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Logistics and Supply Chain Strategies in Grain Exporting

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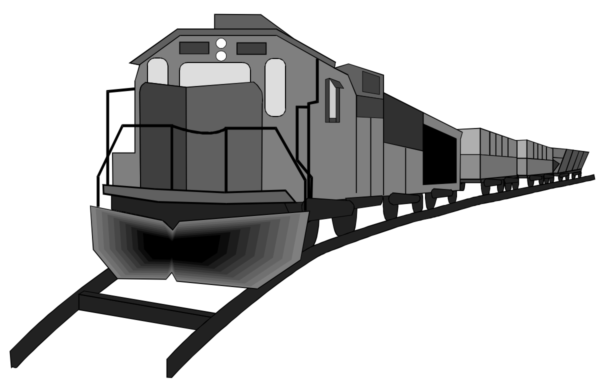

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ABSTRACT

During the past decade, the grain shipping industry has become highly competitive and technologically advanced. These changes, along with the introduction of innovative shipping mechanisms, have made logistics management an important source of opportunity and risk for grain shippers. In this study, a stochastic simulation model was developed to evaluate the tradeoffs and effects of key variables on logistical performance in managing the grain supply chain. Average demurrage cost for the supply chain was $2.03 million with the greatest cost being for railcars and the least cost being for barges. Of the stochastic variables modeled, changes in export demand had the greatest impact on demurrage costs.

Key Words: Supply Chain, Grain Shipping, Logistics, Demurrage, Guaranteed Freight

HIGHLIGHTS

During the past decade, the grain shipping industry has become highly competitive and technologically advanced. These changes, along with the introduction of new shipping mechanisms, have made logistics management an important source of opportunity and risk for grain shippers.

Compounding difficulties in managing domestic and international grain logistics is the number of uncertainties confronting grain shippers. Uncertainties exist throughout this system for various reasons. Supply uncertainties ultimately stem from the dependence of production on environmental factors (weather, disease, pests, etc.) and the seasonality of production and marketing. Placement and transit times for the various transportation modes depend on scheduling, equipment problems, weather, and time required to load and unload. Vessel demurrage depends on the need for the grain and the negotiating skills of the shipper and the transportation provider. Each uncertainty has unique characteristics and makes management of the pipeline more challenging for shippers.

The objective of this study was to develop a model to evaluate tradeoffs and effects of key variables on logistical performance in managing the grain supply chain. Specific objectives were: 1) to develop a model of the grain supply chain containing stochastic variables capturing the uncertainties grain shippers manage; 2) to evaluate the effects of strategic and policy variables on the efficiency of the supply chain; and 3) to analyze the effects of various variables and strategies on demurrage costs.

A model was developed to analyze logistical strategies applied to a typical grain supply chain. Demurrage costs are evaluated for each mode of transportation at each facility. In the base case, average demurrage charges for the supply chain were $2.03 million per year. Barge demurrage costs account for $1.54 million or 76.3% of the average demurrage.

Simulations on stochastic variables indicate changes in export demand cause the greatest disruptions to the supply chain and increase demurrage costs the most. Increasing the amount of grain exported by 10% increased average demurrage costs three-fold to $6.17 million per year. Uncertainty in railcar placement is critical to shippers and affects ordering strategies. Decreasing this uncertainty leads to more reliable placement times and vice versa. Demurrage costs increase as standard deviations for placement times increase. Doubling COT, SWAP, and general tariff car placement standard deviations increased vessel demurrage 47%. Increasing the window for vessel arrival times, from two weeks in the base case to four weeks, increased vessel demurrage by 25%.

Sensitivity analysis was performed on strategic variables, including freight ordering, guaranteed rail freight strategies, rail want dates, and export unload priority. Freight ordering is based on a forecast of export demand a number of weeks in the future. Sensitivities indicate demurrage costs are the lowest when freight ordering decisions are made 6 weeks forward. In the base case, the demand forecast error was assumed to be nil. A 15% forecast error caused a 42.5% increase in total demurrage. Inland barge demurrage and vessel demurrage contributed the most to the increases.

Combinations of COT and SWAP unit trains were run to determine an ordering strategy for shippers. Results indicate that 3 COT and 6 SWAP trains in the first half and last half of each month accrue the lowest average demurrage costs. Shippers specify want dates for railcar placements. They can use a “naive” or an “anticipatory” strategy for specifying a want date. Anticipatory strategies take into consideration past railroad performance, while naive strategies have shippers specifying a want date to coincide with the day equipment is needed. Optimal want dates were a combination of the want date and car placement distribution for the type of railcar in question. Results indicated optimal want dates with current railcar performance of the first day of delivery period (day 0) for general tariff and day 2 of the delivery period for COTs and SWAPs.

Several innovations, such as demurrage/despatch and guaranteed rail freight are becoming more sophisticated in defining grain flows through a supply chain. The model demonstrates relationships between key stochastic, strategic, and policy variables in the supply chain. It also identifies their effects on demurrage costs. With the advent of changing demurrage/despatch policies and offerings of guaranteed rail freight, shippers have more options and considerations when shipping grain. Demurrage costs increase as transportation providers tighten allowances contained in demurrage policies. Further, shippers must carefully monitor carrier service reliability when making shipping decisions. Changes in service levels can increase demurrage costs for shippers.

Defining mechanisms to induce a smooth flow of grain through the pipeline has implications for carriers. Transportation reliability improves shippers’ ability to manage the supply chain. This is demonstrated by the reduced demurrage costs with smaller standard deviations. Poor service reliability leads shippers to choose alternate modes of transportation. Shippers must continue to balance the penalties and premiums to encourage efficient shipments.

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William W. Wilson, Donald C. E. Carlson, and Bruce L. Dahl[*]

INTRODUCTION

During the past decade, the grain shipping industry has become highly competitive and technologically advanced. These changes, along with the introduction of new shipping mechanisms, have made logistics management an important source of opportunity and risk for grain shippers. Throughout the industry, logistics management has become known as *managing the pipeline* which involves all functions, from originating grain at the producer level to selling grain to end users. Taken together, these activities could be referred to as supply chain management using a recently popular managerial concept.[1]

Compounding difficulties in managing domestic and international grain logistics, are the number of uncertainties confronting grain shippers. Yearly supplies of grain commodities are unknown in advance of harvest and deliveries into the system within the year are highly variable. Shippers face a number of logistical uncertainties. Timing of railcar and barge placements are uncertain, as are transit times. In the case of vessel shipments, demurrage penalties are uncertain until they are negotiated. Also, modal arrivals are designated in a window specified in days, rather than on a specific date. Finally, demand and timing of prospective sales is uncertain.

Uncertainties exist throughout the pipeline for various reasons. Supply uncertainties ultimately stem from the biological nature and dependence of production on weather, as well as producer storage decisions. Placement and transit times for the various transportation modes depend on scheduling, equipment problems, weather, loading times, and unloading times. Vessel demurrage depend on shipping costs and the negotiating skills of the shipper and the transportation provider. Each uncertainty has unique characteristics and makes management of the pipeline more challenging for shippers.

The objective of this study was to develop a model to evaluate the tradeoffs and effects of key variables on logistical performance in managing the grain supply chain. Specific objectives were: 1) to develop a model of the grain supply chain containing stochastic variables capturing the uncertainties grain shippers manage; 2) to evaluate the effects of strategic and policy variables on the efficiency of the supply chain; and 3) to analyze the effects of various variables and strategies on demurrage costs.

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[1] See Davis; Ballou; Billington and Lee, 1992 and 1995; and Thayer for recent discussion of supply chain management.

LOGISTICS STRATEGIES AND SHIPPING MECHANISMS IN GRAIN MERCHANDISING

Grain traders make decisions on logistical components of the supply chain ranging from the type of freight to purchase to how much grain should be sold relative to the type of freight purchased. Logistical strategies continue to evolve and guaranteed freight and demurrage/ despatch are a part of this evolution.

Logistical Strategies

Grain traders develop logistical strategies to manage uncertainties while coordinating the flow of grain through the supply chain. Logistical strategies aim to accomplish getting "the right goods or services to the right place, at the right time, and in the desired condition, while making the greatest contribution to the firm" (Ballou). Ballou indicates logistics strategies have three purposes: 1) cost reduction, 2) capital reduction, and 3) customer service improvement.

Customer service is important because it has a direct impact on revenues. Traditionally, customer service is defined by order fill rates, order cycle times, and other measurements (Ballou, p.105). Grain supply chains have lead and transit time uncertainty. In an attempt to improve service, the industry introduced demurrage and guaranteed freight mechanisms which provide incentives for delivering improved service.

Supply chain problems are a driving force in the development of logistical strategies. Common characteristics embedded with supply chains include bottlenecks, safety stocks, and the bullwhip effect. Grain industry bottlenecks occur in facilities which handle high volumes of grain in short time periods. Safety stocks or inventories held at various points in the supply chain are a strategy to offset the large numbers of uncertainties in the grain supply chain. The bullwhip effect is a distortion in ordering as the supply chain moves further from the customer.[2]

Logistical strategies include both short and long term commitments. Examples of long term strategies include location and configuration of storage facilities and physical ownership of equipment. Shorter term strategies involve the rate of sales relative to expected capacity, transportation selection, as well as mechanism selection within the rail mode, timing of modal orders, and timing of grain shipments. These strategies determine how smoothly grain flows through the supply chain under different conditions. Logistical strategies should be developed taking uncertainties into consideration. Two prominent policies in grain transportation include guaranteed freight and demurrage/despatch. These policies have a profound effect on the logistical strategies of grain industry players.

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[2] Billington and Lee 1992; Lee, Padmanabhan, and Whang 1997; and Powell and Pyke 1996, address these concepts.

Guaranteed Freight Mechanisms

Guaranteed freight allows shippers to reduce uncertainties associated with grain transportation. There are two main benefits to shippers. First, guaranteed freight allows for reduced stocks or inventories at different nodes in the pipeline, thus reducing the carrying costs of inventory. Second, it improves the shippers' ability to make shipping and sales decisions based on current market conditions about freight availability.

Various forms of guaranteed freight have been introduced to increase the efficiency of car allocation. These have provided grain shippers with more options for managing the supply chain. Guaranteed freight offers short and long term strategies for grain shippers. Short term guarantees allow shippers to pay a premium for guaranteed rail service. Long term guarantees allow shippers to purchase transportation equipment and lease it to the railroad in exchange for a guaranteed number of monthly loadings. Each type has service reliability /cost tradeoffs that affect shipping decisions.[3]

Demurrage and Despatch

Equipment sitting idle while waiting to load and unload incurs high opportunity costs for carriers. For this reason, carriers use demurrage and despatch policies which comprise a system of rewards and penalties to encourage desirable behavior by grain shippers. Demurrage and despatch policies vary across modes and are important elements affecting a grain supply chain. These policies can affect transportation mode selection, timing of transportation, ordering, and shipments, as well as storage.

