased by 40% during the span between 1977 and 1997. However, firm size has increased in terms of storage capacity. For instance, the total industry storage capacity for the 20 largest firms in the US increased from 45.4 mmt[2] in 1985 to 64.4 mmt in 1998 (Wilson & Dahl, 1999).

As a result of the acquisitions and mergers that have taken place within the past 15 years, the grain industry is highly competitive and is composed of large grain companies such as Cargill, Cenex Harvest States (CHS) and Archer Daniels Midland (ADM). "The largest U.S. firms have a complement of each type of facility (country elevators, subterminal, river and port elevators) and are highly integrated throughout the handling sector" (Wilson & Dahl, 1999, p. 10). Grain firms have been integrating into commodity processing in order to grow in areas related to adding value to commodities. Thus, these global firms have become vertically integrated in the recent past in order to improve quality control, mitigate market power of competitors, and to gain greater control over logistics (Wilson & Dahl, 1999).

For example, CHS not only handles grain, but it also provides agricultural inputs to producers, handles more than 7 million tons of crop nutrients, processes roughly 90 million bushels of soybeans into soy-based products, and sells more than 3 billion gallons of refined fuels (CHS Inc., 2009a). CHS also has a strong focus on logistics in that they

[2] Million metric tons

manage their own fleet of railcars, operate one of the nation's largest private truck fleets, and manage their own ships (CHS Inc., 2009b). In addition, CHS has looked into the feasibility of international markets, and as a result, have expanded into other countries.

Thus, CHS is a prime example of traditional grain firms becoming vertically integrated and more diversified in their operations. CHS has control over their logistics and is able to efficiently manage the transportation of their products because they have rail, barge, and trucking capabilities. These are the 3 primary modes of transportation and they can be used together to ship goods from one point to another.

## Modes of Transportation

Successful grain shippers always make the best use of their resources in an effort to achieve the greatest possible net return. When it comes to grain logistics, or the actual physical movement of grain from one point to another, the 4 modes of transport that exist for shippers are rail, truck, barge, and ocean vessel. Each mode has its own attributes that provides shippers with different alternatives for transporting commodities. No matter what the advantages and disadvantages are for each mode, one of the most important factors impacting a shipper's decisions is the transportation cost. Transportation costs are directly related to the location of shipper's plants, warehouses, and customers (Murphy & Wood, 2008). The different levels of costs incurred by a shipper are a function of the different rates offered by carriers within each mode of transportation. The rate structure is different for each mode of transportation and is worth noting. Table 2.1 displays the rate structure for rail, truck, barge, and ocean vessel. It is important to distinguish between the types of auctions that take place in rail versus truck transportation. For rail transportation, the shipper with the highest bid is selected by the railroad as the winner. However, for truck transportation, the shipper becomes the auctioneer and several carriers place bids in an effort to win contracts and be able to haul that shipper's freight for a specified time period (Caplice & Sheffi, 2006). This type of auction is known as a procurement auction and the lowest total cost carrier is chosen; simply put, the carrier that has the lowest bid is selected as the winner.

**Table 2.1. Rate structure for the 4 key modes of transportation**

| Mode | Description of Rate System |
|---|---|
| **Rail** | General tariff: shippers are chosen via random selection process<br>Short-term commitment: auction<br>Long-term commitment: auction |
| **Truck** | Rates are determined via auction.<br>Two types of auctions (Caplice & Sheffi, 2006):<br>(1) Simple bid: several carriers submit a per load-mile rate to the shipper who then chooses the carrier offering the lowest rate.<br>(2) Combinatorial auction: Utilizes a series of package bids in which carriers place bids on a combination of specific shipping routes or regions rather than uindividual routes. |
| **Barge** | Rates are traded as a *percentage of tariff*. Benchmark tariff rates from 1976 are used in conjunction with the current barge freight rates. |
| **Ocean Vessel** | Rates are *negotiated* between shippers and carriers.<br>Two types of transactions (Stopford, 1997):<br>(1) Freight contract: shipper purchases trips from the carrier at a fixed rate.<br>(2) Time charter: ship is hired by the day and allows shippers to operate and manage it themselves. |

Other factors influencing a shipper's decision toward one mode or another include the loading/unloading capabilities of a shipper's grain facility, speed and flexibility of the mode, reliability, and lastly, mode capacity. The remainder of this section describes the 4 modes of transportation available for grain shippers and evaluates the tradeoffs that exist among them.

### Rail

Rail transportation has been providing a means of moving grain throughout the pipeline for over a hundred years. The rail industry, much like that of truck and barge, has experienced government regulation and deregulation. A background of the rail industry and all of the changes it has been through will be provided later in this chapter.

From a grain shipper's perspective, cost is a function of distance; the longer the distance between two points, the greater the cost. Because of this, grain shippers not only need to compare costs between different routes, but also need to determine whether one specific mode of transport is better than another or if a combination of modes should be used. Figure 2.1 displays the differences in cost associated with the 3 primary modes of transportation for grain shippers assuming a given origin and destination (Koo, Tolliver, & Bitzan, 1993).

As shown below, the rail transportation cost curve is depicted by RR', and it has a higher initial fixed cost than truck, but less than barge (WW'). The slope of RR' is less than that of the cost curve for truck (TT') which means that it has a lower marginal cost than truck. Thus, economies of haul are achieved for rail over greater distances because the high initial fixed cost is spread out over a greater number of miles (Koo, Tolliver, & Bitzan, 1993).

Rail will have the advantage over the other two modes in markets composed of distance CD because it has the lowest cost associated with distance. However, in distances greater than OD barge transportation is optimal. Thus when comparing the 3 primary modes of transportation, it is evident from Figure 2.1 that truck is optimal for short distances (OC) whereas rail and barge are optimal for greater distances (CD and greater).

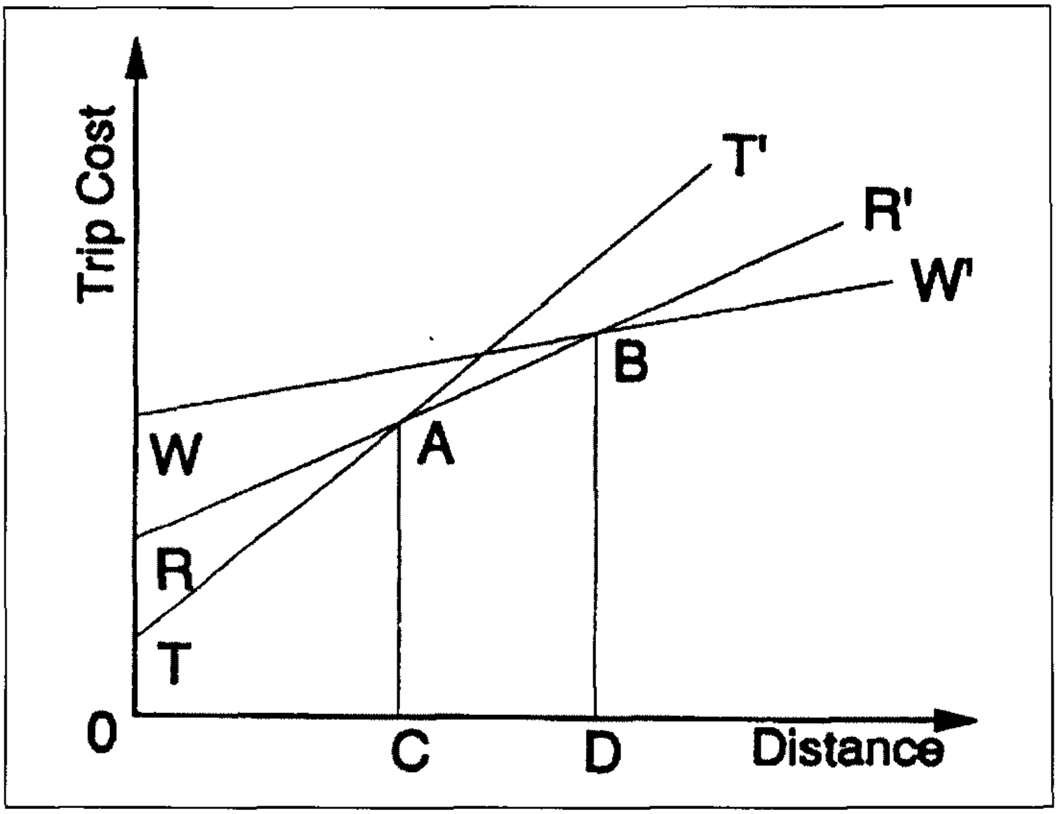

**Figure 2.1. Truck, rail and barge cost curves (Koo, Tolliver, & Bitzan, 1993).**

Similar to the cost structures of the 3 primary modes, rail also stands between truck and barge in other areas of concern for shippers: rail transportation is faster than barge, but it is slower than truck (Murphy & Wood, 2008).

When comparing flexibility, rail is less flexible than trucking because it restricted to rail lines, but it is more flexible than barge. In terms of capacity, there are different types of railcars available for transporting grain such as heavy-axel[3] cars and light-axel cars. Railcars have greater capacity than trucking, but much less than that of barge. Finally, just like barge and truck, rail transportation has its issues with reliability. For example, adverse

[3] Heavy-axel cars can be loaded to a gross weight of 286,000 lb whereas light-axel cars can be loaded to a gross weight of 268,000lbs (BNSF Railway Company, 2009)

weather conditions, locomotive issues and shortages of crews can cause inconsistent service levels.

**Truck**

In the 1950s, the smaller branch lines operated by the railroads were becoming less reliable and it was difficult for shippers to acquire cars when they were needed most (Kenney, 2006). Because of this, trucking emerged as a viable alternative for shipping grain to terminal markets. Thus, grain shippers located out in small rural communities started utilizing truck transportation rather than trying to deal with the unreliable branch lines.

Truck transportation was made possible because of the Interstate Highway System which was implemented after World War II. "The improved roads that resulted from those efforts helped foster the development of commercial trucking" (Kenney, 2006, p. 149). Even today, many grain facilities are strategically located along key interstates to allow efficient movement of grain between two points. Movement of grain by truck is normally conducted by producers when they are transporting grain straight out of the field, and this generally starts the process of moving grain through the pipeline (see Chapter 1). In addition, grain is commonly trucked from one country elevator to another, and it can also be trucked from country or terminal elevators to processors and mills.

Depending on the weight of the load, truck shipments can be classified into 2 categories: less-than-truckload (LTL)[4] or truckload (TL) traffic (Murphy & Wood, 2008). Grain shipped by truck falls under the latter category. TL carriers would consist of farmers hauling their grain into a country elevator, as well as grain being trucked from country to

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[4] LTL shipments range from 150-10,000 lb whereas TL shipments are greater than 10,000 lb (Murphy & Wood, 2008).

terminal elevators or processors. Grain shippers should take advantage of the backhaul, or the return trip from hauling to a destination. That way, shippers will not only be continuously hauling grain between two points, but they will also be operating in a cost-effective manner.

In terms of transportation costs, trucks are not as efficient as rail or barge when transporting over long distances. Trucking costs are represented with curve TT' in Figure 2.1 and this curve has the greatest slope in the graph. Thus, as distance increases, trucking costs increase at a rate faster than that of barge or rail. However, when transporting across short distances, trucking is more cost effective because it has lower fixed costs than the other 2 modes. Overall, because trucking has a comparative advantage for short hauls; it will be the best choice for distance OC in the graph (Koo, Tolliver, & Bitzan, 1993).

Other attributes impacting a grain shipper's decisions regarding truck transporting include flexibility, speed, reliability, and capacity. Trucks have a huge advantage over rail and barge in that they are very flexible because the only factor stopping a truck from delivering its goods to customers is a lack of access to roads (Murphy & Wood, 2008).

In terms of speed, truck transportation is faster than that of barge and rail, but it is influenced by speed limit and hours-of-service (HOS)[5] restrictions (Murphy & Wood, 2008). Even though speed is an advantage over barge and rail, trucks are at a disadvantage when it comes to carrying capacity[6]. Because of highway weight and size restrictions, trucks have a smaller carrying capacity than rail or barge. Another disadvantage of trucks

[5] Trucks can only be driven a certain number of hours in a 24-hour period, and they are limited a certain number of hours driven in a one-week period (Murphy & Wood, 2008).
[6] Maximum carrying capacity for trucks using the Interstate Highway System is a gross vehicle weight of 80,000 lb (Murphy & Wood, 2008).

is reliability. Adverse weather conditions and highway congestion can affect the consistency of delivery.

**Barge**

River barge, or simply barge, transportation became popular in the 1950s and 60s for purposes of moving grain from country and terminal elevators to latter nodes in the pipeline such as exporters in the U.S. Gulf. The Mississippi River is one of the main, if not the most important, waterway for barge transportation in the US. It connects the Upper Midwest to the U.S. Gulf and provides shippers access to the numerous export facilities that exist in that region.

Barge transportation became a viable option for grain shippers around the same time that trucking emerged as a prevalent mode of transportation. During this period in the 1950s and 60s, trucks were taking away from rail transportation and a majority of the grain headed to key markets in the US (Minneapolis, Chicago, etc.) was now being moved by truck. Because of this, the shipper would have to pay the railroad an additional sum for moving grain out of a key market by rail if it was brought there by truck (Kenney, 2006). Rather than having to pay this additional charge for railcars, shippers instead chose to turn to barge transportation. As a result, new grain terminals capable of loading barges began emerging along the Minnesota and Mississippi Rivers in the 50s and 60s.

Barge transportation is still a huge part of grain logistics. After the barge industry was deregulated in 1976, tariff rates became effective immediately and they are still used today (Wilson, 2009a). Barges rates are traded as a percentage of tariff and are typically reported in dollars/ton; they are calculated by multiplying the current barge rate by the 1976 benchmark tariff rate and then dividing by 100.

The percent of tariff rate can vary, but typically, the rate is based on 100% of the tariff. Therefore, the barge rate at 100% tariff is figured by multiplying 1.00 and the benchmark rate, whereas for 200% of the tariff rate, the barge rate would equal 2.00 times the benchmark rate, and so on (Marathon, 2010). For example, at 100% of tariff, the 1976 benchmark rate for the Twin Cities is 6.19 (1.00 x 6.19), and if the southbound rate for grain moving from the Twin Cities is 450, then the barge rate per ton is $27.86[7].

When comparing the cost of barge transportation to rail and truck, barge has the highest initial fixed cost (see Figure 2.1). However, barges have an advantage over the other modes for long hauls because they have the lowest unit cost associated with distance: this low unit cost is portrayed by the flatter slope of curve WW' in Figure 2.1. Therefore, even though barge has the highest initial fixed cost, overall costs increase at a very small rate as distance increases. In other words, barge transportation can realize economies of scale similar to that of rail by spreading out large fixed costs over a greater distance (Koo, Tolliver, & Bitzan, 1993).

Besides having an advantage in transporting long distances, barge transportation also is capable of transporting greater volumes than truck or rail. One barge has the capacity of approximately 15 railcars and approximately 60 semi-trailers (Murphy & Wood, 2008). However, barge transportation is limited in terms of speed and reliability. Barges move much slower than truck or rail transportation, and because of adverse weather conditions, can be unreliable at times. For example, droughty conditions can lower water levels beyond the required depth[8] for barges, while icing during the winter months in northern states can prevent movement (Murphy & Wood, 2008).

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[7] (450 x 6.19)/100 = 27.855
[8] The minimum depth required for barge transportation is 9 feet (Murphy & Wood, 2008).

Another disadvantage of barge transportation is that it is very inflexible in terms of where it can operate (Murphy & Wood, 2008). Major waterways are needed for barge transportation and even if they are present, shippers have a limited number of destinations of where they can ship to. In addition, grain shippers need to have their facilities equipped with the appropriate loading and unloading equipment to accommodate barges.

**Ocean Vessel**

Rail, truck and barge transportation make up the inland transportation system in the US. These modes utilize roads, railways, and inland waterways in an effort to transport grain throughout the pipeline (Stopford, 1997). These modes of transportation link grain shippers to international markets through the use of export ports located in the U.S. Gulf and the Pacific Northwest (PNW). At these ports, grain can either be unloaded and placed into storage at an export facility, or directly loaded onto the vessel from railcars and barges, depending on specific constraints.

Shipping grain overseas is made possible through the use of ocean vessels. Maritime or sea shipping has allowed access to new markets which in turn, leads to economic growth. Sea trade has allowed traditionally isolated communities to progress into an integrated global community (Stopford, 1997).

Grain is mainly shipped as a bulk commodity rather than as a containerized unit, and it is classified under short sea shipping (Stopford, 1997). This entails shipping grain within distinct regions from port-to-port. In terms of cost, grain shipped as a bulk commodity has its advantages over other products shipped as standardized cargo. Bulk shipments consist of large cargo parcels[9] that can maximize the capacity of a vessel (Stopford, 1997). Thus, bulk shipments have a lower unit cost per ton than non-bulk or

[9] A parcel is defined as "an individual consignment of cargo for shipment" (Stopford, 1997, p. 13).

standardized cargo because grain can occupy the entire carrying capacity of a vessel; this allows grain shippers to achieve economies of scale and control their costs.

Grain shippers typically charter, or hire, a single voyage from a ship-owner through the Baltic Exchange[10] (Stopford, 1997). The grain shipper and the ship-owner then negotiate a freight rate.[11] Ocean freight rates are based off of the Baltic Exchange and market rates differ among the Gulf and PNW. According to industry experts, a typical ocean freight rate for the PNW is anywhere from $25,000-$30,000/day whereas a Gulf rate is roughly $45,000-$50,000/day (Klein, 2010); there are a greater number of vessels available in the PNW region, so they are offered at lower rates.

Because grain movements and price and basis levels are seasonal, shippers will normally just have to hire a single voyage at a time. Market volatility and weather conditions affect crop production which makes it difficult for shippers to plan shipping requirements and sign up for long-term commitments (Stopford, 1997); compounding these difficulties is that fact that shippers are subject to non-performance penalties if they are not utilizing the vessel in an efficient manner. These penalties imposed on shippers are discussed at length later in this chapter.

In conclusion, grain shippers rely on four key modes of transportation for moving their grain; these include rail, truck, barge, and ocean vessel. The four modes each have tradeoffs based on speed, reliability, flexibility, capacity, and cost. Transportation cost is the most critical factor in determining which transportation mode(s) to utilize. Rail and barge transportation are best suited for long hauls because economies of scale can be achieved by spreading out their high fixed costs. On the other hand, truck transportation is

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[10] The Baltic Exchange is a maritime market for trading physical and derivative contracts in ocean transportation of bulk commodities (Baltic Exchange Information Services Ltd., 2010).
[11] Ocean freight rates are quoted in $/metric ton.

best suited for short distances because its costs increase at the fastest rate when increasing the distance covered.

Finally, ocean vessels allow shippers to access foreign markets and take advantage of the global demand for grain. Because grain is a bulk commodity, it can occupy a vessel's entire carrying capacity and thus, spread out high fixed costs associated with operating a vessel. This allows grain shippers to achieve economies of scale and makes exporting grain more appealing. Lastly, the inland transportation system composed of rail, truck and barge transportation are linked to global markets through export ports and ocean shipping.

## Background of the Rail Industry: Pre & Post Deregulation

Throughout the past 200 years, the railroad industry in the US has evolved into one of the most important transportation modes in the nation because of its carrying-capacity, flexibility, numerous capabilities, and speed. The trucking industry has become more prominent and widespread in the recent past, but railroads still account for the largest share of ton miles (Murphy & Wood, 2008).

The railroad industry has always been a very important component of the agricultural sector in the US. The very first country elevators were introduced in the late 1800s and were constructed along rail lines. The rail network allowed country elevators to be placed in small rural communities and it provided the first means of transportation to terminal markets in Chicago, Minneapolis and Duluth. Thus, rail was the first mode of transportation used for moving grain through the pipeline and it paved the way for other modes of transportation to emerge in the industry.

But just as important as the railroads' very existence, are the changes it has undergone and how these changes have affected agribusiness. For example, the trucking and barge industries, rail rates, and merchandising practices have all been affected by changes within the rail sector. These changes include deregulation of the industry, efficiency and productivity gains, car allocation mechanisms, rate differentials over time, and intermodal competition. The first major change in the rail industry came with the passage of the Staggers Rail Act of 1980.

**Staggers Rail Act**

The presence of the rail industry in the US dates back to the 1800s. Passengers, freight, and bulk commodities were transported great distances all over the country. Because grain is a bulk commodity, the railroads provided a means for shipping it in large quantities to regions of high demand. Grain shippers depended on an efficient rail system to move their bulk shipments to their destinations. Grain is a low-value, high-volume commodity when compared to other goods such as coal or primary metals; this means that the cost of transportation makes up a large portion of the delivered cost of grain (Bitzan, Vachal, VanWechel, & Vinje, 2003). Thus, rail service began providing an important service to grain shippers and as a result, new rail carriers started emerging in the early 1900s. By 1920, there were 186 Class I carriers[12] and in total, 1,117 railroads in the US (Tolliver & Bitzan, 2005). Then by 1930, railroad mileage peaked and there was a combination of several Class I railroads, regional railroads[13], and local railroads[14].

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[12] Class I carriers are defined as "line-haul freight railroads with 2007 operating revenue in excess of $359.6 million" (Association of American Railroads, 2008).
[13] Regional railroads are defined as "line-haul railroads with at least 350 miles and/or revenue of between $40 million and the Class I threshold" (AAR - Policy and Economics Department, 2008).
[14] Local railroads are defined as "line-haul railroads that operate less than 350 miles and earn less than $40 million per year" (AAR - Policy and Economics Department, 2008).

During this period of rapid expansion, the rail industry, along with the other primary modes of transportation, was being heavily regulated by the government in an effort to protect shippers. The Interstate Commerce Commission (ICC) was created to regulate railroads, inland waterways, and the trucking industry (Mahoney, 1985). It did so by regulating rates and preventing monopoly power within each mode by inhibiting discriminatory pricing practices. The ICC also regulated mergers among rail firms and routes traveled (Wilson, 1994).

Rate bureaus were prominent in the rail industry up until the 1980s. Their primary responsibility was to approve rate and service changes set by individual railroads (Wilson & Wilson, 1998). Rate increases required an advance notice of 90 days to inform shippers of the change. Thus, rates were very stagnant and when changes did actually occur, the 90-day notice reduced a shipper's risk associated with rate changes (Wilson & Wilson, 1998).

In general, regulation of the industry caused railroads to be inflexible and unable to adapt to current market conditions. They needed the approval of rate bureaus to change their rate and service levels; because of this, price competition among firms was non-existent (Murphy & Wood, 2008). In addition, there were significant barriers to entry in the industry, mergers and acquisitions among firms were very limited, and they didn't have the freedom to develop unique shipping options and levels of service for shippers. In other words, firms weren't able to implement any aspects of strategy into their operation in terms of pricing, mergers, line abandonment, or differentiated levels of service or product quality.

As a result, railroads started experiencing financial problems because of competition from the trucking industry and an inability to set rates and abandon unprofitable rail lines (Fulton & Gray, 1998). In addition, there was a growing consensus among not only rail carriers, but Congress as well, for a change toward less regulation and interference from the government. The major concerns were centered on a lack of intermodal transportation, as well as higher costs being incurred by firms and inefficient rail movements. Rail firms were so inflexible in setting their own rates and levels of service that they couldn't operate efficiently nor respond to changing market conditions. Ultimately, rail carriers had no ability to grow or expand their operations to achieve higher levels of profitability.

The creation of the Department of Transportation (DOT)[15] in 1967 and the National Transportation Policy Statement of 1975[16] paved the way for deregulation of all transportation modes in the US (Mahoney, 1985). In 1976, the Railroad Revitalization and Regulatory Reform (4R) Act was passed to allow railroads more flexibility in their operations. Finally, after these mild advances in the transportation industry took place, the Staggers Rail Act (SRA) of 1980 was passed and it significantly changed the industry.

Initially, Staggers allowed railroads to abandon unprofitable branch lines and it allowed the railroads more freedom in setting their own rates. More specifically, railroads could now offer lower rates to shippers for longer hauls. Rate bureaus no longer played a role in approving rate changes. Instead, carriers had the freedom to quickly change their rates to match current market conditions. Rather than the 90-day notice for rate increases, rail carriers now were required to give a 20-day notice for increases and a 1-day notice for

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[15] The Department of Transportation (DOT) encompassed all modes of transportation and was created with the focus of intermodal competition among shippers being more beneficial than "uni-modal," or single-mode service (Mahoney, 1985).

[16] This policy statement was pushed for an act toward deregulation by calling for reduced support and interference from the government. It basically called for less regulation of rates, freer entry into the industry, and more intermodal cooperation among transportation providers (Mahoney, 1985).

decreases (Wilson & Wilson, 1998). Thus, railroads had more flexibility to adjust their rates which in turn created more risk for grain shippers in terms of increasing rail rates.

The SRA also allowed railroads to establish their own trucking services and it gave them the freedom to merge with one another; this started the trend toward fewer, but large rail carriers (Mahoney, 1985). In addition, the SRA promoted intermodal competition and it gave shippers a wider selection of intermodal carrier combinations to choose from. Lastly, the SRA allowed firms to offer greater levels of service in terms of private contracts offered to shippers and innovative car allocation mechanisms.

**Private Contracts.** Private contracts between shippers and carriers became prevalent during the 1980s after the passage of Staggers. Contract rates were very important in starting a new level of service offered by rail carriers that had been essentially non-existent before 1980. These confidential contracts were normally offered at a rate well below the existing tariff rate, and they were strict in specifying the minimum size for single shipments, as well as the minimum volumes to be shipped over the entire length of the contract (MacDonald, 1989). In addition, the carrier had to commit to allocating a certain number of railcars and the shipper had to commit to a specified loading speed. Because the private contracts offered lower rates for predictable high volume shipments, they typically favored larger shippers. Thus, smaller shippers didn't receive the same rates and the traditional system of equal rates across all types of shippers and ports no longer existed (MacDonald, 1989). Because of a lack of price transparency associated with confidential contract rates, shippers couldn't see what rates their competitors were receiving. Thus, this created inefficiencies associated with the negotiation and allocation processes. Not until the evolution of forward shipping mechanisms did this problem disappear. Forward shipping mechanisms will be covered in detail later in this chapter.

The rail industry was significantly changed with the passing of the Staggers Rail Act of 1980. However, the Act didn't pass without its skeptics. Many industry experts felt that there was growing monopoly power among railroads and that some form of strict regulation was still needed to protect shippers (Mahoney, 1985). For example, shippers with access to only one rail line were forced to accept whatever rates were charged by that carrier. The following section provides an overview of some of the previous studies conducted on the SRA and deregulation of the rail industry, and it highlights their key findings.

## Impact of Staggers on the Rail Industry

The effects of the Staggers Rail Act have been analyzed and studied many times. Some of the findings contradict one another, but overall, the effects of the SRA have been beneficial to shippers and the industry as a whole. This literature review of deregulation is important and is fundamental to understanding how the rail industry has evolved into what currently exists today.

### Rate Levels, Productivity and Efficiency of Railroads

Staggers allowed for carriers to set their own rates without the approval of rate bureaus. Some industry experts predicted rates to fall while others expected an increase after deregulation of the industry. One researcher that contradicts most other findings regarding changes in rates is Boyer (1987). He examined movements in railroad rate levels and analyzed the market share for railroads following deregulation. Boyer (1987) utilized the econometric techniques OLS and GLS[17] and found that rate levels increased approximately 2% since deregulation. However, he points out that not enough time had passed since Staggers to determine the final effects of deregulation, and Bitzan et al. (2003) noted that Boyer's results contradict most findings because of a lack of explanatory variables and a low number of observations.

MacDonald (1989) examined the early effects of rail deregulation on grain transportation through the use of econometric modeling techniques. He used the price spreads between elevators at export ports and inland origin points rather than the actual rate level in order to get more accurate results. His main finding indicated there were large rate declines present in the post-Staggers period. MacDonald (1989) also found that rates are inversely related to distance, shipment size, and volume, whereas a positive relationship exists between rates and the distance from rivers and lake ports. These findings were very similar to those derived by Koo et al. (1993) and Bitzan et al. (2003). In addition, Bitzan et al. (2003) found that rates for wheat, corn and soybeans have declined since Staggers.

Several other studies (too numerous to list) have found decreases in the level of rail rates since deregulation. For example, McMullen et al. (1989) used a network flow model of PNW (Pacific Northwest) wheat transportation that included data from 1977 and 1985. They found that lower rates under deregulation have decreased the total cost of shipping wheat from country origins to export ports. Wilson (1994) used econometric techniques on 34 different commodities spanning over 17 years to find that by 1988, deregulation had significantly lowered rates for all commodities. Lastly, Winston (1998) states that real rail rates have fallen by over 50% since deregulation.

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[17] Ordinary Least Squares (OLS) and Generalized Least Squares (GLS)

The decline in rail rates since deregulation was made possible by railroads becoming more efficient and being able to increase their level of productivity. Vellturo et al. (1992) separated the cost savings directly attributable to mergers from those caused by other changes among carriers permitted by deregulation. They examined 4 mergers within the rail industry and compared their cost savings to those obtained by railroads not involved in mergers. Their results indicated that mergers were not a prerequisite for achieving economies of scale and that if railroads increased their average length of haul and their route miles, they enjoyed efficiency gains through cost savings.

Wilson (1997) examined the cost and productivity gains achieved by rail carriers over the period 1978-1989. He found that deregulation resulted in a 40% reduction in costs and that the initial impact of productivity immediately following Staggers was substantial: 6-7.5% reductions in costs per year. His findings are very similar to Wilson and Wilson (1998) in that they found rates and average length of haul to have an inverse relationship, which is a major source of cost savings. In addition, both studies found that deregulation had resulted in an instant decrease in rates and a large improvement in productivity.

Finally, Dennis (2000) took the studies previously conducted on changes in rates and productivity since Staggers and examined the specific effects of various factors on rail rates since deregulation. His econometric analysis analyzed factors such as increases in bulk shipping, length of haul, shipment size, and cost savings to see which were most important. Dennis (2000) found that cost reductions in the form of productivity changes accounted for about 90% of rate reductions since deregulation, and that overall rates for agricultural products decreased by 48% since Staggers.

**Unit Trains.** Another form of efficiency gained since the passage of Staggers was the rapid increase in usage of unit trains. Unit trains changed the rail freight system by allowing grain shippers to ship huge quantities of grain directly from country elevators to domestic processors or exporters rather than having to stop at some intermediary point (Kenney, 2006). For instance, some of the largest grain firms at the time (e.g. Cargill, Peavey Co.) had always shipped their grain through Minneapolis at some point in time. However, with the advent of unit trains, they could take their grain produced in Minnesota, Montana, and the Dakotas and ship it directly from the country to the processor.

Unit train movements were concentrated on mainline routes and they covered long distances in route to domestic processors and export ports; this lowered the total costs incurred by railroads because their fixed costs were spread out over longer distances, and as a result, their level of efficiency improved (Tolliver & Bitzan, 2005). In addition, unit trains allowed railroads to take advantage of economies of scale since the passage of Staggers, and thus, shippers were rewarded in the form of reduced rates for shipping in larger quantities (Koo, Tolliver, & Bitzan, 1993). This encouraged grain shippers to make high volume shipments and started a trend toward high-volume, more efficient movements. Both Wilson (1997) and Bitzan et al. (2003) found an inverse relationship between unit train miles and rail rates because per unit costs decrease as train weight grows and loading efficiencies associated with large train size are realized.

**Rationalization and Class I Dominance**

The Staggers Rail Act of 1980 allowed railroads to abandon unprofitable branch lines that were detrimental to their success during government regulation. During the time period between 1979 and 1992, roughly 33,000 miles of track were abandoned which was about 18% of the total Class I and II road miles in 1980 (Tolliver & Bitzan, 2005). This process of downsizing through abandonment and line closure is known as rationalization. The pace of abandonment significantly increased after 1980 and as a result, traffic was concentrated on fewer miles of road; this increased railroad productivity and lead to cost savings (Wilson & Wilson, 1998).

Tolliver and Bitzan (2005) note that the impact of rationalization has not been uniform across all shippers and regions; instead, they suggest that while some shippers benefit from cost savings in the form of reduced rates, others have incurred higher transportation costs because line abandonment has caused them to switch from rail to truck.

As a result of rationalization, mergers, and acquisitions, the number of Class I railroads has dwindled down from 186 in 1920 to only 7 that currently exist today (Association of American Railroads, 2008). During the 1970s and 80s, the number of class I railroads rapidly decreased due to mergers and acquisitions. Government regulation resulted in many inefficient rail movements and high costs that ultimately put railroads in bad financial shape. Thus, firms had to merge with one another or sell their operation to a competitor. For example, the Southern and Norfolk-Western railroads merged to become the Norfolk-Southern System which is still one of 7 remaining Class I railroads operating today (Vellturo, Berndt, Friedlaender, Shaw-Er Wang Chiang, & Showalter, 1992).

Between 1929 and 1999, there was a 55% reduction in total Class I rail line, and the majority of this decline has been due to rationalization (Tolliver & Bitzan, 2005). However, the 7 Class I railroads account for over 90% of both the rail industry's ton-miles and total revenue (Murphy & Wood, 2008). Thus, the Class I carriers dominate the current rail industry and some of them are heavily used in grain transportation, such as the

Burlington Northern Santa Fe, Union Pacific, and Canadian Pacific railroads. These large Class I carriers are spread throughout the US, and in some regions, only 1 or 2 of them are available for shippers to utilize. This has led shippers to believe that railroads may exercise monopoly pricing practices because of a lack of competing carriers.

**Monopoly Pricing Concerns**

Even though 30 years have passed since the Staggers Rail Act was introduced, there are still concerns among shippers that railroads operating in regions with little or no competition practice discriminatory pricing. MacDonald (1987) used an econometric model to analyze the extent of rail competition among carriers for export shipments of corn, wheat, and soybeans since the passage of Staggers. He found that rates increase as the distance a shipper is from competing water transportation increases, and that rates fall as competition among railroads in a specific region increases. These results are very similar to his findings in a later study: lower rates existed in areas where barge competition was prevalent, such as regions of the Corn Belt (MacDonald, 1989).