Demurrage is a monetary penalty imposed on a shipper for holding a carrier's equipment longer than agreed. These penalties occur while either loading or unloading the carrier's equipment. The penalty serves three purposes. It compensates carriers for the lost revenue incurred from not being able to use their equipment. Second, it encourages shippers to move grain in a timely fashion, which reduces the need for carriers to make additional capital intensive investments in equipment. Third, it punishes shippers for not meeting the provisions of their shipping contracts. Demurrage penalties make the grain supply chain more efficient (Cavinato, Langley, and Tyworth, p.302). Despatch is an incentive for grain shippers to load transport equipment in shorter than allowed time periods. It originated with ocean vessels and is diffusing throughout the industry.

Demurrage penalties affect a number of decisions in grain shipping. Mode selection and export selling arrangements are two examples. Depending on the cost per day of demurrage and the uncertainty about the timing of demand, different modes may be chosen for transport to reduce demurrage costs or shipping times. It originated in ocean shipping when shipowners imposed penalties on shippers who failed to meet provisions outlined in shipper contracts for the use of a vessel.

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[3] See Wilson, Priewe, and Dahl for a detailed presentation of each mechanism.

Railroad Demurrage. Rail demurrage received increased attention during 1997 as the grain industry attempted to move two crops simultaneously. Car shortages plagued both industries as rail carriers examined ways to improve car turnaround times to alleviate the problem. Changes in Class I carriers' demurrage policies became a critical component of controlling the problem. The Burlington Northern and Santa Fee (BNSF) railroad implemented a revised policy from October 1997 until March 1998 to address the issues.[4] An evolution of rail demurrage is discussed in this section.

Regulation of railroads by the Interstate Commerce Commission (ICC) prior to the 1980's was the basis for a uniform demurrage policy across the industry. Government regulation had further implications during periods of war and national emergencies. These events warranted aggressive demurrage charges, which were used to alleviate car shortages. An example would be when typical demurrage charges of $5 to $15 per car per day in the 1960's increased to $25 to $50 per car per day after a car shortage announcement. Shortly after charges returned to previous levels, the railroad was allowed to raise charges to $10, $20, or $30 per day depending on the number of days the shipper was in default (Tolliver).

The uniform rail demurrage policy allowed shippers one day for loading and two days for unloading cars. Time allowances were known as "free days." Loading was considered completed when the shipper billed the cars by notifying the railroad of a railcar's destination. Unloading was completed when the shipper notified the railroad that the cars could be picked up. Equipment held longer than the time allowed incurred demurrage charges.

The official time start for demurrage charges was 7:00 a.m. Any cars not billed or empty at this time were charged demurrage provided that cars had been placed correctly and the shipper was notified of the placement. Weekends and holidays were exempt from demurrage charges unless they occurred after the second chargeable demurrage day (Cavinato, Langley, and Tyworth).

Shippers had the option of participating in an agreement averaging demurrage costs. Shippers earned credits or debits for releasing cars before or after their allocated free time. Debits represented one day of demurrage and were charged to shippers for each day after free time was depleted. One credit could be earned by releasing a car early. Credits and debits offset each other at the end of a shipping month. Whenever debits were greater than credits, shippers paid demurrage penalties.

Shippers could seek relief from demurrage charges due to extenuating circumstances over which they did not have control. Examples included strike interference, bunching, run around, weather interference, and railroad error. Bunching is when a shipper receives all of his orders at one time, even though the orders were spread out over time. Run around is similar to bunching in that the railroad would place recent orders before placing cars previously ordered.

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[4] Details for specific carriers' demurrage/dispatch policies are located in Appendix A. Further, the BNSF has proposed changes in their policy during the peak harvest season which would reduce times allotted for loading and unloading and increased daily demurrage costs (*Grain Journal*, Sept/Oct 2000, pp. 199-201).

Since deregulation in 1980, railroads have established individual demurrage policies. The terms of these policies have changed over the years, but most of the policies are similar to the basic demurrage plan established by the ICC. However, a trend toward fewer exempted and free days is apparent.

Barge Demurrage. The National Grain and Feed Association (NGFA) publishes barge freight trading rules. These rules are applicable to active and allied NGFA members concerning barge freight markets. They are general guidelines and are only enforced in so far as the parties involved have not altered the provisions contained in them. Buyers and sellers in this manner can establish their own provisions when trading barge freight. Key provisions contained in the NGFA's rules affecting barge demurrage include contract placements, barge placements, barge release instructions, and trade definitions.

Contract provisions for placement periods are designated as weekly, semi-monthly, and monthly. Placement periods begin at 00:01 hours Central Time the first day of a contract placement period. Periods designated as weekly begin on Sunday, semi-monthly periods begin on the first and sixteenth of the month, and monthly periods begin on the first day of the month.

Before placement, it is the duty of the buyer to notify the seller with instructions to place the barge at a facility in a given port. Actual placement occurs when the buyer's instructions have been met and the barge is physically placed. Constructive placement occurs when the seller is unable to physically place the barge at the buyer's facility so the barge is held at a location near the buyer's facility. Placement for loading or unloading begins at 7:00 a.m. Central Time the first day the seller notifies the buyer by telephone before 11:00 a.m. Central Time. The seller must also follow up with a written statement before the end of the next business day. Barges that are deemed unfit for loading are not considered placed. Provisions for releasing barges after loading and unloading are identical.

Demurrage charges are calculated on a daily basis in accordance with the provisions for placing and releasing barges. Barge contracts specify free time for the buyer to load and unload barges without incurring demurrage charges. Legal holidays including New Year's Day, Memorial Day, Independence Day, Labor Day, Veteran's Day, Thanksgiving Day, and Christmas Day are exempt from demurrage charges and do not count as free days. When free days are exhausted the buyer must pay demurrage based on a scale. The charges begin at 7:00 a.m. the day after free days expire. Demurrage charges on barges are $100 per day for the first 10 days, $150 per day for the next 10 days, and $250 per day for any additional days the barge is held. Therefore, total charges on a barge released 22 days after free time has expired would be $3,000.

Ocean Vessel Demurrage. Contracts between the exporter and importer and how the importer decides to purchase the grain dictate responsibility when grain is shipped. There are three conventional ways in which importers purchase grain for export. They include free on board (FOB), cost and freight (C&F), and cost insurance and freight (CIF). An FOB purchase indicates that the buyer takes ownership of the grain as it is loaded into the vessel. The buyer is responsible for securing the ocean vessel and insuring the cargo during the voyage. When grain is purchased C&F or CIF, the seller is responsible for delivering the grain to a buyer's destination. Sellers must provide the grain and the ocean vessel for transport. Ownership of the grain is transferred from the seller to the buyer when the bills of lading are exchanged. Therefore, the buyer owns the grain aboard the vessel. However, the seller controls the vessel, making disagreements more likely.

Regardless of the type of purchase contract, there are several negotiable terms the ocean vessel charterer must consider. Vessel size is important as charters indicate tolerances for cargo weight and dead weight. Payment is a fixed dollar amount per metric ton so underloading a vessel can result in dead weight penalties. Laydays define the window during which the vessel must be placed for loading. FOB contracts generally give the buyer a 15- to 30-day window to place the vessel they are responsible for chartering. Vessel charters have the option to cancel vessels not placed by the end of the last allowed layday. The number of loading and unloading facilities at which the ocean vessel must dock can change cargo rates. Premiums are accessed when vessels must load or unload at more than one port.

Demurrage penalties in the ocean vessel industry are based on laytime and guaranteed load rates. Laytime represents the "free time" during which no demurrage penalties are assessed. A guaranteed load rate is when sellers agree to deliver a specified number of long tons per a 24-hour weather working day. For example, a 5,000 mt guaranteed load rate for a 25,000 mt vessel would allow a shipper five free days to load a vessel. Sundays, Saturdays, and holidays are excluded as free days. However, Saturdays can be included if a rider is attached to the contract.

In the event that the vessel is not loaded or unloaded in the laytime allowed, demurrage is paid to the vessel owner. Demurrage charges are negotiable and range from the daily value of the vessel to the value of the vessel plus a penalty. In this way, penalties are based on the ocean vessel market. In July 1998 demurrage charges were approximately $7,000 to $10,000 per day for vessels with 60,000 to 80,000 mt capacity. Two years earlier, charges were $24,000 per day on an equivalent ocean vessel (Rudge). Incentives to load and unload vessels in less than the time allowed are called despatch payments. These payments are usually half the demurrage penalty.

Demurrage responsibilities are expressed in the contracts. Demurrage at the loading port is the responsibility of the seller. The only way for the buyer to be responsible for demurrage is if the grain is purchased FOB and the contract with the ocean vessel owner specifies fewer loading days than the contract the buyer has with the seller. For example, assume the loading rate and cargo size allow the seller five days to load the vessel, but the buyer charters a vessel for three days loading. If the loading is completed in five days the buyer is responsible for paying demurrage penalties for two days. The receiver or buyer is responsible for the demurrage once the grain is delivered to the destination.

A representative comparison of the demurrage rules across modes is made in Table 1. Results suggest that the highest demurrage generally is applied to railcars followed by ocean vessels and barges.

Table 1. Modal Comparison of Demurrage Policies

	Free Days			Demurrage Rates*	
Mode	**Loading**	**Unloading**	**Exemptions**	**$/unit**	**¢/bu/day**
Truck	Unspecified	Unspecified			
Railroad					
BNSF	2	2	Sundays and 12 Holidays	$50/car/day	1.5
CP	2		Sundays and 8 Holidays	$60/car/day	1.8
UP	1	2		$50/car/day	1.5
Barge	Specified in Contract		Legal Holidays	$100/day for day 1-10 $150/day for days 11-20 $250/day for beyond	.18 .27 .46
Ocean Vessel	Specified in Contract			$7-10,000/day	.36

* Derived for comparison using common units (using 3,300 bu/railcar, 55,000 bu/barge, and 50,000 mt/ocean vessel).

STOCHASTIC SIMULATION MODEL OF A GRAIN SUPPLY CHAIN

The classic logistics tradeoff is between customer service and inventory levels. Increased inventory ties up capital and is an operating cost, while higher levels of customer service create additional revenue and increase customer satisfaction for an organization. As inventory levels increase so does operating cost. Increased inventories also lead to higher fill rates and an improvement in customer service. Business organizations must evaluate at what point increases in inventory are costing more than the additional revenue obtained from higher levels of customer service (Ballou, p. 41).