MacDonald's (1989) result is analogous to the findings of Bitzan et al. (2003): the amount of market power and the distance of the shipping origin to the nearest water loading facility both are positively related to rates. They also found that rate savings were greater in regions containing intermodal competition.

McFarland (1987) examined whether deregulation has allowed shippers to charge captive shippers[18] unreasonably high rates. By employing Tobin's q as a measure of long-run monopoly profits, he found that railroads do not earn monopoly profits in the long-run

[18] McFarland (1987) classifies captive shippers as those that are served by only one railroad and can't readily use other forms of transportation. In addition, he notes that they typically are not located near a navigable waterway and normally ship bulk commodities over long distances.

and that railroad's value of q was much lower than that of non-financial firms. Lastly, he concludes that railroads face enough competition sufficient to protect shippers.

Thompson et al. (1990) studied the extent of competitive pressures on rate-to-variable cost (R-VC) ratios of railroads and found there to be inelastic demand and less competitive pressures on short trips to barge loading facilities. In addition, interregional competition affects rates in regions far from inland water transportation, and lastly, market conditions are less competitive in the Upper Great Plains regions[19] than in others. Stemming from this particular result, Koo et al. (1993) examined the pricing behavior existent in North Dakota since it is a captive shipping market. He found rail rates are higher as distance from shipping points in ND to water access points increase and that rates for prominent ND crops such as barley, durum and spring wheat are higher than other crops.

Lastly, Miljkovic (2003) used an econometric technique to examine the dynamic nature of rate adjustments by different railroads across different regions. He found that as barge rates increase, merchandisers will substitute rail for barge. In addition, a lack of competition in Minnesota causes rates to converge at different speeds for shippers shipping to the PNW; this is in contrast to rates in Illinois that converge to their desired levels at the same speed since there are several rail and non-rail (e.g. barge) shipping opportunities for shippers, and thus, competition among modes. Finally, he concluded that grain transportation by rail is far from being perfectly competitive.

**Summary**

In conclusion, deregulation has allowed railroads to reduce their costs, and in turn, offer lower rates to shippers. More specifically, the Staggers Rail Act of 1980 allowed rail

[19] Montana and Minnesota are the two states in this region studied by Thompson et al. (1990)

carriers greater flexibility in pricing and allowed them to differentiate their level of service. This opened the door for carriers to start offering private contracts and unique forward shipping mechanisms.

Numerous studies have shown that rate levels for agricultural commodities have declined since deregulation. In addition, railroads have been able to offer lower rates because of cost savings achieved through mergers and acquisitions, more efficient rail movements, and rationalization. Lastly, the section on monopoly pricing indicated that competition among railroads (intramodal) and different modes of transportation (intermodal) significantly influence rates. Thus, grain shippers need to incorporate strategy when making logistical and merchandising decisions. In order to determine the optimal logistical strategy, shippers need to have a good understanding of the shipping mechanisms offered to them by the railroads. The following section provides an overview on different forward freight mechanisms available to shippers.

## Car Allocation Mechanisms

Since deregulation of the rail industry, railroads have had the freedom to develop differentiated levels of service for grain shipments. Staggers allowed the new services offered to grain shippers to be charged at premium rates. Thus, railroads could charge premium rates for premium services which gave them incentive to develop innovative car allocation mechanisms (Wilson & Wilson, 1998). The new freight mechanisms acted as forward commitments to shippers and they allowed carriers to address car availability problems and inefficient allocation methods that had been troubling grain shippers for years.

The car allocation mechanisms developed by the railroads were more efficient than the primitive private contracts that were being offered in the early 1980s, and they acted as a source of strategy for gain shippers. Both short-term and long-term freight mechanisms were eventually created to meet the needs of shippers. The Burlington Northern Railroad (BN)[20] introduced its Certificates of Transportation (COTs) program as the first mechanism that offered guaranteed cars and service to shippers.

**Certificates of Transportation (COTs)**

Before the introduction of the Certificates of Transportation (COT) program, grain shippers had to deal with a first-come/first-serve allocation system that often left shippers with few opportunities to acquire freight when they needed it most, such as during harvest (Wilson, Priewe, & Dahl, 1998). In addition, there were no car guarantees which meant even if a shipper was successful in acquiring cars, the railroad couldn't guarantee when they would arrive at the shipper's facility or if the full quantity of cars would even be placed. Also, car cancellation penalties did not exist; thus shippers could order more cars than necessary, use what they needed, and then cancel the remaining orders. Ultimately, grain shippers had to base their logistical decisions around car availability rather than market conditions and they had to face a great deal of risk when trying to acquire railcars.

Finally in 1987, the BNSF introduced its COTs program and it was met with a sigh of relief from grain shippers. COTs provide forward service guarantees to shippers. They allocate cars through an auction in which shippers place bids for guaranteed railcar placement (Wilson & Dahl, 2005). The submitted bids are placed at a premium over a

[20] Currently known as the Burlington Northern Santa Fe (BNSF) Railway after the merger between the Burlington Northern and the Atchison, Topeka and Santa Fe Railway in 1995 (Miljkovic, 2001).

minimum bid rate. Thus, the shipper with the highest bid places the greatest value on the COT and is the winner of the auction.

In their simplest form, COTs allow shippers to place bids for the guaranteed forward placement of cars and they allow shippers to lock in rates for forward shipments before the cars are needed (Wilson & Dahl, 2005). Thus, the costs incurred with shipping are locked in, and when combined with fixed prices from contracting and hedging, merchandisers can calculate their expected net margins several months in advance.

**COT Auction.** The auction for COTs takes place every week on Tuesday, Wednesday and Thursday in which shippers place their bids for different types of COTs each day on the BNSF website. The main types of COTs are Monthly Grain Singles, Monthly Grain Units, Yearlong Grain Singles, and Yearlong Grain Units (BNSF Railway Company, 2010, Item 10300). In addition, a Destination Efficiency Train (DET) can be formed from 4 Monthly and/or Yearlong Grain Units. Also, Yearlong COTs are significant because they can be purchased for 1 shipping period per month for 12, 24 or 36 consecutive months; it is very common for large grain firms to have 2 or 3 yearlong COT commitments. The different types of COTs are summarized below in Table 2.2. This thesis utilized Monthly Grain Units that were composed of 24 cars. Therefore, COTs are referred to as "24-car COTs" throughout the remainder of this thesis.

24-car COTs are offered for 3 different shipping periods[21] every month: First Period (FP), Middle Period (MP) and Last Period (LP). Thus, shippers can bid on FP, MP or LP 24-car COTs and they will be placed for loading at a shipper's facility in the shipping period specified by the shipper. For example, if a shipper bids on a First Period (FP)

[21] First Period: 1st through 10th of the month; Middle Period: 11th through 20th of the month; Last Period: 21st through the end of the month (BNSF Railway Company, 2010).

Yearlong Grain Unit, then he expects cars to be delivered during the first 10 days of every month for the entire year. In addition, shippers can bid on 24-car COTs up to 6 months forward from when the first shipment will actually take place.

**Table 2.2. Types of COTs offered by the BNSF Railway**

| Type of COT | Default Shipment Size (cars) | Maximum Shipment Size (cars) | Number of Shipping Periods | COT Duration |
|---|---|---|---|---|
| **Monthly Grain Single** | 1 | 15 | 1 Period | 1 month |
| **Monthly Grain Unit** | 24<br>Can be placed as 25, 26 or 27 | 48 - combine two 24-car units | 1 Period | 1 month |
| **Yearlong Grain Single** | 1 | 15 | 1 Period/month | 12 consecutive months |
| **Yearlong Grain Unit** | 24<br>Can be placed as 25, 26 or 27 | 48 – combine two 24-car units | 1 Period/month | 12, 24 or 36 consecutive months |

Table adapted from BNSF COT Rules Book 4090.

The auction differentiates shippers based on their valuation of the shipping guarantee. Minimum bids are specified in a per-unit amount that is required for shippers to purchase a COT; this minimum bid is known as the Base COT Prepay and it is basically a minimum partial prepayment amount (BNSF Railway Company, 2010, Item 10650). For example, the current Base COT Prepay for a Yearlong Grain Unit is $11,520/unit for the entire year.

Bidders can place their bids at a premium above the Base COT Prepay to increase the probability that a COT bid will be accepted. In addition, the Total COT Prepay is the total prepayment amount that is required to purchase the COT and because it is non-refundable, it discourages COT cancellations. The Total COT Prepay is determined by multiplying the Base COT Prepay and any premiums by the total number of cars. For example, if a 24-car Monthly Grain Unit has a Base COT Prepay of $200/car and a $5 premium is included, then the Total COT Prepay for the unit is $4,920 (205 x 24).

Shippers wishing to take place in the COT auctions and accept the minimum bid offer or place a bid at a premium above the minimum have to do so by 3 P.M. Central each day of the auction. If the bid demand exceeds the available cars for Yearlong Grain Units, first preference is given to bids of the longest duration (i.e., 36, 24, or 12 months), and then in descending order of bid dollar value until all remaining 24-car COTs are allocated (BNSF Railway Company, 2010, Item 10400). For Yearlong Grain Singles, Monthly Grain Singles and Monthly Grain Units, preference is given to bids in descending order of dollar value starting with the highest.

Winning bidders are notified the same day as the auction via email, and rates for monthly 24-car COTs are those effective on the day of the auction or those on the first day of the shipping period, as declared by the shipper when the bid was placed (BNSF Railway Company, 2010 Item 10350). For yearlong 24-car COTs and DETs, the effective rates are those that exist on the first day of the shipping period. Tariff rates are specific to each destination/origin pair, and they must be paid in addition to the Total COT Prepay. Lastly, if a shipper owning a Yearlong Grain Unit or Yearlong Grain Single wishes to cancel a shipment within a particular month, he will be charged $160/car for every cancelled shipment.

**COT Guarantee.** In order for the BNSF service guarantee to remain valid, grain shippers have to provide the BNSF with the loading station (s) no less than 10 days before the first day of the specified shipping period (BNSF Railway Company, 2010, Item 10450). If a shipper fails to do so, the BNSF will not guarantee to supply the required number of cars. In addition, the shipping facility must be approved by the BNSF (i.e., track capacity) in order for the guarantee to remain valid. Lastly, shippers need to specify want dates for their COT units within the specified shipping period even though the BNSF reserves the right to place the cars at anytime within the shipping period.

In addition to the COT guarantee, a carrier non-performance penalty exists: if the BNSF fails to deliver the guaranteed equipment by 00:01 A.M. on the 16$^{th}$ day after the specified want date,[22] the shipper is paid $200/car for each car ordered under the COT program (BNSF Railway Company, 2010, Item 10500). Thus, the COT guarantee essentially states the BNSF will deliver cars no later than 15 days after the want date, or else they are subject to a carrier non-performance penalty.

**Secondary Market.** If merchandisers are committed to railcars but do not have the grain to fill them, they can sell the cars on the secondary market. Secondary markets allow merchandisers to sell COT units and shuttle COT trips to other merchandisers who are in need of cars. The guaranteed freight can be sold at premiums or discounts to tariff. For instance, tariff is considered $0/car so if a COT is offered for $200/car, it is "200 above tariff." When freight is sold at a discount, merchandisers are basically "giving away" the railcars and paying someone to take them; this is acceptable because trip incentives on shuttle COTs still allow a profit to be made, and selling at a discount prevents a shipper from forfeiting his prepayment on a 24-car COT unit.

Ultimately, merchandisers are given more flexibility because forward car guarantees can be transferred to other shippers on the secondary market (Wilson, Priewe, & Dahl, 1998). Brokers match up buyers and sellers and help with the transaction process. For example, a broker will tell the freight trader from CHS that Cargill is looking to sell a shuttle COT trip at 200 over tariff. CHS can either accept or provide a different offer for Cargill by working through the broker. If CHS decides to buy the shuttle COT trip for 200

[22] A want date is the day a shipper prefers the railcars to be placed at the loading facility.

over tariff, they can turn around and sell this trip to another firm such as ADM or Gavilon if they choose to.

In addition, shippers don't have to incur cancellation penalties when they can't fulfill their forward car agreement. Regions that are lacking grain to fill a unit-train or shuttle COT that has already been committed to leaves no choice but to sell it on the secondary market in order to avoid cancellation penalties; thus, merchandisers can sell them to other merchandisers and still turn a profit. Because guaranteed forward freight can be transferred among shippers via secondary market, shippers can reduce their level of risk, and this option of transferability granted to shippers increases the value of guaranteed freight (Wilson & Dahl, 2005).

**General Tariff Units and Singles**

The general tariff car allocation system offered by the BNSF has existed in the rail industry long before deregulation took place. However, it has changed significantly since both deregulation of the industry and the introduction of 24-car COTs to operate in a more efficient manner. It exists to satisfy the common carriage obligation of the railroad: smaller shippers unable to access the shuttle program are still able to acquire small unit and single cars through general tariff. For example, shuttle-loading facilities cannot even request general tariff cars (BNSF Railway Company, 2009b). Thus, it complements 24-car COTs and shuttle COTs to provide service to all grain shippers and to avoid discrimination against smaller shippers.

Rather than the first-come/first-serve car allocation system that existed prior to 1980, cars are allocated through general tariff according to shipper demand and historical usage provided that car demand does not exceed car supply (Fulton & Gray, 1998). When the demand for cars does exceed supply, a random selection process is used in which shippers can either place requests for a single-car order (up to 15 cars) or one unit order (up to 48 cars) depending on the size of the shipper's facility (BNSF Railway Company, 2009b). Shipping facilities have to be deemed appropriate by the BNSF and contain sufficient track and loading capacity.

Once the number of car requests exceeds the available supply, shippers are assigned a 9-digit, computer-generated random number that is entered into a lottery system. The requests are then prioritized and awarded according to the Lottery Week[23] they were received and by the random number assigned to them (BNSF Railway Company, 2009b). If a shipper does not receive cars in that Lottery Week, he has to resubmit his car request in the following week in order for the request to remain prioritized in the database; as a result, he will ultimately receive cars.

Lastly, orders for single car and unit car requests have to be submitted online between 12:01 A.M. Monday through 11:59 P.M. Wednesday of every Lottery Week. Shippers that successfully acquire cars from the lottery will have their cars placed at their facility sometime within the following 30 days of the Lottery Week depending on the want date. Want dates are chosen by the BNSF within each shipping period of every month. Shipping periods for general tariff are similar to those available for 24-car COTs in that they specify delivery within 3 different periods[24] of each month.

**Shuttle COTs**

After the creation of the COTs Program in 1987, several other Class I railroads created short-term car guarantees. Similarly, long-term car guarantees were eventually

[23] Lottery Weeks are the first 3 full weeks of each month (BNSF Railway Company, 2009b).
[24] FP, MP and LP

developed. Today, the long-term car guarantee program of the BNSF has evolved into what are known as shuttle COTs which are larger than 24-car COTs.

Shuttle COTs were created as an extension of the 24-car COT program and they are becoming the dominant mechanism used for rail transportation because of their large carrying capacity, long-hauls, shipping incentives, and transferability on the secondary market. According to industry experts, roughly 80-90% of the total rail shipment volume for a single grain firm is comprised of shuttle movements during periods of intense grain movement (Pope, 2010, Holz, 2010).

Shuttle COTs consist of 104-110 car units that make a specified number of consecutive trips within a specified window of time between different origin/destination combinations. There are 3 types of shuttle train commitments: 3 month, 1 year, and 2 year (BNSF Railway Company, 2009, Item 13101). Shuttle COTs are currently auctioned on Monday of every week on the BNSF website specific to each shipping period: FP, MP and LP. The 3 month shuttle COTs have a minimum bid set at $82,500, whereas for the 1 year and 2 year shuttle COTs, the base rate is set at $0/car, or "tariff," and bids are made at a premium to tariff (BNSF Railway Company, 2010, Item 1001). Lastly, the shipping period for shuttle COTs determines the placement of cars for the first trip. Customers choose the initial want date within the specified shipping period only for 1 and 2 year shuttle COTs (BNSF Railway Company, 2010, Item 2100). The BNSF will then make "reasonable efforts" to accommodate the want date.

**Shuttle Program.** In order for grain shippers to utilize the BNSF shuttle program, their shipping facility has to meet the requirements set forth by the BNSF Shuttle Train Program. The facility must have adequate track capacity to handle a minimum of 104-110 cars, the loading (unloading) capacity to load (unload) all 104-110 cars in 15 hours, and a certified scale system (BNSF Railway Company, 2009, Item 13600). In addition, the shipper needs to have Electronic Data Exchange (EDE) capabilities to submit billing information electronically. If a shipper fails on more than 1 occurrence throughout the duration of a shuttle to meet any of these requirements, the BNSF has the right to disqualify the facility from loading/unloading shuttle COTs.

Shuttle COTs consist of consecutive shipments or "trips" from orgins to destinations. The origin for the first shuttle trip must be submitted at least 10 days in advance of the start-up period or else the shipper will inccur a $100/car penalty (BNSF Railway Company, 2009, Item 13600). Once a shuttle is loaded at its origin and then reaches its destination to unload, the trip is considered over. Shippers have the option of cancelling a shuttle trip, but in doing so, they will inccur a penalty of $400/month/car (BNSF Railway Company, 2009, Item 13101).

Shippers need to specify the subsequent loading origin for the next trip before the loaded shuttle reaches its destination on the current trip. In addition, shippers need to advise the BNSF on the unloading destination on the current trip before the empty shuttle reaches its origin. Failure to notify the BNSF on the origin for the upcoming trip or the destination for the current trip results in a penalty of $100/car inccured by the shipper. Lastly, if shippers wish to change origins or destinations, they must do so before the shuttle reaches the nominated geographic region, or else they will incur a penalty of $1000/train (BNSF Railway Company, 2009, Item 13503).

When selecting the subsequent origin/destination for the next trip, shippers needs to specify a want date for 2-year and 1-year shuttle COTs. Shuttle COTs are not typically placed on the want date; the cars are usually placed a couple days either before or after the want date. In addition, the BNSF will notify the shipper within 2-4 hours prior to the acutal placement at the shipper's facility (BNSF Railway Company, 2009, Item 13600). Unlike 24-car COTs, shutte COTs cannot be constructively placed given their nature of continuous movment or else they will be subject to demurrage penalties (see next section). Thus, all shuttle COTs must be immediately accepted for placement upon arrival at the shipper's facility and then released as a unit within 15 hours of acutal placement.

Finally, the BNSF guarantees a minimum of 2.5 trips/month (BNSF Railway Company, 2009, Item 13600). However, if 5 trips per conecutive 61-day period cannot be met, the shipper can cancel the remaining trips without a penalty, or request additional shuttle trips to make up for the difference. It's very advantageous for shippers to make use of short-hauls in order to get their shuttle COTs moving as fast as possible because each trip earns an "allowance" and shippers can receive incentive payments (see later section). Thus, the more trips generated on a shuttle, the greater the revenue earned by the shipper. Lastly, it is worth noting that being under-committed to shuttle COTs is a problem because if a grain terminal has reached its total storage capacity, it is missing out on revenue opportunities. According to industry experts, shuttle COTs are currently averaging about 3 trips per month (Mack, 2010). Thus, grain shippers need to consider this when planning future logistical needs.

**Shuttle Rates.** A shuttle rate contains 3 components: a shuttle premium/discount, the tariff rate and the fuel surcharge. Shuttle COTs trade at premiums/discounts depending on the shipping demand for railcars. The tariff rate differs depending on each specific origin/destination pair, and the fuel surcharge is set on a monthly basis to compensate the carrier for fuel. Changes in fuel prices result in changes in the fuel surcharge rather than carriers having to change their rates with every change in the price of fuel. Fuel surcharges are calculated by taking the distance (miles) between the origin and destination and multiplying it by the monthly fuel surcharge rate. For instance, suppose the March fuel surcharge rate is $0.40/mi and because the distance between Jamestown, ND and the PNW is 1,474 miles, the fuel surcharge cost is $589.60. In addition, suppose the March shuttle premium is 200 over tariff and the current tariff rate for a wheat shipment from Jamestown to the PNW is $4,033/car. Then, the total shuttle rate is $4,822.60/car[25].

Shuttle rates contain a high degree of seasonality depending on the demand for shipping. The peak shipping demand period for both 24-car COTs and shuttle COTs occurs from September through December. Since shippers know that shipping demand is highest during this period, they can also expect freight rates to be at their highest. Thus, acquiring shuttle COTs or 24-car COTs several months forward allows shippers to lock in lower rates.

**Shipper Incentives.** A unique feature of shuttle COTs that separates them from 24-car COTs and general tariff cars is the shipping incentives available to shippers. These incentives are in place to encourage efficient loading/unloading and the release of equipment back to the BNSF. For every trip, a "shuttle allowance" is paid to the owner of the shuttle. Even if a shuttle trip is sold on the secondary market, the original owner of the shuttle will receive the allowance. For 2-year shuttle COTs, a shuttle allowance of $150/car/trip is paid to the shuttle owner, whereas a $100/car/trip allowance is paid on 1-

[25] The total rate is found by taking the summation of the shuttle premium, total fuel surcharge, and the tariff rate: 200+589.60+4033 = 4822.60.

year shuttle COTs (BNSF Railway Company, 2009, Item 13101). No shuttle allowances are paid on the 3-month shuttle COTs.

In addition to shuttle allowances, shippers can also qualify for loading and unloading efficiency payment programs. These programs are known as Origin Efficiency Payments (OEP) and Destination Efficiency Payments (DEP). Both incentives are used to promote efficient car utilization and loading/unloading operations at origins and destinations (BNSF Railay Company, 2009, Item 13500). The standard OEP is a payment of $100/car to a shipper that loads and releases a shuttle within 15 hours of acutal placement. The standard DEP is a payment of $100/car paid to a shipper that unloads and relases a shuttle within 15 hours of actual placement. Both types of payments currently offered by the BNSF are outlined in Table 2.3.

In order to qualify for OEP and DEP incentives, shipping facilities have to meet the BNSF Shuttle Train Program requirements as specified earlier in this thesis. However, not all shuttle loading/unloading facilities are eligible, and claims to receive the payment must be submitted to the BNSF no more than 5 business days after the waybill date (BNSF Railay Company, 2009, Item 13501).

**Table 2.3. BNSF efficiency payments**

| **Time of Shuttle Release after Actual Placement** (hrs) | **Origin Efficiency Payment** (OEP) | **Destination Efficiency Payment** (DEP) |
|---|---|---|
| **21** | **$50/car** | - |
| **15** | $100/car | $100/car |
| **10** | **$150/car** | - |

Table adapted from BNSF 4022-M: Items 13500 and 13501.

If a shipper's facility is inaccesible and the BNSF cannot place the cars, they will be constructively placed short of the loading/unloading facility and the shipper will be disqualified from receiving an OEP or DEP. If a shuttle is loaded within 21 hours, but is not billed and released from the loading facility within that 21 hours of actual placement, the shipper can either forfeit the OEP payment or be charged $1,000/hr until the cars are billed and released (BNSF Railay Company, 2009, Item 13500).

Finally, shippers trying to receive an OEP have to submit a "pre-release" at least 4 hours before the shuttle is going to be released, or else the OEP will be failed (BNSF Railway Company, 2008). The pre-release cannot be entered less that 4 hours before the actual release of the shuttle, and the waybill (shipping instructions) must be received by the BNSF by the actual release time. For example, suppose a shuttle is actually placed at a shipper's facility at 6 A.M. for it to be loaded. If the shipper is trying to get the 10 hour OEP, then the shuttle has to be loaded, billed and released to the BNSF by 4 P.M. Thus, the pre-release must be entered by 12 P.M. in order for the 10 hour OEP to pass. A pre-release simply exists for planning purposes and it lets the BNSF know when the shuttle can be pulled from the facility and it helps them to set up crews and power (locamotives) in advance.

If the 4-hour pre-release for a 15-hour or 21-hour OEP is not met, the OEP will not be paid to the shipper (BNSF Railway Company, 2008). However, if the 4-hour pre-release for a 10-hour OEP is not met, but the shuttle is released from the facility within 15 hours of actual placment, the OEP is reduced to $50/car; otherwise, no OEP is paid.

**Demurrage.** Demurrage is a late penalty charged by railroads for inefficient use of their equipment. It is charged on a per-car basis and designed to keep the loading and unloading of cars as efficient as possible. Carriers lose out on revenue opportunities and incur opportunity costs when their equipment sits idle, and then in turn penalize grain shippers for causing inefficiencies in the pipeline (Wilson, Carlson, & Dahl, 2004). Both the barge and ocean vessel industries have their own set of provisions regarding the cost of demurrage. Similar to rail, both of these modes specify "free time" (non-chargeable days) for loading and unloading.

Grain shippers have to factor the cost of demurrage into their logistical decisions because it's one of the most significant costs associated with logistics. To stay consistent with the discussion of 24-car COTs and shuttle COTs, the demurrage plan employed by the BNSF Railway is analyzed as it pertains to grain shipments. The BNSF Demurrage Book 6004-A contains all demurrage provisions set forth by the BNSF for all commodity types, car types, and loading/unloading procedures. Therefore, this section first analyzes the railcar demurrage program employed by the BNSF Railway and then discusses barge and vessel demurrage.

The demurrage system of the BNSF is comprised of a debit and credit system with specific provisions assigned to different train sizes, commodity type and cars held for loading and unloading. According to the BNSF Demurrage Book 6004-A, cars held for loading are allowed either 1 or 2 credits per car, depending on the commodity and car type, for each empty car ordered by the shipper and released to the BNSF once it is loaded. Shippers acquire 1 debit, or demurrage day[26], per car for every 24 hour period until the cars are loaded and released to the BNSF. For non-shuttle trains, cars being held for both loading and unloading incur a demurrage cost of $75/car/day and an excess charge of $150/car/day is assessed after the third chargeable debit day has passed. For shuttle COTs, trains held for both loading and unloading incur a demurrage cost of $75/car/day. Credits earned in one month cannot be used to offset debits earned in another month, and shippers

[26] A demurrage day, or debit, is a "24 hour period, or fraction thereof" (BNSF Railway Company, 2009a, p. 9).

having 2 or more facilities cannot combine debits and credits from differing facilities. Also, credits can only offset debits on the same car in which they were earned.

The actual computation of demurrage is directly related to when cars are considered "released": whether or not cars are released in a timely fashion dictates when demurrage charges are assessed. For both shuttle COTs and non-shuttle trains, the date and time for when railcars are considered released is when the BNSF receives both forwarding instructions for the cars and a notice that the cars are available for movement (BNSF Railway Company, 2009a).

The BNSF Demurrage Book 6004-A notes that demurrage for non-shuttle trains is calculated differently depending upon whether cars are classified under actual placement[27] or constructive placement,[28] but cars held for loading and unloading are calculated the same. For COT and general tariff cars under constructive placement, the "demurrage clock" begins after the first 12:01 A.M. after constructive placement notification until the shipper orders the cars to be spotted, or placed, at the loading/unloading facility. If cars are held past the second 12:01 A.M., then demurrage charges are assessed.

Demurrage for COT and general tariff cars that have been actually placed is calculated as the time from the first 12:01 A.M. after actual placement until the cars are released with forwarding instructions. For example, if a COT unit arrives at a shipper's facility at 6 P.M., the demurrage clock starts at 12:01 A.M. and the allocated credit is used up during the loading day. If the shipper doesn't have the cars loaded and billed by the following 12:01 A.M., then he will incur a demurrage penalty of $75/car/day. If the

[27] Actual placement occurs when cars are either placed in an accessible position for loading or unloading, or in a position specified by the grain shipper.
[28] Constructive placement occurs when cars cannot be actually placed or delivered because of any condition attributable to the shipper. These cars are then held on BNSF tracks and a notice will be sent to the shipper indicating that cars are held and awaiting disposition instructions.

shipper loads and bills the car before the first 12:01 A.M., he would earn the credit rather than using it up on the following day while loading the cars (Mack, 2010). Lastly, it is worth noting that if cars are placed prior to the want date, the demurrage clock begins on 12:01 A.M. of the want date. Thus, shippers that receive their cars before the want date and are able to load them are at an advantage.

For shuttle COTs being loaded, demurrage is calculated from the time of actual or constructive placement at the loading facility until the train is released. Shippers dictate how fast they load their cars contingent upon the type of OEP they are anticipating. The demurrage clock starts once the cars are placed, and if the shipper fails to load them within 21 hours, a demurrage charge of $75/car is assessed. Similarly, for shuttle COTs being unloaded demurrage is calculated from the time of actual or constructive placement of the train until it is released. In addition, if a shuttle is constructively placed short of an unloading facility, the facility is charged $1000/hr until it is unloaded and released (BNSF Railay Company, 2009, Item 13501). Lastly, if cars are constructively placed at either a loading or unloading facility, the total hours between the shipper's order for placement and actual placement are deducted from the total demurrage time. Table 2.4 summarizes the demurrage calculations for both shuttle COTs and non-shuttle trains.

Lastly, "free-days" are days in which demurrage is not charged against shuttle COTs; these days include all the major U.S. holidays. For loading facilities, demurrage is not charged on Sundays and if cars are placed on Friday, the first Saturday is non-chargeable (BNSF Railway Company, 2009a). However, for unloading facilities, Sundays are not free-days and Saturdays are always chargeable. Table 2.5 displays the non-chargeable days offered by the BNSF for shuttle COTs. In addition to those free-days listed in Table 2.5, 24-car COTs and general tariff cars cannot incur demurrage on Sundays or the first Saturday after a unit has been placed on Friday. In addition to free-days, carriers are penalized for non-performance. The BNSF pays shippers $75/car for failure to deliver loaded shuttle COTs to an accessible position at an export facility within 24 hours of the interchange date or arrival at the facility (BNSF Railway Company, 2009a).

**Table 2.4. BNSF demurrage program**

| Car Type | Car Function | Applicable Credits | Chargeable Amount ($/car/day) | Excess Charge* ($/car/day) |
|---|---|---|---|---|
| **Non-shuttle** | Held for loading | 1 | $75 | $150 |
| **Non-shuttle** | Held for unloading | 2 | $75 | $150 |
| **Shuttle** | Held for loading | 1 | $75 | - |
| **Shuttle** | Held for unloading | 1 | $75 | - |
| **total credits > total debits**, no demurrage charges. | | | | |
| **total credits < total debits**, total credits are subtracted from total debits to determine the total number of chargeable demurrage days. | | | | |

* Begin after 3rd chargeable debit day

Table adapted from BNSF Demurrage Book 6004-A.

**Barge Demurrage.** Demurrage is also calculated on barges when they are kept longer than permitted. But unlike 24-car COTs or shuttle COTs, grain shippers acquire barges through the use of contracts which are specfic to each buyer/seller transaction. For example, the buyer and seller of a barge are able to dictate several provisions within a contract such as rates, the number of barges, free-days, and demurrage terms. Thus, contracts between buyers and sellers are highly differentiated in the items they entail.

Barge freight trading rules are published by the National Grain and Feed Association (NGFA) and are used as a basis for all barge contracts (2009). Essentially, they are ground rules for buyers and sellers engaging in the purchase and sale of barge freight. Buyers and sellers have the freedom to agree on any provisions they find appropriate as long as they don't alter the terms of the rules set forth by the NGFA. This section outlines the barge trade rules employed by the NGFA that affect the calculation of barge demurrage.

**Table 2.5. BNSF free-days**

| Date | Station Type | Start Date | Start Time | End Date | End Time |
|---|---|---|---|---|---|
| New Years | Loading | Dec. 31 | 00:01 | Jan. 2 | 06:00 |
| | Unloading | Dec. 31 | 06:00 | Jan. 2 | 06:00 |
| Easter | Loading/Unloading | Saturday | 18:00 | Monday | 06:00 |
| Thanksgiving | Loading/Unloading | Wednesday | 18:00 | Friday | 06:00 |
| Christmas | Loading | Dec. 24 | 00:01 | Dec. 26 | 06:00 |
| | Unloading | Dec. 24 | 06:00 | Dec. 26 | 06:00 |
| Independence | Loading/Unloading | July 4 | 00:01 | July 4 | 23:59 |
| Each month | Portland, OR<br>Vancouver, WA | 2nd Wed. | 15:00 | 2nd Wed. | 24:00 |
| | Seattle, WA<br>Tacoma, WA | 2nd Thurs. | 15:00 | 2nd Thurs. | 24:00 |

Table adapted from BNSF Demurrage Book 6004-A.

The first step for shippers to undertake when acquiring a barge begins with brokers helping to match up buyers with sellers; their primary function is to facilitate the creation and execution of contracts. If a trade is not made through a broker, then the buyer and seller send a written confirmation to each other by the close of the business day[29] following the date of trade. This process gets the contract specifications in writing and allows both parties to review them and make any necessary changes. After the contract has been

[29] Defined as Monday-Friday during hours of 8:00 A.M. to 5:00 P.M. excluding Saturdays, Sundays and all legal holidays (National Grain and Feed Association, 2009).

specified and confirmed by both parties, it cannot be altered without the consent of both the buyer and seller.

After the negotiation process is over, the buyer has to supply the seller with the river on which the grain will travel by 4:00 P.M., two business days prior to the contract placement period. The buyer must also supply the origin to the seller by the second business day of the contract period. The contract placement period depends on whether the buyer and seller have a weekly, monthly or semi-monthly contract. For weekly contracts, the window of placement, or delivery period, starts at 12:01 A.M. on Sunday. For monthly contracts, the delivery period starts at 12:01 A.M on the first day of the month, whereas for semi-monthly contracts, it starts at 12:01 A.M. on the first and sixteenth days of the month. Lastly, the seller cannot supply a barge to the buyer before the last business day preceding the contract period.

Similar to railcar placement, barges can also be constructively or actually placed. If a barge is placed at an origin before commencement of the contract period, it will be deemed constructively placed at 7:00 A.M. on the first day of the contract period. However, if the barge is loaded prior to the contract period, placement is effective the same day the loading commences. Whether or not the barge is constructively or actually placed, placement for loading begins on the first 7:00 A.M. after a barge is placed at the loading facility; the same is true for placement at an unloading facility.

After a shipper has started loading a barge, he needs to be aware of free days and actual demurrage charges. According to industry experts, barge contracts typically regard the first 3 days after placement as free or non-chargeable. Then, the next 10 days are set at $200/day, and every day after that is $300/day (Gergen, 2010, Gibson, 2010). Holidays such as Memorial Day or Labor Day are non-chargeable, as well as Sundays as long as they are in the 3 free-days. Lastly, it's worth noting that the amount of free time and other demurrage terms are specified by the contract and thus, are not the same for every transaction.

After a barge is loaded and ready to be picked up, the buyer notifies the seller by telephone. In order for a barge to be released as of 7:00 A.M., it must be loaded by then and notice of release must be given by 11:00 A.M. of that day. Barges can only be released on Saturday, Sunday or legal holidays if the buyer notifies the seller no later than the preceding business day or if the buyer notifies the seller by telephone no later than 11:00 A.M. on any of those days. The same release policy exists for unloading barges, except the consignee, or buyer of the grain at the destination, takes on the role that the buyer (grain shipper) previously played.

Finally, if a seller or a buyer cannot honor their part of the contract, they have to notify the other party. In addition, both parties have to choose to either extend their existing contract at contract price or fair market value, buyout the defaulted portion of the contract, or cancel the defaulted portion at fair market value. Therefore, similar to the rail industry, contract provisions exist to guard against non-performance of one or more parties involved in the transaction.

**Vessel Demurrage.** In addition to rail and barge demurrage, ocean vessels can also accrue demurrage charges. Factors affecting demurrage charges are placement within the delivery period, futures and basis levels, free days, and unloading capacities. The 2 main types of export contracts are free on board (FOB) and cost, insurance, and freight (CIF). They differ in their terms of sale, but both are still used for exporting grain. FOB export contracts consist of the buyer, or importer, supplying the freight and paying the cost of insurance on the commodity (Stopford, 1997). Thus, the buyer supplies the vessel, pays the freight rate, and takes ownership of the grain as soon as it is loaded. The seller is responsible for loading the vessel and paying demurrage if it takes longer to load than the time allowed. On the other hand, CIF export contracts involve the seller supplying the vessel, loading it, and paying for insurance and the freight rate (Stopford, 1997). Thus, this process involves the seller delivering grain to the buyer's port, and the costs of insurance and freight are included with the grain purchase price.

According to industry participants, the window of placement for ocean vessels is normally 10 days (Klein, 2010). Thus, vessels can be placed on any day within this 10-day window. In addition, futures and basis levels are continuously changing and they determine the ultimate price that grain will be sold for. Thus, futures markets in a "carry" (deferred price is greater than nearby) or an "inversion" (deferred price is less than nearby) affect shipping decisions. This can act as a source of risk for grain shippers when operating under a FOB system. Recall under FOB that buyers of the grain are responsible for acquiring vessels and delivering them to export facilities. Therefore, when a carry exists in the market, sellers want vessels to be placed at the end of the 10-day window in order to take advantage of the carry and receive a higher price when they sell their grain. However, the buyer wants to purchase the grain at the lowest possible cost so they will place the vessel at the beginning of the 10-day period. This situation can be risky for the seller (grain shipper) because if the buyer places the vessel at the beginning of the window but the seller doesn't have enough grain at the export facility to load it, he will incur demurrage charges. When an inverse market exists, the exact opposite is the case: buyers want to place the vessel at the end of the period whereas the seller would prefer it to be placed on Day 1 of the 10-day period.

Vessel demurrage is a function of a "loading rate guarantee" set forth by the seller of the grain. This guarantee states how many metric tons of grain the seller will load per day. If the entire vessel isn't loaded and released within the guaranteed number of days, the shipper will be charged demurrage (Klein, 2010). Demurrage rates are stated in $/day and are typically the same as the market rate for acquiring a vessel. If the vessel is loaded and released before the guaranteed number of days is used up, despatch is paid to the shipper. Despatch is the opposite of demurrage in that it is an incentive payment awarded to the shipper. Despatch amounts are also stated in $/day and are typically half of the demurrage rate. Consider the following example: if a shipper guarantees to load a 60,000MT[30] vessel in 6 days, he has to load 10,000MT per day. If the shipper finishes loading on Day 7, he will be charged demurrage, but if he finishes loading on Day 5, he will be awarded despatch.

Lastly, it is worth noting that vessel demurrage is similar to that of rail and barge because it cannot be charged on certain days. The North American Grain Association specifies that Saturdays, Sundays and certain holidays are exempt from demurrage charges for an FOB export contract (2000). In addition, their FOB contract contains certain provisions, such as commodity type, parties involved, and loading rate, that must be specified between the buyer and seller before the shipment takes place.

**Conclusion**

In conclusion, 24-car COTs and shuttle COTs allow shippers to bid for guaranteed railcar service and acquire railcars several months before they are needed. Thus,

[30] MT = metric ton

merchandisers can plan ahead several months and base their car needs on expected harvest numbers and future grain shipments rather than having to place several orders for fear of car shortages. In addition, general tariff cars exist for smaller shippers not capable of loading shuttle COTs or acquiring enough grain to load large unit-trains. Thus, the 3 alternatives for shippers offered by the BNSF (i.e., shuttle COTs, 24-car COTs and general tariff) complement each other nicely and allow merchandisers the freedom to make decisions based on their needs. The forward car guarantees offered by the BNSF are summarized in Table 2.6.

Forward car guarantees have allowed grain shippers to strategically integrate logistics and merchandising decisions into the same decision-making process (Wilson, Priewe, & Dahl, 1998). In addition, the secondary market is available for grain shippers to purchase or sell pre-ordered freight based on their needs. For instance, if a shipper doesn't have enough grain to fill an entire shuttle, he can sell it on the secondary market to another shipper and avoid cancellation penalties and demurrage charges.

Demurrage charges are imposed as a means of keeping movement within the grain supply chain as efficient as possible. It is imposed not only on railcars, but also on shipping barges and vessels. Therefore, shippers need to implement strategy in their logistical decisions through the use of forward freight mechanisms. This in turn allows shippers to avoid demurrage costs, cancellation penalties, and most importantly, reduce their exposure to risk.

**Table 2.6. BNSF forward freight mechanisms**

| | General Tariff | 24-car COTs | Shuttle COTs |
|---|---|---|---|
| **Allocation Mechanism** | Demand ≤ Supply: according to shipping demand and historical usage. Demand > Supply: lottery system. | Bidding Process | Bidding Process |
| **Type of Guarantee** | None | Short-term | Long-term |
| **Forward Duration** | 30 days | 6 months | 1 year |
| **Shipper Cancellation Penalty** | $100/car | $160/car/trip + Total COT Prepay amount | $400/month/car |
| **Transferability of Mechanism** | Intra-firm | Secondary Market | Secondary Market |
| **Total Cost to Shippers** | Tariff rate + FSC | Total COT Prepay + Premium/Discount + Tariff rate + FSC | Premium/Discount + Tariff rate + FSC |
| **Effective Rate** | Tariff rate | Existing rate on day of auction or the rate on the first day of the shipping period | Lowest applicable rate for the shipment date between the date the shuttle is purchased and the shipment date |
| **Railroad Non-performance Penalty** | None | $200/car | Shipper can cancel remaining trips or request additional trips to make up the difference |
| **Window of Placement** | 30 days | 15 days | None |
| **Shipment Size** | Single-car order: up to 15 cars One-unit order: up to 48 cars | 1 car min. and 15 car max. for "Singles." 24-27 cars min. and 48 car max. for "Units" | 104-110 cars |
| **Duration of Availability to Shipper** | 1 shipment | 1 month, or 12, 24 or 36 consecutive months | 3 month, 1 year or 2 year |
| **Percent of Total Fleet** (BNSF Railway Company, 2010a) | 8% | 75% | |

Source: BNSF periodic tariff filings.

## Strategies for Grain Shippers

Grain shippers need to make merchandising and logistical decisions a priority in their normal course of business operations. Both types of decisions should be integrated into a formal plan of strategy that seeks to find the optimal scenario. Today, there are several forward shipping mechanisms offered by the railroads and several contracts and methods for buying and selling grain. Thus, grain shippers have a slew of alternatives available to aid them in their decision process. The only problem that remains is to decide which mechanisms to utilize in order to reach maximum profitability.

Once merchandisers buy grain from producers or other merchandisers, they need to decide if they should store it as inventory, and if so, how much can be stored relative to capacity and cost constraints. If the market conditions are favorable, merchandisers then need to make a sale to some market participant further down the pipeline. However, the question that remains is how much grain should be sold in order to maximize net margin. In addition, merchandisers need to acquire freight if they recognize future shipping opportunities will be available to them. Thus, if the decision to make a sale has already been made, then merchandisers need rail and/or barge transportation available to them in a timely fashion.

Ultimately, grain shippers need to know the optimal amount of grain to sell and the optimal amount of freight to acquire in order to maximize net margin. In other words, the element of strategy comes into play as merchandisers try to balance future logistical needs with the timely purchase and sale of grain. Compounding difficulties is the element of risk and shippers will incur high costs if favorable opportunities are missed.

**Prototypical Grain Shipper**

The grain shipper modeled in this research was a prototypical or standard grain exporting firm that operates its own elevator network similar to that of Cargill or CHS. In addition, it has rail and barge capabilities and manages its own aggregate freight position along with an aggregate commodity position. This multi-elevator grain firm buys and sells grain to and from other firms within the pipeline and decides which export market is most profitable to ship to, all while accruing demurrage and despatch on railcars, barges, and vessels.

The grain exporting firm represented in this thesis was modeled to represent the typical grain companies that currently exist in the industry (e.g. Cargill, ADM, etc.). Thus, a vertically integrated firm that aims at maximizing aggregate profit was modeled. More specifically, this particular firm looks at maximizing total net margins for the entire elevator network rather than each separate elevator within the company working individually in its own interest. Even with coordinating the merchandising and logistical decisions for the entire company and the large number of grain contracts and shipping mechanisms available, shippers still face a lot of risk in their day-to-day business decisions. The sources of risk present in the industry are numerous, and they force merchandisers to always be thinking ahead.

**Sources of Risk**

Risk is present throughout the grain supply chain. During the 2008 crop year, volatile grain markets led to large price swings in many farm commodities such as wheat, corn and soybeans. Country elevators were particularly hurt by the volatile markets because they incurred large margin calls on their hedged positions, and as a result, had to liquidate their futures position (McKenzie & Kunda, 2009). Thus, futures price spreads can be very volatile and thus, act as a source of risk. In addition, basis levels at export facilities also are large sources of risk. Basis levels are very important because they are the determining factor in choosing which export market to ship to.

Before merchandisers start hedging, they first have to predict how much grain is going to be delivered to them by farmers. Predicting cash and forward-contracted grain purchases is a huge source of risk. Merchandisers need to have a good idea of how much grain will be delivered to them at harvest in order to plan their logistical needs and future grain sales. If they plan for a huge crop by committing to a lot of freight and the crop size ends up being the opposite, they will be faced either with cancellation penalties or hefty demurrage costs.

Merchandisers not only have to deal with volatile grain prices and future grain purchases, but they must also be able to deal with disruptions in the supply chain. For instance, changes in transit times will affect modal arrival at the grain shipper's location. If a grain shipper specifies a want date for rail cars, there is good chance that the cars will be 2 or 3 days late and the actual car placement will take place after the want date. Thus, transit time and modal arrival are sources of risk because they are hard to predict and aren't 100% dependable. If a merchandiser has a full grain terminal and cannot take in anymore grain from producers, he is missing out on revenue opportunities until the freight arrives. Thus, merchandisers are forced to depend on freight showing up on time and when transit time is affected by weather, disaster, or internal railroad issues, they have to change their plans.

Lastly, changes in tariff rates and car premiums associated with acquiring short-term and long-term guarantees are sources of risk because they affect total costs. Thus, when freight becomes more expensive, total costs increase. All of the previous risk factors listed affect the level of shipping demand. Shipping demand ultimately determines when it is profitable to ship grain by comparing futures price spreads with costs such as storage, tariff rates, and car premiums. Thus, shipping demand can be considered a source of risk and it should be carefully estimated by merchandisers. Even though merchandisers face a lot of risk in their decision making regarding the optimal quantities of grain to sell and freight to acquire, they can implement different strategies to mitigate a lot of the risk.

## Logistical and Merchandising Strategy

The first type of strategy covered in this section will be concerned with logistical decisions. Earlier in this chapter, the current railroad mechanisms offered by the BNSF were discussed in great deal; the other Class I railroads that ship a lot of bulk commodities such as grain (e.g. UP and CP) currently offer forward shipping mechanisms similar to those offered by the BNSF. Thus, grain shippers have several forward mechanisms available to them for shipping their grain to domestic customers and export ports. In addition, barge transportation provides another viable option for shipping grain along major water routes to nodes in the pipeline. The problem that many merchandisers face is how much freight to acquire for shipping their grain in an effort to maximize net margin. This can be any combination of short-term shipping guarantees, long-term shipping guarantees, and barges.

The issue of determining the optimal amount of freight to acquire along with the optimal amount of grain to sell in the pipeline has been examined by few researchers. The studies that most closely represent this thesis are: Wilson, Priewe and Dahl (1998) and Wilson, Carlson and Dahl (2004). The next section reviews these studies and the logistical strategies found by the researchers to be most beneficial to shippers. In addition, these studies are compared and contrasted with this thesis.

**Related Studies**

Wilson, Priewe and Dahl (1998) examined the portfolio of rail shipping alternatives available to grain shippers in an effort to find the optimal combination of grain sales and shipping strategies that maximizes net payoffs. The researchers focus only on rail transportation, and thus, analyze rail logistic strategies containing different periods of forward commitment. Wilson et al. (1998) model a single-origin elevator that has the choice of shipping grain to either Minneapolis or Portland and is faced by several sources of risk such as shipping demand, car premiums, and basis levels. They use the supply chain methodologies distribution requirements planning (DRP) and material requirements planning (MRP) to develop a dynamic stochastic simulation model to simulate the inventory management and logistical decisions a typical grain shipper is faced with.

Their stochastic model included several random variables such as car premiums, basis levels, and car placements. In addition, several nonrandom variables were included: train size, car capacity, and storage car capacity. Shipping strategies defined in the study were general tariff, short-term guarantees, and long-term guarantees. Key data was collected from several industry experts, BNSF's website, and the North Dakota Agricultural Statistics Service.

Wilson et al. (1998) found that maximum profit was reached with a strategy of no long-term guarantees, but risk is reduced with a longer-term guarantee strategy of 4-5 trains per month. In addition, profits and the level of risk increased with less use of long-term guarantees and more short-term guarantees. Also, a long-term intensive strategy removes flexibility and leads to more cancellation penalties. Finally, risk associated with farmer sales caused the greatest disruption in shipping demand.

Wilson, Carlson and Dahl (2004) analyzed the effects of random factors, such as demand and transit times, on logistical costs within the grain supply chain. They specifically looked at how these sources of risk affect the cost of demurrage incurred by a shipper who has rail, barge, and ocean vessel shipping capabilities. A grain supply chain model was developed to examine the impacts of several sources of risk on logistical costs within the grain supply chain for a single-origin shipper. More specifically, they utilized a stochastic simulation model to examine the impacts of several random variables on the marginal cost of exporting grain.

Wilson et al. (2004) modeled a grain supply chain with a single inland river terminal that loads railcars and barges to deliver grain to the U.S. Gulf. The model encompasses several sources of risk, such as transit time and vessel arrivals, and it considers grain sales, inventories, and grain unloads all with a focus on minimizing total cost within the supply chain. Random variables included in the study included shipping demand, modal arrivals, and other sources of risk, while strategic variables included general tariff cars and long-term and short-term forward shipping guarantees. In addition, past railcar placement was examined through the use of anticipatory and naïve strategies on total cost.

Data was obtained from the USDA, National Grain and Feed Association, and industry experts. They found demurrage to have the greatest amount of cost variability out of any of the cost components, and when export demand was increased, both demurrage and other shipping costs increased at an increasing rate. In addition, taking an anticipatory strategy when considering car placement reduced demurrage, and total demurrage costs were minimized when freight was ordered 6-weeks forward.

**Logistical Strategy**

Overall, both Wilson, Priewe and Dahl (1998) and Wilson, Carlson and Dahl (2004) found that the shipping strategy chosen depended on the risk preferences of the grain shipper. In addition, the forward car guarantees, both long-term and short-term, act as sources of strategy for grain shippers to reduce their level of exposure to risk. For example, merchandisers that buy cash grain from farmers or other merchandisers acquire not only a long cash position for their grain, but also establish a short freight position (Wilson, Priewe, & Dahl, 1998). Thus, shippers will end up buying freight at some point in the future, and therefore are susceptible to increases in rates. Forward car guarantees (e.g. 24-car COTs, shuttle COTs) can lock in rates several months prior to shipping and can minimize risk associated with increasing rates. However, even if the perfect freight-ordering strategy is chosen, not all risk can be mitigated; several disruptions can occur in the grain supply chain (as described previously in this chapter) such as modal arrival and transit time. Disruptions in the supply chain are out of a merchandiser's control, and as a result, they need to adjust their strategies when disruptions occur. The biggest concern for shippers when disruptions occur is how to deal with the cost of demurrage.

Since Wilson et al. (2004) found demurrage to be the most important cost factor, they recommend shippers should order freight forward 6-weeks forward rather than ordering freight through general tariff, or periods of high-car demand such as harvest. Some combination of short-term and long-term guarantees should be utilized to minimize demurrage, and the more accurate shippers can predict farmer sales patterns, the more they will be able to reduce the risk in shipping demand.

Too many long-term car guarantees can force shipments in suboptimal shipping periods rather than relying on market spreads to determine shipping needs (Wilson, Priewe, & Dahl, 1998). In addition, a short-term intensive strategy (0 long-term car guarantees) can lead to the highest amount of profit, but will also incur the greatest amount of risk. Thus, a mix of short-term and long-term car guarantees should be used with general tariff cars to minimize risk and total costs while still being able to achieve a good return.

In addition, past railcar placement performance should be considered when ordering cars to make sure they arrive when they are most needed. Barge transportation should be included in the mix of viable transportation alternatives because they are cost effective for shipping long distances over major water-routes. Lastly, Wilson et al. (2004) found ocean vessels accounted for the greatest portion of total demurrage costs so barges and railcars need to be placed and unloaded at the export facility in an efficient manner.

**Conclusion**

This thesis differs from Wilson et al. (1998) and Wilson et al. (2004) in that it models a multi-elevator firm with the capability to ship grain by rail and barge to more than one export market. Wilson et al. (1998) modeled a single country elevator origin with no barge capabilities and they did not include demurrage costs in their analysis. Wilson et al. (2004) modeled a supply chain consisting of only one single-shipping origin and one export destination in an effort to minimize total cost. However, this thesis looked to maximize profit by not only choosing the optimal mix of forward guarantees, but also the optimal quantity of grain to sell. Finally, the methodology in this thesis differs from the 2 studies examined: Wilson et al. (1998) used a stochastic simulation model based on MRP and DRP techniques while Wilson et al. (2004) used a stochastic simulation model based on MRP.

This thesis used a stochastic simulation technique based on a "push" inventory system in which grain was "pushed" through the supply chain whenever favorable sales opportunities occurred. Ultimately, the goal of this research was to build upon these two studies and contribute to the grain transportation industry.

**Merchandising Strategy**

In its simplest terms, merchandising encompasses the timely purchase and sale of grain both at the local level and regional level. The large grain firms that exist today are mainly buying grain from their own elevator network and other independent country elevators, with some buying taking place from other merchandisers and local producers. They then have the option of selling the grain immediately, or storing that grain as inventory and waiting to sell it at a more favorable time. Thus, merchandisers (i.e., large grain firms) need to be able to organize the purchase and sale of grain at particular prices and then coordinate this with logistics.

It is important for merchandisers to understand the relationship between the local cash price and the futures price. Futures prices are determined through a futures exchange, whereas local cash prices are set by elevator managers. Cash prices are impacted by local crop conditions. For instance, the quality of the local crop is determined by protein levels, test weight, yield, and disease factors. If these factors are adversely affected by weather or growing conditions, there will be a shortage of bushels in the region forcing merchandisers to offer a high price, and vice versa. In addition, local cash prices are influenced by transportation costs and storage costs incurred by the merchandiser. On the other hand, the futures price is impacted by the world supply and demand conditions, hedge funds, and index funds (Chafin & Hoepner, 2002).

Futures contracts are offered for several different contract months looking forward and these months represent the value of grain at different future points in time (Lorton & White, 2006). For instance, corn futures contracts are offered only for certain months rather than every calendar month. Thus, there is a corn futures price for December, March and May, but not November, January or February. The difference between the futures price for different contract months is known as the spread. When the nearby month is trading at a higher price than the deferred price, there is an inverted market; this encourages immediate selling. When the deferred month is trading at a higher price than the nearby month, there is a carry in the market; this encourages storage. Storing grain as inventory is part of merchandising and it is a viable alternative to selling as long as storage costs can be recouped later when favorable market conditions occur. The importance of inventory management is discussed at length in Chapter 3.

**Contracting.** Compounding difficulties for merchandisers is the daily price risk that is realized when a grain position is taken. Price risk is characterized by grain prices that are constantly changing. Managing price risk has become even more important lately because of volatile grain markets. Recent volatility in grain prices can be attributed to the presence of index funds and large private investors taking on enormous positions in the futures markets. But ultimately, a rapid decline in the stocks/use ratio[31] has been the most important factor causing the volatility (Wilson W. , Grain Contracting Strategies to Induce Delivery and Performance in Volatile Grain Markets, 2009c). This volatility can be reduced through contracting. Contracting is a means of strategy that can be utilized by merchandisers to reduce the chance of unexpected future events.

[31] This ratio denotes the percentage of how much grain is actually used out of the total grain stocks that are carried over from the marketing year.

Grain buyers offer contracts as a means of mitigating risk and because of the rising volatility in grain prices, contracting has become even more important. Risk is shared among buyers and sellers when they enter into a cash contract, but entering into a futures contract allows risk to be transferred to a third party (Wilson, 2009c). Futures contracts are standardized and are specific in price, quality, quantity, and delivery whereas cash contracts between merchandisers and producers are specific to each transaction; details on delivery and quantity are specific to each contract, and they offer premiums and discounts relative to quality which ultimately affects the price received by the producer. Types of cash contracts that involve risk being shared between the merchandiser and producer include forward contracts, delayed pricing contracts, and deferred pricing contracts. Contracts involving the use of the futures market include futures contracts, basis contracts, and hedge-to-arrive contracts.

**Hedging.** Managing price risk is done through hedging grain in the futures market. Hedging is a strategy that allows merchandisers to lock in a price, establish a basis, and eliminate price risk. The act of placing a hedge involves taking an opposite and equal reaction in the futures market: buying cash grain is hedged by selling futures, and selling cash grain is hedged by buying futures (Lorton & White, 2006). For instance, if a merchandiser has a long cash position, a short futures position of roughly the same quantity of bushels should be taken. This hedge will eliminate price risk, or the risk of declining grain prices, and should be terminated once an offsetting cash sale can be made which in turn results in liquidating (buying) the futures position.

Merchandisers can take on several different types of hedges. The most common is a storage hedge in which grain is owned by the merchandiser and as a result, a long cash position is hedged with a short futures position. The merchandiser then waits for favorable market conditions to sell the cash grain and liquidate the futures position. Other hedging strategies are noted in the following section.

**Basis.** Even though price risk is eliminated by hedging, basis risk is still present and it is characterized by unfavorable moves in the basis. The basis is the difference between the cash and future price. In a survey conducted by Kliethermes, Parcell and Franken (2009), understanding the basis was deemed the most important skill set for a merchandiser to posses. Thus, a good understanding of the basis is invaluable for being a successful merchandiser.

The basis is constantly changing to attract grain in and out of the marketplace. As of late, volatility in the basis in several markets has been just as prevalent as the volatility in futures prices (Wilson W. , 2009c). Figure 2.2 displays the volatility in the Minneapolis basis for hard red spring wheat. As one can see, the Minneapolis basis contained the most variability in 2008 and has since been very sporadic in 2009. The basis levels at terminal markets (Minneapolis) and at export ports (U.S. Gulf) relative to transportation costs ultimately determine which market to ship to. Both transportation costs and basis levels change over time, and arbitrage opportunities can be realized by shipping to one market versus another. Evaluating different markets and taking advantage of arbitrage opportunities when shipping grain is very valuable to a merchandiser's success.

Factors affecting the basis include the cost of transportation, time, availability of supplies and demand in the region, futures spreads, and quality (Lorton & White, 2006). The basis differs among different locations because of transportation costs (rail, truck and barge costs). The cost of shipping from an interior location to an export facility is factored into the basis and is the reason why many basis levels at terminal or export markets are trading at a premium to futures: they are providing some compensation for the transport of grain. Time also affects basis because during harvest the basis is typically at its lowest point, but over time it appreciates. Thus, a strategy for grain shippers is to buy cash and

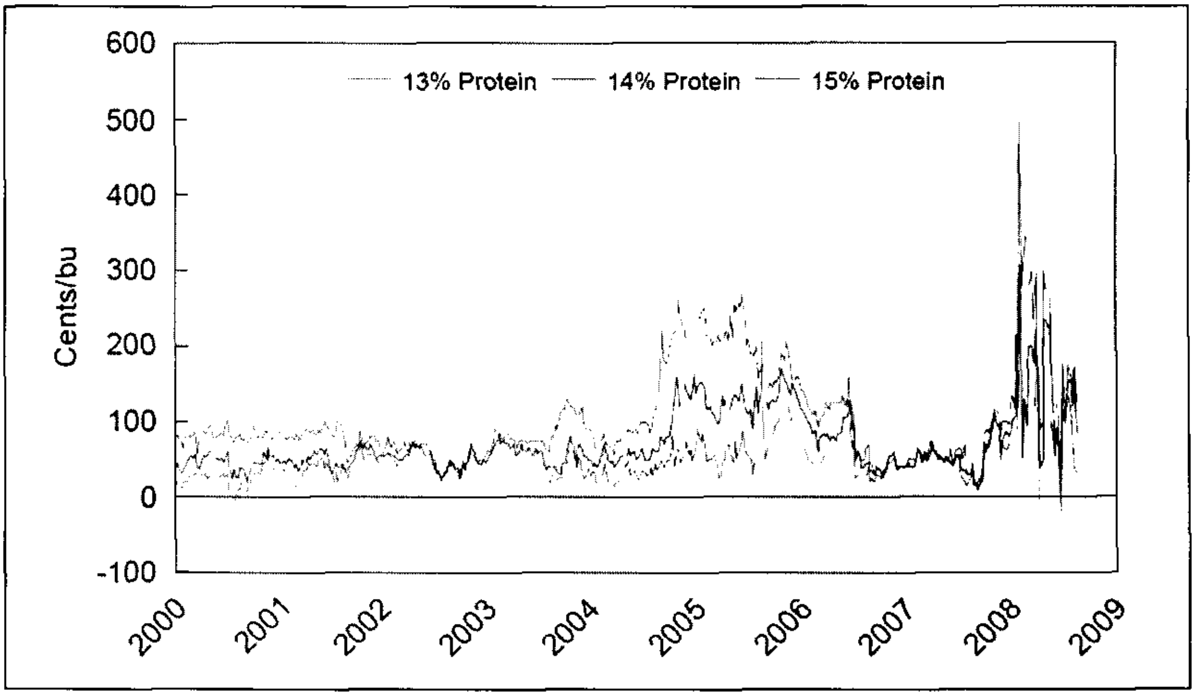


**Figure 2.2. Minneapolis basis for HRS wheat** (Wilson W. , 2009c).

sell futures, let the basis appreciate until it is greater than storage costs, and finally liquidate the position.

Basis is also affected by the supply and demand of a region; if a region has a large supply of grain after harvest, the basis will trade at a discount to futures. However, if a region has a limited supply of grain after harvest, then there is a high demand for bushels and the basis trades at a premium to futures. In addition, basis values are driven upward when there is a carry in the market because of excess supply, whereas an inverse market characterized by tight grain supplies tends to guide the basis downward. Lastly, quality affects basis because basis levels are quoted in standard units (typically based on protein), and deviations from the standard quotes are subject to discounts and premiums; these deviations affect price which in turn affect basis levels.

The basis can be used as a means of strategy for merchandisers. Even though basis risk is still present when merchandisers are 100% hedged, it is still manageable. Lorton and White (2006) outline 2 different sets of strategies for merchandisers to utilize: taking a "long-the-basis" position or a "short-the-basis" position. Both of these strategies emphasize the concept of placing time between the purchase and sale of grain in order to allow for favorable basis movement. A long-the-basis position involves buying cash grain and hedging it in futures when the basis is low, carrying the grain over time, and then selling cash grain and liquidating futures once the basis has appreciated enough to cover storage costs. Lorton and White (2006) note that this strategy can be accomplished through a storage hedge, which was discussed earlier, or by making forward purchases.

Short-the-basis entails merchandisers to sell what they don't yet own. Thus, they sell cash grain to be delivered in the future and hedge with buying futures. Then, the cash grain is purchased later when a lower basis is available, the long futures position is liquidated, and the cash grain is delivered. Lorton and White (2006) note that this strategy can be done by either making forward sales or through price later grain (i.e., delayed pricing). Table 2.7 below provides a summary of the 4 hedging methods previously discussed.

## Conclusion

In conclusion, the grain industry has been constantly evolving since World War II. Grain supply chains from then differ significantly than those found in the industry today. For example, the methods for shipping grain from one point to another have become focused on efficiency, reliability and speed. The 4 predominant modes of transportation currently available to grain shippers include truck, barge, rail, and ocean vessel. Each of these is different in terms of capabilities and rate structures.

**Table 2.7. Basis hedging strategies**

| | Long-the-Basis | | Short-the-Basis | |
|---|---|---|---|---|
| | Storage Hedge | Make Forward Purchases | Price later grain | Make Forward Sales |
| **Cash** (5/1/10)* | Long position | Long position | Short position on farmer price later grain and deliver immediately[32] | Short position on grain to be delivered later |
| **Futures** (5/1/10) | Short position | Short position | Long position | Long position |
| **Desired Basis** | Weak[33] | Weak | Strong | Strong |
| **Cash** (7/1/10) | Short position | Short position | Long position once farmer prices grain[34] | Long position and farmer delivers grain |
| **Futures** (7/1/10) | Long position | Long position | Short position | Short position |
| **Desired Basis** | Strong[35] | Strong | Weak | Weak |
| **Time of Farmer Delivery** | 5/1/10 | 7/1/10 | Prior to 5/1/10 | 7/1/10 |
| **Storage Costs** | Yes | No | Yes | No |

*Hypothetical date

Table adapted from Lorton and White (2006).

As a result of the Staggers Rail Act of 1980, rail firms have constantly been creating and refining car allocation mechanisms for grain shippers. Each Class I railroad now has their own system of car mechanisms. The BNSF Railway and their car programs were utilized in this thesis. These include 24-car COTs, shuttle COTs and general tariff cars.

[32] The revenue received from the sale can be used or left alone to generate interest.
[33] Weak basis occurs when basis is trading at a depreciating relative to futures.
[34] Strong basis occurs when basis is appreciating relative to futures.
[35] Farmer is paid current cash price but has been charged with "delayed price" service charges over time.

Grain shippers that acquire 24-car COTs or shuttle COTs are given a lot of flexibility because these instruments have a high degree of liquidity; they are transferable on informal secondary markets since they aren't specified to a fixed/origin destination pair unlike general tariff cars. In addition, 24-car COTs and shuttle COTs are sold at premium levels on the primary market, whereas they can trade at premiums or discounts to tariff on the secondary market.

Risk is present throughout the grain supply chain and the only way mitigate it is to implement strategy in the decision-making process. Types of risk include farmer deliveries, basis and futures spreads, transit times, and mode placement. To combat this risk, merchandising strategies such as hedging and contracting need to be employed. In addition, logistical strategies involve committing to forward freight guarantees and utilizing a combination of available transportation modes.

Finally, two studies exist that are most closely related to this thesis: Wilson, Priewe and Dahl (1998) and Wilson, Carlson and Dahl (2004). This thesis differs in comparison to those in that it modeled a prototypical grain shipper (e.g. Cargill, CHS) that currently exists in today's grain industry. Therefore, the current predominant car mechanisms and current industry norms were modeled. In addition, 3 elevator origins and 2 destination markets were simulated through the use of stochastic simulation and a pull inventory system.

# CHAPTER 3. THEORY OF SUPPLY CHAIN MODELS

## Introduction

The grain supply chain is only one of many that function to transform raw materials into end-products that provide consumers utility. The process of integrating and coordinating all the key functions involved in a supply chain is known as supply chain management. Greater emphasis has been placed on supply chain management within the past decade to ensure the efficient movement of goods at the lowest cost possible and with little or no disruption in supply. As a result, firms within the supply chain have benefitted from working together and have been able to offer greater levels of customer service.

An important component of successful supply chain management is effectively managing inventory. One industry that depends heavily on inventory management is the grain industry. Storing grain as inventory is an everyday occurrence for grain shippers and it is a viable alternative to shipping. In addition, grain shippers need to balance carrying too much costly inventory from not having enough on hand and being susceptible to stockouts. Several methods exist for determining the optimal quantity of inventory to carry on hand.

This chapter discusses the motives behind supply chain management and the factors that affect it. In addition, relevant supply chain models pertaining to carrying inventory and scheduling operations are reviewed. Lastly, the concept of demand forecasting and its relevance to this thesis are examined.

## Supply Chain Management

A basic supply chain consists of a series of firms performing business functions in an effort to make products and services available to consumers (Wisner, Tan, & Leong, 2008). These general functions include organization, production, delivery, storage, and logistics; these functions are performed to transform goods from raw materials to finished products. All of these activities are driven around the ultimate goal of making products and services available to consumers. Firms throughout a supply chain have key responsibilities that contribute to the overall supply chain. Core competencies firms are involved in are displayed in Table 3.1. Firms focus on doing these tasks well in order to be successful.