Uncertainty is a key issue in managing grain supply chains as well (Davis). Supply chain management relies on accurate planning and coordination among stages in the production and distribution of products. Questions regarding quantities and timing of shipments between facilities and mode must all be considered. Due to the trade-offs between stages of the supply chain, emphasis is placed on the importance of taking a systems approach to supply chain modeling. These models have become known as scheduling models and are sometimes referred to as Materials Requirements Planning (MRP) from supply chain management.[5]

Model Logic and Specification

The model developed in this paper consists of an inland river terminal connected by rail and barge transportation to an export terminal at the U.S. Gulf. The logistical system is typical of a vertically integrated firm buying corn in the Upper Mississippi River area and exporting it through the U.S. Gulf. The model was parameterized to represent this individual firm. Grain is originated at an inland terminal based on demand. The terminal loads barges and unit trains needed to ship grain to the export facility. Shipping decisions are based on export demand (sales) which pulls grain through the supply chain. Export demand is 10% of the USDA's weekly corn export inspections since 1996, approximately the share of the individual exporter. Export demand in each shipping period is determined represented by a distribution estimated from USDA weekly corn inspection numbers. Due to its' importance to system demand, sensitivities are analyzed.

Export demand determines transhipping needs from each facility. Railcars and barges are ordered for placement at the inland terminal subject to two constraints. First, barges have priority loading at the inland terminal. Second, freight orders cannot exceed load out capacities. Shippers choose the quantity of guaranteed freight to use and the remainder is purchased from the general tariff fleet. Railcar placements are determined by distributions estimated from BNSF performance data and shipper want dates. Shippers specify a want date within a shipping window determined by the type of rail freight purchased. Sensitivities are performed on both the want dates and railroad placement data. Barges are placed according to a distribution obtained from industry participants.

Transit time is defined as the time from when grain is shipped from the inland terminal until the grain is in position to unload at the export facility. Again, a distribution is used to reflect the uncertainty surrounding transit times. Grain arriving by rail and barge is unloaded and stored at the export facility. Export facilities load ocean vessels from inventory or can load directly from rail or barges arriving when inventories are low. Vessels arrive in a shipping window designated by the seller in accordance with the terms of a CIF contract. A probability distribution is used to reflect uncertainty in vessel arrivals.

Demurrage is incurred at each point in the supply chain where freight is held longer than prescribed by the carrier. Equipment held an additional week has demurrage charges applied for the full week. Any equipment with demurrage applied against it is first in line for loading or unloading in the next shipping period.

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[5] Examples of these types of models include just-in-time (JIT), materials requirements planning (MRP), and distribution requirements planning (DRP) (Ballou). Of these, DRP is an extension of MRP applied throughout the distribution channel from suppliers to customers. Bookbinder and Sereda have applied DRP methods to managing railcar inventories.

The model is of the logistical system, including most of the major functions with a focus on sales, inventories, and grain unloads at port terminals. The model is specified and evaluated using stochastic simulation (Palisade Corporation 1994). A base case was formulated representing the marketing characteristics of a typical year. This was used to calibrate the model, demonstrate results, and conduct sensitivities. The cost function is described below, and subsequent sections describe specific treatment of each variable.

The mathematical specification of the model includes the logistical costs associated with movements from the interior to export. Costs are defined to include the shipping costs (barge and rail which include premiums for railcars under different shipping mechanisms), as well as costs associated with demurrage and interest. Total costs is defined as:

$$C = \sum_{t=1}^{n} RT \cdot QR_t + RC \cdot QC_t + BR \cdot QB_t + Dem_T \cdot QTL_t + Dem_E \cdot QEL_t + Dem_B \cdot QBL_t + Dem_V \cdot QVL_t + Int_R \cdot Inv_t$$

where C is total cost, RT is rail tariff, QR_t is the quantity of railcars arriving in week t, RC is COT premiums, QC_t is the quantity of COT cars arriving in week t, BR is barge rate, QB_t is the quantity of barges arriving in week t, Dem_T is the rail demurrage rate at the terminal elevator, QTL_t is the number of trains delayed at the terminal elevator, Dem_E is the rail demurrage rate at the export elevator, QEL_t is the number of trains delayed at the export elevator, Dem_B is the demurrage rate for barges, QBL_t is the quantity of barges delayed at terminal and export locations, Dem_V is the demurrage rate for vessels, DVL_t is the quantity of vessels delayed at export terminal, Int_R is the interest rate on short term capital, and Invt is the value of grain stocks in the marketing channel which includes inventory at terminal and export locations and grain in transit in week t. All of these costs are simulated over an n period shipping season taken and reported here as 52 weeks (1 year).[6]

Model Set-up

Inland terminals are an intermediate step for grain shippers in an export supply chain. Three key logistical functions are performed at the facility. Grain is stored and positioned for movement as producers, country elevators, and brokers deliver grain. Second, decisions concerning freight options are evaluated and executed by shippers. Third, shipments are loaded for movement to export facilities depending on demand for grain, availability of freight, inventories, and facility capacities.

[6] It is assumed for this study that the inland terminal has the option to ship by barge year-round and the river is not closed. Location of inland terminal on the Upper Mississippi would normally require closing of the river during winter months.

The model's inland terminal is located on the Upper-Mississippi River system with 12 million bushel storage capacity and in the base case has a beginning inventory of 1 million bushels (inventories are low due to pre-harvest conditions). Load out capacities are 7 unit trains and 40 barges per week. Industry participants supplied facility and load out capacities for the region (Konsor and Olson).

Demand for grain being shipped is pulled through the system using MRP methodology. Shippers make forward shipping decisions on supply chain performance levels. Demand at the inland terminal is demand four weeks forward at the export facility in the base case. Unloads at the inland terminal are a function of forward export demand. In the base case, unloads are assumed to be a normal distribution function with a mean equal to forward demand and a standard deviation of zero. Once sales are made, the inland terminal buys enough grain to meet export sales by bidding the basis to open the pipeline.

Grain shipments occur each week as the model evaluates beginning inventories, unloads, freight availability, and facility capacities. Inventories and unloads are evaluated first to determine grain availability for shipment that week. Next, the model evaluates freight availability by determining the number of unit trains and barges placed for loading by their respective companies. Unit trains receive loading priority over barges due to shorter transit times and higher demurrage costs per bushel. Provided there is enough grain available, any combination of up to 7 unit trains and 40 barges can be loaded as long as a barge is never loaded when there is a unit train available for loading and less than 7 unit trains have previously been loaded.

Shippers first determine how many weeks of export demand forward they want to base their equipment ordering decisions. Quantities and combinations of guaranteed freight to meet shipping needs are also specified. These are purchased as combinations of SWAP and COT cars for delivery in two-week windows. It is assumed shippers are consistent with their ordering strategies over the course of the shipping year (same order each month for COTs and SWAPs).

Transportation ordering is based on information from the inland elevator terminal and strategic variables entered above. First, the model evaluates export demand as many weeks forward as specified. It then orders enough barges to meet demand, but not to exceed load out capacity at the inland elevator. Any demand not filled by barge orders becomes a residual demand to be shipped by rail. The model calculates how many unit trains are needed. Next the model compares the number of unit trains calculated to previously bought guaranteed unit trains. The model then orders general tariff cars equivalent to rail demand or load out capacity for the week, depending on which is greater.

Rail cars and barges arrive at the inland facility based on placement lead times and want dates. Barge transportation is purchased one week forward of the want date and has a 90% chance of being placed that week (Konsor and Gross). All barges are placed on the first day of the week. Rail placements vary for guaranteed and non-guaranteed freight. Rail want days are important strategy variables for grain shippers. Want dates combined with the different car placement distributions have profound effects on supply chain demurrage charges.

Shippers are modeled to choose either an "anticipatory" or "naive" strategy in defining unit train want dates. Anticipatory strategies anticipate the past railroad performance (in placing cars on want dates) and adjust the new want dates based on this information. Naive strategies ignore past performance. Having want dates staggered for COTs, SWAPs, and general tariff cars may be naive if the distributions indicate arrival dates in the same shipping week. Once transportation arrives at the inland terminal, that module evaluates when the grain is shipped from the facility. Transit times were obtained from industry participants. Grain arriving at the export elevator is physically unloaded by the export facility module.

Vessel arrivals have 15-day placement windows. Arrivals are random based on a binomial distribution. The export facility has storage capacities and load out capabilities equal to industry averages for export elevators in the Gulf region: storage capacity is 130,295 mt and load out capacity is 20,832 mt/day. Assuming a five-day work week, weekly vessel loading capacity is 104,160 mt in the model. Export facility unloading capacities in the base case are assumed to be equal to the load out capacities (Gibson).

Beginning inventories at the export facility are set at 50,000 mt. Export facilities generally maintain some minimum level of safety stock to handle blending problems and supply chain disruptions. Furthermore, the model has grain flowing through the pipeline when the export year begins. Barges and unit trains are being loaded and shipped in the weeks prior to the start of the shipping year. This allows the pipeline to be "full" or have grain in transit from the inland elevator to the export facility based on the stochastic variables. Therefore, depending on the ordering strategies, transportation placements, and transit times, beginning inventory can vary as the shipping year begins.

Unloading of barges and unit trains occurs after arriving at the export facility. Two important distinctions are needed for the model to evaluate what and when railcars and barges are unloaded. First, shippers determine whether barges or unit trains have unloading priority at the facility. Next, available unloading space is derived by subtracting beginning inventories from storage capacity and adding vessels available for loading. Vessel space in port is added because grain is being unloaded as the vessels are being loaded and because some facilities have the capability to direct load vessels from unit trains and barges. Once the model has unloaded the correct number of unit trains, it goes through the same logic for barges. In both cases, a barge or unit train held an additional week would incur demurrage charges.

As grain is being unloaded at the export facility, vessels are arriving in accordance with export sales for grain shipments. Grain shipments are determined by the supply of grain at the facility, the vessels available for loading, and the facility's load out capacity. Grain supply is beginning inventory plus unloads for the shipping period. Vessels available for loading include vessel arrivals and any vessel held over from previous shipping periods. Grain is loaded provided grain supplies are in excess of vessel availability and facility load out capacity is not exceeded. Vessels available and not loaded are held over until the next shipping period when they are considered available to load again. Equipment held over to the next shipping period incurs demurrage.