**Table 3.1. Core competencies of a supply chain**

| | |
|---|---|
| **Demand Forecasting** | This encompasses all activities involved with predicting the demand for a product in a future time period. |
| **Inventory Management** | This refers to managing the amount of inventory on hand with a goal of balancing customer service and carrying costs; by knowing when and how much to order. |
| **Materials Handling** | This occurs when a participant within a supply chain moves a product from one warehouse or storage facility to another. |
| **Procurement and Sales** | Procurement (sales) refers to the buying (selling) of raw materials, components, and end-products at any node along the pipeline. |
| **Transportation Management** | This involves managing all logistical activities associated with moving goods from one point to another in an efficient manner throughout the supply chain. |

If these key functions are coordinated among business participants in a supply chain, all firms stand to benefit rather than just one or two. To be successful, firms need to cooperate with one another and integrate key business processes regarding the flow of materials from origination to consumption (Wisner, Tan, & Leong, 2008). This process of collaboration among participants in a supply chain is known as supply chain management. Supply chain management (SCM) is a means for participants to effectively plan and manage key business functions in an effort to get products where they need to be in a timely fashion and at the lowest possible cost. Thus, effective supply chain management is a function of efficient logistics.

Transporting products among nodes in a supply chain in a timely fashion allows firms to adequately meet the needs of the end consumer in the form of high levels of customer service and lower prices. Therefore, the overall goal of supply chain management is to transport products along the supply chain in a timely fashion and at the lowest possible cost in order to serve the needs of the customer. The following subsections review the motives and initiatives for adopting supply chain management, and later, factors affecting supply chain management will be discussed.

**Motives.** Motives for firms to practice supply chain management include improving operating efficiencies, producing higher quality products and being able to provide higher levels of customer service to consumers (Wisner, Tan, & Leong, 2008). In addition, firms can lower their transportation, purchasing, and inventory costs, focus on core capabilities rather than having to perform several external tasks, and share risk associated with having to predict demand and manage inventory. Lastly, because supply chains have adapted from traditional factory driven "push" systems to customer-focused "pull" systems, the concept of supply chain management is even more relevant today because it seeks to satisfy customer needs (Murphy & Wood, 2008).

**Initiatives.** Firms wishing to introduce the concept of supply chain management need to be willing to work together. Cooperation among supply chain participants is critical for supply chain management to work. Therefore, firms need to share information with one another such as demand forecasts, production plans, new products, new technology, delivery dates, and many other things that affect a firm's purchasing, production and distribution plans (Wisner, Tan, & Leong, 2008).

In order for this type of information to be shared, participants need to be able to trust one another and be willing to communicate. In addition, firms need to adapt their corporate culture and make a commitment toward supply chain management rather than conforming to their single-minded individual interests (Wisner, Tan, & Leong, 2008). Then, once long-term relationships are established among participants, the supply chain will be able to function like a single vertically integrated firm and participants will receive competitive benefits in the form of reduced costs and lower risk. Cost savings will then in turn allow greater investment in research and production activities to produce better quality products.

Lastly, firms in a supply chain that initiate supply chain management will develop long-term strategic relationships with one another rather than traditional unfavorable short-term relationships (Murphy & Wood, 2008). Then, participants in the supply chain will be able to gain a competitive advantage over other supply chains through strategic and cooperative supplier-buyer-customer relationships (Wisner, Tan, & Leong, 2008). In the end, firms that decide to initiate supply chain management achieve competitive advantages and develop beneficial long-term relationships.

**Factors Affecting Supply Chain Management**

Firms employing supply chain management gain a significant advantage over firms choosing not to do so. However, several factors still affect supply chain management and the firms benefitting from it. These include several sources of risk, the optimal transportation mode chosen by firms, government restrictions, and inventory management.

**Risk.** No factor affects supply chain management greater than risk. Firms that benefit from employing supply chain management still confront risk in their every-day business operations. Risks associated with customer demand patterns, transit time and product lead times, fluctuating costs, and the timing of sales all can be detrimental to the success of a company.

Customer demand is rarely ever constant because consumer's tastes and preferences are always changing. Retailers at the end of supply chains need to predict consumer demand for end products with a high degree of accuracy because over-producing can lead to significant increases in inventory costs, while under-producing can lead to stockouts, or shortages of goods and unsatisfied customers. In addition, the wholesalers, distributors and manufacturers located farther up the supply chain need to rely on demand estimates for end-products because they produce and handle the components and materials used to make the finished good. Thus, if customer demand predictions are inaccurate at the retail level, then demand predictions for the parts and subcomponents at nodes higher up in the supply chain will also be inaccurate; this "chain-reaction" is known as the bull-whip effect.

The bullwhip effect is a problem within the supply chain caused by increased levels of safety stock and erratic demand patterns being passed up the supply chain to more distant suppliers (Wisner, Tan, & Leong, 2008). It is characterized by independent planning and a lack of coordination among supply chain participants, and it begins when a retailer at the end of the supply chain starts incurring erratic customer demand. As a result, this participant starts ordering more from the wholesaler and increases its safety stock. In turn, the wholesaler has to order more and increase its level of safety stock to continue supplying the retailer. This "domino-effect" is then passed onto the distributor, then the manufacturer and so on up the supply chain. The bullwhip effect is caused by a lack of coordination and firms being uncertain on how much inventory to order and when to reorder it.

In addition to risky consumer demand patterns, supply chain management is affected by lead time and transit time variability because these risks affect all firms within a supply chain. Lead time for a product encompasses all the processes associated with producing, developing and packaging an item before it is shipped to the customer. Therefore, when lead times for a product begin to vary, all of the functions within a supply chain before and after the production and packaging of goods is affected. This can alter short-term plans associated with inventory, transportation and customer sales. The timing of customer sales can also act as a source of risk because missed revenue opportunities can financially "hand-cuff" a firm. For example, if merchandisers don't sell grain when a favorable basis is present, their net return will be smaller even though it could have been avoided.

Variation in transit time, or the time it takes a good to be transported from one point to another, can increase costs, affect other members in the supply chain, and decrease customer service levels. Transit time of goods is a very important factor for firms relying on fast, efficient delivery because failing to provide that service increases the chance of losing customers. Lastly, fluctuating costs can result in lost revenue and they affect a firm's budget and planning process.

**Transportation Modes.** The optimal transportation mode for a firm not only depends on minimizing costs associate with shipping goods and acquiring the mode, but also the quality of service provided. The level of service provided by transportation mode depends on the speed, reliability and flexibility of the mode. These attributes for different transportation modes were discussed in detail in Chapter 2. There is a tradeoff among modes involving customer service and cost; firms can spend more on choosing a mode, say truck instead of rail, to get the goods to arrive at their destination faster. In contrast, a firm may spend less on choosing a transportation mode, but this will slow down transit time and increase the risk of unreliable service; this in turn slows down the movement of goods and customers won't be able to access their goods as fast as they'd like.

The choice of an optimal transportation mode affects supply chain management because firms must cooperate and strategically choose which transportation modes and routes to utilize when trying to reach their ultimate goal: minimize cost or provide great customer service. The location of nodes relative to one another in a supply chain also influences the choice of a mode. Participants need to coordinate their routes along different nodes in the pipeline and construction of new facilities to achieve a competitive advantage over other firms.

**Government Restrictions.** Firms employing supply chain management are affected by government regulations pertaining to shipping restrictions and environmental concerns. Firms need to follow certain regulations related to producing, shipping, packaging, and recycling of products (Wisner, Tan, & Leong, 2008). Especially today, greater emphasis is put on controlling potentially hazardous activity. For example, a lot of countries now restrict the inbound shipments of hazardous materials. Thus, participants within a supply chain need to have the same understanding of ethics, or how they conduct business. If one company in a supply chain is caught doing something unethical, then consumers will portray that firm negatively; this in turn affects the rest of firms in the supply chain and thus, how the overall supply chain performs as a whole. Therefore, supply chain management even encompasses business ethics and how well firms within a supply chain portray themselves to consumers because their image affects the entire supply chain.

## Inventory Management

Inventory is held by firms to satisfy product demand. It is a key component required for most firms to function because it allows firms to produce goods in a timely manner and meet customer needs. Items are typically held in one period and carried into the next so as to act as a buffer against any shortages. For example, grain stocks that aren't processed, exported, or used as feed are held in inventory and carried over to the next year. It then has to be rationed out accordingly over the next several months until the following harvest.

Supply chain management is affected by several factors pertaining to inventory-related decisions. These include costs associated with carrying inventory, the decision of how much inventory to carry on-hand, or even the type of inventory management strategy to employ. These issues will be discussed in the following sections.

**Types of Inventory.** Inventory that is carried on-hand by firms to satisfy normal demand patterns is classified as base stock (Murphy & Wood, 2008). Traditionally, inventory is stored from one period to the next and is drawn from warehouses when it is required to meet customer needs. Alternative strategic approaches related to carrying inventory are more customer-driven rather than factory-driven. Firms utilizing these alternative approaches are employing "just-in-time" (JIT) and vendor-managed-inventory

(VMI) approaches to eliminate the higher costs associated with carrying too much inventory. Both of these approaches are discussed later in this section.

In addition to base stock, inventory that is carried to protect firms against uncertainties associated with product lead time, transit time and customer demand is known as safety stock (Murphy & Wood, 2008). Safety stock is carried in addition to base stock to avoid stockouts or shortages of goods. For example, consider a manufacturing firm that carries 150 units of base stock to satisfy demand. In addition to the 150 units, it will also carry 25 units of safety stock just in case the original 150 is depleted before more inventory arrives.

**JIT and VMI.** Rather than the traditional method of carrying large amounts of inventory on-hand, firms have turned to more efficient methods to manage their inventory. These strategic alternatives include the "just-in-time" (JIT) approach and the vendor-managed inventory (VMI) approach which both seek to cut inventory levels and the costs associated with them. The JIT approach minimizes inventory by either reducing or eliminating safety stock and by having the required amount of materials arrive at the exact time they are needed for production (Murphy & Wood, 2008). JIT is characterized by smaller and more frequent orders; thus, suppliers need to be located close to manufacturers, capable of handling a higher number of orders and deliver non-defective products because of little or no safety stock available on hand. As a result, collaboration among supply chain participants is essential for JIT to be effective.

Whereas the JIT approach is controlled by the buying firm, the vendor-managed inventory (VMI) approach is controlled by the supplier. Suppliers are responsible for replenishing buyers' orders rather than the traditional method of a buyer contacting the supplier when products are needed. Thus, suppliers need to have access to the buyer's sales and inventory data in order for VMI to work (Murphy & Wood, 2008). Thus, manufacturers and other buyers in the supply chain (e.g. distributors, retailers) need to allow suppliers control over their inventory and must be able to trust their supplier with their confidential information. VMI benefits both parties by reducing inventory and stockouts, as well as cutting costs.

**Inventory Costs.** No matter if a firm carries base stock and safety stock, or just one of the two, inventory is a significant cost. Costs associated with inventory are greatest once value has been added to a product through manufacturing or processing (Murphy & Wood, 2008). Thus, finished goods are more expensive to hold in inventory than raw materials.

The costs associated with holding inventory from one period to the next are known as carrying costs. Carrying costs encompass all the expenses associated with storage, handling, and insurance. Thus, when a high level of inventory is carried and when inventory turnover is low, carrying costs for firms are high, and vice versa. In order to reduce carrying costs and induce a higher turnover rate, firms need to be willing to incur a greater risk of stockouts by lowering their inventory levels (Murphy & Wood, 2008). However, if stockouts do occur they are costly and can be more expensive than the carrying costs associated with carrying too much inventory. In addition, firms run the risk of losing customers if customers demand a product that isn't immediately available; this is the biggest risk associated with incurring a stockout.

A tradeoff exists among higher levels of inventory and carrying costs: carrying high amounts of inventory provides greater levels of customer service but also incurs higher carrying costs and wastes resources, whereas holding a low level of inventory can reduce carrying costs but at the same time increases the risk of a stockout. Firms need to consider the opportunity cost of carrying a great deal of inventory and the return on investment on the funds tied up in that inventory; if a greater return can be achieved somewhere else on the money invested in the inventory, then inventory levels need to be reduced and the time and money associated with carrying a lot of inventory needs to be re-invested (Murphy & Wood, 2008). This tradeoff among higher levels of inventory and carrying costs presents one of the most challenging tasks to firms: how much inventory should be carried?

Methods exist to combat decisions of when and how much inventory to order. Whether firms are employing a just-in-time approach, vendor-managed inventory approach or a traditional factory-driven approach, they can utilize inventory management models and resource planning techniques to limit risk. These methods can in turn prevent inventory problems, such as stockouts and rising costs, and are discussed in the following section.

## Supply Chain Models

Different types of supply chain models exist to aid firms in their decision-making process. Some models focus on finding the optimal amount of inventory to be ordered and when it should it should be ordered, while others pertain to scheduling operations and forecasting demand. All of these different supply chain models involve the efficient production and movement of goods to meet demand requirements, all while trying to minimize costs.

Participants in a supply chain face several sources of risk, such as unreliable transit times, fluctuating inventory costs, and volatile consumer demand patterns. However, supply chain models work to mitigate sources of risk by implementing elements of strategy. The following subsection discusses inventory models and their importance to controlling inventory costs. Then, resource planning techniques are examined, and finally, the concept of demand forecasting is described.

**Inventory Management Models**

Firms that rely mainly on a traditional inventory system characterized by holding inventory over time and carrying safety stock as a buffer against shortages are greatly impacted by the bullwhip effect and the tradeoff between customer service and carrying costs. Thus, models concerned with ordering inventory and minimizing total inventory costs are particularly beneficial to these types of firms. These models typically fall under two types: fixed order quantity models and statistical order quantity models.

**Fixed Order Quantity.** Fixed order quantity models, such as the economic order quantity model, assume that demand, product lead time, and other parameters are held constant over time (Wisner, Tan, & Leong, 2008). These fixed parameters then generate an optimal order quantity that minimizes total costs for a firm. In addition, under a fixed order quantity system, fixed amounts of inventory are ordered even though the time interval may fluctuate with when the orders are placed (Murphy & Wood, 2008). For example, a manufacturing firm will always place an order for 200 ball-bearings, but the time interval between the placements of orders will fluctuate; sometimes it may be a 4-day interval, while other times it may a 7-day interval.

The first issue for firms to address when managing their inventory is associated with when products should be ordered. To combat this problem, firms can utilize a reorder point (ROP) method. Reorder points indicate to firms when a new order must be placed. Once a certain level of inventory is reached, a reorder, or trigger point, indicates to a firm that more inventory needs to be ordered to avoid a stockout (Murphy & Wood, 2008). A reorder point can be calculated by multiplying the average daily demand by the order lead time. Also, if the firm carries safety stock, then it can simply be added to this calculation to determine the reorder point. For example, suppose a manufacturing firm has an average demand of 50 units per day and the current order lead time is 4 days. In addition, this firm carries 25 units of safety stock. Their reorder point (ROP) is reached at 225 units[36]; thus, when inventory reaches 225 units, the firm needs to place an order.

After determining when an order should be placed, firms still need to decide how much inventory needs to be ordered. This particular problem can be addressed by utilizing the economic order quantity (EOQ) model. This model seeks to find the optimal order size that minimizes total inventory costs (Wisner, Tan, & Leong, 2008). The two main inventory costs included in this model are carrying costs of holding the inventory and the order costs associated with placing an order. A tradeoff exists between these two costs: holding a low level of inventory keeps carrying costs low, but forces firms to place frequent orders which raise ordering costs. Conversely, if a high level of inventory is held, then order costs are low because orders don't have to be placed as often, but carrying the greater quantity of inventory is expensive. Thus, the EOQ model finds the order quantity that minimizes these two costs.

Similar to the ROP method, the EOQ model assumes that demand and order lead time are fixed and constant (Wisner, Tan, & Leong, 2008). In addition, entire orders are delivered at one time (no partial shipments), stockouts are not allowed, and price, carrying costs and ordering costs are held fixed. Calculus can be applied to the total annual

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[36] (50x4) + 25 = 225

inventory cost formula to determine the EOQ. The total annual inventory cost formula is the summation of annual purchase costs, annual holding costs and annual ordering costs. It is represented below in Equation 3.1 (Wisner, Tan, & Leong, 2008).

$$TAIC = APC + AHC + AOC = (R \times C) + \left(\frac{Q}{2} \times k \times C\right) + (\frac{R}{Q} \times S) \quad \textbf{(3.1)}$$

where:

TAIC = total annual inventory cost

APC = annual purchase cost

AHC = annual holding cost

AOC = annual ordering cost

R = annual demand

C = purchase cost per unit

S = cost of placing one order

k = carrying cost

Q = order quantity

By taking the first derivative of Equation 3.1 with respect to Q and then setting it equal to zero, the optimal Q or economic order quantity (EOQ) formula is obtained. Thus, the EOQ model determines the minimum value of TAIC (total annual inventory cost). The EOQ is shown below in Equation 3.2.

$$EOQ = \sqrt{2RS}/kC \quad \textbf{(3.2)}$$

Figure 3.1 provides a graphical representation of the underlying result of the EOQ model (Murphy & Wood, 2008). The economic order quantity is located where ordering costs and carrying costs are minimized; this point is denoted as Q* in Figure 3.1. Because annual ordering costs and annual carrying costs are at their lowest levels at Q*, it is the optimal order quantity that minimizes total annual inventory cost (TAIC).

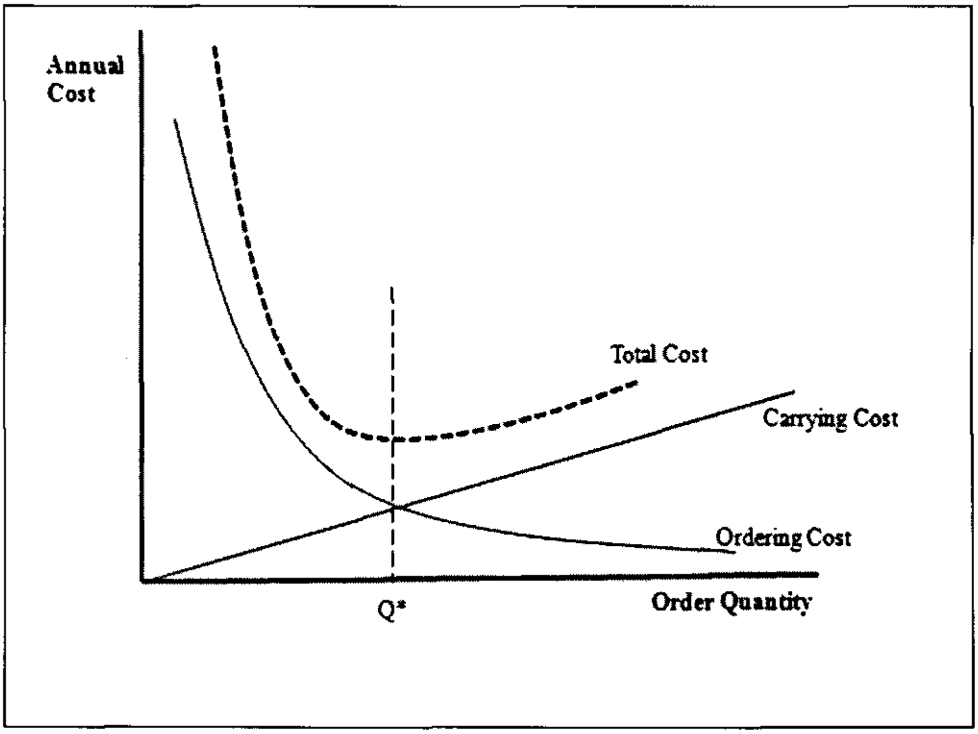


**Figure 3.1. Economic order quantity** (Murphy & Wood, 2008).

The EOQ model can be used in conjunction with the ROP method to determine the optimal order size for a firm when ordering inventory, and when firms should place an order to replenish their inventory and avoid a stockout. Firms that employ both of these methods will be able to have greater control over their inventory. However, both the EOQ and ROP techniques assume that demand and lead time are constant which may be unrealistic in most cases.

**Statistical Order Quantity.** Fixed order quantity models make the assumption that demand and lead time are constant. However, this is rarely ever the case because customer demand fluctuates depending on tastes and preferences, the price and quantity of substitute goods, and among other things, the income levels of consumers. In addition, disruptions in a supply chain can lead to uncertain delivery lead times. Thus, models for managing inventory need to be more realistic and able to handle volatile market conditions.

The statistical reorder quantity model can be employed by firms wanting to allow demand and lead time to vary (Wisner, Tan, & Leong, 2008). The statistical reorder point method can be used when both customer demand and lead time vary, or if just one of them is allowed to vary. Its objective is to find the reorder point and level of safety stock that guarantee inventory will be sufficient to cover demand. It assumes that unknown variables (customer demand, lead time, or both) can be represented by a normal distribution and utilizes a Z-table containing probability values that correspond to a certain number of standard deviations away from the mean. For example, if a manager wants to attain a 95% probability that inventory will cover demand, the statistical reorder point method can be used to determine the reorder point and the required safety stock that would reduce stockouts to 5%. The calculations for determining these objectives are beyond the scope of this thesis, and the statistical reorder point method is introduced simply to give readers proof that an alternative to the EOQ model exists.

**Operations Planning Techniques**

When firms in a supply chain are faced with having to decide how much of a good to produce, they need to accurately determine the demand of that specific good. In addition to forecasting demand, firms need to make sure they are efficiently utilizing the capacity of their facilities to meet customer demand. Once again, this leads back to the issue of inventory management; there are significant costs to carrying too much inventory, whereas carrying too little inventory can be detrimental to customer service capabilities.

The concept of inventory management is captured under the notion of operations planning which simply refers to the planning process that firms undertake to make sure they can produce goods and components to meet customer demand and efficiently utilize their plant's capacity (Wisner, Tan, & Leong, 2008). Inventory requirements for finished goods and the components used in producing finished goods are planned out ahead of time and are used in conjunction with demand forecasts to efficiently monitor production and employ resources. Operations planning techniques can be separated into 3 different types based on their duration: long-range, medium-range, and short-range. Long-range plans involve major changes to a firm's capacity such as expanding, purchasing capital, or constructing a new facility. Medium-range plans are typically more detailed than long-range plans and are characterized by small-scale capacity changes, whereas short-range operations planning are the most detailed in that they specify certain items and the exact quantities of those items to be produced. Specific types of each of these 3 categories are listed below in Table in 3.2 (Wisner, Tan, & Leong, 2008).

**Table 3.2. Operations planning techniques**

| | Aggregate Production Planning (APP) | Master Production Scheduling (MPS) | Materials Requirements Planning (MRP) |
|---|---|---|---|
| **Type of Operations Planning** | Long-range | Medium-range | Short-range |
| **Forward Planning Horizon** | ≥ 1 year | 6-18 months | Several days/weeks |
| **Description** | Combines business and marketing plans with demand forecasts to create a production plan for all products in a single facility. | Disaggregates APP by listing the exact quantity and timing of end items to be produced within a certain time frame. | Uses the end items from the MPS and calculates the exact quantities of parts and components for making final products. |

Table adapted from Wisner et al. (2008).

Operating plans that are classified as long-range plans are typically very broad in that they cover all products in a single facility (Wisner, Tan, & Leong, 2008). Table 3.2 shows that the aggregate production plan (APP) is a long-range plan and this particular method can be addressed by several different strategies such as adjusting capacity to meet demand patterns by altering the size of the work force, fluctuating inventory levels and backlogs to meet demand, or a mixture of both. APP is great for planning purposes because firms can devise their production plans 1 or 2 years looking forward. Medium-range plans, such as the master production schedule (MPS), use the APP as a point of departure to calculate the exact quantity of final products to produce within a certain period of time to meet demand. Thus, the MPS is more detailed than the APP because it pertains to small-scale changes in capacity and it calculates the exact quantity of finished goods that need to be produced.

Lastly, the MPS is the basis for short-range plans such as the material requirements planning (MRP) technique. According to Wisner et al., this short-range materials plan is "a system of converting the end items from the master production schedule into a set of time-phased component and part requirements" (2008, p. 175). This plan is the most detailed out of the 3 types because it not only specifies which parts and components need to be made, but also the exact quantities of those items.

Out of the 3 types of operations planning techniques listed in Table 3.2, material requirements planning (MRP) is the most closely related to this research and therefore, is discussed in greater detail in the following section. In addition, distribution requirements planning (DRP) is an extension of MRP and is relevant to aggregating demand and inventory across different firms. Thus, a section on DRP is also included.

**MRP.** Material requirements planning (MRP) has been used by for many years, especially by manufacturing firms that produce parts and components to create finished goods. Both Ballòu (1992) and Wisner et al. (2008) give examples of manufacturing firms that use MRP in scheduling the production of components used to construct end-items in order to meet demand. Both of their examples carry the same overall theme in that MRP determines the required raw materials used to manufacture finished goods. More specifically, MRP takes the end items from the master production schedule (MPS) to calculate the exact quantity, want dates and planned order releases for components and materials used to make final products (Wisner, Tan, & Leong, 2008). It accounts for on-hand inventory, levels of safety stock, production times and lead times when calculating the raw material ıequirements.

MRP calculates the requirements for dependent demand items, which are subassemblies, components, or raw materials whose demand depends on the independent demand of finished goods (Wisner, Tan, & Leong, 2008). The reason why MRP is closely related to this thesis is because grain is a dependent demand item since its demand depends on that of finished goods such as flour, cooking oils, or other types of consumer products. MRP assumes the demand for raw materials is known with a high degree of certainty because the demand patterns for raw materials and components are derived from end-product demand (Ballou, 1992). Thus, once the demand of the end-product is known, the requirements for the raw materials and sub-components can be calculated since the parent-component relationship is known beforehand.

As a result of the demand for raw materials being dependent on finished goods, demand patterns can be very "lumpy" or bunched together for materials and components

(Ballou, 1992). These lumpy demand patterns create variability in inventory requirements and in order to compensate for the variability, high amounts of inventory must be kept on hand. MRP works to reduce unnecessary inventory and keep carry costs as low as possible. Wisner et al. describes how MRP determines the net requirements of the final product and then "offsets the net requirements with appropriate lead times to ensure orders are released on time for fabricating higher-level components" (2008, p. 189). As a result, MRP can cut inventory carrying costs by scheduling the flow of materials to meet end-item requirements when the demand for these end-items is known.

According to Wisner et al. (2008), the actual MRP process can begin once the requirements for the final product are obtained from the master production schedule (MPS). This first step is critical in order for MRP to work. The following step uses this information from the MPS to calculate the requirements of the components directly used to make the final products. This step is then repeated until having worked down the entire list of materials until the requirements for the lowest-level of components have been calculated. The major disadvantage of MRP is that it can't calculate the net requirements for these lowest-level components very far into the planning horizon because they are lagged so many periods after the final product (high-level) demand. On the other hand, MRP methodology is great for planning purposes in that firms can generate information pertaining to production, inventory, net requirements, and product order quantities several weeks forward.

**DRP.** Distribution requirements planning (DRP) is an extension of MRP and it determines the aggregate net requirements of finished goods that need to be produced and transported in a timely fashion to meet consumer demand (Wisner, Tan, & Leong, 2008).

These aggregate requirements are then used to make adjustments to the master production schedule (MPS). Basically, DRP allows the method of MRP to be used in the entire distribution channel because it combines the planned shipments for a good from several warehouses and generates the gross requirements for that good which are needed to meet demand (Ballou, 1992). Thus, DRP isn't only for end-items since it can continue back up the supply chain until the first node, or point of origination is reached.

DRP is different from MRP in that it ties the distribution system to the manufacturing system (Wisner, Tan, & Leong, 2008). In addition, DRP is driven by customer demand of the finished goods, whereas MRP is based off of the master production schedule (MPS) to compute the net requirements of materials and components. Also, MRP results in the production of finished goods at the manufacturing site while DRP allows for the timely movement of end-items from different distribution centers into 1 central warehouse. This central warehouse then contains the aggregate gross requirements for each independent good generated across all the distribution centers.

The benefits of employing DRP methodology include reducing finished-goods inventory levels and the costs associated with them. For example, rather than using a traditional "pull" inventory system, DRP can coordinate the timely flow of goods with production requirements. Thus, minimal inventory is carried on hand when the amount and timing of the end-product are known (Ballou, 1992). Also, independent items from multiple warehouses can be managed collectively. Lastly, DRP shows future demand requirements for end items similar to that of MRP which allows firms to plan ahead and it gives them more flexibility to respond to changes.

The process of DRP begins with forecasting demand of an end-item several periods forward for each warehouse. These demand requirements are gathered from customer orders, future promotions, and the actual predicted demand of the good (Ballou, 1992). Next, the gross requirements for the end-item from each warehouse are combined into 1 central inventory requirement.

Wisner et al. (2008) use an example of a manufacturing firm that produces all-terrain-vehicles (ATVs) at 2 different distribution centers in the US: Las Vegas and East Lansing (p. 196). Neither of the distribution centers has to maintain safety stock, and there is a product lead time of 2 weeks at the Las Vegas distribution center whereas the East Lansing distribution center has a lead time of 1 week. This example is illustrated in Figure 3.2. The gross requirements for the firm's ATVs are located in the Central Supply Warehouse in Figure 3.2. These gross requirements were generated from the planned order releases contained in both the Las Vegas and East Lansing distribution centers. A planned order release is simply a product order that is submitted to the materials and component manufacturer when on-hand inventory runs low. For instance, in week 1 Las Vegas places an order for 6 ATVs while East Lansing has an order for 12. Thus, the aggregate gross requirement for ATVs at the Central Supply Warehouse in week 1 is 18 (12+6). In week 4 the Central Supply Warehouse has a gross requirement of 4 ATVs, but it appears that only 2 are held in inventory. However, because there is a 2 week lead time at the Central Supply Warehouse, the planned order release of 4 units in week 2 is delivered in week 4 to meet the demand requirements. Lastly, it is worth noting that Figure 3.2 is only a simple representation of DRP and that an actual DRP system would forecast the gross requirements 8-10 weeks forward rather than just 4. Thus, when it appears that demand is going to increase in a future time period, a firm can order more ATVs and offset this demand with the appropriate lead time to ensure the ATVs will arrive at the distribution centers on time.

**Las Vegas Distribution Center**

| Model A ATV | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Gross Requirements | | 0 | 1 | 5 | 1 |
| Scheduled Receipts | | | | | |
| On-hand Inventory | 1 | 1 | 0 | 1 | 0 |
| Planned Order Releases | | **6** | 0 | 0 | **2** |

**East Lansing Distribution Center**

| Model A ATV | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Gross Requirements | | 2 | 11 | 0 | 1 |
| Scheduled Receipts | | | | | |
| On-hand Inventory | 3 | 1 | 1 | 1 | 0 |
| Planned Order Releases | | **12** | 0 | 0 | **2** |

| Central Supply Warehouse | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Gross Requirements | | **18** | 0 | 0 | **4** |
| Scheduled Receipts | | | | | |
| On-hand Inventory | 20 | 2 | 2 | 2 | 0 |
| Planned Order Releases | | 0 | 2 | 0 | 0 |

**Figure 3.2. DRP operations planning**
Table adapted from Wisner et al. (2008).

**Demand Forecasting**

Both MRP and DRP rely heavily on the fact that end-product demand is assumed to be known with a high level of certainty. However, in most circumstances, predicting demand is no easy task for supply chain participants. The demand for a retailer's final product affects the demand for all the materials and components that go into producing that final product. Thus, when firms are able to pinpoint their future demand requirements, they will have a competitive advantage over other firms in the supply chain.

Accurate demand forecasting in a supply chain results in matching supply with demand (Murphy & Wood, 2008). If firms are over-supplied, they are carrying too much costly inventory, but if they are under-supplied, they run the risk of losing customers because of poor customer service. Therefore, being able to forecast future demand is invaluable to a firm's success.

Murphy and Wood (2008) list three different methods used to predict future demand; these include judgmental models, time series models, and cause-and-effect models. Judgmental models involve using a best judgment or intuition when forecasting demand because of a lack of historical data. This type is normally characterized by surveys and is used mainly when a new product is introduced. On the other hand, time series models use past demand data to predict future demand. This is done by utilizing a simple moving average in which each past time period is assigned the same weight, or through the use of a weighted moving average in which more weight is put on the most recent data. The last type, cause-and-effect, is characterized by econometric analysis because it involves simple and multiple regression techniques. This econometric analysis looks at the relationship between a dependent variable and several independent variables.

**Forecasting Shipping Demand.** Shipping demand is a source of risk for grain shippers in this thesis. Thus, the concept of demand forecasting is relevant because it allows merchandisers more flexibility in their planning horizon and they are able to more run their operations more effectively after reducing the risks associated with shipping demand. As stated in Chapter 2, shipping demand in this research determines whether it's more profitable to ship or to store grain as inventory. This decision is based on the comparison of futures price spreads with costs associated with storage and transportation.

For example, the basis levels at export facilities and grain futures prices are sources of revenue, whereas carrying costs, car premiums/discounts, and tariff rates are all sources of costs.

Thus, rather than forecasting the demand for a product, this thesis forecasted shipping demand associated with shipping grain through the pipeline. This entailed having to forecast futures prices and basis levels, the costs incurred by a merchandiser, and the amount of grain farmers will contract versus the bushels they will deliver in the spot market. These issues and how they were addressed are discussed in greater detail in Chapter 4.

## Conclusion

A supply chain is made up of several firms operating to make products and services available to consumers. Some of the basic functions performed by supply chain participants include production, delivery and logistics. In addition, firms have key responsibilities such as demand forecasting and inventory management. Coordinating these core business functions among participants to get products where they need to be in a timely fashion at the lowest possible cost to meet customer demand is known as supply chain management.

Motives for firms to employ supply chain management were discussed, and some of the main motives include lowering costs, sharing risks, and increasing customer service. In order for these benefits to be attained, firms need to trust one another, and once they start cooperating, they can achieve a competitive advantage over other firms. However, even though supply chain management provides several benefits, it is still impacted by government policy, sources of risk, logistics, and inventory management. Risks associated with product lead time, transit time and customer demand can adversely affect firms. In addition, the classic tradeoff in inventory management is concerned with carrying costs and customer service; greater levels of inventory increase customer service but also incur a greater cost, whereas less inventory decreases cost but reduces customer service. Luckily, this tradeoff can be solved and the risk present in supply chains can be mitigated by employing certain techniques.