Stochastic Variables

Stochastic variables affect the logistical uncertainty inherent in the grain supply chain. In this model these include placement, transit times, export demand, and vessel arrivals. Uncertainty arises from grain shipper's dependence on transportation providers and weather occurrences. Compounding the problem is the dependence of each supply chain module on other modules. Shippers order transportation for specified shipping periods in coordination with grain sales. For railcars, shippers are allowed to specify a want date within a shipping period. Data for the model's rail service performance was provided by the BNSF railroad for COT, SWAP, and general tariff cars from August 20, 1998 to October 22, 1998. *BestFit* is used to fit the data into statistical distributions (Palisade Corporation 1997).

Each mechanism for purchasing rail freight is fitted with a different distribution. The statistical distribution for each is shown in Table 2. The data indicates the number of days cars are placed from the want date specified by shippers. COT car placements were represented with a Pearson 6 distribution with a mean of 7.59 days and a standard deviation of 1.98 days. This can be interpreted as cars are placed on average 7.59 days after the shipper-specified want date. SWAP car placements fit a Weibull distribution with a mean of 7.53 days and a standard deviation of 0.99 days. General tariff car placements have a gamma distribution with a mean of 13.24 days and a standard deviation of 4.57 days.

Barges are purchased for placement in weekly time periods. Barges can be placed any time within the purchase week. Industry participants estimate barges are placed during the purchase week 90% of the time (Konsor and Gross). For this reason, a discrete distribution was used with a 90% chance of placement in the purchase week and a 10% chance of placement in the following week.

Vessel shipping windows are based on the terms of grain sales.[7] A binomial distribution with a 50% chance of vessels arriving each period calculates arrivals in the first week. Second week arrivals equal total sales for the time period minus first week arrivals.

Grain transit times are defined from the completion of loading to arrival at the prescribed location. Data were unavailable for rail movements so a uniform discrete distribution was used with an equally likely chance unit trains would arrive in one, two, or three weeks from loading. Cycle times are available for the short term for BNSF and were used as a guide in selecting the distribution. Due to the importance of transit time, sensitivities were run on the distribution.

[7] FOB contracts require the buyer to provide transportation and usually offer a 30-day shipping window, while CIF contracts require the seller to provide transportation and offer 15-day shipping windows. U.S. grain is mostly exported in a 2-week shipping window.

Table 2. Stochastic Variable Distributions

Stochastic Variable	Distribution	Parameters
General Tariff Placement	Gamma	(8.38, 1.58) with a mean of 13.24 days late and a Std of 1.98 days
COT Placement	Pearson 6	(9.15, 7.95) with a mean of 7.59 days late and a Std of 1.98 days
SWAP Placement	Weibull	(280, 17.61, 0.45) with a mean of 7.53 days late and a Std of 0.99 days
Barge Placement	Discrete	90% arrive in 1 week and 10% in week 2
Rail Transit Time	Uniform Discrete	Unit trains have an equally likely chance of arriving in 1, 2, or 3 weeks
Barge Transit Time	Discrete	5% arrive in week 3, 70% in week 4, 20% in week 5, and 5% in week 6
Vessel Arrivals	Binomial	Ships arrive in 2-week windows with a 50% chance in each week
Export Demand	Normal	Normally distributed with a mean of 23 million bu. and Std of 6.2 million bu.

Barge transit times are considerably longer than rail. Industry participants estimate 70% of barges arrive four weeks from departure. Seldom do they arrive before the beginning of week 3 or after week 5. A discrete distribution with probabilities of 5%, 70%, 20%, and 5% for arrivals in the third, fourth, fifth, and sixth weeks from loading is used in the model.

This model represents corn exports out of the U.S. Gulf region. Weekly USDA export inspections data for corn was used from 1996 until October of 1998 to represent Gulf corn demand. Using *BestFit*, a normal distribution with a mean of 24.3 million bushels and a standard deviation of 6.5 million bushels was estimated. Because of storage and load out capacities of Gulf elevator facilities, it is estimated an elevator can handle 10% of the corn export activity in a base case model.

In the base case model, export demand is assumed known with certainty. This number is probably a best guess or forecast of future export demand. In the sensitivities, actual demand is replaced by a normal distribution with a mean and standard deviation equal to the mean of export demand multiplied by the forecast error. Forecast errors are varied as a percentage difference from the mean.

Despatch is a premium paid to shippers for loading vessels in a shorter time period than agreed upon in the grain sale contract. It is not included in the base case model due to a lack of data on volume affected. Sensitivities are performed using a binomial distribution to demonstrate how despatch premiums affect overall demurrage costs in the grain supply chain.

Strategic Variables

Strategic decisions for grain shippers are when, what, and how to ship grain, as well as how much to sell, relative to capacity. These decisions are heavily impacted by the stochastic variables and demurrage penalty structures of the grain supply chain. Base case values and constraints for each of these strategic variables are shown in Table 3. Grain sales are made for "spot" and future shipping periods. Coordinating freight with sales and anticipated demand is a concern for grain shippers. This model allows grain shippers to base freight decisions off export demand 3, 4, 5, 6, or 7 weeks forward according to market information.

Mode selection is limited in the model to rail and barge from the inland river terminal and vessel from the export facility. Barge is given preference to rail when longer lead times are available due to cost considerations.[8] Preference is given to rail when shorter lead times are required due to transit time considerations. Rail shipments arrive in 1 to 3 weeks verses barge destination arrivals of 3 to 6 weeks.

Rail freight options include short and long term guaranteed cars and general tariff cars. Shippers choose a combination of COT and SWAP cars and ship the remainder using general tariff cars. Sensitivities are performed on COT and SWAP combinations to demonstrate the tradeoffs between demurrage charges in the supply chain.

Regardless of the type of railcars purchased or the window they are purchased in, shippers specify want dates for car placements. These depend on the terms of a sale and market knowledge. However, an important consideration is past rail performance. In the base case, shippers want cars to arrive in the middle of each shipping period and account for expected rail late placement. Because of late placements, shippers use an anticipatory strategy by specifying want dates in advance of when the cars are needed. Sensitivities are run to demonstrate a "naive" strategy in which a shipper specifies a want date without considering railroad performance.

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[8] Shipping corn by rail costs approximately $0.61 per bushel versus $0.24 per bushel for barge shipments. Rail calculations are based on a Union Pacific Railroad rate from Savage, MN to Baton Rouge, LA of $2,150 per car. Barge calculations are based on a $619 per short ton 100% tariff rate using a yearly 150% average tariff rate (Konsor).

Table 3. Values of Strategic Variables

Strategic Variable	Base Case Value	Constraints
COT Cars Purchased	4 Unit Trains first half and last half of a month	N/A
SWAP Cars Purchased	2 Unit Trains first half and last half of a month	N/A
COT Want Date	Day 0	Day 0 to Day 14
SWAP Want Date	Day 0	Day 0 to Day 14
General Tariff Want Date	Day 0	Day 0 to Day 28
Unload Priority at Gulf	Unit Trains Have Priority	Either Barge or Unit Train
Export Demand Forward	4 Weeks Forward	Based ordering decisions on demand 3, 4, 5, 6, or 7 weeks forward

Policy Variables

Carrier demurrage policies are exogenous in the grain supply chain. Barge policies and considerations are taken from the *NGFA Trade Rules and Arbitration Rules Booklet*. Rail demurrage charges are based on the BNSF's demurrage policy. The model uses their demurrage policy on January 1, 1999 in the base case. Proposed changes during the 1997 marketing year are used to demonstrate the effects of rail demurrage policy changes on grain shippers.

Demurrage Calculations

Demurrage calculations transcend across the analysis. Any time barges, unit trains, and vessels are available for loading or unloading and are not loaded or unloaded, they are held until the next shipping period. They incur their demurrage charges and have priority amongst their own mode in the next shipping period.

Unit trains incur demurrage at the inland terminal and the export facility. Rail demurrage charges are $50 per car/day.[9] Barges incur demurrage at the inland terminal and export facility. Demurrage charges are $100/day for days 1 to 10, $150/day for days 11 to 20, and $250/day for every day after day 20. For this reason the model evaluates the number of weeks each barge is

[9] A calendar calculates the number of chargeable demurrage days in a week and applies them to all cars held for that week.

held by the shipper. Vessel demurrage occurs at the export facility at $1.40 per metric ton per week.[10]

The model derives output on demurrage and shipping costs for each mode of transportation at each facility. Rail demurrage occurs at both facilities and is incurred on a weekly basis on any unit trains available and not loaded. Barge demurrage is tracked by the number of weeks each individual barge is held at a facility due to the progressive demurrage penalty policies of barge providers. Vessel demurrage is applied to ships arriving in port unable to load. Shipping costs included are carrying or interest costs on grain, rail tariff costs, COT premium costs, barge costs, and an aggregated total cost.

Data Sources

Data was obtained from several sources in the grain trading industry. Following is a brief summary of the data used in the model (Table 4). Daily rail performance data for railcar placements were obtained from the BNSF railroad from August 20 to October 26, 1998. Barge placement data were obtained from industry participants (Konsor). Transit times are from industry participants. Weekly grain inspections for corn exports were obtained from the USDA. Industry norms regarding vessel demurrage and despatch were from industry participants (Rudge). Barge demurrage was taken from the *NGFA Trade Rules and Arbitration Rules Booklet*. Rail demurrage was calculated using the BNSF's demurrage policy on January 1, 1999 (BNSF).

Table 4. Data Sources

Variable	Source
Rail Order Placements	BNSF Railroad performance, Aug. 20 to Oct. 26, 1998
Barge Order Placements	Industry Interviews
Rail Transit Times	Industry Interviews
Barge Transit Times	Industry Interviews
Rail Demurrage	BNSF demurrage policy as of January 1, 1999
Barge Demurrage	*NGFA Trade Rules and Arbitration Rules Booklet*
Vessel Demurrage and Despatch	Industry Interviews
Inland Terminal Elevator	Industry Interviews
Export Terminal Elevator	Derived from Industry Data

[10] This is a common demurrage charge of $10,000 per day over five days divided by a 70,000 metric ton ship was used to calculate the cost per metric ton (Rudge).

RESULTS AND SENSITIVITIES

Base Case Results

A base case was defined to demonstrate logistical strategies and costs applied to a typical grain supply chain. Stochastic variables included export demand, vessel arrivals, transportation placements, and transit time. Freight ordering, mode and mechanism, as well as unloading priorities are key strategic variables. Base case results incurred a mean demurrage cost of $2.03 million per year. There is a wide range between the minimum yearly demurrage cost of $0.87 million and the maximum yearly demurrage charge of $12.95 million. A complete distribution of demurrage is shown in Figure 1.