These techniques include the reorder point method, the EOQ model and the statistical reorder method. In addition, MRP and DRP were introduced to combat the task of resource planning. Lastly, demand forecasting techniques were introduced because they are invaluable to a firm's success and the concept was applied to this thesis.

In conclusion, the concept of supply chain management can be applied to the grain industry because it is a classic example of a supply chain. Participants within the grain pipeline perform several of the core responsibilities that were introduced earlier in this chapter such as inventory management, demand forecasting, and transportation management. In addition, the supply chain models introduced in this chapter can be used by merchandisers to help with inventory management and operations planning. Lastly, grain firms in the grain pipeline face the same risks and have to address the same issues that firms in basic manufacturing supply chains have to face. Thus, the concepts of supply chain management can be used to model a prototypical grain shipper.

# CHAPTER 4. STOCHASTIC MODEL OF A PROTOTYPICAL GRAIN SHIPPER

## Introduction

The focus of this chapter is to explain the stochastic model used to analyze a prototypical grain shipper in this thesis. The stochastic model is composed of 3 different inland elevator locations that originate grain from area farmers. Depending on the elevator facility, rail and/or barge transportation are available for shipping grain to either the U.S. Gulf or Pacific Northwest (PNW) for export, contingent upon the most viable option.

This chapter is organized to explain the development of the stochastic model of a prototypical grain exporting firm. It is organized into 4 primary sections. The first section presents the empirical model specification and a description of the variables, logic, and setup of the model used to simulate the merchandising and logistical decisions of a large grain firm. The next section provides a discussion on the simulation modeling software used in this thesis to incorporate risk and decision analysis. The third section presents the data sources and finally, the fourth section presents the base case of the model and the sensitivity analysis conducted on the base case.

## Model Overview

A model of a prototypical grain shipper composed of 3 different elevator locations was created to analyze merchandising and logistical decisions involved in the management of an individual grain supply chain. The model was designed in 2 steps. The first involved developing the basic framework in Microsoft Excel as a means of formulating the costs and revenue associated with making logistical and merchandising decisions. This spreadsheet was the foundation to the rest of the model. The second step incorporated this spreadsheet into @Risk which is a simulation software package used as an "add-on" to Microsoft Excel (Palisade Corporation, 2002). Using @Risk allows certain variables to be stochastic, or random, which incorporates risk into the model. Allowing certain variables to vary over time rather than remaining fixed provides a more realistic modeling approach. The following section discusses the logic or science behind the model.

A prototypical grain shipper in today's grain industry is composed of several different points of origination, all capable of shipping grain to export markets. This required formulating a model with multiple country elevator locations, each with their own specific characteristics. In addition, multiple destination points for export were specified in the model to allow for the possibility of arbitrage opportunities.

Three country elevators and 2 export markets were specified in the model. The country elevators include a River-terminal facility located in southern Minnesota, a Shuttle-loading facility located in western Minnesota, and a Small-shipper located in southeast North Dakota. Each origin is specific in its own loading capabilities, storage capacity and freight ordering strategies. Table 4.1 displays the characteristics of each country elevator and the restrictions placed on each. Also, the 2 export markets included are the Pacific Northwest (PNW) and the U.S. Gulf, and each market differs in its forward basis offered for grain and provides shippers with two alternatives. Each export facility is restricted by the model in what it is capable of doing (e.g., loading and unloading capacities) and these are shown in Table 4.2. The data sources used to derive the information in Table 4.1 and Table 4.2 are discussed later in this chapter.

**Table 4.1. Country elevator facilities**

| | River-Terminal | Shuttle-Loader | Small-Shipper |
|---|---|---|---|
| **Loading Capabilities** | Barge and rail | Rail | Rail |
| **Load Capacity/week** | 330 cars/week<br>10 barges/week | 330 cars/week | 100 cars/week |
| **Car Load Capacity/day** | 110 cars | 110 cars | 24 cars |
| **Storage Capacity** | 800,000 bushels | 2,700,000 bushels | 1,000,000 bushels |
| **Beginning Inventory** | 320,000 bushels | 1,500,000 bushels | 500,000 bushels |

**Table 4.2. Grain export facilities**
(All units shown in metric tons)

| | PNW | Gulf |
|---|---|---|
| **Beginning Inventory** | 40,000 | 50,000 |
| **Storage Capacity** | 84,000 | 100,000 |
| **Rail Loading/Unloading Capacity (mt/day*)** | 18,000 | 20,000 |
| **Barge Loading Capacity (mt/day)** | - | 20,000 |
| **Barge Unloading Capacity (mt/day)** | - | 14,000 |
| **Vessel Capacity** | 65,000 | 55,000 |

*mt/day = metric tons per day

Soybeans were chosen as the commodity to be used in the thesis because it is one of the few major commodities that is shipped to either the PNW or U.S. Gulf for export (Pope, 2010). Corn and winter wheat, on the other hand, typically only ship to the Gulf for export whereas spring wheat typically ships to the eastern part of the US. Therefore, soybeans were chosen as the commodity to be modeled.

## Model Specification

The decisions a grain shipper makes regarding the purchase and sale of grain, and those pertaining to the acquisition of freight act as the foundation to the model. Thus, the model is designed to simulate shipping decisions for the prototypical shipper. The logistical and merchandising decisions implemented by a merchandiser are directly correlated; all decisions made concerning freight are a function of merchandising decisions. Grain shippers estimate how much grain will be delivered by producers during any given month of the year. Then based on those deliveries, they plan when to sell their grain by expected movement in the local and terminal basis levels. After they develop a marketing strategy, they plan their freight ordering decisions several months forward based on sales and capacity constraints. Thus, logistical decisions are a direct function of merchandising decisions. Because of the large number of factors that go into both types of decisions, it is simplest to separate the two and calculate one at a time.

Since decisions regarding the purchase and sale of grain are made first, a merchandising module was developed first in Microsoft Excel. Based on the logic from that module, a logistics module was created in Microsoft Excel. Both modules were then incorporated into @Risk to introduce randomness in certain key variables. This entire process is presented in order from start to finish by first analyzing the buying and selling decisions of a merchandiser.

To summarize, the following sections present the merchandising module and the logistics module. Each section contains a description of key variables specific to each model, and the purpose of both modules is explained. These sections are then followed by a discussion of the processes used in both modules.

**Merchandising Module**

It is imperative for merchandisers to plan ahead in terms of farmer deliveries, basis and futures spreads, and costs incurred at the facility. Therefore, a modeling framework that could account for these key variables was required to accurately simulate a merchandiser's buying and selling decision-making process. Such a module was based around a main payoff function in addition to several freight-based calculations that factored in the basis levels less shipping costs to both destination markets. Overall, the merchandising module seeks to answer half of the primary objective of this thesis: what is the optimal quantity of grain that should be sold in the pipeline?

The basic foundation of the merchandising module included the 3 country elevators. After grain is purchased from producers, expected sales throughout the marketing year are forecasted based on expected basis levels and futures spreads. Also, movement in the terminal basis levels at the PNW and the U.S. Gulf determined the optimal times to sell grain and indicated to which market to ship. The merchandising analysis was conducted on a weekly basis and grain is stored until favorable market conditions or capacity constraints determined when to sell.

The merchandising portion of the model maximizes net payoff. This is based on revenue derived from sales and costs incurred from procurement, storage, handling, and transportation. The net payoff function determines the demand for shipping and the model assumes that each elevator maximizes the payoff function every week by choosing to sell to the market in which the basis is most favorable. Therefore, weekly shipping demand is determined by evaluating the following for each week:

$$WNP_{Net} = Max[GM - (CC + HC + DC + PSC)] \quad \textbf{(4.1)}$$

given

$$PSC = Max\left(Basis_{pnw} - Min(T_{i,pnw})\right), \left(Basis_{usg} - Min\left(T_{i,usg}\right)\right)\Big] \quad \textbf{(4.2)}$$

where

$WNP_{Net}$ = Weekly net payoff

GM = Gross margin

CC = Cost of carry

HC = Handling cost

DC = Hedge cost

PSC = Preferred shipping cost from choosing among the maximum net payoff to each market

$Basis_{usg}$ = U.S. Gulf basis

$T_{i,usg}$ = shipping cost for origin i to market U.S. Gulf

$Basis_{pnw}$ = Pacific Northwest basis

$T_{i,pnw}$ = shipping cost for origin i to market PNW

Equation 4.1 was evaluated every week when grain was bought from farmers and delivered to the elevator. For instance, if grain was bought on the first week of the year, the module would evaluate the net payoff function for each of the remaining 51 weeks of the year and it would determine which week the grain should be sold in; this selling decision was based on whichever week maximized the net payoff function. Ultimately, all of the planned sales throughout the course of the marketing year were based off this function for each elevator. The week that corresponded to the payoff derived from Equation 4.1 was chosen as the most profitable opportunity to make the sale based on when the grain was bought.

The following sections discuss the random and non-random variables contained within Equation 4.1 and those that affect it. The data sources used to generate these random and non-random variables are discussed in a separate section later in this chapter.

**Random Variables**

Stochastic or random variables are those that are allowed to vary in the model and they introduce risk into the decision-making process. Several variables were treated as being random. The following subsections discuss the random variables that affect the weekly net payoff function (Equation 4.1).

**Spot vs. Forward Purchases.** The first step that initiates the merchandising process for any grain shipper involves the purchase or procurement of grain from local area producers. Grain can be bought from farmers in a variety of different ways and the two methods of buying grain in the merchandising module were spot purchases and forward purchases. Spot purchases include those in which grain is bought on the cash or spot market from farmers when no form of a contract is included in the transaction. This type of buying strategy creates risk for merchandisers because they have to base storage and shipping decisions soley on their best estimate of how much grain will be delivered througthout the year. For instance, if favorable marketing conditions occur right at harvest, farmers will deliver a high volume of bushels on the spot market. However, if favorable marketing conditions occur well ahead of harvest, then farmers will forward contract a lot of their grain and merchandisers won't buy as much on the spot market.

The other buying strategy evaluated was in the form of forward purchases involving the use of contracts. Forward contracts still utilize the cash market and are specific to each farmer relative to quantity, price and grade. Thus, unlike futures contracts which are standardized for all buyers and sellers, forward contracts are differentiated. Lastly, forward purchases of grain are typically made by merchandisers before the crop is ready to be harvested. Therefore, there is less risk with this type of purchase because bushels are bought in advance and are known with certainty.

The fact that grower deliveries are random forces merchandisers to forecast ahead several months to try and estimate what percentage of total deliveries will be on the spot market and how many will be forward contracted. The percentage of forward contracted soybeans used in the base case of the model was 46%. The remaining 54% was purchased on the spot market.

In addition, the percentage of soybeans marketed by month differs over the course of a marketing year. The percentages incorporated into the merchandising module are shown below in Table 4.3 (National Agricultural Statistics Service, 2009). Averaged percentages and standard deviations for each month were calculated and converted to weekly amounts. The weekly averages were then multiplied by the total yearly volume handled to get the amount of bushels received each week. This amount was multiplied by the forward purchase weight (46%) and the remainder was bought on the cash market. Finally, a lognormal distribution was used to introduce randomness in the amount of spot purchases by using the mean and standard deviation values for each week. This process was used for all 3 country elevators in order to introduce randomness into the amount of bushels delivered on the spot market.

**Hedging.** Another source of randomness incorporated into the merchandising module includes futures prices. The model assumed that whenever grain was purchased, it was immediately hedged in the futures market. Thus once cash grain was bought, it was sold in the futures market; this type of hedge is known as a storage hedge.[37] This hedging

[37] See Chapter 2 for a discussion of hedging strategies.

strategy allows grain to be stored as inventory until favorable market conditions dictate a sale should be made.

**Table 4.3. Percent of soybeans marketed in Minnesota by month**
(Numbers shown are in percentages)

| Month | 2004-05 | 2005-06 | 2006-07 | 2007-08 |
|---|---|---|---|---|
| September | 3 | 7 | 8 | 10 |
| October | 19 | 18 | 19 | 18 |
| November | 7 | 6 | 9 | 7 |
| December | 10 | 12 | 8 | 8 |
| January | 9 | 8 | 12 | 14 |
| February | 11 | 5 | 6 | 8 |
| March | 13 | 6 | 5 | 6 |
| April | 5 | 6 | 5 | 5 |
| May | 5 | 7 | 8 | 5 |
| June | 8 | 8 | 8 | 8 |
| July | 5 | 10 | 6 | 8 |
| August | 5 | 7 | 6 | 3 |

Table adapted from Annual Statistical Bulletin (National Agricultural Statistics Service, 2009).

Hedging grain requires the use of a futures market. Soybean futures prices from 2000-2010 were fitted to a distribution using BestFit. As a result, a lognormal distribution was estimated. This distrbution was used to determine the futures price in the first week, and then a normal distribution was created to generate a value that represented the change in price for each successive week. For example, the lognormal distribution generated a price for Week 1, and the normal distribution generated a price change that was added to the price from Week1 to derive the soybean price in Week 2. Lastly, the model assumed that no spreads were executed. Rather, each elevator hedged its grain in the week corresponding to the payoff derived in Equation 4.1.

**Basis Levels.** As stated previously in Chapter 2, the basis (cash less futures) is what merchandisers analyze when deciding to sell their grain. Changes in the basis determine when to sell. Therefore, for each week the model evaluated basis movements and calculated a gross margin which is simply the "buy basis" less the "sell basis." The gross margin is denoted as GM in Equation 4.1. A buy basis is established when grain is bought from farmers and a sell basis is the result of a sale to either the PNW or the Gulf.

The merchandising module assumed a storage hedge was initiated when grain was purchased and it evaluated the gross margin (GM) from changes in the basis for each deferred week. As seen in Equation 4.1, the difference between the gross margin and all costs determine the weekly net payoff (WNP). Essentially, Equation 4.1 chooses the market/week in which to sell to/in that will maximize net payoff.

For instance, if grain was bought in Week 17, then the model calculated the buy basis and potential sell basis in Week 17 to determine the gross margin and if the grain should be immeditately sold. It also did this for all the remaining 35 weeks of the year to determine if grain should be stored. If it determined grain should be stored and not sold until Week 51, then the elevator would incur storage charges from Week 17 to Week 51. This process conducted in Week 17 was repeated for all the remaining 51 weeks of the year. Therefore, once the expected spot and forward purchases were entered for all 52 weeks, the merchandising module for all 3 elevators immediately calculated when the grain received in each week should be sold by evaluating Equation 4.1 for every successive week.

The spot and deferred soybean basis values for the Gulf and PNW are denoted in Equation 4.2 as $Basis_{usg}$and $Basis_{pnw}$, respectively. Both of these basis values are classified as being a sell basis because they represent the markets where grain is sold. Equation 4.2 chooses which market to ship to by comparing the difference between the basis at each port and the minimum transportation cost (shuttle, barge, etc.) to each port. The merchandising module chooses to ship to either the Gulf or the PNW depending on which of the two has the greatest difference between the basis offered there and the transportation cost to get there.

The local basis, or buy basis, offered at each of the 3 country elevator locations is important because it determines the cash price that is paid to farmers for their grain. It is part of the calculation for determing the gross margin (GM) in Equation 4.1. The local basis at each elevator was determined by evaluating the returns generated from shipping to both ports. The difference between the basis level at each port and the transportation cost to each port were derived. The greater of the two returns was chosen and then a "target margin" was subtracted from this value to derive the local basis, or buy basis, value. A target margin is the gross amount the merchandiser hopes to make on every sale and it is large enough to account for several elevator related costs (e.g., handling, hedge, interest) and logistical costs. Deducting these costs from the gross margin results in the net realized margin.

**Shipping Demand.** Grain buying, futures price spreads, and basis levels ultimately determine when grain needs to be shipped. Because these three variables are all random, then shipping demand is also random. Shipping demand is comprised of "planned sales" and "unplanned sales" in the merchandising module. Planned sales are determined by Equation 4.1 in that they are the grain sales made when the basis is most favorable and they are comprised of the existing grain that is being stored as inventory. In addition, planned sales are those in which the merchandiser expects to make when creating a marketing plan at the beginning of the year. However, planned sales outlined at the beginning of the year are not 100% accurate because they won't perfectly predict when sales will be made; farmer deliveries and freight placements ultimately dictate when grain is actually sold and can alter expectations. These sources of uncertainty in farmer deliveries and freight placement cause shipping demand to be a huge source of risk for shippers.

The second aspect encompassed in the shipping demand variable is an unplanned sale. Unplanned sales occur when existing on-hand inventory in the elevator is growing too large and will eventually exhaust the storage capacity of the elevator. Therefore, a reorder point for freight is set 100,000 bushels below storage capacity in order to compensate for the undependable placement of freight. If the reorder point was set equal to storage capacity, then freight wouldn't be ordered until the terminal was full and it wouldn't be able to take in additional grain and would miss key revenue opportunities.

Lastly, because forecasted shipping demand is based on expected basis levels, expected futures prices and expected farmer deliveries, there is a chance it might overestimate or underestimate what actually occurs. Freight placements at each elevator won't always be on schedule which can be inconvenient for shippers. The shipping demand for each week is composed of planned sales and unplanned sales from the following week. Thus, shipping demand is always looking forward one week to allow for the timely purchase and placement of freight and any unexpected changes in farmer deliveries. For instance, the forecasted shipping demand in Week 34 is actually the planned and unplanned sales that are going to take place in Week 35. This allows for freight to be ordered in advance and have a reasonable chance of being placed sometime within that following week for shipment.

In conclusion, Table 4.4 summarizes the random variables used in the merchanding module and their distributions. Each of the distributions used were generated using BestFit which is an application available in @Risk. BestFit will be discussed in greater detail later in this chapter.

**Table 4.4. Stochastic variables used in merchandising module**

| Random Variable | Variable Distribution | Distribution Criterion |
|---|---|---|
| **Spot Purchases** | Lognormal | Distribution parameters depend on the week being evaluated (see Table 4.3). The mean is 243,692 bushels and a Std of 13,959 bushels |
| **Soybean Futures Prices** | Lognormal and Normal | Lognormal(3.47, 3.74) and Normal(0, 30) with a mean of $7.27 and a Std of $3.63 |
| **PNW Basis** | Lognormal | (560.96, 0.02) with a mean of $0.72 and a Std of $0.02 |
| **Gulf Basis** | Lognormal | (0.11, 0.05) with a mean of $0.46 and a Std of $0.05 |

**Non-random Variables**

Fixed or non-random variables in Equations 4.1 and 4.2 are those that are assumed to stay constant in the merchandising module. These include the costs associated with the grain at the elevator, costs associated with the actual shipment of grain, and the quantity of forward purchased grain. The following subsections will describe these in greater detail.

**Forward Purchases.** Forward purchases refer to grain bought prior to harvest through the use of some type of contract mechanism; since they are bought in advance, they are known with certainty and are non-random. Note that earlier in this chapter; the base case assumes that 46% of total grain deliveries were a result of forward contracting.

**Elevator Costs.** The costs incurred by each of the 3 country elevators in the model include storage, handling and hedging costs, and are denoted as CC, HC and DC in Equation 4.1, respectively. These costs are assumed to be non-random or fixed in the model. The storage cost, or cost of carry, is a cost incurred when grain is stored as inventory by an elevator. Therefore, it is a very significant cost when storage hedging is being utilized. The cost of carry formula used in the model was adapted from Lorton and White (2006) and is denoted as follows:

$$CC = OP \times R \times \frac{W}{52} \qquad \textbf{(4.3)}$$

where

CC = Cost of carry

OP = Estimated opportunity price

R = Interest rate

W = Number of weeks stored

Equation 4.3 was used throughout the merchandising module and as the number of weeks stored increases, the cost of carry also increases. Lastly, it is worth noting that an interest rate was selected and the estimated opportunity price (OP) is simply the cash grain price at the time of its purchase.

The handling cost (HC) from Equation 4.1 is the cost of moving or handling a bushel of grain when loading it into a barge or railcar. It is the per bushel cost of physically handling the grain at the elevator. The hedging cost (DC) is the per bushel cost incurred by the merchandiser for hedging grain in the futures market. This cost covers fees and other miscellaneous expenses that have to be paid to a broker or a futures exchange every time a futures position is established.

**Transportation Costs.** Equation 4.1 contains a preferred shipping cost (PSC) variable which is simply the cost associated with the selected destination market. This cost is included in the weekly net payoff formula because often times the transportation cost dictates whether or not a sale should be made and grain should be shipped. Equation 4.2

indicates that the preferred shipping cost (PSC) is determined by the basis values at the PNW and the U.S. Gulf and the transportation cost to each market. Therefore, PSC is a random variable because the basis values are random. However, the transportation costs to each port ($T_{i,pnw}$ and $T_{i,usg}$) are non-random, so they are included in this section. The transportation cost to either the PNW or the U.S. Gulf is simply determined by taking the minimum of all transportation options to each destination. For example, the River-terminal elevator facility can utilize barges, shuttle COTs and 24-car COTs when shipping to the Gulf. The $T_{i,usg}$ for the river-terminal facility is the minimum cost of each of those three available transportation options to the Gulf. The actual cost values for each of these modes will be disucssed later in this chapter.

**Logistics Module**

The second step a merchandiser faces is focused around the transportation of grain to a specific destination. The two major questions regarding logistics are concerned with when freight should be ordered, and how much should be ordered. The last half of the primary objective of this thesis is answered by the logistics module in that it seeks to determine how much freight to order for each week looking forward from the current week.

Determining how much freight to order and when it should be ordered both directly correspond to the merchandising module because it determines shipping demand. The logistics module determines how much freight to order when it is needed and in the right quantity to satisfy shipping demand. The logistics module was developed to handle three different ordering strategies, one for each of the 3 country elevators modeled in this thesis. The following section discusses the logistical aspects at the country elevator level and then later, a section will discuss logistics at the export facility level.

**Terminal Elevator Logistics**

The logistical process starts at the elevator-terminal and ends at the export-facility. The merchandising module creates shipping demand to dictate when freight needs to be ordered and in what quantity. All 3 country elevators contained a specific freight-ordering strategy based on their shipping capabilities (see Table 4.1).

**Freight-ordering Strategy.** The freight-ordering strategies used in the base case of the model are displayed in Table 4.5. The model assumes that all types of freight are ordered once a week, but can arrive anytime within a week. In addition, shuttle COTs can be ordered on any day within a week, but all other modes have to be ordered on the first day of a week. Thus, even though the merchandising module was evaluated on a weekly-basis, the logistics module was evaluated on a daily basis to account for railcar and barge placements anytime within a week. Also, assuming all 4 modes can be ordered, shuttle COTs are ordered first because they are the most efficient mode in terms of capacity, speed and cost per bushel. Once shuttle COTs are ordered, barges are also ordered if shipping demand consists of enough bushels. Then if there is a need for more freight, 24-car COTs are ordered, and finally, general tariff cars are ordered last if any bushels remain to be shipped.

As shown in Table 4.5, the Small-shipper facility cannot ship shuttle COTs because its track capacity is too small, and because the River-terminal and Shuttle-loader are both shuttle-loading facilities, they are restricted from ordering general tariff cars (BNSF Railway Company, 2009b). In addition, the Shuttle-loader and Smaller-shipper do not have access to a water-route so they cannot ship barges. Lastly, shuttle-loading facilities typically only load shuttle COTs rather than 24-car COTs because they are more efficient and can ship greater volumes. Therefore, the Shuttle-loader only utilizes 24-car COTs if needed.

**Table 4.5. Freight-ordering strategies in base case**

| | River-terminal | Shuttle-loader | Small-shipper |
|---|---|---|---|
| **Shuttle COTs** | None | Fixed at 1FP, 1MP and 1LP | N/A* |
| **24-car COTs** | Random | Random | Random |
| **General Tariff** | N/A | N/A | None |
| **Barges** | Random | N/A | N/A |

*Not Applicable

Table 4.5 denotes some modes are random while others are fixed. A random freight ordering strategy simply means that the specific mode is ordered as needed and that the quantity needing to be shipped dictates how many will be ordered. The amount ordered varies over the course of the year and is random since it depends on shipping demand. Loading capacities and track-sizes restrict the amount that can be loaded in a week. A fixed strategy refers to a specific quantity of freight being ordered only once in duration of the year. For example, since the freight-ordering strategy for the Shuttle-Loader is fixed at 3 total shuttle COTs, they are ordered just at one point in the year. The reason for this is because of a shuttle COT's continuous nature; once ordered, they continue to cycle back to the elevator throughout the remainder of the mechanism duration. If shipping demand increases to a quantity greater than that of 3 shuttle COTs, the River-elevator can order as many 24-car COTs as needed because they expire after 1 trip to the destination. Lastly, it is worth noting the model assumes that 24-car COTs are monthly grain units meaning they expire after 1 trip. Also, general tariff orders are 15 cars each and the duration of all shuttle COTs is 1 year.

**Freight Placement.** The arrival of railcars or barges at any of the 3 country elevators depends on the window of placement specified in the model for each shipping mechanism. The window of placement refers to the time frame that freight can be placed at the elevator. Distributions were created to introduce randomness into the placement of freight at each elevator and are given in Table 4.6.

**Table 4.6. Freight placement distributions**

| Mode | Distribution | Description |
|---|---|---|
| **Shuttle COT** | None | Start-up shuttle COTs are assumed to arrive exactly 10 days after the order date. Transit time back to elevator determines further placement |
| **24-car COT** | Triangular(1,3, 18) | Cars are most likely to be placed on the 3rd day of the shipping period but can be placed either before or after the want date |
| **General Tariff** | Discrete Uniform({1, 2, 3, 4}) | Cars have an equal chance of being placed 1, 2, 3 or 4 weeks after the order date |
| **Barge** | Discrete(1, 2, 0.9, 0.1) | 90% of barge orders arrive 1 week after the order date while 10% arrive 2 weeks after the order date |

Table 4.6 indicates that start-up shuttle COTs arrive exactly 10 days after they are ordered, and placement at the elevator from when it cycles back from the export facility depends on the transit time distribution (see subsequent section). The model assumes 10 days because the BNSF specifies that the first shuttle COT order must be placed at least 10 days in advance of the start-up period (BNSF Railway Company, 2009, Item 13600). In practice, the first shuttle COT order arrives on the first day of the specified shipping period; thus, no randomness exists for the placement of the first shuttle COT trip at the origin. However, after a shuttle COT is unloaded at the export facility and starts the next trip to the new origin, it will arrive roughly 3 or 4 days later than the want date at the new origin.

This source of randomness is captured in the model with a transit time distribution for the return trip to the origin.

A triangular distribution was used to represent the placement of 24-car COTs at the elevator facilities. The BNSF COT guarantee states that car placement for 24-car COTs can be anytime within a 15-day window following the want date, and if they are placed anytime after the $15^{th}$ day they have to pay the shipper a non-performance penalty (BNSF Railway Company, 2010, Item 10500). Therefore, the triangular distribution allows cars to be placed anytime within 18 days after the want date, with the most likely being closer to 3 days.

The BNSF has 30 days to place general tariff cars after the want date, and if they are not placed within 30 days then they have the right to cancel the order without penalty (BNSF Railway Company, 2009b). Therefore, they have an equal chance of being placed 1, 2, 3 or 4 weeks after the want date (Pope, 2010). Lastly, according to industry participants, barges have a 90% chance of being placed 1 week after the order date and a 10% chance of placement after 2 weeks. Therefore, a discrete distribution was used for barge placement.

Once freight is placed at any one of the elevators, it can only be loaded if the loading capacity for the week or the track capacity has not been exceeded. Railcars and barges can be loaded simultaneously, but certain rail mechanisms take loading priority over one another: shuttle COTs load first, 24-car COTs second, and general tariff cars load last.

If the model determines that freight cannot be loaded the same day it is placed, it is held until the following day. The model then repeats the calculation by accounting for freight that has already been held from the previous period and loads these first. The calculation for determining what is available to load is simply the prior day's arrivals less the number of units loaded in that prior day plus the current day's new arrivals. Once freight is completely loaded (no partial loads), it is shipped to the export facility that was determined in the merchandising module. The model assumes that the destination market for shuttle COTs is specified 3 days prior to it being shipped because specifying the destination prior to 3 days before it was shipped (e.g., 4 or 5) restricts the shipper's ability to take advantage of favorable basis opportunities; whereas specifying it 1 or 2 days before it is shipped results in the shipper being penalized by the BNSF. For 24-car COTs and general tariff cars, the destination is specified on the day the unit is billed and shipped (Pope, 2010). Lastly, barges don't have the option of shipping to either market because they can only physically ship to the U.S. Gulf.

**Demurrage.** Demurrage guidelines for each mode of transportation were specified in Chapter 2. If freight is held longer than specified by the carrier, then demurrage charges are incurred at the shipper's facility. If the model determines that freight cannot be immediately loaded and has to wait until the following day, the model calculates demurrage charges. For example, if the loading capacity for a facility has been exceeded for the day, or the track capacity is exceeded, then freight needs to be held until it can be loaded. This causes the elevator to incur demurrage on this idle freight. Demurrage at any of the 3 elevator facilities can be assessed on shuttle COTs, 24-car COTs, general tariff cars, or barges, depending on the ordering strategy being employed. Table 4.7 displays the demurrage costs for each of these 4 modes of transportation.

**Table 4.7. Demurrage costs**

| Mode | Initial Rate | Excessive Rate |
|---|---|---|
| **Shuttle COT** | $0.02/bushel/car/day | N/A* |
| **24-car COT** | $0.02/bushel/car/day | $0.04/bushel/car/day** |
| **General Tariff** | $0.02/bushel/car/day | $0.04/bushel/car/day** |
| **Barge** | $0.004/bushel for 4-10 days | $0.006/bushel for >10 days |
| **Vessel** | U.S. Gulf - $0.02/bushel/day<br>PNW - $0.01/bushel/day | N/A |

*Not applicable
**Begins after 3rd chargeable demurrage day

**OEPs.** When shippers load their shuttle COTs within a certain time frame after being placed at their elevator, they qualify for an Origin Efficiency Payment (OEP)[38]. They exist to encourage efficient loading of equipment at a shipper's facility. Since this is an intra-day variable and the logistical module was evaluated on a daily basis, a random distribution had to be created to determine how often they are awarded to shippers.

The logistical module assumes that shippers are awarded an OEP on a random basis. A discrete uniform distribution was created to introduce risk into the variable. The distribution states that shippers have an equal chance of being awarded a 10-hour OEP, a 15-hour OEP, a 21-hour OEP, or failing the OEP and receiving nothing. If a shuttle is loaded the same day it arrives at an elevator, it has an equal chance of receiving any one of the three payoffs or nothing.

**Transit Time.** Transit time from each elevator facility to either destination was specified as being random in the model. Therefore, they were based on distributions created using information from industry experts. These distributions are located below in Table 4.8.

[38] See Chapter 2 for discussion of OEPs.

**Table 4.8. Transit time distributions**

| Mode | Distribution | Description |
|---|---|---|
| **Shuttle COT** | **Discrete ({3, 4, 5},{0.3,0.6,0.1})** | **Shuttle COTs have a 30% chance of arriving at destination 3 days after departing, 60% chance of arriving 4 days after departing and a 10% chance of 5 days after departing** |
| **24-car COTs/General Tariff** | **Discrete Uniform({7, 10, 13, 16, 19})** | **Both mechanisms have an equal chance of being placed 7, 10, 13, 16, or 19 days after being shipped** |
| **Barge** | **Discrete({10,11,12,13},{0.05,0.7,0.2,0.05})** | **Barges are most likely to arrive at their destination 11 days after being shipped (70% of the time)** |

Table 4.8 indicates when loaded freight will arrive at either the PNW or the Gulf after being shipped from Eastern North Dakota/Western Minnesota. According to industry participants, shuttle transit time is most likely 4 days when shipping from this region to either destination. In addition, industry experts stated that both 24-car COTs and general tariff will arrive at either of the 2 destinations within 1-2.5 weeks after being shipped (Pope, 2010). Lastly, the discrete distribution was based around the fact that barges shipped from Southwestern Minnesota typically have a transit time of 11 days to reach the U.S. Gulf (Marathon, 2010). In addition, a transit time of 10 days was 5% likely to occur, 12 days was given a 20% chance of occurring, and 13 days had a 5% chance of occurring.

**Export-Facility Logistics**

Once grain reaches either the PNW or the Gulf, it is unloaded into the port's facility and then eventually loaded onto an ocean vessel. Each export facility differs in terms of its beginning inventory, storage capacity, and unloading/loading capacity (see Table 4.2). However, the same unloading process occurs at each facility, and the following subsections will discuss this process.

**Mode Arrivals.** Transit time distributions determine when loaded freight arrives at its destination. Each export facility maintains a level of beginning inventory to guard against shortages of grain or any blending problems. In addition, each has a specified unloading capacity per day and a total storage capacity. Therefore, if an export facility reaches its storage capacity or exhausts its unloading capacity for the day, it will remain at the facility and possibly incur demurrage charges until it is unloaded (see previous demurrage section for these values).

Assuming that storage capacity or the daily unloading rate has not been reached, all available freight will be unloaded into the facility. The calculation for determining what freight is available to unload is similar to the loading calculation at the country elevator in that it observes how many units arrived on the previous day less how many were unloaded that day, and adds any new arrivals on the current day. In addition, if grain is simultaneously being unloaded into a facility and then loaded onto a vessel, the model continues to allow grain to be unloaded until the storage capacity of the facility is reached. Therefore, all the space in the facility is utilized and none of it is wasted. Lastly, different rail units are assigned different unloading priorities at the export facilities: shuttle COTs have unloading priority over 24-car COTs which in-turn have priority over general tariff cars. At the U.S. Gulf, barge and rail can be unloaded simultaneously.

**Vessel Placements.** The logistical module assumes that vessel contracts are free on board (FOB). Therefore, the buyer is responsible for acquiring the vessel, placing it, and paying the freight rate and insurance on the commodity. The seller is only responsible for loading the vessel and paying demurrage charges if it is held longer than the time allowed.