Demurrage is incurred by every mode at each facility in the system and are summarized in Figures 2 and 3, and in Table 5. Inland and export barges held three weeks have a 50% chance of incurring nil in demurrage, but average $810 and $3,860 per year respectively. Barges experience the highest demurrage costs of the three modes in the supply chain. Barge demurrage costs represent 39% of the total. Vessel demurrage costs are slightly less and rail demurrage is the least at $485,000 per year and only 23.9% of the total.

Shipping costs in the base case are $42.19 million per year at the 50th percentile. Rail and barge tariffs represent 94% of these costs. Interest costs are $2.5 million dollars a year. COT premiums for the year are paid on 8 unit trains per month for a cost of $120,000 using average monthly COT premiums from 1996-1998.

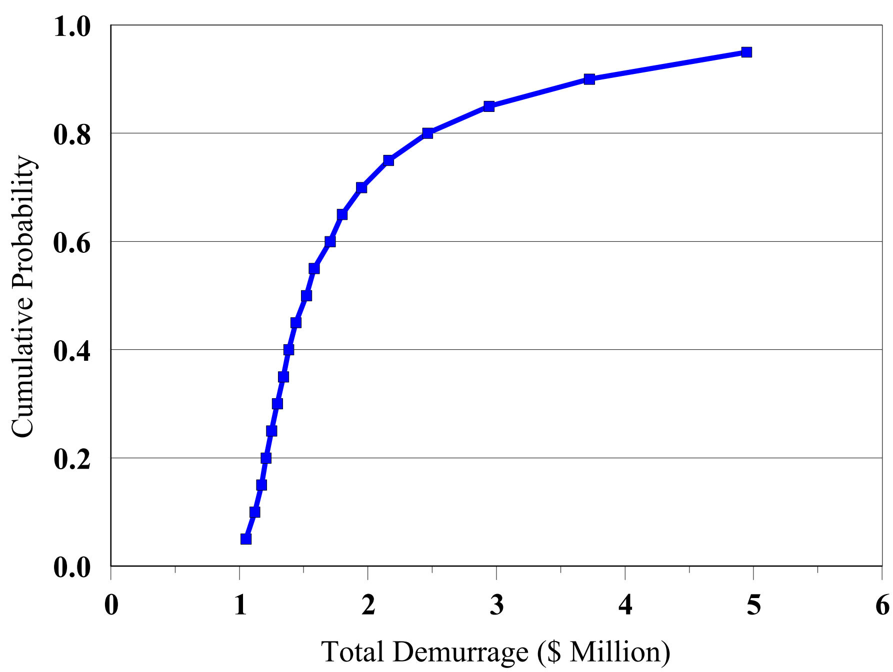

Figure 1. Cumulative Distribution of Total Demurrage: Base Case.

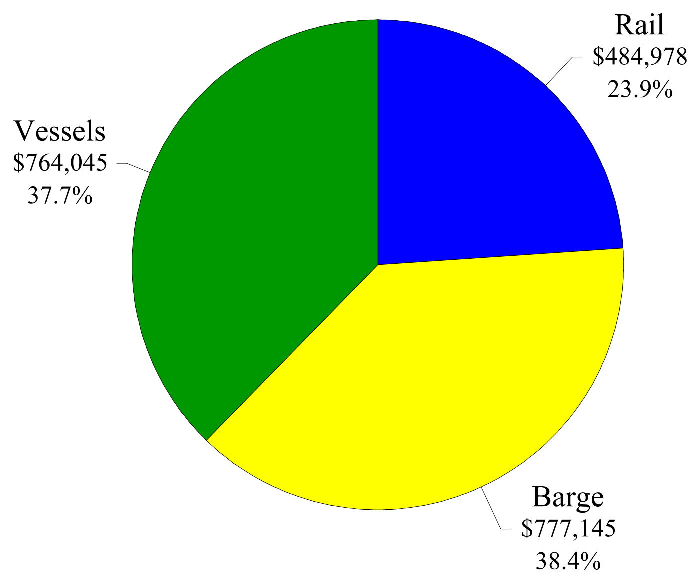

Figure 2. Demurrage Costs by Transportation Mode, Base Case.

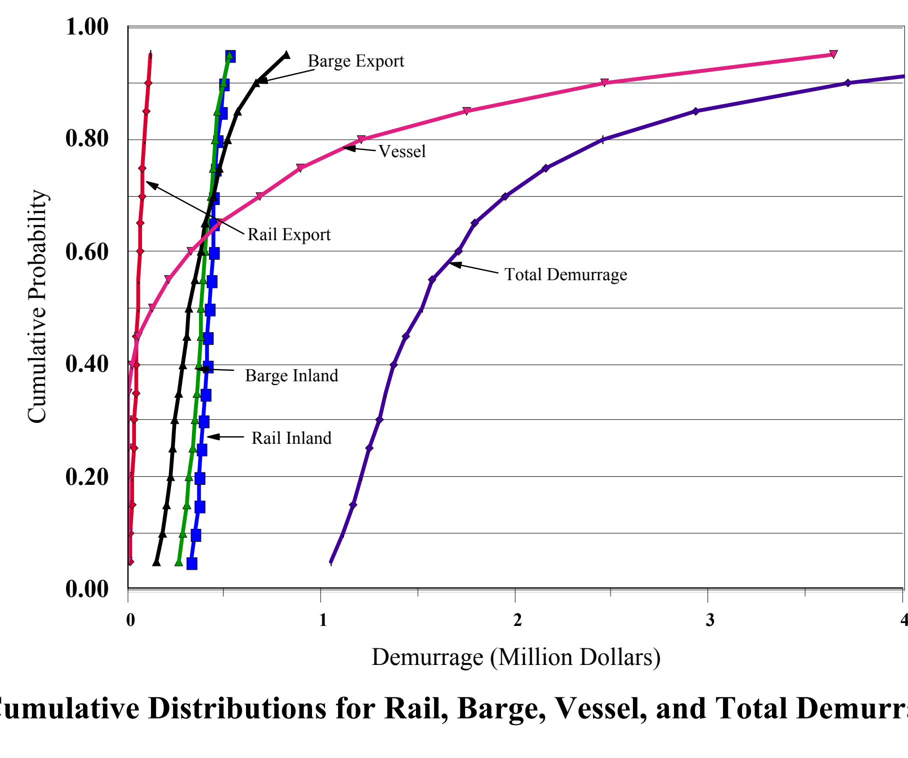

Figure 3. Cumulative Distributions for Rail, Barge, Vessel, and Total Demurrage Cost, Base Case.

Table 5. Average Levels for Components of Demurrage, by Type and Location: Base Case

	Demurrage	Percent of Total	Modal
Rail	**$**	**Individual Element**	**%**
Rail Inland	423,395	21	
Rail Export	61,582	3	
Total Rail	484,978		24
Barge			
Barge Inland			
1 Week	361,327	18	
2 Weeks	29,641	2	
3 Weeks	810	0	
Total Barge Inland	391,778		19
Barge Export			
1 Week	342,530	17	
2 Weeks	38,975	2	
3 Weeks	3,861	0	
Total Barge Export	385,366		19
Total Barge	777,145		38
Vessel	764,045	38	38
Total	2,026168		

Sensitivity on Stochastic Variables

Simulations were run to quantify the relationship between the stochastic variables and demurrage costs.

Export Demand. Simulations were run decreasing and increasing demand in 10% deviations from the base case (Figure 4). As export demand increases, so do expected demurrage and shipping costs. These results indicate that costs escalate as grain exports increase. Increases in exports above base case values thereafter result in sharp increases in cumulative demurrage costs.

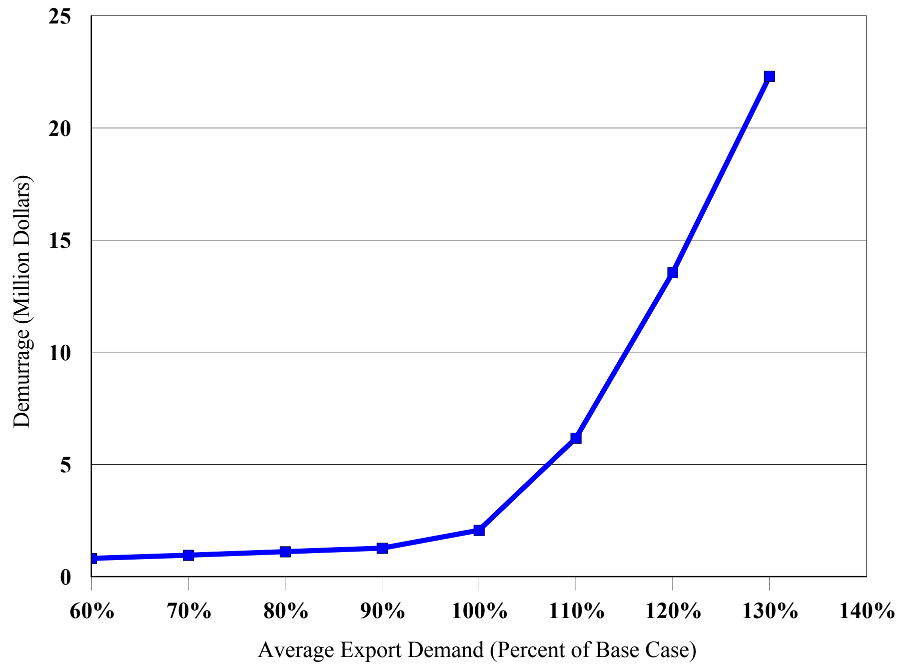

Figure 4. Effect of Export Demand on Average Total Demurrage.

Rail Placement Performance. Car placements for guaranteed freight and general tariff cars are based on railroad performance.[11] Probability distributions were adjusted by increasing and decreasing the reliability of railcar placements (standard deviation of the fitted distributions for railcar placements). COT and SWAP car standard deviation adjustments yielded small changes in overall demurrage charges. The simulations demonstrate that improvements in railroad reliability reduce system demurrage costs as well as vessel demurrage costs (Figure 5).

Reliability of general tariff train placements has a greater impact (higher standard deviation) due to the railroad not having guaranteed performance. Decreasing the reliability of general tariff cars (increasing standard deviation 200%) increased inland rail demurrage costs 11.5% and increased average total demurrage for the entire supply chain 16%.[12]

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[11] It is important to note that rail performance data were obtained during a high performance time period from the BNSF railroad, making placement data less volatile.