Vessels orders are a function of grain that is loaded and shipped from a country elevator. Once freight is shipped from a country elevator, a lag period occurs until the vessel is actually ordered; this lag period differs among modes. On average, shuttle COTs arrive at either export facility 4 days after departure, barges 11 days after departure, and 24-car COTs/general tariff are 13 days after departure. On the fourth day after a shuttle COT is shipped from a country elevator, the order for a vessel is submitted and the first day of the placement period for a vessel occurs simultaneously. For barges, the lag period is 11 days after a barge is shipped from an elevator until the window of placement for a vessel begins. For 24-car COTs and general tariff cars, the lag period is 13 days after departing from a country elevator until the actual window of placement for a vessel begins.

Under a FOB contract, vessels can be placed by the buyer anytime within a 10-day window (Klein, 2010). Therefore, the actual placement of a vessel is not chosen by the seller or merchandiser. This can create problems for merchandisers because when vessels don't arrive when they are expected to, they can incur costly demurrage charges.

The model assumes that vessel placement is random and will differ over time. A uniform distribution was created to introduce risk into the model because vessels have a 10-day shipping window in which they can be placed anytime (Klein, 2010). Ocean vessels have an equal chance of being placed on any of the 10 days within the window. Only 1 vessel at a time can be loaded at either facility. As soon as the vessel arrives, grain is loaded onto it until the daily loading rate capacity is reached. After that point, the vessel departs if it is full; otherwise it will remain idle at the port until waiting to be filled and could possibly incur demurrage.

**Vessel Demurrage/Despatch.** Vessel demurrage rates are equivalent to the current market rate (see Chapter 2). The model assumes that the demurrage rate for vessels in the PNW is \$25,000/day and \$45,000/day in the Gulf. Also, demurrage rates are based off a guaranteed load rate per day specified by the shipper. The model assumes a 5-day guaranteed load rate for vessels. Therefore, the guaranteed load rate at the Gulf is 11,000 metric tons/day whereas it is 13,000 metric tons/day at the PNW. These load rates are also assumed to be the load rate capacity per day for each respective port.

Lastly, despatch is paid to the shipper if a vessel is loaded in a time period shorter than the guaranteed load rate per day. Despatch is typically half the demurrage rate (Klein, 2010). Therefore, the model assumes a despatch payment of \$12,500/day at the PNW and \$22,500/day at the Gulf.

**DEPs.** Shippers that can unload their shuttle COTs within 15 hours of being placed at either export facility qualify for Destination Efficiency Payments (DEPs)[39]. These are available to encourage shippers to unload their freight in an efficient manner. Similar to OEPs, this is an intra-day variable. Therefore, a random distribution had to be created to determine how often they are awarded to shippers.

The logistical module assumes that shippers are awarded a DEP on a random basis. Therefore, a discrete distribution was created to introduce risk in this variable. According to the distribution, shippers that unload their shuttle within 24 hours of placement at a facility have a 75% chance of achieving a 15-hour DEP if unloading took place within 15

[39] See Chapter 2 for discussion of DEPs.

hours and a 25% chance of failing the DEP if unloading took greater than 15 hours within the 24-hour period.

**Empty Shuttle COTs.** Once shuttle COTs are unloaded at either export facility, they are then shipped back to the elevator facility where they were ordered from. The model assumes that it takes the same length of time for a shuttle to return to its origin as it did to reach its destination. The same transit time distribution is used for shuttle COTs returning to their country-elevators. This introduces randomness into shuttle COTs returning from an export facility. Recall, the distribution used was a discrete distribution in which a probability of 30% is assigned to a transit time of 3 days, a probability of 60% assigned to 4 days of transit, and a probability of 10% assigned to a 5 day transit. Once a shuttle arrives back at its country elevator, the loading process starts over again.

**Merchandising and Logistical Assumptions**

Several assumptions regarding both merchandising and logistics were made in both modules and are addressed here in this section. These assumptions are regarded as fixed in the model because in practice they are constant over time, or else they seldom change over the course of one year; if they do change, their presence is not large enough to significantly impact the analysis.

Recall the merchandising module assumes that all grain purchases are hedged in the futures market. Also, the logistics module assumes that railcars and barges are ordered, loaded and unloaded in a specified order (see previous sections). Lastly, vessel contracts between the buyer and seller are assumed to be free on board (FOB).

Table 4.9 displays the 24-car COT, general tariff and shuttle COT rates used by each of the 3 country elevators. These tariff rates are used to calculate the total freight costs in the model. The assumed origin and destination pair for each elevator location is also included in Table 4.9. These origins are specific to the region where each of these elevators is found. Table 4.10 displays the secondary variables which were assumed to be constant in the model.

Table 4.10 also indicates that the shuttle COT and 24-car COT premiums are fixed. The reason they are considered fixed is because when either mechanism is purchased, the premium is "locked-in" or fixed over the remaining duration of the mechanism. They are known with certainty once they are purchased. Also, the base COT prepay in Table 4.10 is assumed to be fixed because this variable is simply the prepay amount required to purchase a 24-car COT. In addition, it is paid whenever a 24-car COT is purchased and is held fixed by the BNSF. Lastly, Table 4.10 indicates the barge tariff rate to be 331. This is the assumed southbound rate for grain moving from the Twin Cities, and the model also assumes that the barge rate it at 100% tariff. Therefore, the barge rate in the model is $20.49/ton[40].

**Table 4.9. Rail tariff rates in logistics module**

| | PNW Shuttle COT Rate | Gulf Shuttle COT Rate | PNW 24-car COT/GT Rate | U.S. Gulf 24-car COT/GT Rate |
|---|---|---|---|---|
| **River-Terminal** | $4,170/car (Springfield, MN to Tacoma, WA) | $4,100/car (Springfield, MN to Reserve, LA) | $4,730/car (Florence, MN to Tacoma, WA) | $4,592/car (Florence, MN to Beaumont, TX) |
| **Shuttle-Loader** | $4,120/car (Herman, MN to Tacoma, WA) | $4,070/car (Herman, MN to Reserve, LA) | $4,660/car (Herman, MN to Tacoma, WA) | $5,062/car (Herman, MN to Beaumont, TX) |
| **Small-Shipper** | N/A* | N/A | $4,760/car (Alton, ND to Tacoma, WA) | $5,557/car (Alton, ND to Beaumont, TX) |

Source: BNSF Rate Book 4022-M (2009). *Not applicable

[40] (331*6.19)/100 = 20.49

**Table 4.10. Variables assumed to be fixed**

| Variable | Value |
|---|---|
| **Fuel Surcharge** | $0.39/mile |
| **Premiums** | Shuttle - $225/car<br>COT - $25/car |
| **Shuttle COT Trip Allowance** | $100/car |
| **Base COT Prepay (24-car COTs only)** | $4,800/unit |
| **Carrier Non-performance (24-car COTs only)** | $200/car |
| **Barge Tariff Rate** | 331 |
| **Handling Cost** | $0.10/bushel |
| **Hedge Cost** | $0.01/bushel |
| **Interest Rate (Cost of Carry)** | 7% |
| **Target Margin** | $0.35/bushel – River-terminal<br>$0.30/bushel – Shuttle-loader<br>$0.40/bushel – Small-shipper |
| **Rail Mileage** | Alton, ND – Tacoma, WA: 1,536 miles<br>Alton, ND – Beaumont, TX: 1,603 miles<br>Herman, MN – Tacoma, WA: 1,602 miles<br>Herman, MN – Beaumont, TX: 1,479 miles<br>Herman, MN – Reserve, LA: 1,772 miles<br>Florence, MN – Beaumont, TX: 1,327 miles<br>Florence, MN – Tacoma, WA: 1,754 miles<br>Springfield, MN – Reserve, LA: 1,566 miles<br>Springfield, MN – Tacoma, WA: 1,808 miles |
| **Shuttle Size** | 110 cars |
| **COT Size** | 24 cars |
| **General Tariff Size** | 15 cars |
| **Car Capacity** | 3,750 bushels/car |
| **Barge Capacity** | 50,000 bushels |

## Stochastic Simulation Procedure

The prototypical grain shipper was modeled utilizing a stochastic simulation procedure. Stochastic simulation is a modeling technique that represents "real-life" events by incorporating uncertainty into the model (Palisade Corporation, 2002). Analytical models are different in that they involve mathematical equations that contain input values derived from their expected values. Simulation models introduce randomness into uncertain variables by representing them with a range of possible values rather than an expected value.

The stochastic simulation software used in the model was @Risk which is an "add-on" to Microsoft Excel (Palisade Corporation, 2002). This software package incorporated randomness into certain input variables such as farmer deliveries, transit times, and car placements. The following sections discuss @Risk and how it utilizes BestFit to create probability distributions.

**@Risk**

Risk analysis can be adapted to several different situations by firms considering events with uncertain outcomes. For example, the decision whether to enter a new market or introduce a new product that contains a great deal of uncertainty can be modeled using risk analysis. Risk analysis essentially determines how often certain events will occur through the use of Monte Carlo simulation (Palisade Corporation, 2010). Monte Carlo simulation is performed by @Risk to model uncertain variables. A probability distribution is created for these variables, which is simply a range of possible values that can have different outcomes of occurring. Every time a model is simulated in @Risk, random samples are drawn from the input probability distributions and the resulting outcome and its probability of occurring is recorded. Therefore, the stochastic simulation procedure utilized by @Risk differs from analytical models and "bootstrapping" techniques because it performs Monte Carlo simulation whereas analytical models depend on expected values and bootstrapping is econometric based.

**BestFit**

BestFit is a function contained within @Risk and it is used to fit data sets to a statistical distribution. Several distribution types exist, such as normal, discrete, or triangular distributions. It essentially chooses the statistical distribution that fits the data the best (Jankauskas & McLafferty, 1996). The distributions created by BestFit are used to represent uncertain variables within a model. It generates basic statistics for each distribution that can be compared to the actual statistics of the inputs. These statistics then are used to measure how well the distribution fits the data sets of the inputs and ultimately, it indicates how confident one can be in knowing that the data was produced by the random distribution.

## Data Sources

The data obtained for the merchandising and logistical modules were obtained from numerous sources. This section provides a review of the key variables used in both modules and the sources that were used to obtain data on those key variables. Table 4.11 provides a summary of these.

Soybean futures price data from 2000-2010 were obtained from the Chicago Board of Trade (CBOT) and incorporated into the merchandising module to evaluate hedging decisions. The spot and deferred soybean basis values for the PNW and Gulf were the daily bids/offers obtained from a multinational grain trading company. A barge rate for southbound shipments from the Twin Cities was obtained from the Grain Transportation Report on April 15, 2010 (Agricultural Marketing Service, 2010).

Barge data relative to placements, transit time and typical demurrage charges were obtained from industry experts (Gergen, 2010, Marathon, 2010). Rail placement data was also obtained from industry experts (Mack, 2010, Pope, 2010). In addition, rail transit time to the U.S. Gulf and PNW was obtained from industry experts (Holz, 2010, Pope, 2010).

**Table 4.11. Summary of data sources**

| Key Variable | Data Source |
|---|---|
| **Soybean Futures Prices** | Chicago Board of Trade January 3, 2000 to April 12, 2010 |
| **PNW and Gulf Basis** | Industry Participants |
| **Barge Rate** | Grain Transportation Report from April 15, 2010 |
| **Barge Placement** | Industry Participants[41] |
| **Barge Transit Time** | Industry Participants |
| **Barge Demurrage** | Industry Participants[42] |
| **Rail Rates** | BNSF Rate Book 4022 – M as of March 1, 2009 |
| **Rail Placement** | Industry Participants[43] |
| **Rail Transit Time** | Industry Participants |
| **Rail Demurrage** | BNSF Demurrage Book 6004-A as of October 2, 2009 |
| **Vessel Placement** | Industry Participants[44] |
| **Vessel Demurrage/Despatch** | Industry Participants |
| **Elevator Capabilities** | Industry Participants[45] |
| **Export Facility Capabilities** | Grain Inspection, Packers and Stockyards Administration |
| **Farmer and Spot Deliveries** | Economic Research Service |

Data regarding forward and spot farmer soybean deliveries were obtained from a 2005 survey conducted by the USDA's Economic Research Service. This data revealed that roughly 46% of soybeans were contracted in Minnesota in 2005, while the remainder was sold on the cash market or kept for on-farm use.

Rail rates were obtained from the BNSF Rate Book 4022-M as of March 1, 2009 and rail demurrage charges were taken from the BNSF Demurrage Book 6004-A from October 2, 2009. Vessel placement and demurrage/despatch data were obtained from industry experts (Klein, 2010). Lastly, elevator capabilities such as loading/unloading capacities were given by industry experts (Stein, 2010, Gergen, 2010). Information regarding the capabilities of U.S. Gulf and PNW export facilities was obtained from the

[41] Barge placement and transit time data were obtained from Nick Marathon in April 2010.
[42] Barge demurrage data were obtained from Clint Gergen and Matt Gibson in March 2010.
[43] Rail placement and transit time data were obtained from David Pope and Chris Holz in April 2010.
[44] Vessel placement and demurrage/despatch data were obtained from Mike Klein in March 2010.
[45] Elevator capability data were obtained from Kevin Stein in April 2010.

2009 Directory of Export Elevators (Grain Inspection, Packers and Stockyards Administration, 2009).

## Base Case and Sensitivities

A base case was first created to model logistical and merchandising decisions a grain shipper is faced with. The base case parameters are displayed below in Table 4.12 for each of the 3 elevator locations. These parameters were applied to each elevator in the model, and results were extracted. Some of the variables in Table 4.12 are stochastic, whereas the others are important enough to significantly impact the analysis when changed. The base case will be discussed in greater detail in Chapter 5.

**Table 4.12. Base case settings**

| Variable | River-Terminal | Shuttle-Loader | Small-Shipper |
|---|---|---|---|
| **Beginning Inventory** | 320,000 bushels | 1,500,000 bushels | 500,000 bushels |
| **Logistical Strategy** | Barges are random<br>24-car COTs are random | 1FP, 1 MP and 1 LP shuttle<br>24-car COTs are random | 24-car COTs are random |
| **Total Yearly Volume Handled** | 12,000,000 bushels | 25,000,000 bushels | 5,000,000 bushels |
| **Hedging Strategy** | All elevators are assumed to be 100% hedged.<br>Change in futures price is assumed to follow normal distribution with 0 mean and 30 cent standard deviation | | |
| **Grain Purchases** | Spot: 54% of total yearly volume<br>Forward: 46% of total yearly volume | | |

### Sensitivities

A sensitivity analysis was conducted on the base case by changing certain random and non-random variables to analyze their impact on the results. Five sensitivities were chosen to be modeled for each of the 3 country elevators. These allowed for further evaluation of key logistical and merchandising relationships, as well as certain cost impacts throughout the supply chain. The sensitivities were conducted as follows:

1. Shipping strategies for all 3 country elevators were changed to include different combinations of freight mechanisms.
2. The percentage of spot purchases was changed to introduce more uncertainty in grower deliveries.
3. The distribution of ocean vessel placement was altered to introduce alternative placement times.
4. The intermonth spread for both the PNW and U.S. Gulf basis were changed to encourage the merchandisers to either sell or store grain.
5. The distribution of car placements was changed to introduce more uncertainty in the placement of rail freight.

Sensitivities were chosen to be conducted on these stochastic variables because they induce the greatest amount of risk for shippers. The sensitivity analysis is explained in greater detail in Chapter 5. In addition, results from the base case and all sensitivities are also discussed in Chapter 5.

# CHAPTER 5. SIMULATION RESULTS AND SENSITIVITIES

## Introduction

The merchandising and logistical modules were combined, and the resulting model was simulated in @Risk. A base case was simulated first, and then sensitivities were conducted on the base case. This chapter presents the base case and sensitivity results derived from the simulation scenarios. The following section presents the results generated in the base case for each of the 3 country elevators. The second section presents sensitivities conducted on specific merchandising variables, and the third section presents sensitivities conducted on key logistical variables. The fourth and final section provides a summary of the results.

## Base Case Results

A base case was created to analyze merchandising and logistical decisions of all 3 country elevators owned by the grain exporting firm. The prototypical shipper modeled in this thesis is a large grain exporting firm. Thus, the terms "prototypical shipper" and "firm" will be used interchangeably throughout this chapter. Key random and non-random variables representing current industry conditions were included in the model to represent the grain firm (see Chapter 4). Random variables included in the model were transit times, freight placements, spot deliveries by farmers, and basis spreads. Several fixed variables such as transportation rates, car capacities and fixed elevator costs were treated as non-random.

The expected values of the random and non-random variables were included in the base case to generate a representation of normal operating conditions found at each of the country elevators and export ports. Table 4.12 in Chapter 4 presented a summary of the key base case settings. Not only was the base case used to simulate normal operating conditions, but it was also used as a benchmark for evaluating each of the sensitivities.

The model provided output for key variables from the 3 country elevators and the 2 export ports. These variables are summarized in Table 5.1. Net margin is an important aspect of running a business, and it is monitored by merchandisers throughout a given year because it ultimately determines whether an elevator is making money. Net margin depends on revenue generated from sales, efficiency payments, carrier non-performance penalties, and vessel despatch. In addition, several cost components such as storage, transportation, handling, and the cost of buying grain from producers impact the net margin calculation.

The model generated a distribution for average net margins for each of the 3 elevators on an annual basis. Base case results indicate that the River-terminal generated an average annual net margin of roughly $6.5 million whereas the Shuttle-loader and Small-shipper generated net margins of about $1.6 million and $261 thousand, respectively. Therefore, the total annual net margin for the prototypical shipper was about $11.8 million on average.

The coefficient of variation[46] for net margin was 1.32 for the Shuttle-loader, which was the highest of all the elevators. Thus, the Shuttle-loader had the greatest risk associated with generating a positive net margin each year. One of the main reasons the Shuttle-loader was the riskiest in the base case is because its logistical strategy was fixed at 3 shuttle COTs per year; this means that it had to fill three, 110-car unit trains every 1.5-2 weeks no matter if there was enough grain to fill all 330 cars or there wasn't. If there wasn't enough track space or enough grain at the elevator, then the railcars would sit idle

[46] Coefficient of Variation = Standard deviation/mean

and incur demurrage charges. In addition, shuttle COTs are the only mode that includes a return trip in which the transit time back to the elevator is random. Thus, all 3 shuttle COTs might return to the elevator at once or may arrive later than expected.

**Table 5.1. Base case results**

| | River-Terminal | | Shuttle-Loader | | Small-Shipper | |
|---|---|---|---|---|---|---|
| | Mean | Std | Mean | Std | Mean | Std |
| Storage Cost/bu | $0.03 | $0.02 | $0.01 | $0.00 | $0.12 | $0.07 |
| Net Margin/bu | $0.59 | $0.09 | $0.06 | $0.08 | $0.07 | $0.08 |
| Total Costs for Elevator | $22,769,940 | $1,319,440 | $71,139,290 | $4,304,865 | $10,524,350 | $1,154,914 |
| Total Annual Profit | $6,537,154 | $982,218 | $1,613,040 | $2,131,108 | $261,543 | $290,258 |
| Spot purchases (bu) | 6,647,510 | 843,119 | 13,848,980 | 1,756,498 | 2,769,796 | 351,300 |
| Forward purchases (bu) | 5,533,800 | n/a | 11,528,750 | - | 2,305,750 | - |
| Total Deliveries (bu) | 11,074,870 | 393,814 | 25,377,730 | 1,756,498 | 3,550,576 | 373,746 |
| Total 24-car COT Orders | 22 | 7 | 26 | 7 | 40 | 4 |
| Total GT Orders | - | - | - | - | - | - |
| Total Barge Orders | 184 | 11 | - | - | - | - |
| Actual Grain Shipped | 11,117,400 | 401,975 | 26,755,330 | 1,759,547 | 3,550,576 | 373,746 |
| Inventory Turnover | 15 | - | 9 | - | 5 | - |
| | Mean | Std | Mean | Std | Mean | Std |
| OEP Payment at Elevator | - | - | $104,516 | $39,146 | 0 | 0 |
| Number of shuttle COT trips | - | - | 60 | 5 | 0 | 0 |
| **PNW Port** | | | | | | |
| Total Bushel Flow | - | - | 28,549,110 | 3,306,807 | 3,374,103 | 360,678 |
| Shuttle COTs unloaded | - | - | 60 | 5 | - | - |
| 24-car COTS Unloaded | - | - | 26 | 7 | 37 | 4 |
| GTs Unloaded | - | - | - | 0 | 0 | 0 |
| Vessel Arrivals | - | - | 11 | 1 | 1 | 0 |
| Vessels Loaded | - | - | 11 | 1 | 1 | 0 |

**Table 5.1. (continued)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Total Vessel Despatch | - | - | $27,892 | $13,006 | - | - |
| | | | **U.S. Gulf Port** | | | |
| Total Bushel Flow | 10,682,440 | 350,058 | 54,908 | 223,104 | 162 | 6,853 |
| Shuttles Unloaded | | - | 0 | 0 | | |
| 24-car COTS Unloaded | 20 | 7 | 0 | 1 | 0 | 0 |
| GTs Unloaded | - | - | - | - | - | - |
| Barges Unloaded | 177 | 11 | - | - | - | - |
| Vessel Arrivals | 5 | 0 | 0 | 0 | | - |
| Vessels Loaded | 4 | 0 | - | 0 | 0 | 0 |
| Total Vessel Despatch | $726,852 | $46,594 | $4,001 | $16,176 | $12 | $502 |
| Total DEP for PNW & Gulf | - | - | $406,187 | $47,369 | 0 | 0 |

The second key reason the Shuttle-loader was riskiest is because since it has the largest storage capacity and handles the most grain out of the 3 elevators, it has to buy the most grain on the spot market out of all three.[47] This results in the Shuttle-loader having the greatest exposure to risk in terms of farmer deliveries. Finally, it is also worth noting the coefficient of variation for the Small-Shipper was also greater than 1 because it relies only on 24-car COTs in the base case.

The standard deviations of net margin for the Shuttle-loader and the Small-shipper were both larger than their means. Beside the reasons stated above, the high degree of variability in net margins for the Shuttle-loader was caused by the large variability in shuttle COT demurrage costs. For the Small-shipper, the high degree of variability in net margins was mostly caused by the lead time for car placement. The Small-shipper can order just 24-car COTs and general tariff units. Because there is a great deal of

[47] Recall from Chapter 4 that 54% of total grain purchases are made on the spot market in the base case.

randomness in the placement of these 2 types, the Small-shipper incurs the greatest risk in the placement of railcars; the other elevators mainly depend on shuttle COTs which contain the least variability in placement. Other key sources of risk affecting the net margin in the base case for the 3 elevators was the percentage change in futures prices, transit time to both ports, and the basis offered at each port. Even though the prototypical hedger is always assumed to be 100% hedged, the change in futures over time will affect the cash price that is received for a grain sale. For instance, the cash price received on grain that has been stored and hedged for 10 weeks will be the sum of the current futures price and the sell basis. Lastly, the transit time to either port was based on a random distribution and it differed for each mode of transportation (see Chapter 4).

The cumulative distribution functions of annual net margin for the Shuttle-loader, Small-shipper, and River-terminal are shown in Figure 5.1, Figure 5.2, and Figure 5.3 respectively. Figure 5.1 indicates there is about a 15% chance that average net margins will be negative for the Shuttle-loader. In addition, there is a 50% chance that average net margins will be less than $1.9 million per year and a 10% chance it will be greater than $3.8 million per year.

According to Figure 5.2, there is roughly a 10% chance that average net margins will be negative for the Small-shipper. In addition, there is a 50% chance that average net margins will be less than $0.3 million per year and a 10% chance it will be greater than $0.5 million per year.

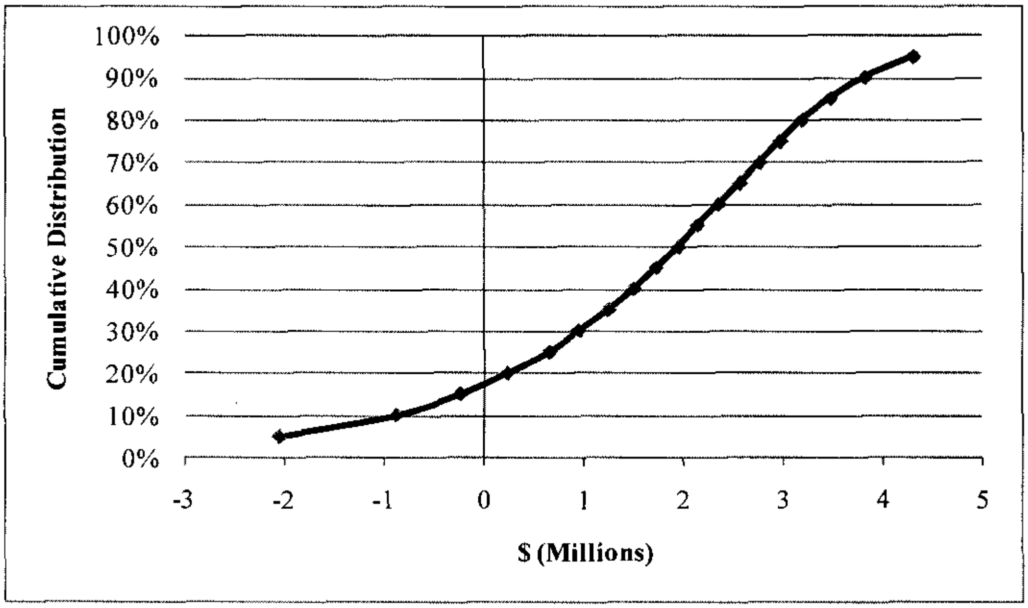


**Figure 5.1. Average annual net margin for Shuttle-loader, base case**

Finally, after examining Figure 5.3 it is evident that the River-terminal has the least variability or risk associated with net margin for any of the 3 elevators. It has no chance of generating negative returns and a 50% chance of earning $6.5 million per year. Lastly, it is worth noting the River-terminal has a 10% chance that net margin will be greater than $7.7 million per year.

When considering the prototypical shipper's 3 elevators, the River-terminal has the potential for the greatest profit and is the least risky of the three. The Shuttle-loader is the most risky in terms of net margin and the Small-shipper generates the least amount of net margin, but is not as risky as the Shuttle-loader. In other words, the Shuttle-loader was the biggest liability to the overall firm in the base case because it had the greatest chance of a negative net margin.

Figure 5.4 displays the number of bushels shipped each week via 24-car COTs by the Small-shipper. Because this elevator is not capable of shipping shuttle COTs, they are forced to order freight on a "needs basis" rather than being forced to fill a shuttle COT.

Freight loadings are equivalent to actual grain sales because when grain is sold, freight is acquired and loaded to move the grain. Therefore, the level of 24-car COT loads is a function of grain sold in the pipeline.

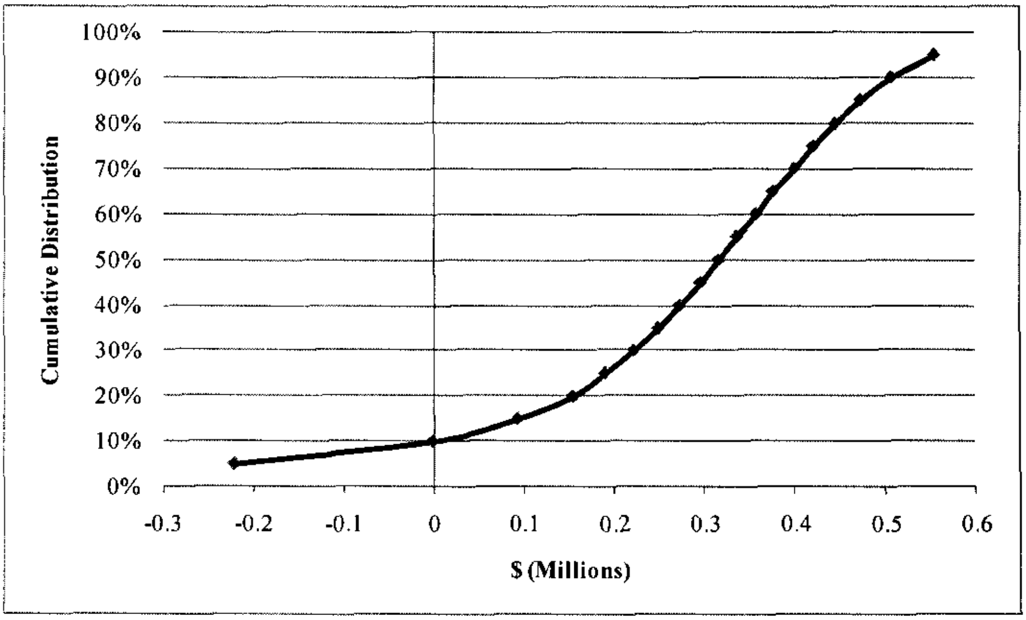


**Figure 5.2. Average annual net margin for Small-shipper, base case**

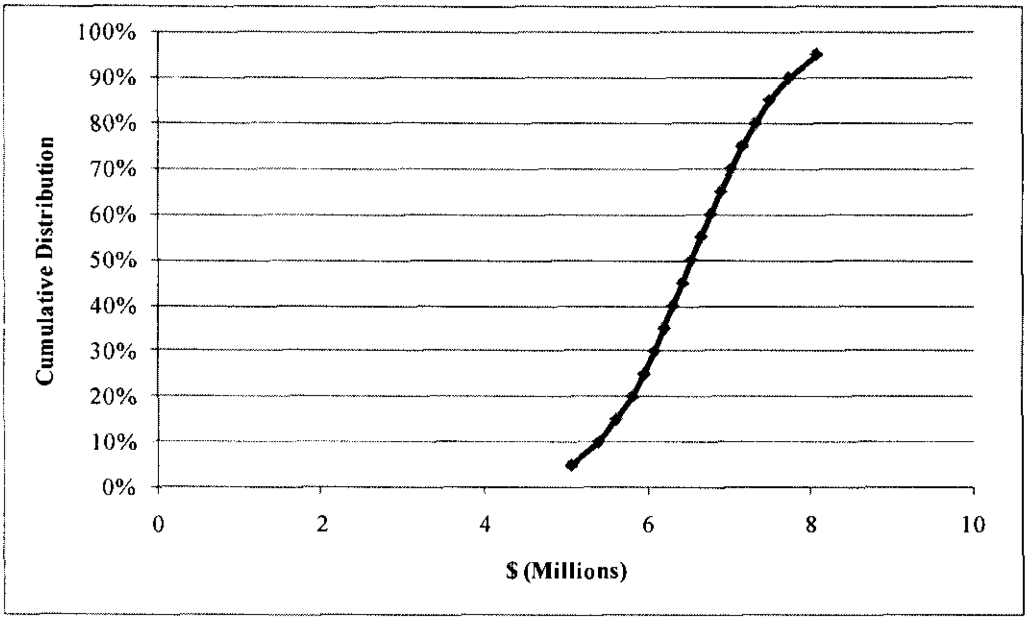


**Figure 5.3. Average annual net margin for River-terminal, base case**

Figure 5.4 indicates that an increase in grain sales for the Small-shipper occurred in the weeks leading up to Week 40, and then continued to fluctuate at a high level throughout the remainder of the year. Grain sales were expected to rise sharply around Week 40 because soybean harvest in the Upper Midwest starts in late September/early October. Therefore, an increase in both grain buying and grain sales took place around harvest.

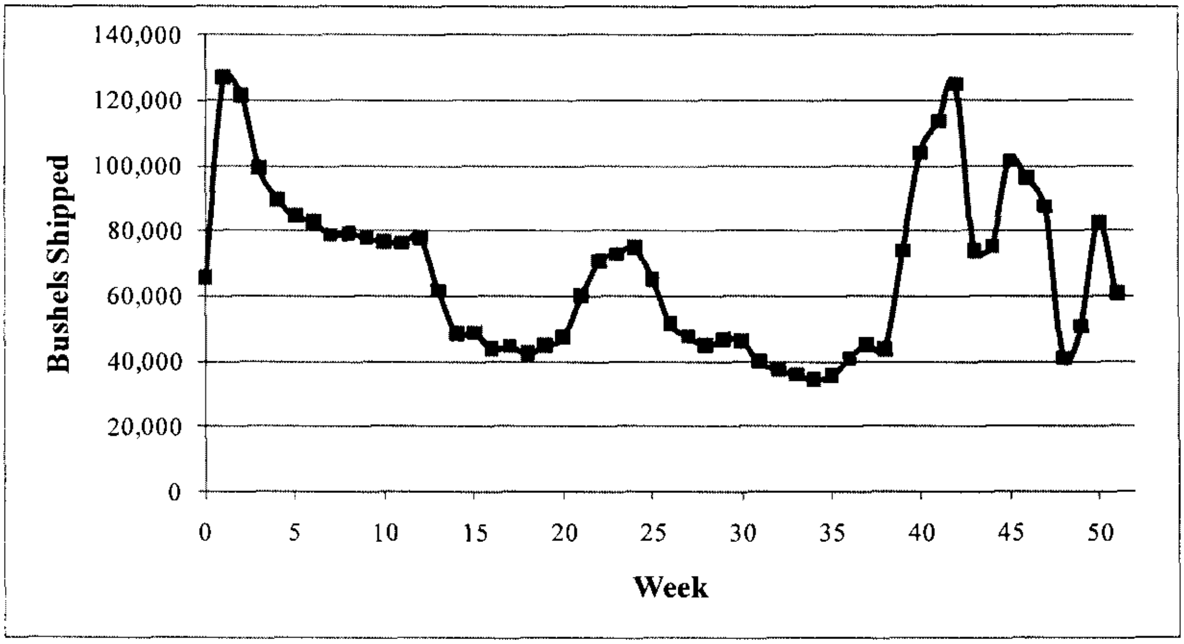


**Figure 5.4. 24-car COT loadings for Small-shipper, base case**

The Shuttle-loader ships shuttle COTs which means it ships regularly scheduled quantities of grain every 8-10 days. In doing so, its grain sales follow this pattern very closely because without selling grain, shuttle COTs wouldn't be filled and would incur demurrage. In addition to shuttle COTs, the Shuttle-loader also ships 24-car COTs whenever needed.