[12] Further simulations were run examining railroad reliability on COT, SWAP, and general tariff placement distributions simultaneously. Using a 200% change in standard deviation, total demurrage increases more in this analysis than in the single analyses performed on each mechanism. Other interesting relationships are noted from the simulation results. Vessel demurrage increases $355,000 or 47% from the base case, while export barge demurrage decreases 3% from the base case.

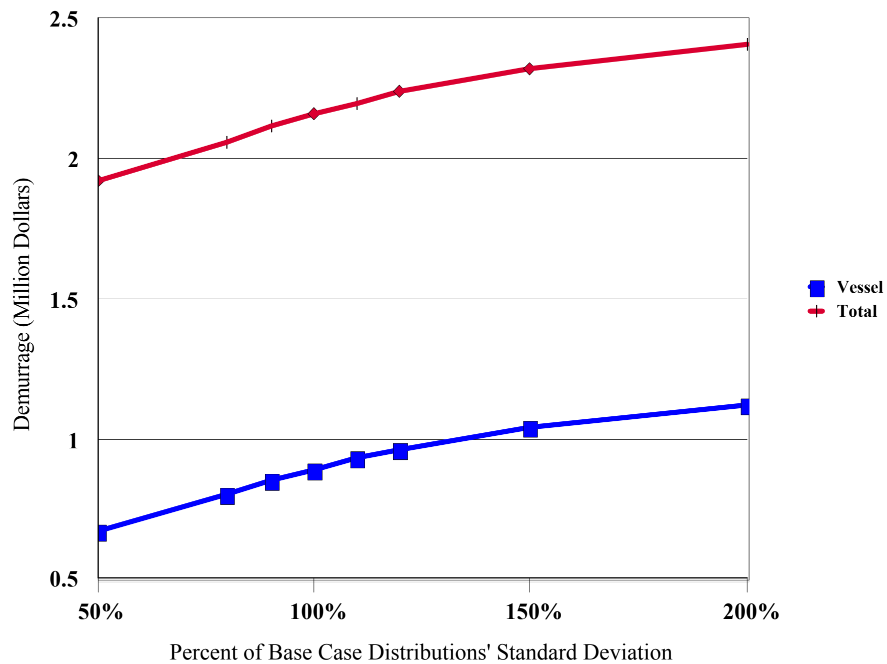

Figure 5. Effect of Railcar Placement Reliability on Average Total Demurrage.

Vessel Arrival. Vessels arrived in two-week windows in the base case. However, FOB contracts in some cases allow the buyer to supply the ocean vessel normally within a four-week shipping window reducing the seller's control of the supply chain (Wilson, Dahl, and Carlson). The model was adjusted to allow export demand in four-week windows and make it equally likely for vessels to arrive in each shipping period. In this case, demurrage costs increased for each mode at the export facility due to the increase in demand uncertainty. Rail demurrage costs increased the least due to priority unloading. Vessels' demurrage costs increased the most, increasing 24.2% over that of the base case (Figure 6).

Barge Transit Time. Base case barge transit times were discrete distributions. Barges had a 5% chance of arriving at the export facility in 3 weeks, a 70% chance in 4 weeks, a 20% chance in 5 weeks, and a 5% chance in 6 weeks. As an alternative, the distribution for transit times was 1) changed to represent an equally likely transit time among the 4 weeks, and 2) changed to a steeper distribution (90% arrive in week 4 and 10% in week 5) than in the base case.

Changing the distribution for barge transit times to a distribution with an equally likely chance of a vessel arriving at the export facility in each of the four shipping periods increased vessel demurrage costs to $963,000, a 26% increase over vessel demurrage in the base case. Export barge demurrage increased from $385,000 in the base case to $467,000; a 21.3% increase. Changing the distribution to a steeper distribution (more likely to arrive in smaller window) decreased demurrage costs. Vessels and export barges contribute cost savings with 16% and 18% reductions in demurrage costs.

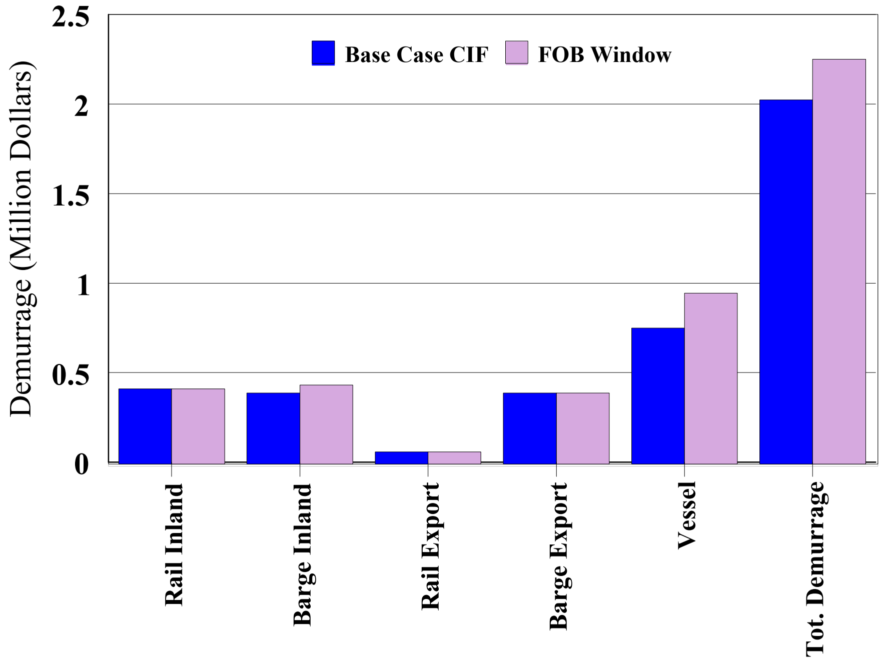

Figure 6. Average Demurrage Cost Comparison: CIF Versus FOB Sales.

Strategic Variables

Simulations were run on the strategic variables in the model to determine their effects on demurrage costs.

Forward Ordering. An important strategic variable for shippers is the specification of want dates for car placements. The model allows grain shippers to make freight ordering decisions on demand 3, 4, 5, 6, or 7 weeks forward based on given shipping information. In the base case, freight is assumed to be ordered based on export demand 4 weeks forward. Results indicate average demurrage costs are the lowest with an ordering strategy based on export demand 6 weeks forward (Figure 7).

Freight ordering decisions are based on export demand in a future period in which demand is assumed known. Sensitivities are performed by making actual demand on a normal distribution with a mean equal to export demand and a standard deviation equal to the mean of export demand (determined by a normal distribution in the case of corn to the Gulf) multiplied by a forecast error. Past forecast errors are corrected when ordering in the next shipping period.

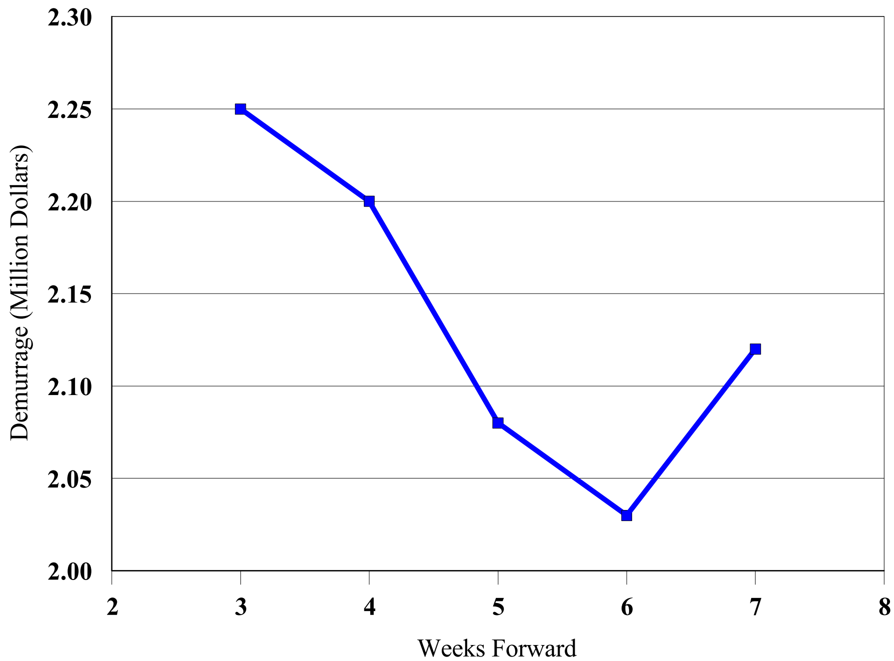

Figure 7. Effect of Freight Ordering Forward on Average Total Demurrage.

The following results were obtained with forecast errors ranging from 5% to 25% in increments of 5%. Average demurrage costs increase substantially as forecast errors increase (Figure 8). Demurrage cost increases were due primarily to barges and vessels. A 15% forecast error increased inland barge demurrage from $360,000 in the base case to $611,000. Vessel demurrage increased to $1.93 million from $764,000 in the base case. Imperfect information causing a 15% forecast error in a freight ordering strategy causes a 42.5% increase in average total demurrage.

Freight Guarantees. Guaranteed freight offers shippers an opportunity to purchase rail freight with greater service reliability by the railroad. This is demonstrated by the means and standard deviations of the placement distributions. In the base case, shippers are assumed to order 4 COT unit trains for the first and last half of a month (2-week period) and 2 SWAP unit trains for the first and last half of the month. This provides them with rail freight coverage of 12 unit trains per month.

The model was simulated using combinations of COT and SWAP freight for the first and last half of a month (0 COT, 0 SWAP; 0 COT, 1 SWAP; 0 COT, 2 SWAP; etc.). Results indicated that using no guaranteed freight increased average demurrage costs $270 thousand to $2.29 million. Average demurrage costs were minimized at $2.01 million using a combination of 3 COT and 6 SWAP units for the first and last half of a month. Effectively they are covered for 18 unit trains per month with this strategy. Each combination yielded a total number of guaranteed unit trains per shipping period. Combinations guaranteeing 9 unit trains using any combination of COTs and SWAPs resulted in the lowest average demurrage cost for the year.