The loadings for the Shuttle-loader are shown in Figure 5.5. An increase in grain sales for the Shuttle-loader occurred in the weeks leading up to Week 40, and then continued to fluctuate at a high level throughout the remainder of the year. Again, grain sales were expected to rise sharply around Week 40 because of soybean harvest. Lastly, the number of 24-car COT loads is significant at the beginning of the year because the 3 shuttle COTs were ordered then but hadn't arrived yet. Thus, 24-car COTs were needed to ship grain in the first 4 weeks of the year since the shuttle COTs weren't running yet and favorable selling opportunities required freight for shipping. After Week 4, the number of 24-car COT loads starts a steady decline until it reaches zero around Week 17 because after all 3 shuttle COTs were running and the quantity of stored grain had been depleted, additional shipping capacity was not necessary.

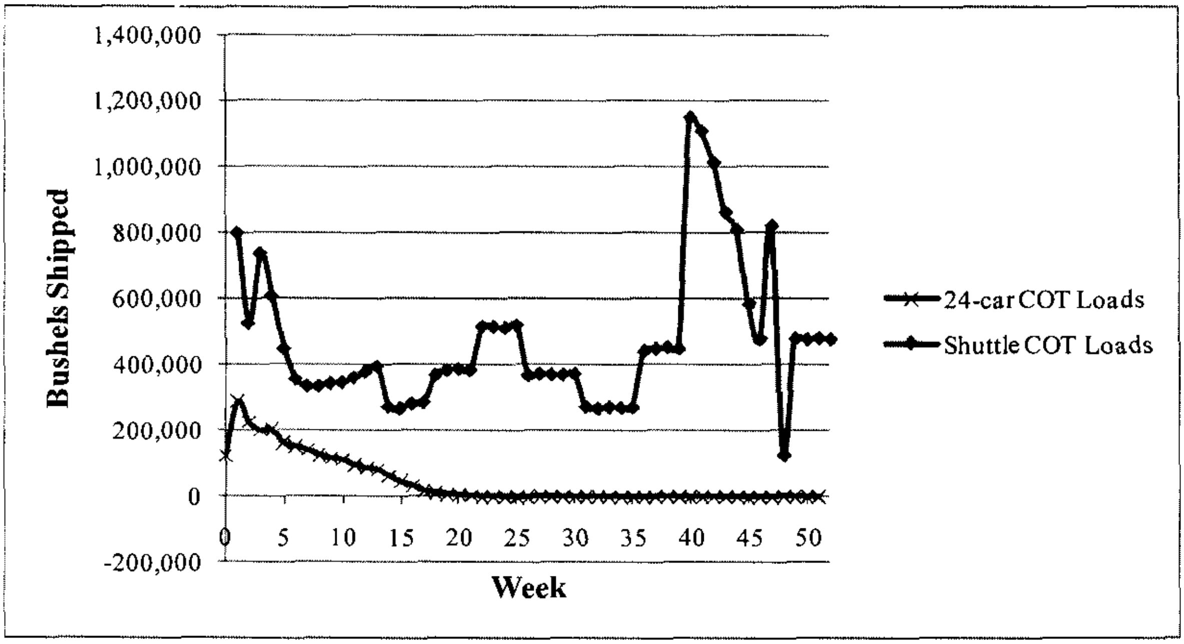


**Figure 5.5. Shuttle COT and 24-car COT loadings for Shuttle-loader, base case**

The River-Terminal loads barges in much same the way the Small-shipper loads 24-car COTs because they are ordered at random or on a "needs basis." In addition, they also load 24-car COTs in the base case. The River-terminal's barge and 24-car COT loadings are found in Figure 5.6.

Figure 5.6 indicates that the majority of the River-terminal sales were shipped via barge. As in the previous 2 cases, an increase in grain sales for the River-terminal occurred in the weeks leading up to Week 40 and then continued to fluctuate at a high level throughout the remainder of the year. These again were the result of soybean harvest. The River-terminal relies on 24-car COTs when shipping demand exhausts barge capacities, but barge transportation still remains the key mode of grain transportation for this elevator.

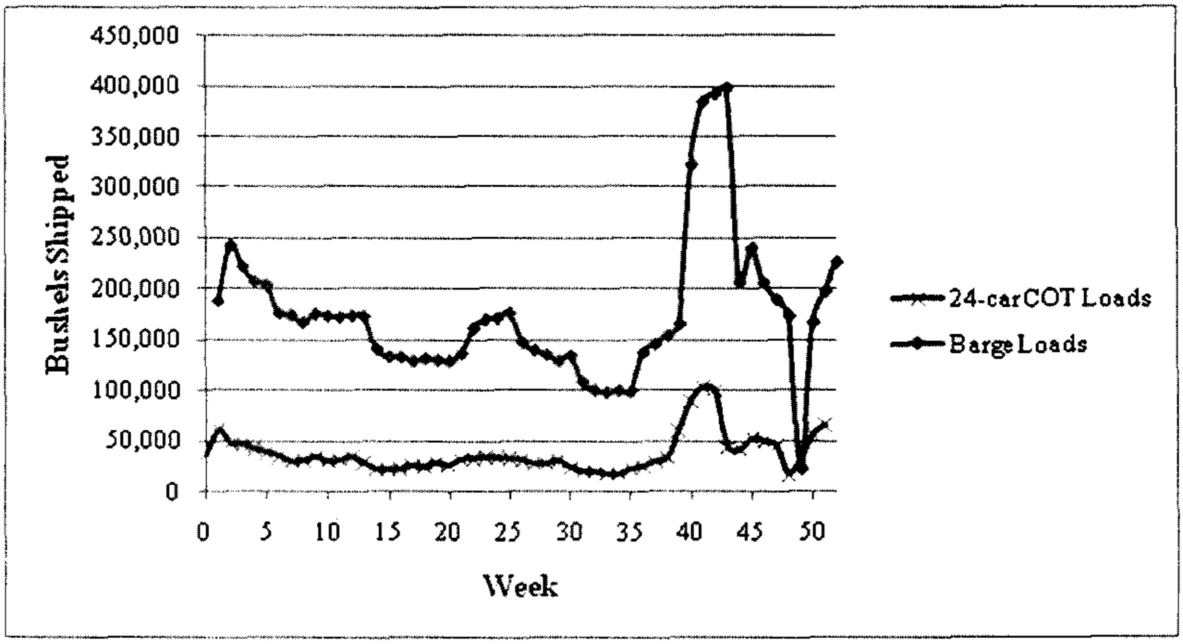


**Figure 5.6. Barge and 24-car COT loadings for River-terminal, base case**

Merchandisers monitor certain cost components, farmer deliveries, and available loading/unloading time. Table 5.1 contains important output generated for each elevator owned by the firm. The model determines available storage capacity, and if it is exceeded, grain cannot be received until space becomes available. Actual deliveries are also shown in Table 5.1. The Shuttle-loader took in the greatest amount of bushels. This is indicative of its storage capacity and total bushels handled per year. Overall, the entire firm shipped an average of roughly 41 million bushels of soybeans for the entire year.

The total yearly volume handled per year for each elevator was discussed in Chapter 4 (see Table 4.12). This is an important statistic because the greater the volume handled, the greater the quantity of grain moving through the pipeline. Therefore, if a merchandiser is making 10 cents per bushel, he will generate even greater revenue by increasing volume. This statistic can be determined by the level of inventory turnover per year. The level of turnover, or number of times storage capacity is shipped during the year, is greatest for the River-terminal because it acts as more of a transfer facility rather than a storage facility. The level of inventory turnover is also displayed in Table 5.1

Table 5.1 indicates that 26% of total grain handled was shipped to the U.S. Gulf. In addition, 99% of the twenty-six percent that was moved to the Gulf was shipped by the River-Terminal. In addition, 60 shuttle COT trips were generated by the Shuttle-loader. The minimum number of shuttle COT trips guaranteed by the BNSF is 30 per year for one shuttle COT (BNSF Railway Company , 2006). Therefore, the number of shuttle COT trips should be closer 90 trips rather than only 60 in the base case. Also, a total of forty, 24-car COTs were ordered by the Small-shipper in the base case.

Table 5.1 indicates that eighty-eight 24-car COTs were ordered across all 3 elevators. Also, 184 barges were ordered by the firm throughout the year. No general tariff units were ordered by the entire firm because they were not included in the base case.

The Small-shipper had the highest average storage cost per bushel for the year; this is expected because they are not committed to any shuttle COTs and therefore, aren't required to fill one every 8-10 days. The annual net margin per bushel for each elevator was generated by dividing total annual net margin by the total grain shipped. The net margin is simply the gross margin less all fixed elevator costs such as transportation, handling and hedging. The Shuttle-loader generated an average net margin of $0.06/bushel on every sale, whereas the River-terminal and Small-shipper earned $0.59/bushel and $0.07/bushel, respectively. The River-terminal generated the highest average net margin/bushel because it utilized the cheapest mode of transportation (i.e., barge) in terms of cost and demurrage for the bulk of its grain shipments. It also had the highest target margin ($0.35/bu) of any of the three grain elevators[48]. Finally, Figure 5.7 displays the cumulative distribution functions for average net margin for the 3 elevators.

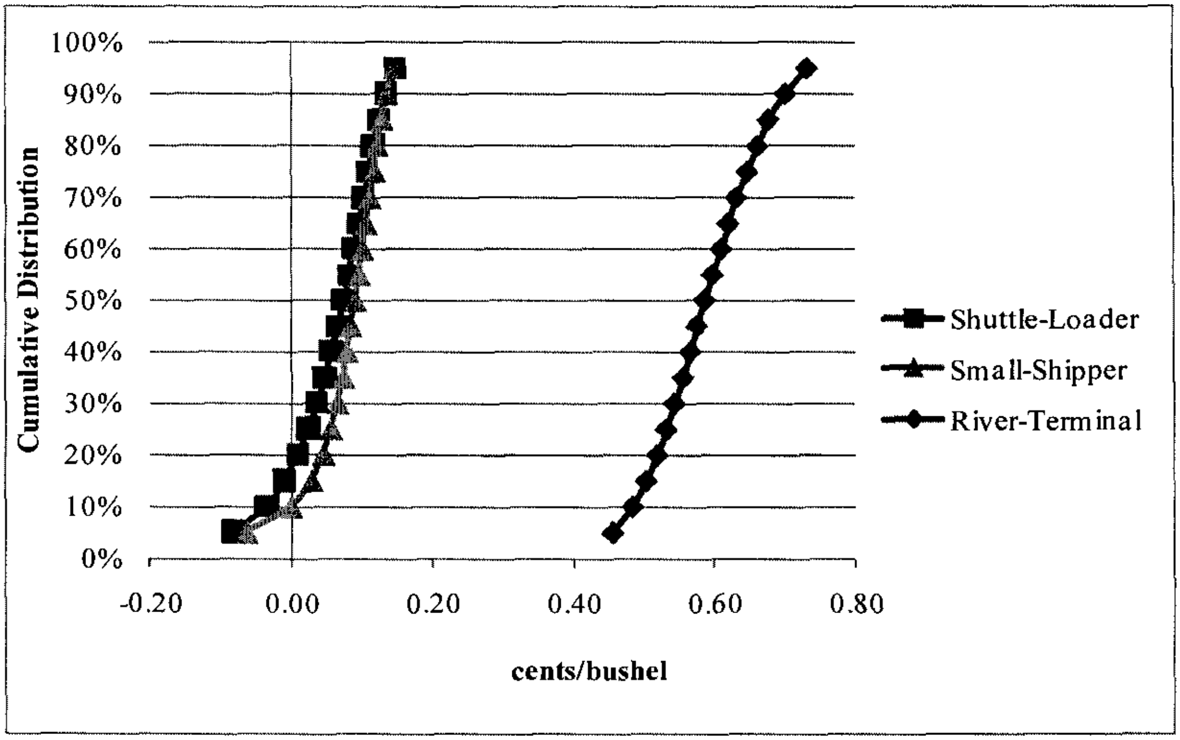


**Figure 5.7. Annual net margin for all elevator locations in base case**

Figure 5.7 indicates that the River-Terminal has very little variability associated with its annual net margin, whereas the other 2 locations risk more of earning a negative net margin in the base case. This suggests that the base case is not the optimal strategy for either the Small-shipper or the Shuttle-loader. The sensitivity conducted on the freight

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[48] See Table 4.10 in Chapter 4.

ordering strategy later in this chapter will reveal the optimal strategy to maximize net margin.

Other base case results indicate that the Shuttle-loader loaded the most vessels (11) during the year. In total, the prototypical shipper ordered 17 vessels during the year and loaded and shipped 16 of them. The Shuttle-loader also generated about $406 thousand in revenue from Destination Efficiency Payments (DEPs) because it was the only elevator to ship shuttle COTs in the base case. Vessel despatch proved to be a significant source of revenue for the River-Terminal because they generated roughly $730 thousand throughout the course of the year.

Demurrage charges for each of the 3 elevators are located in Table 5.2. Demurrage charges are a significant cost for a grain shipper because they imply that freight was either sitting idle or loaded/unloaded inefficiently. The firm incurred about $7 million in demurrage charges in the base case. Over half of the total annual demurrage at the elevator level was incurred by the Shuttle-loader; this elevator had a logistical strategy comprised of 3 shuttle COTs which generated only 60 total shuttle COT trips for the year. Recall from earlier that the BNSF guarantees at least 30 trips per year for one shuttle COT. Therefore, this logistical strategy resulted in one of the three shuttle COTs sitting idle a majority of the year and incurring demurrage because not enough grain was available to completely fill it.

Table 5.2 indicates that the majority of the 24-car COT demurrage was incurred at the elevators rather than the export facilities, especially for the Shuttle-loader. The reason for this is because loading priority at each of the elevators states that shuttle-COTs are unloaded first, and then barges, and finally, 24-car COTs. Thus, 24-car COTs incur demurrage until track space and a crew is available to start loading them. The standard deviation of 24-car COT demurrage for the River-terminal is about six times greater than its mean. The reason for this is because barges take loading priority over 24-car COTs, which is similar to shuttle COTs taking priority over them at the Shuttle-loader. Also, after 24-car COTs are ordered, they may not be placed for as long as 18 days; therefore, their placement is more variable than that of shuttle COTs and barges. As a result, the amount of 24-car COT demurrage is highly variable because it depends on how many barges are ordered and when they are loaded. This is evident for the Small-shipper which has a coefficient of variation of 9.05 which means they are exposed to a great deal of variability in demurrage charges in comparison to the average demurrage that is expected.

**Table 5.2. Base case demurrage charges**

| | River-Terminal | | Shuttle-Loader | | Small-Shipper | |
|---|---|---|---|---|---|---|
| **Total Demurrage at Elevators** | | | | | | |
| | Mean | Std | Mean | Std | Mean | Std |
| Shuttle COT | - | - | $4,557,836 | $382,160 | - | - |
| 24-car COT | $483 | $3,057 | $54,048 | $52,824 | $1,307 | $396 |
| General Tariff | - | - | - | - | - | - |
| Barge | $25,309 | $20,749 | - | - | - | - |
| **Total Demurrage at Export Facilities** | | | | | | |
| Shuttle COT | - | - | $580,841 | $154,318 | - | - |
| 24-car COT | - | - | $1,080 | $6,774 | - | - |
| General Tariff | - | - | - | - | - | - |
| Barge | - | - | - | - | - | - |
| Vessel | $1,788,036 | $569,703 | $127,456 | $627,692 | $209 | $13,321 |
| Total | $1,813,828 | $593,509 | $5,321,262 | $1,223,768 | $1,516 | $13,717 |
| Coefficient of Variation | 0.33 | | 0.23 | | 9.05 | |

Vessel demurrage for the River-terminal proved to be significant because it accounted for about 8% of their annual total costs. Factors most affecting vessel demurrage for the River-terminal are shown in Figure 5.8. Soybean futures price and the Gulf soybean basis had the largest effect on vessel demurrage at the U.S. Gulf. For instance, every $1 increase in futures will increase vessel demurrage at the Gulf $0.13/bushel for the River-terminal. Futures price and basis have a large impact on vessel demurrage for the River-terminal because if futures and the Gulf basis appreciate to favorable levels, this will induce shipping to the U.S. Gulf. Then once freight is loaded and shipped at the River-terminal, vessels are ordered. Therefore, if more grain is being shipped to the U.S Gulf, more vessels are ordered and the chance of vessel demurrage significantly increases because it depends on transit time (random variable) to the U.S. Gulf.

Lastly, the level of spot purchases is a random variable and can create a lot of uncertainty in freight ordering decisions for a merchandiser. Once more grain is delivered on the spot market; additional freight has to be ordered for shipping from the River-terminal to the U.S. Gulf; this causes more vessels to be ordered to the U.S. Gulf. Similar to before, vessel demurrage depends on transit time. Thus, as the level of spot purchases increases, the amount of vessel demurrage at the U.S. Gulf for the River-terminal increases.

Figure 5.9 displays the total demurrage cost by mode for the prototypical shipper. Vessel demurrage accounted for about 27% of total demurrage costs whereas shuttle COTs accounted for roughly 72%. Twenty-four car COTs accounted for about 1% of total demurrage, and barges accounted for less than 1% of total demurrage cost. Shuttle COTs had the highest amount of demurrage because the Shuttle-loader had ordered 3 shuttles in the base case and they only generated 60 trips. Recall, 1 shuttle COT is guaranteed to generate 30 trips per year. Thus, the number of shuttle COT trips is too small which means railcars are sitting idle at the Shuttle-loader since there is not enough grain to fill 3 shuttle COTs throughout the duration of a year.

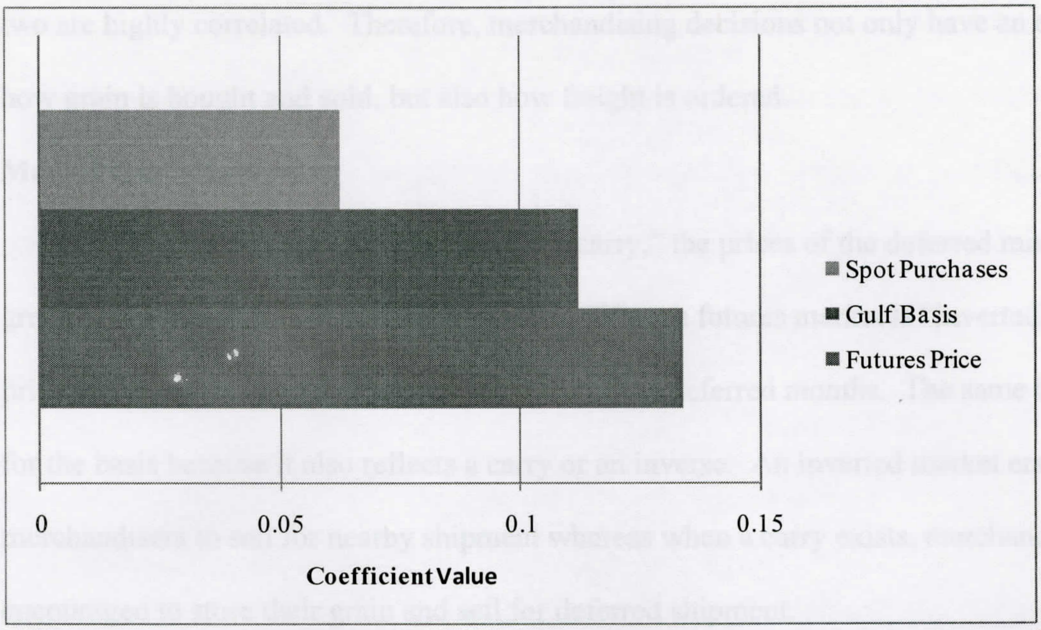


**Figure 5.8. River-terminal total vessel demurrage-U.S. Gulf: regression coefficients**

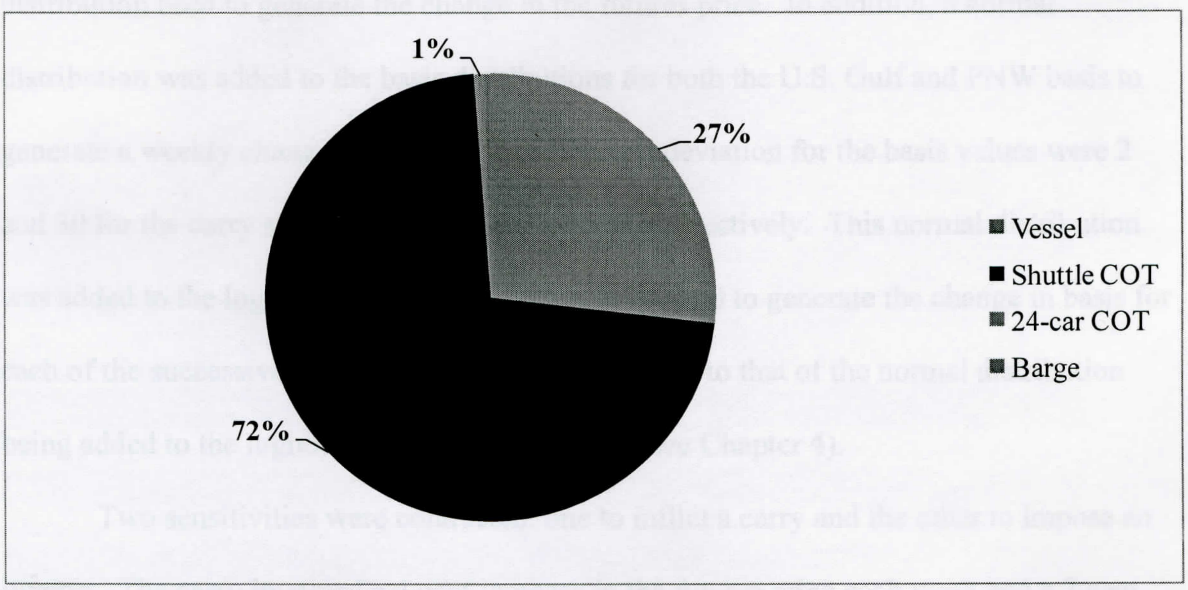


**Figure 5.9. Total demurrage costs by mode, base case**

## Sensitivity on Merchandising Variables

Sensitivities were conducted on the random merchandising variables that are present in model. Changing these key variables force merchandisers to alter their buying and selling decisions. Ultimately because grain logistics depends on merchandising, the two are highly correlated. Therefore, merchandising decisions not only have an effect on how grain is bought and sold, but also how freight is ordered.

**Market Carry/Inversion**

When the futures market is in a "full carry," the prices of the deferred months are greater than the prices of the nearby months. When a futures market is "inverted", the price of the nearby month is greater than that of the deferred months. The same is also true for the basis because it also reflects a carry or an inverse. An inverted market encourages merchandisers to sell for nearby shipment whereas when a carry exists, merchandisers are encouraged to store their grain and sell for deferred shipment.

This tradeoff among shipping and selling was evaluated by changing the normal distribution used to generate the change in the futures price. In addition, a normal distribution was added to the basis distributions for both the U.S. Gulf and PNW basis to generate a weekly change. The mean and standard deviation for the basis values were 2 and 30 for the carry and -2 and 30 for the inverse, respectively. This normal distribution was added to the lognormal basis distribution in Week 0 to generate the change in basis for each of the successive weeks; this process was similar to that of the normal distribution being added to the lognormal futures distribution (see Chapter 4).

Two sensitivities were conducted: one to inflict a carry and the other to impose an inverse. The carry involved a 4 cent increase in the futures price each week and a 2 cent increase in the U.S. Gulf and PNW basis each week. The inversion involved a 4 cent decrease in futures each week and a 2 cent decrease in both basis values. The results are shown in Table 5.3.

The results indicate that only the River-terminal is more profitable than the base case when the market is either in full carry or is inverted. Both the Shuttle-loader and Small-shipper earn negative net margins when the market is inverted or is in full carry. In addition, storage costs are highest for the 3 elevators when the market is in a full carry because merchandisers are encouraged to their store grain now and wait to sell until a favorable selling opportunity.

The River-terminal makes more money than the base case when the market is at either extreme because it is able to adapt to market conditions more easily than the other two; it primarily ships barge which is the cheapest of the available transportation modes ($0.61/bushel). The Shuttle-loader is committed to shuttle COTs which forces shipments in suboptimal shipping periods. Even though the Small-shipper isn't committed to shuttle COTs, it ships 24-car COTs which are the most expensive of any mode ($1.71/bushel). Therefore, it can't adapt to current market conditions very easily because shipping when storage space is exhausted requires ordering expensive 24-car COTs, and inverse market conditions forces continuous shipping which is more suited for shuttle-COTs.

**Table 5.3. Market carry vs. inverse for elevators**

| | River-Terminal | Shuttle-Loader | Small-Shipper |
|---|---|---|---|
| **2 Cent Carry** | | | |
| Net margin/bu | $1.09 | ($4.05) | ($0.24) |
| Storage cost/bu | $0.04 | $2.14 | $0.20 |
| **2 Cent Inversion** | | | |
| Net margin/bu | $0.95 | ($2.84) | ($0.28) |
| Storage cost/bu | $0.03 | $1.19 | $0.13 |
| **Base Case** | | | |
| Net margin/bu | $0.59 | $0.06 | $ 0.07 |
| Storage cost/bu | $0.03 | $0.01 | $ 0.12 |

The number of bushels loaded on 24-car COTs is a function of grain sales made throughout the course of the year. Figure 5.10 displays the number of bushels loaded on

24-car COTs each week by the River-terminal for both a carry and an inverted market. The number of bushels sold/loaded is fairly constant at 200,000 bushels per week when the market is inverted. This is the result of shipping all grain deliveries immediately rather than storing it for deferred shipment. The number of bushels loaded in 24-car COTs when a carry exists gradually increases as the year progresses in order to exploit the favorable selling opportunities generated by a carry in the market. The selling that takes place in the first 15-20 weeks of the year is very minimal and occurs only to free up storage space and not exceed storage capacity. Once soybean harvest begins around Week 37, as much stored grain as possible is shipped; this is a result of storage capacity of the elevator being reached and advantageous selling opportunities being realized in a carry market.

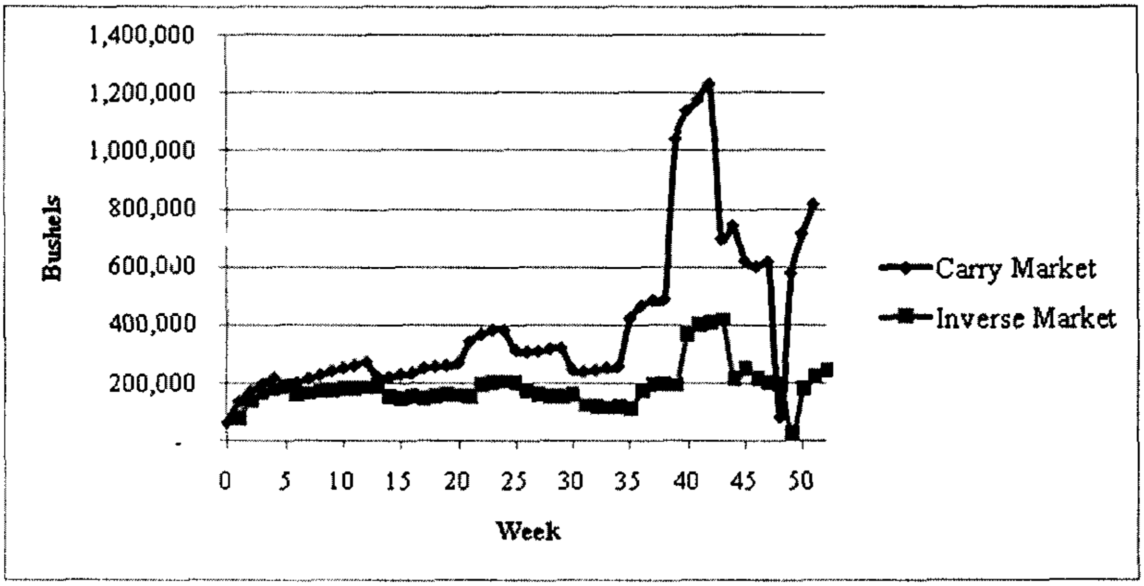


**Figure 5.10. 24-car COT loads for River-terminal while operating under different markets**

### Uncertainty in Grower Deliveries

Farmer deliveries for each week were classified as either spot or forward. Spot deliveries were random and were represented by a lognormal distribution whereas forward deliveries were assumed to be pre-determined and fixed. The base case assumed that 54%

of the total volume handled by each elevator was comprised of spot deliveries while the remainder was forward contracted.

For each elevator, the percentage of spot deliveries was increased to 100% while forward deliveries were set to 0. This implies that 100% of the total deliveries made by farmers to each elevator were random; this was thought to introduce a great deal of risk to the firm. After simulating these sensitivities for each of the firms, the level of demurrage increased as the percentage of spot purchases increased. This positive relationship was expected because if the uncertainty in grain deliveries increases, then the chance that freight orders will either be underestimated or overestimated increases. If a merchandiser expects a lot of grain to be delivered in the next couple of weeks, then a large amount of freight will be ordered to ship that grain. However, if the grain does not get delivered as expected, either due to crop size or harvest delays, freight will remain at the elevator until loaded and demurrage will accrue over time.

For the River-Terminal, barge transportation saw the most significant increase in demurrage at the elevator when 100% of farmer deliveries were made on the spot market. The River-terminal found barge demurrage to increase 29% when 100% of deliveries were made on the spot market when compared to 0% delivered on the spot market. This increase is shown in Figure 5.11.

The Shuttle-loader also experienced an increase in demurrage at the elevator. Shuttle COT demurrage increased 19% when 100% of farmer deliveries were on the spot market compared to when 0% of deliveries were on the spot market. This is depicted in Figure 5.12. Notice the low level of shuttle COT demurrage during harvest (Week 40).

Demurrage decreases dramatically here because farmer deliveries greatly increase which means a surplus of grain is available to load shuttle COTs. Before when shuttle COT demurrage was accruing, not enough grain was available to load them. Lastly, the Small-shipper saw no change in demurrage when 100% of farmer deliveries were made on the spot market.

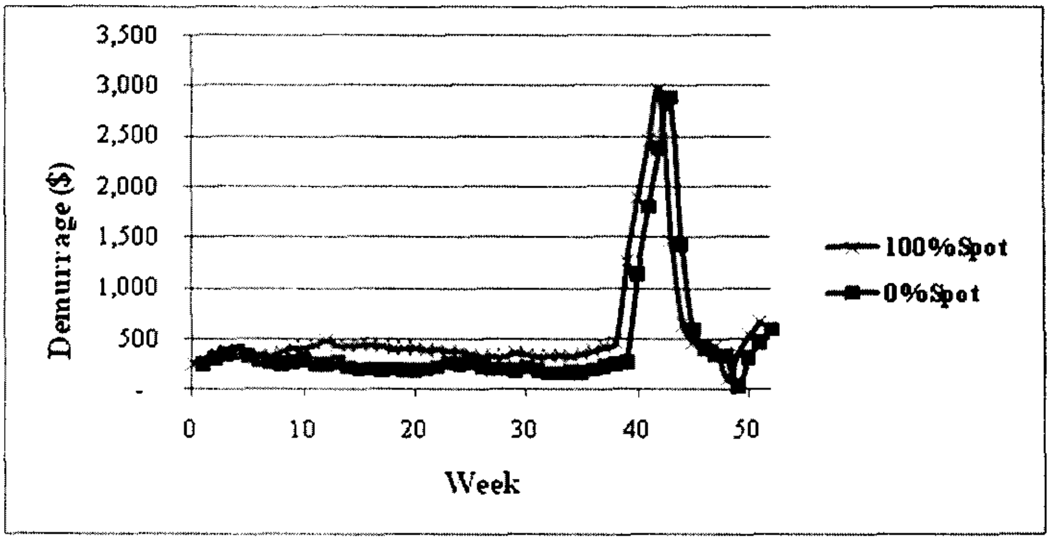


**Figure 5.11. Elevator barge demurrage for River-terminal**

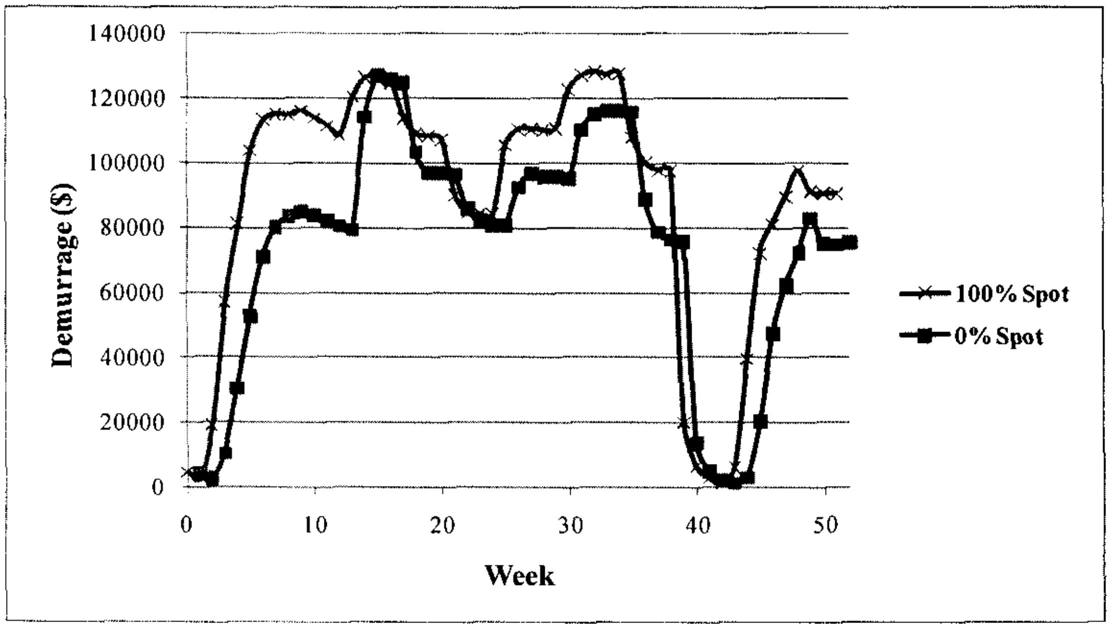


**Figure 5.12. Shuttle COT demurrage for Shuttle-loader at elevator**

## Sensitivity on Logistical Variables

A sensitivity analysis was also conducted on key logistical variables such as the freight ordering strategy employed by each country elevator, the placement of vessels, and the placement of 24-car COTs at each elevator. These variables greatly impacted the total annual net margin for each elevator in the base case. Therefore, they are significant in that if they change even a small amount, they can greatly impact the analysis.