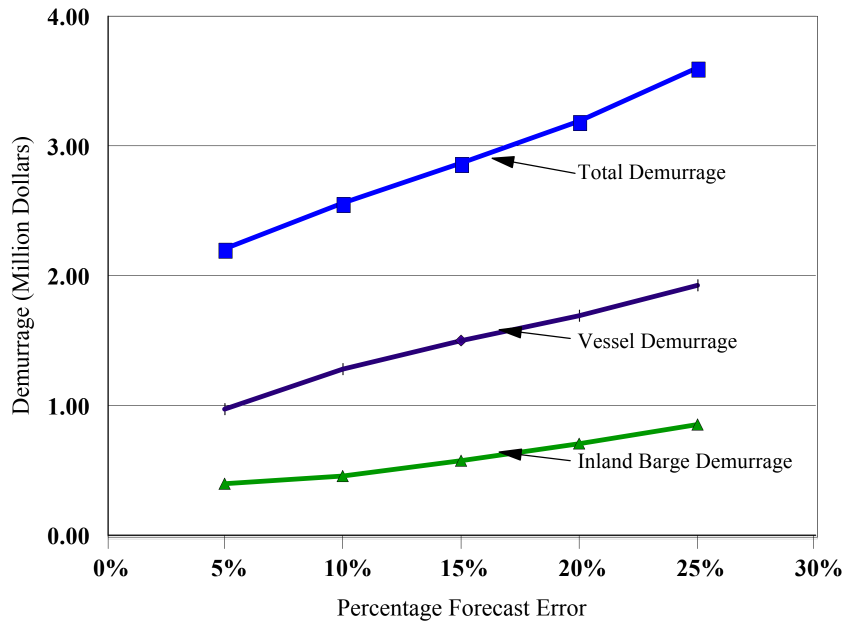

Figure 8. Effect of Forecast Error on Average Total, Vessel, and Inland Barge Demurrage.

Car ordering can be based on desired want dates or by accounting for past car placement performance. In the base case, an anticipatory car ordering strategy was used in which the shipper takes into account the past performance of the railroad. Specifically, the shipper is assumed to want unit trains placed in the middle of the deliver window for the respective types of rail freight. In the case of guaranteed freight, this would be the 7th day of a 2-week window. Since shippers were on average 7-8 days late for guaranteed freight and 13-14 days late for general tariff cars, want dates for guaranteed freight and general tariff cars in the base case were set at 0 (first day of the shipping period). Simulations were conducted for a range of order want days first for each of the car types separately. Then combinations of car types were evaluated.

General tariff car want dates were simulated for days 1-7, 10, 15, and 20. Results indicate that relative to base case assumptions average total demurrage costs increased for all other want dates (Figure 9). Increases ranged from 5.3% to 15.7% in the case of average total demurrage. Vessel demurrage changed the most with an increase from $764,000 in the base case to $1.1 million with a want date of day 20. Some of the fluctuations in demurrage costs may have been the result of a distribution and want date close to the beginning of a new week. This would cause bunching where railcars ordered in different time periods all arrive in the same time period.

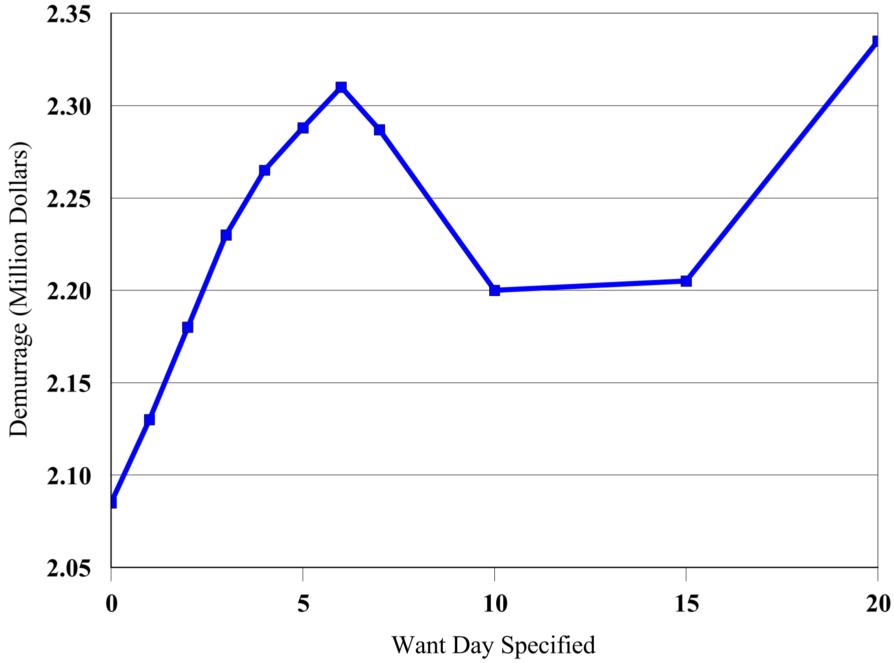

Figure 9. Effect of Alternative General Tariff Car Want Dates on Demurrage.

Guaranteed car want dates were simulated for days 0-7. Average demurrage cost was the lowest with a want date of day 3 (Figure 10). COT and SWAP cars both have placement distributions with an average days late of approximately 7. Their standard deviations range from 1 to 2 days. With a want date of day 3 the shipper can almost guarantee placement in the second week of the shipping period and eliminate bunching as a concern. This strategy creates a $95,000 or 4.7% reduction in average total demurrage costs.

Combinations of want dates mixing COT and SWAP want dates with general tariff want dates were examined next. COT and SWAP want dates were varied 0, 2, 4, 6, and 7, while general tariff want dates were varied 0, 4, 7, and 10. A combination of a COT and SWAP want date of day 2 and a general tariff want date of day 0 had the lowest average demurrage (Table 6). Inland rail and vessel demurrage increased, while export barge demurrage decreased slightly as want date combination simulations were run.

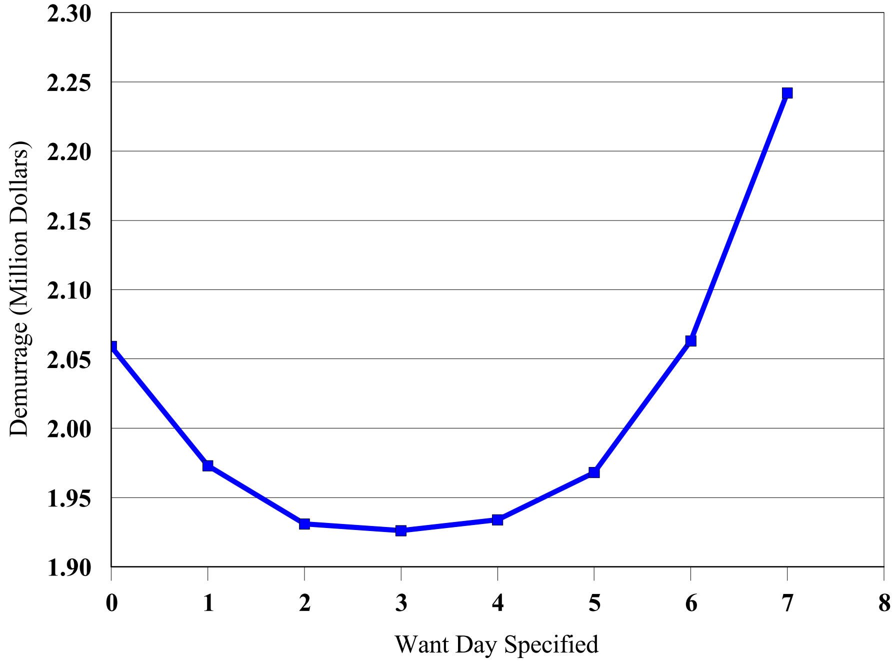

Figure 10. Effect of Alternative COT/SWAP Want Dates on Demurrage.

Table 6. Average Total Demurrage for Alternative Want Dates by Car Type.

COT/SWAP Want Date (Day of 2-Week Shipping Period)	Want Date for General Tariff Cars (Day of 4-Week Shipping Period)			
	Day 0	Day 4	Day 7	Day 10
Day 0	2.08	2.24	2.26	2.19
Day 2	1.94	2.56	2.65	2.20
Day 4	1.95	2.57	2.62	2.20
Day 6	2.08	2.34	2.35	2.22
Day 7	2.27	2.17	2.14	2.27

Policy Variables

The model was used to evaluate the effects of the policy change on shippers as proposed by BNSF railroad to change rail demurrage policies from November 1, 1997 to March 15, 1998. The policy at the time of the proposal allowed for 2 free days for loading at the origin and 2 free days for unloading at the destination. Saturdays and Sundays and several holidays were also free days. The proposed policy cut free days for loading at the origin to 1 and eliminated Saturdays and Sundays as free days. It also cut the number of holidays considered free days from 11 to 3.

The model was changed by correcting the number of free days and holidays allowed shippers. It was then simulated for each policy to determine demurrage cost changes. The base case policy had an average demurrage cost of $1.90 million, with rail demurrage inland of $314 thousand, and average export rail demurrage of $46,000. Under the proposed policy, inland rail demurrage was $650,000 and export rail demurrage is $78,000 with total demurrage costs increasing to $2.27 million. On average the additional cost to rail shippers under the new policy would have been $370,000 per year (Figure 11).

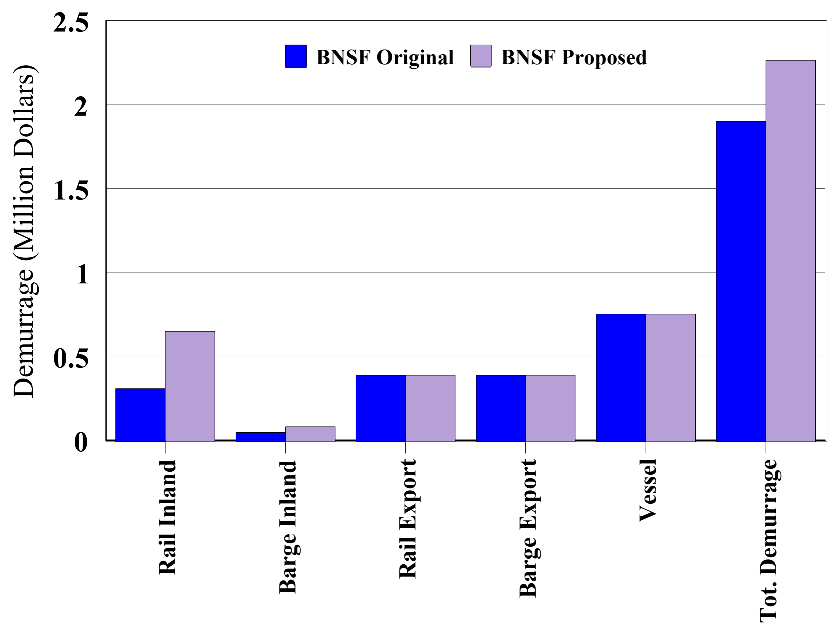

Figure 11. Average Demurrage Cost Comparison: BNSF Original Demurrage Policy Versus BNSF Proposed Demurrage Policy.