### Freight Ordering Strategy

The freight ordering strategy for each country elevator was changed from the base case and sensitivities were conducted to determine the optimal amount of freight and the optimal amount of grain that should be sold to maximize net margins. The optimal strategy for each elevator maximized net margin, and in some instances, it was more favorable than the base case strategy. The results from the sensitivity analysis on alternative logistical strategies for the 3 elevators are in Table 5.4.

Table 5.4 indicates that the River-Terminal's optimal freight ordering strategy is comprised of ordering barges only. This strategy resulted in roughly 9.1 million bushels being sold at $0.77/bushel which ultimately maximized net margins. The Shuttle-Loader's optimal strategy was to order just 1 shuttle COT and not utilize 24-car COTs. This strategy resulted in a net margin of $0.30/bushel and roughly 17 million bushels being sold.

Lastly, the Small-shipper's optimal freight ordering strategy was the base case. This involved only ordering 24-car COTs only rather than including general tariff cars. This strategy sold about 3.5 million bushels at $0.07/bushel to maximize annual net margin.

**Table 5.4. Freight ordering strategies**

| River-Terminal | | Total Demurrage | Amount of Grain Sold (bushels) | Net Margin per bushel |
|---|---|---|---|---|
| Base (Barge + 24-car COTs) | Mean | $ 1,813,828 | 11,117,400 | $ 0.59 |
| | Std | $ 593,509 | 401,975 | $ 0.09 |
| Barge only | Mean | $ 966,736 | 9,164,030 | **$ 0.77*** |
| | Std | $ 241,214 | 575,939 | $ 0.06 |
| 1 shuttle COT | Mean | $ 1,271,387 | 12,313,870 | $ 0.30 |
| | Std | $ 644,834 | 807,553 | $ 0.07 |
| 2 shuttle COTs | Mean | $ 4,221,829 | 12,382,920 | $ 0.06 |
| | Std | $ 699,955 | 849,157 | $ 0.07 |
| 1 shuttle COT + Barge | Mean | $ 3,632,843 | 12,312,460 | $ (0.003) |
| | Std | $ 873,450 | 809,290 | $ 0.08 |
| 1 shuttle COT + 24-car COT | Mean | $ 1,371,882 | 12,314,930 | $ 0.28 |
| | Std | $ 638,313 | 808,461 | $ 0.07 |
| **Shuttle-Loader** | | | | |
| Base (3 Shuttle-COTs + 24-car COTs) | Mean | $ 5,321,262 | 26,755,330 | $ 0.06 |
| | Std | $ 1,223,768 | 1,759,547 | $ 0.08 |
| 1 shuttle COT | Mean | $ 434,097 | 17,465,250 | **$ 0.30*** |
| | Std | $ 375,277 | 289,132 | $ 0.06 |
| 2 shuttle COTs | Mean | $ 2,090,914 | 26,440,260 | $ 0.24 |
| | Std | $ 879,611 | 1,622,713 | $ 0.05 |
| 4 shuttle COTs | Mean | $ 7,946,847 | 26,348,190 | $ 0.03 |
| | Std | $ 1,009,791 | 1,759,875 | $ 0.06 |
| 1 shuttle COT + 24-car COT | Mean | $ 1,353,922 | 26,360,620 | $ 0.02 |
| | Std | $ 1,210,115 | 1,573,274 | $ 0.18 |
| **Small-Shipper** | | | | |
| Base (24-car COTs only) | Mean | $ 1,516 | 3,550,576 | **$ 0.07*** |
| | Std | $ 13,717 | 373,746 | $ 0.08 |
| General Tariff only | Mean | $ 1,863,209 | 3,448,590 | $ (8.04) |
| | Std | $ 449,688 | 410,667 | $ 1.85 |
| General Tariff + 24-car COT | Mean | $ 17,845 | 3,786,701 | $ 0.03 |
| | Std | $ 45,887 | 413,101 | $ 0.15 |

*Indicates optimal shipping strategy

**Vessel Placement**

The distribution of placement on ocean vessels in the base case was a uniform distribution with each day in the 10-day window getting an equal chance of the vessel being placed. Two sensitivities were conducted on this value by creating a triangular distribution. The first distribution resulted in the vessel being most likely placed on the second day of the window whereas the other had the vessel being most likely placed on the ninth day of the window. Depending on market conditions, buyers of grain will either place their vessels at the beginning of the window or at the end of the window (see Chapter 2).

The results indicate that when vessels are placed at the end of the 10-day window, total vessel demurrage increased and total vessel despatch decreased for all 3 elevators. Total demurrage for all rail units and barge had very little change once vessels were placed at the beginning of the 10-day window when compared to the end of the window. Figure 5.13 displays these results.

Figure 5.13 indicates that total vessel demurrage is always higher when vessels are placed at the end of the 10-day window. Once railcars and /or barges arrive at the export facilities and unload, they either expire after that trip (24-car COTs and barges) or they cycle back to the elevator (shuttle COTs). Either way, they unload all of their grain into the export facilities if there is enough space. Then if vessels are placed at the end of the window, grain can't be directly loaded onto the vessel when railcars and barges arrive. Instead, the available grain is loaded onto the vessel from the facility and if there is not enough grain to load the entire vessel, it has to sit idle in the port and wait for railcars and/or barges to return to load it. Demurrage is incurred on the vessels the entire time it's waiting to be filled.

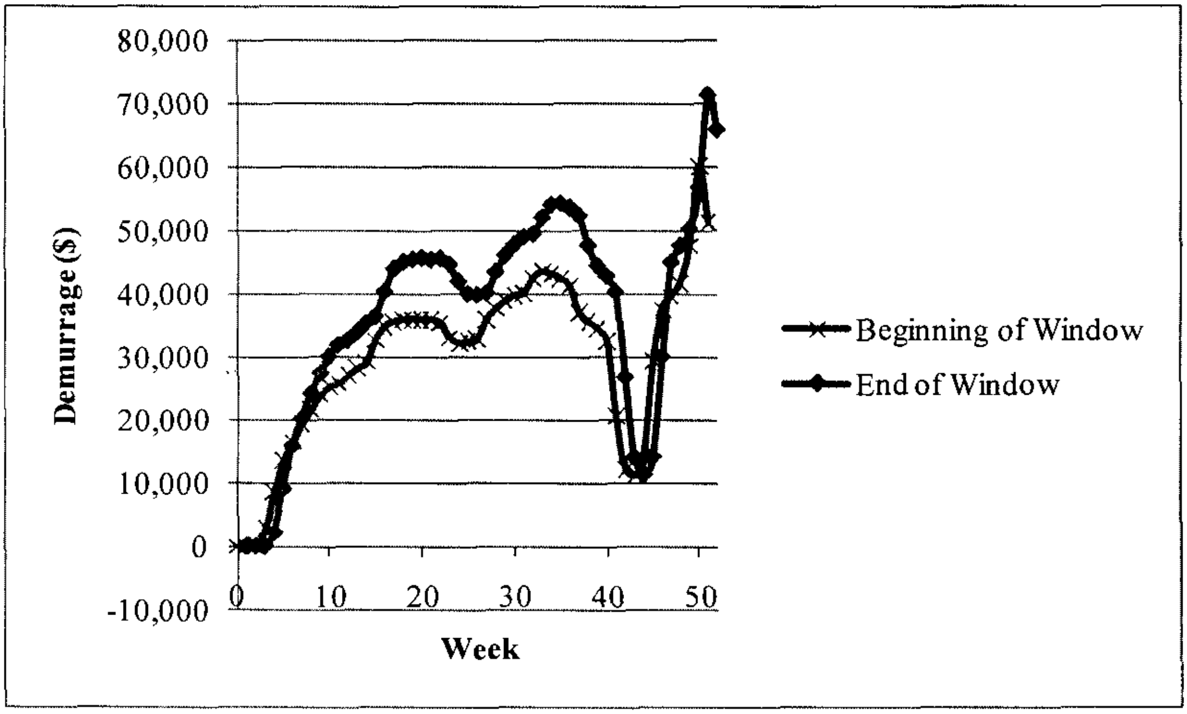


**Figure 5.13. Total vessel demurrage for River-terminal**

Figure 5.14 indicates that despatch on vessels is higher when vessels are placed at the beginning of the 10-day window. This result stems from the increase in demurrage when vessels are placed at the end of the 10-day window. If shippers can't consistently meet their guaranteed load rate/week, then they have a smaller chance of earning despatch.

**24-Car COT Placement**

The distribution of placement on 24-car COT units was a triangular distribution with the most likely value being 3 days in the base case. Therefore, in the base case, 24-car COTs were most likely to be placed on the third day of the shipping period. A sensitivity was conducted and the most likely value was changed to 15. This means the cars were most likely to show up on the 15$^{th}$ day of the shipping period. Twenty-four car COTs are guaranteed to be placed within 15 days of the want date, and if they aren't, a carrier non-performance payment is received. In addition, according to the triangular distribution in the sensitivity there is a chance that the cars won't be placed until after the 15th day which means the shipper is paid a carrier non-performance payment. Figure 5.15 shows the comparison of the base case to the sensitivity performed on 24-car COT placement for the Small-shipper.

Figure 5.15 indicates that once 24-car COTs are placed toward the end of the shipping period, shippers earn a greater amount of non-performance payments from the railroad. For instance, during Week 20 the base case results in the shipper earning less than $100 in carrier non-performance penalties, but the sensitivity resulted in the shipper earning roughly $270 in non-performance penalties. This sensitivity is basically treating the 24-car COTs as general tariff cars since it is making the BNSF guarantee void and cars are not guaranteed to show up within 15 days of the want date.

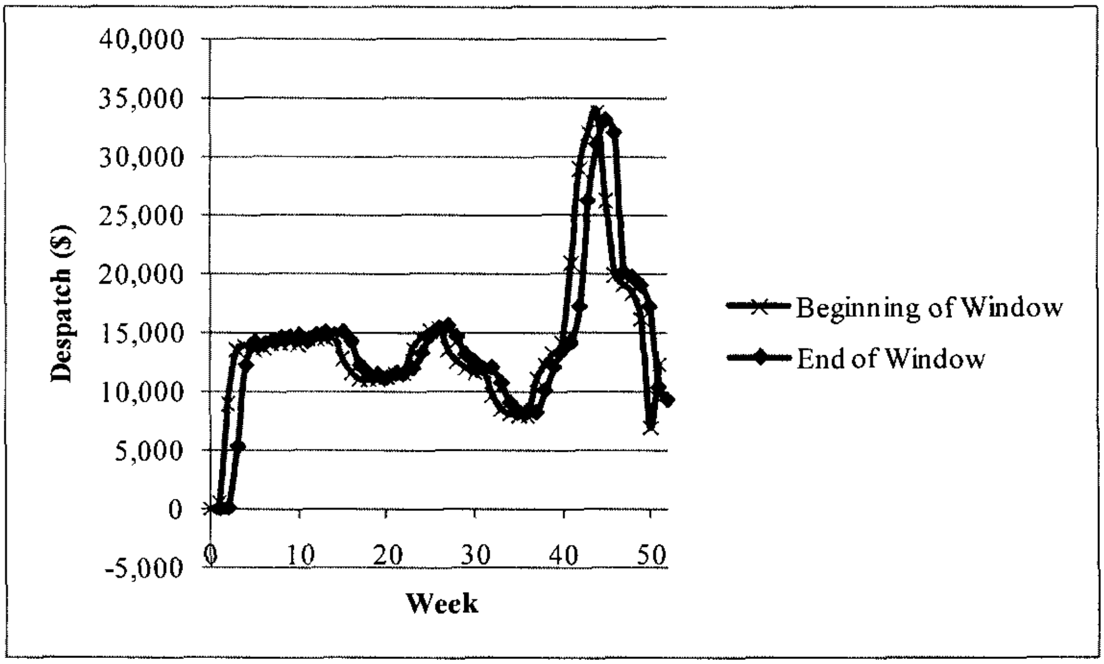


**Figure 5.14. Total vessel despatch for River-terminal**

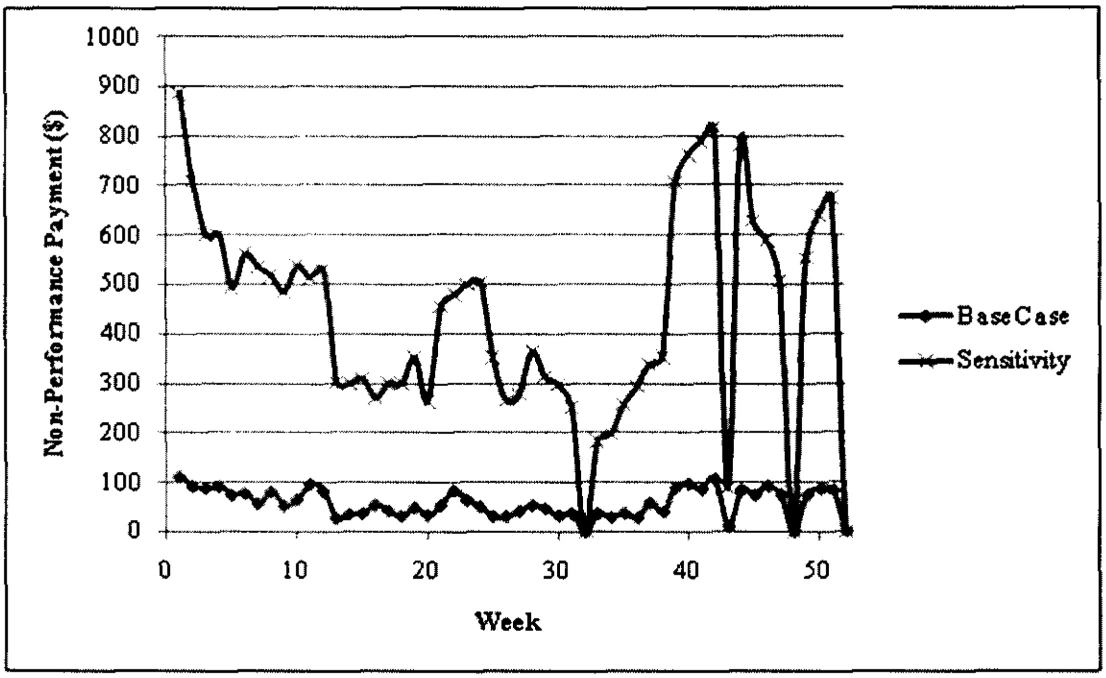


**Figure 5.15. Non-performance payment incurred by Small-shipper**

Even though revenue from non-performance penalties has increased, the Small-shipper is still earning $0.07/bushel which was the net margin earned in the base case. The reason for this is because there was about 2% less grain shipped than there was in the base case. This was caused from a longer lead time for 24-car COT placement which results in less revenue opportunities for the Small-shipper.

## Summary

A stochastic simulation model was analyzed to evaluate key relationships among merchandising and logistical variables. The key variables analyzed were all random and they included freight placements, transit times, farmer deliveries, and futures price spreads. The effect of these variables on net margins was extracted from the results to ultimately determine the optimal amount of grain to sell and optimal amount of grain to hedge. A base case model was first simulated to create a benchmark for the analysis. Then, several sensitivities were conducted on merchandising and logistical variables. Several results were identifiable from the base case and sensitivity analysis.

In the base case, the Shuttle-loader faced the greatest amount of risk associated with net margin because of its logistical strategy and the manner in which grain was sold. The logistical strategy was comprised of 3 shuttle COTs that were fixed annually and ran continuously throughout the year; this resulted in railcars arriving at the elevator and needing to be loaded whether there was enough grain on-hand or not. It is worth noting that the BNSF guarantees at least 30 trips per shuttle COT, but the Shuttle-loader only generated 60 trips while running its three shuttle COTs; this is indicative of an inefficient logistical strategy. Also, employing 3 shuttle COTs forced sales to be made based on freight placement at the elevator rather than favorable selling opportunities. Overall, the Shuttle-loader was committed to too many long-term shipping mechanisms and it limited the shipper's flexibility, forced sales to be made based on car placement rather than market conditions, and ultimately constrained the shipper's ability to effectively sell grain and efficiently order freight.

Other base case results include the River-terminal generating the highest average net margin per bushel on account of being able to utilize the cheapest mode of transportation (i.e., barge) for the majority of its grain shipments. Also, the Shuttle-loader's inefficient logistical strategy generated roughly $4.5 million in demurrage at the elevator level. This accounted for 98% of the prototypical shipper's total elevator demurrage.

In the market carry/inverse sensitivity, the River-terminal remained the most profitable elevator because it shipped barges (cheapest mode) for the bulk of its grain shipments and ordered them on a random or "needs" basis rather than a fixed strategy. The Shuttle-loader did worse while operating in a full carry and an inverted market because it was constrained by a fixed, long-term shipping strategy which forced it to sell grain in suboptimal shipping periods. The Small-shipper had to continuously order the most expensive shipping mechanism (i.e., 24-car COTs) under both market extremes in order to take advantage of favorable selling opportunities; this caused it to do worse than the base case. Lastly, it was found that higher storage costs were incurred by each elevator when the market was in full carry because storage rather than shipment was encouraged.

When 100% of total farmer deliveries were made on the spot market, demurrage costs increased 19% for the Shuttle-loader and 29% for the River-terminal. This positive relationship between percent of spot deliveries and demurrage was expected because as the amount of uncertainty in grower deliveries increases, the chance that freight orders will either be underestimated or overestimated increases.

After sensitivities were conducted on the logistical strategy employed by each elevator, it was found the optimal freight ordering strategy for the River-Terminal was to order barges only and no rail freight. In addition, about 9 million bushels of grain were sold at $0.77/bushel to maximize returns. River-Terminals are mainly designed with focus of loading barges rather than loading shuttle-trains. Thus, their level of net margins increases when more barges are utilized to ship grain.

The Shuttle-loader's optimal strategy was to order 1 shuttle COT because ordering more than one constrained the shipper's ability to make efficient logistical decisions. This strategy resulted in a net margin of $0.30/bushel and roughly 17.4 million bushels being sold. Lastly, the Small-shipper's optimal freight ordering strategy was the same as the base case which included only ordering 24-car COTs. This strategy sold about 3.5 million bushels at $0.07/bushel to maximize annual net margin. In total, the prototypical shipper's optimal freight ordering strategy is to utilize barges and 24-car COTs when necessary and to order 1 shuttle COT. In addition, the optimal amount of grain to sell is roughly 30 million bushels annually which generates about $33 million in net margin.

When ocean vessel placement was changed from a uniform distribution in the base case to a triangular distribution in the sensitivity analysis, the amount of vessel demurrage/despatch was affected. It was found that when vessel placement occurred at the end of the 10-day window, total vessel demurrage increased and total vessel despatch decreased for all 3 elevators. This occurred because railcars/barges would arrive toward the beginning of the 10-day window, dump their grain, and then the vessel wouldn't arrive for another couple of days. If not enough grain was available to fill the vessel, it would have to wait at the export facility for loaded railcars/barges to return in order to be filled. In addition to increasing the amount of vessel demurrage, it also decreased the amount of despatch earned by shippers because if they can't consistently meet their guaranteed load rate per week, they have a smaller chance of earning despatch.

The distribution for 24-car COT placement was changed to force car placement to most likely occur on the 15$^{th}$ day of the shipping period; however, there was still a chance that it could be placed after the 15$^{th}$ day. This basically caused the BNSF's 24-car COT guarantee to be void and it increased the chance that the shipper would receive a carrier non-performance payment in return. As a result, the number of non-performance payments made to the Small-shipper significantly increased because 24-car COTs were rarely placed within the 15-day window. However, the Small-shipper still earned the same net margin as in the base case because there was about 2% less grain shipped than in the base case; this was caused from a longer lead time for 24-car COT placement which resulted in less revenue opportunities for the Small-shipper.

# CHAPTER 6. SUMMARY AND CONCLUSIONS

The grain supply chain is comprised of several participants including producers, merchandisers and exporters, that each function to transform grain from a raw good into a value-added product. In its simplest form, a supply chain consists of all the functions enabling the production, delivery, and recycling of materials in an effort to make products and services available to consumers (Wisner, Tan & Leong, 2008). Therefore, key players in the grain supply chain consist of farmers, country elevators, merchandisers, processors, feeders and exporters. The key player modeled in this thesis was a merchandiser. Merchandisers are a small segment of the grain supply chain; they procure grain from producers, store it as inventory, sell it at a favorable price, and ship it to the next mode in the pipeline.

One aspect of the grain supply chain that moves grain from one player to another is logistics. Transportation of grain functions to move grain from point A to point B at the most efficient way possible. Transportation rates ultimately determine a grain merchandiser's net margin. Although transaction returns from buying and selling grain might be high, transportation costs still need to be accounted for to determine net margins. Thus, grain shippers not only need to know how much of their grain to sell, but also how much freight to commit to.

Grain logistics contains 4 primary modes of transportation: truck, rail, barge, and ocean vessel. Each is specific in terms of capabilities, speed and cost. The mode most utilized by grain shippers to efficiently transport grain long distances is rail. Since deregulation of the rail industry, railroads have had the freedom to develop differentiated levels of service for grain shipments. The Staggers Rail Act of 1980 allowed the new services offered to grain shippers to be charged at premium rates. This resulted in the development of innovative car allocation mechanisms.

Grain shippers choose from several different shipping mechanisms offered by the Class I Railroads. The mechanisms offered by the Burlington Northern Santa Fe (BNSF) Railway were modeled in this thesis and they include general tariff cars, 24-car COTs and shuttle COTs. These three mechanisms offered by the BNSF differ in terms of their duration, cost, allocation method, and how many months forward they are offered. Merchandisers commit to these mechanisms several months forward in anticipation of future grain deliveries during harvest. One of the main difficulties for merchandisers involves determining how much freight to order. This decision depends on how much grain is expected to be delivered by farmers and when it will be sold. If merchandisers overestimate or underestimate their freight requirement, they risk the possibility of incurring demurrage and other significant costs.

Demurrage is a late penalty charged by railroads for inefficient use of their equipment. It is charged on a per-car basis and designed to keep the loading and unloading of cars as efficient as possible. Grain shippers have to factor the cost of demurrage into their logistical decisions because it's one of the most significant costs associated with logistics.

In addition to costly demurrage penalties, several types of risk are present in the grain supply chain. Sources of risk include freight placement, transit times, farmer deliveries, and basis/futures spreads. Minimizing risk is difficult enough for one merchandiser, but when several elevator origins are being considered, the risk is magnified.

Prototypical grain shippers operate several elevator locations and are constantly implementing measures to reduce their exposure to risk.

In order to avoid costly demurrage penalties and suboptimal merchandising decisions, grain shippers need to implement strategy in their merchandising and logistical decisions. Strategy helps to mitigate risk that is present throughout a supply chain. This is accomplished through the use of forward freight mechanisms, hedging, and contracting. These strategies focus on determining when to sell grain and when to acquire freight.

Prototypical shippers in today's grain industry need to determine when they should sell their grain to an exporter or a domestic processor. This decision considers storage costs, terminal basis levels and farmer deliveries. Once a marketing plan is created, they next need to focus on acquiring freight in advance of a sale to assure that they can ship their grain when needed.

## Review of Objectives

The primary objective of this research is to develop a model to determine both the optimal amount of grain that should be sold in the pipeline and the optimal amount of freight that should be acquired by grain shippers through the use of forward shipping mechanisms. This primary objective was created in order to maximize net margin. Specific objectives were:

1. Define key strategic and uncertain variables a grain shipper is faced with.
2. Develop a stochastic simulation model of a prototypical grain exporting firm.
3. Evaluate the effects on output after changing key decision variables.
4. Interpret the results and assess the implications for grain shippers.

## Review of Procedures

The challenges confronting grain shippers in today's industry became apparent after a literature review was conducted to analyze the tradeoffs among the primary modes of transportation for shipping grain, as well as the current rail industry after passage of the Staggers Rail Act. In addition, the forward shipping mechanisms offered by the BNSF were researched to reveal their dynamic nature, and finally, alternative supply chain methodologies were reviewed to develop a model representative of a grain supply chain.

A prototypical grain shipper is composed of several different points of origination, all capable of shipping grain to export markets. This required formulating a model with multiple country elevator locations, each with their own specific characteristics. The model was designed to evaluate the merchandising and logistical decisions involved in the management of an individual grain supply chain.

A stochastic simulation technique was chosen to model the prototypical grain shipper in this thesis. Stochastic simulation is a modeling technique that represents "real-life" events by incorporating uncertainty into the model (Winston, 2001). Analytical models are different in that they involve mathematical equations that contain input values derived from their expected values. Simulation models introduce randomness into uncertain variables by representing them with a range of possible values rather than an expected value.

The stochastic simulation software used in the model was @Risk which is an "add-on" to Microsoft Excel (Palisade Corporation, 2002). This software package incorporated randomness into certain key variables. The model was designed in 2 steps. The first step involved developing the basic framework in Microsoft Excel as a means of formulating the costs and revenue associated with making logistical and merchandising decisions. The second step incorporated this spreadsheet into @Risk. Using @Risk allowed key variables to be stochastic, or random, which incorporated risk into the model. These key variables included farmer deliveries, freight placements, transit times, basis values, and futures spreads.

Three country elevators and 2 export markets were specified in the model. The country elevators included a River-terminal facility located in southern Minnesota, a Shuttle-loading facility located in western Minnesota, and a Small-shipper located in southeast North Dakota. Each origin is specific in its own loading capabilities, storage capacity and freight ordering strategies. The 2 export markets included are the PNW and the U.S. Gulf, and each market differs in its forward basis offered for grain and provides shippers with two alternatives. Each export facility is restricted by the model in what it is capable of doing (i.e., loading and unloading capacities).

A base case was first evaluated in the model with parameters set according to current industry conditions; this provided an accurate representation of a grain firm. After the results were derived, 5 sensitivities were conducted on the base case. Key merchandising variables, such as futures prices and spot deliveries, and logistical variables, such as car ordering strategies and freight placements, were changed to analyze their affect on important sources of revenue and costs. Important sources of revenue were derived from grain sales, efficient loading/unloading, and carrier non-performance penalties. In addition, important costs were included such as demurrage, storage and the acquisition of freight.

## Summary of Results

A stochastic simulation model was analyzed to evaluate key relationships among merchandising and logistical variables. Key variables analyzed were all random and they included freight placements, transit times, farmer deliveries, and futures price spreads. The effect of these variables on net margins was extracted from the results to ultimately determine the optimal amount of grain to sell and optimal amount of grain to hedge.

A base case model was first simulated to create a benchmark for the analysis and to evaluate key merchandising and logistical variables equal to current industry norms. The key output derived by the model included annual net margin, freight orders, and the actual amount of grain sold and shipped in the pipeline. These criteria were evaluated for each of the 3 country elevator origins and then were aggregated across the 3 locations to summarize for the prototypical grain shipper. Then, several sensitivities were conducted on merchandising and logistical variables. Several results were identifiable from the base case and sensitivity analysis.

Base case results indicated the Shuttle-loader faced the greatest amount of risk associated with net margin because of its freight ordering strategy. This logistical strategy was comprised of 3 shuttle COTs that were fixed annually and ran continuously throughout the year; even if grain wasn't available, railcars still needed to be loaded. In addition, employing 3 shuttle COTs forced sales to be made based on freight placement at the elevator rather than favorable selling opportunities. Overall, the Shuttle-loader was committed to too many long-term shipping mechanisms. This limited the shipper's flexibility, forced sales to be made based on car placement rather than market conditions, and ultimately constrained the shipper's ability to effectively sell grain and efficiently order freight.

The Shuttle-loader's inefficient logistical strategy generated roughly $4.5 million in demurrage at the elevator level which accounted for 98% of the prototypical shipper's total elevator demurrage. Other base case results include the River-terminal generating the highest average net margin per bushel on account of being able to utilize the cheapest mode of transportation for the majority of its grain shipments.

A sensitivity was conducted to analyze how all 3 elevators performed under a full carry market and an inverted market. The River-terminal earned a higher net margin than the other 2 elevators while operating under both market extremes because it is able to adapt to market conditions more easily than the other two; it primarily ships barge which is the cheapest of the available transportation modes. The Shuttle-loader is committed to shuttle COTs which forces shipments in suboptimal shipping periods. Even though the Small-shipper isn't committed to shuttle COTs, it ships 24-car COTs which are the most expensive of any mode. Therefore, over-committing on shuttle COTs forced shipments in suboptimal periods whereas only utilizing short-term rail freight (i.e., 24-car COTs) is costly and less efficient. Barge transportation proved to be the most effective mode in extreme market conditions because they are cheaper than rail freight, have a lower demurrage cost, and typically are placed at a shipper's facility within 1 week after they are ordered; this provides shippers with flexibility in making timely grain sales and freight ordering decisions.

It was found when 100% of total farmer deliveries were made on the spot market, demurrage costs increased 19% for the Shuttle-loader and 29% for the River-terminal.

This positive relationship between percent of spot deliveries and demurrage exists because as the amount of uncertainty in grower deliveries increases, the chance that freight orders will either be underestimated or overestimated increases.

After sensitivities were conducted on the logistical strategy employed by each elevator, it was found the optimal freight ordering strategy for the River-terminal was to order barges only and no rail freight because it maximized net margin. This was expected because river facilities are mainly designed with focus of loading barges rather than loading shuttle-trains. Thus, their level of net margins increases when more barges are utilized to ship grain. The Shuttle-loader's optimal strategy was to order 1 shuttle COT because ordering more than one constrained the shipper's ability to make efficient logistical decisions. The Small-shipper's optimal freight ordering strategy was the same as the base case which included only ordering 24-car COTs. In total, the prototypical shipper's optimal freight ordering strategy is to utilize barges and 24-car COTs when necessary and to order 1 shuttle COT. In addition, the optimal amount of grain to sell is roughly 30 million bushels annually which generates about $33 million in net margin.

The sensitivity conducted on ocean vessel placement indicated that when vessels were placed at the end of the 10-day window, total vessel demurrage increased and total vessel despatch decreased for all 3 elevators. This occurred because railcars/barges would arrive toward the beginning of the 10-day window, dump their grain, and then the vessel would arrive a few days later. If not enough grain was available to fill the vessel, it would have to wait at the export facility for loaded railcars/barges to return in order to be filled. In addition to increasing the amount of vessel demurrage, it also decreased the amount of despatch earned by shippers because if they can't consistently meet their guaranteed load rate per week, they have a smaller chance of earning despatch.

The last sensitivity changed the distribution for 24-car COT placement to most likely occur on the $15^{th}$ day of the shipping period; however, there was still a chance that it could be placed after the $15^{th}$ day. This basically caused the BNSF's 24-car COT guarantee to be void and it increased the chance that the shipper would receive a carrier non-performance payment in return. As a result, the number of non-performance payments made to the Small-shipper significantly increased because 24-car COTs were rarely placed within the 15-day window. Overall, this sensitivity caused car placement to be more unreliable and it induced more risk for shippers.

In conclusion, annual net margin for each of the 3 country elevators was affected the most by the type of freight ordering strategy implemented and the current market conditions. The type of freight ordering strategy implemented by each elevator ultimately determines the overall sustainability of the firm; shipper's need to diversify the type of freight they commit to because ordering too much long-term freight can reduce flexibility and result in bad sales decisions whereas relying only on short-term freight is costly and inefficient.

Not being able to quickly adapt to volatile market conditions can result in making bad selling decisions and untimely freight purchases which can hinder the longevity of a firm. Also, it was found that as the level of uncertainty in farmer deliveries increases, the level of demurrage also increases. Finally, without guaranteed freight, car placement becomes unreliable and creates a lot of risk for grain shippers.

**Limitations of the Study**

The research conducted in this thesis served to analyze the merchandising and logistical decisions made by a prototypical grain shipper. It identified certain tradeoffs among different car ordering strategies and merchandising strategies available to grain shippers. In addition, this thesis captured the relationships among random freight placements, uncertain transit times, farmer deliveries, changing basis/futures spreads, and annual net margins. However, certain limitations restricted the capabilities of this research.

The greatest limitation to the study was the limited availability of data. Data on rail performance standards and historic car premiums/discounts were either non-existent or very limited. To compensate for this, the current car premiums/discounts from the secondary rail market were obtained, and performance measures covering only a 3-week span had to be used. In addition, historic forward soybean basis bids were only available for 5 months of the year. Therefore, a lognormal distribution was created around these 5 months to generate random basis levels for the entire year.

Another limitation involved a lack of the secondary market for barges and rail mechanisms. In addition to this, none of the 3 country elevators in the model were allowed to cancel a freight order because of a lack of grain. Rather, the shipper incurred demurrage until the freight was loaded and shipped. In practice, shippers can anticipate when they will be short of grain and rather than incurring demurrage, will most likely sell their freight on the secondary market. If they can't sell it on the secondary market, they will cancel the upcoming trip as a last resort.

## Need for Further Research

Further research on the analysis of logistical and merchandising decisions made by grain shippers may be conducted. For instance, the prototypical shipper in this thesis could be expanded to include more elevator origins, and then Distribution Requirements Planning (DRP) could be used to aggregate the freight requirements across the entire firm. In addition, a secondary market for the shipper to buy and sell freight could be introduced to more accurately represent current industry norms.

The research could also be expanded to include multiple commodities that are handled by the shipper. Also, a different Class I Railroad could be incorporated into the analysis. This would evaluate how alternative forward rail mechanisms affect a grain shipper's decisions and profitability in the supply chain.

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