Vessel despatch premiums were not considered in the base case due to lack of data on the volume of grain on which they are applied. However, the model could evaluate despatch premiums. In the sensitivity analysis, it is assumed that some percentage of grain loaded in each shipping period receives despatch. Using a binomial distribution this percentage is random from shipping period to shipping period. For the sensitivity analysis the percentage that grain despatch is applied to varies from 5% to 30% by increments of 5% with 40% and 50% being included as well. The results indicate that as the percentage of grain receiving despatch premiums increases so do the despatch payments (Figure 12). Despatch payments ranged from $87,000 dollars at 5% to $870,000 at 50%. Essentially, grain shippers could offset 100% of their vessel demurrage costs and 43% of their total supply chain's average total demurrage costs if they receive vessel despatch on half of their grain shipments.

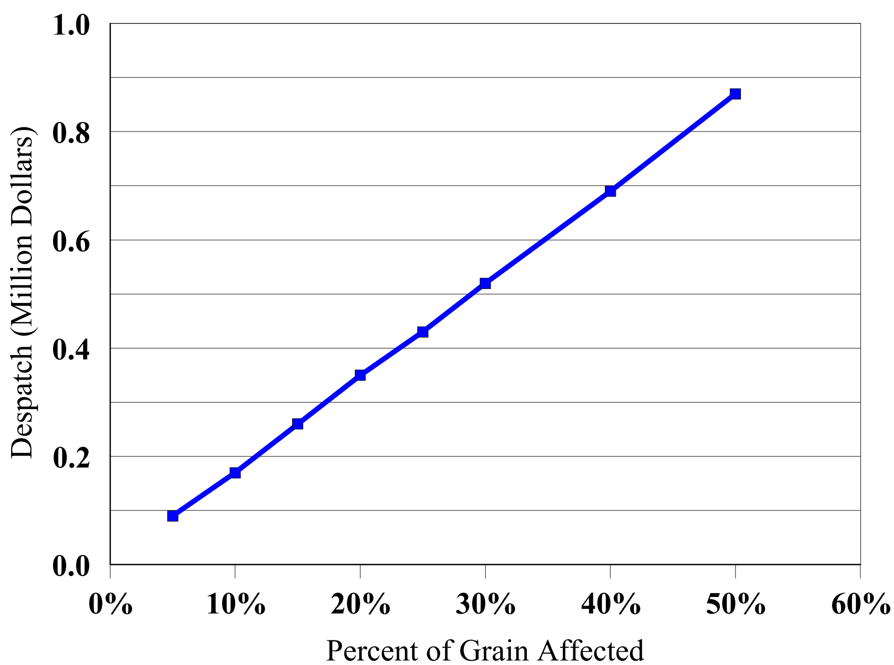

Figure 12. Average Despatch Premiums: Effect of the Percent of Grain Receiving Premiums.

SUMMARY AND CONCLUSIONS

Compounding structural difficulties in managing grain pipelines are uncertainties shippers confront throughout the pipeline. Important shipping uncertainties include railcar and barge placements depending on the reliability of the transportation providers. Rail and barge transit times are a function of scheduling, equipment problems, and weather. Vessels arrive in designated windows based on the terms of CIF sales contracts. Each uncertainty has unique characteristics to challenge grain shippers managing the supply chain.

Demurrage and despatch policies were created to increase the efficiency of the grain supply chain but vary amongst modes. Shippers holding transport equipment longer than stated in a contract pay a demurrage penalty, while shippers who hold transport equipment for shorter times than specified by a contract receive a despatch premium. The rail industry created guaranteed freight to increase the efficiency. Guaranteed freight offers short and long term strategies for grain shippers.

Summary of Results

A model was developed to demonstrate logistical strategies being applied to a typical grain supply chain. Demurrage costs are evaluated for each mode at each facility. Results for the base case indicate average demurrage charges for the supply chain of $2.03 million per year. Barge and vessel demurrage account for $1.54 million or 76.3% of the average total demurrage.

Simulation on the stochastic variables indicated changes in export demand caused the greatest disruptions to the supply chain and increased demurrage costs the most. Increasing the amount of grain exported by 10% increased average demurrage three-fold to $6.17 million per year. Uncertainty in railcar placement is critical to shippers and affects ordering strategies. Decreasing this uncertainty leads to more reliable placement times and vice versa. Demurrage costs decrease as standard deviations for placement times decrease. Doubling COT, SWAP, and general tariff car placement standard deviations increased vessel demurrage by 47%. Vessel arrival windows in the base case are 2-week windows. Simulations indicated that selling grain with a 4-week shipping window would increase vessel demurrage by 25%. In the base case forecast error on demand was assumed to be 0. A 15% forecast error caused a 42.5% increase in total demurrage. Inland barge demurrage and vessel demurrage contributed the most to the increases.

Sensitivity analysis was performed on strategic variables, including freight ordering, guaranteed rail freight strategies, rail want dates, and export unload priority. Freight ordering is based on a forecast of export demand a number of weeks in the future. Sensitivities indicate demurrage costs are the lowest when freight ordering decisions are made 6 weeks forward.

Combinations of COT and SWAP unit trains were run to determine the least cost ordering strategy for shippers. Results indicate that 3 COT and 6 SWAP trains in the first half and last half of each month accrue the lowest demurrage costs. Shippers specify want dates for railcar placements. They can use a "naive" or an "anticipatory" strategy for specifying a want date. Anticipatory strategies take into consideration past railroad performance, while naive strategies have shippers specifying a want date of exactly the day equipment is needed. Optimal want dates were a combination of the want date and car placement distribution for the type of railcar in question. Results indicated optimal want dates of the first day of delivery period (day 0) for general tariff and day 2 of the delivery period for COTs and SWAPs.

Implications

Several innovations, such as demurrage/despatch and guaranteed rail freight have become more important components affecting the efficiency of the supply chain. With the advent of changing demurrage/despatch policies and offerings of guaranteed rail freight, shippers have more options and considerations when shipping grain. The model demonstrates relationships between key stochastic, strategic, and policy variables in the supply chain. It also identifies their effects on demurrage costs. Demurrage costs increase as transportation providers tighten allowances contained in demurrage policies. Further, shippers have to carefully monitor carrier service reliability when making shipping decisions. Changes in service levels can increase demurrage costs for shippers.

Defining mechanisms to aid grain in a smooth flow through the pipeline has implications for carriers. As is well known, transportation reliability affects shippers in managing the supply chain. This is demonstrated by the reduced demurrage costs with smaller standard deviations in model placements. Poor service reliability leads shippers to choose alternate modes of transportation and otherwise increase their costs.

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APPENDIX

Description of Rail Carrier Demurrage Policies

Burlington Northern/Santa Fee (BNSF). The BNSF demurrage policy covers five occurrences that lead to demurrage charges for grain shippers.[13] These include cars held too long for loading, cars held too long for complete or partial unloading, loaded private cars held on public railroad tracks, "refused loaded cars and cars rejected as being unsuitable for loading," and a catch all provision stating all cars held due to the loader or unloader for reasons other than loading or unloading. Demurrage calculations begin on the first day after cars are placed at 12:01 a.m. Credits and debits work in the same manner as described above.

Railcars are placed in two ways. First, cars are considered placed when they are delivered on a loader's or unloader's private tracks. The second method of delivery is constructive placement, which is when cars are delivered to a railroad hold point due to a loader or unloader making placement on their tracks impossible. Constructive placement requires the railroad to notify the shipper of placement.

Shippers receive two credits or free days for each loading and unloading of grain and grain products after car placement. Demurrage exempt days include all Sundays and twelve U.S. holidays. Holidays that have dates occurring on Sunday will be observed on the following Monday. One exception to the information presented is that Sundays are not exempt days for grain and grain products waiting to unload at 11 export facilities in the United States.

Demurrage charges are settled on a monthly basis with the demurrage rate on the day of the car release in effect. During 1998, these rates were $50 per day per car. Loaders at the origin and unloaders at the destination are charged the demurrage. Loading and unloading stations are considered separate entities so credits and debits cannot be combined for a single customer. Each occurrence that leads to demurrage charges is calculated separately. For example, excess credits for loading cannot offset demurrage charges for unloading. Furthermore, credits are not transferable from one month to the next.

The BNSF policy includes three special allowances for grain and grain products shipped by hopper car to be excused from demurrage chargers and one allowance to incur a reduced charge. *Acts of God* related to weather phenomena halting operations for at least two days are excused. Cars arriving in bunches at the unloading destination when originating from the same destination or different destinations at different times and move over identical routes are excused. Also, when cars tendered for recently are placed before cars tendered for previously, charges can be dismissed. Strike interferences are a special occurrence and currently decrease the penalty per day per car to $15.

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[13] Demurrage and other subject matter can be attained from their homepage at http://www.bnsf.com. Information found here is updated as policy changes occur and customers are encouraged to get all their information from these sources. Information about BNSF demurrage policies was taken from BNSF Demurrage Book 6004 found at http://wwwd.bnsf.com/website/demurrage.nsf/Demurrage on the Internet.

A formal despatch policy does not exist in the rail industry. However, the BNSF shuttle program could be considered as having provisions for despatch premiums. Shippers receive $100 per car incentive premiums for loading and unloading cars in a specified time period. This is similar to the definition used in ocean vessel transportation where the concept of demurrage originated.

On September 12, 1997 the BNSF railroad announced a demurrage policy change that had far-reaching effects on grain shippers serviced by the railroad. The BNSF stated the change was imperative for improving car turnaround times. According to railroad statistics, car turnarounds in the grain industry were 16 to 19 days for corn and wheat trains. In comparison coal shipments by rail have car turnarounds of 5.3 days. These statistics indicate to the railroad that the grain supply chain has potential for improvement (*Milling and Baking News*, Sept. 30, 1997, p18).

Anticipating high demand from October 1997 until March of 1998, the BNSF proposed several changes to their demurrage policy. First, loading facilities would be allowed 24 hours instead of 48 hours to load cars before demurrage charges would be incurred. Second, export facilities in the PNW, Gulf, and Head of the Lakes would be allowed 24 hours instead of 48 hours to unload cars before demurrage charges would be incurred. Third, nine holidays would be eliminated as free days on which demurrage would not have been incurred in the past. Finally, Sundays were also eliminated as free days in which demurrage charges would not be incurred.

Trade organizations and the governor of North Dakota expressed concerns about the proposed changes. They stated that the policy would be detrimental to grain shippers and farmers who would end up paying increased demurrage charges. Furthermore, they say the problem isn't only with loading and unloading times, but with the railroads' ability to move the cars in a timely fashion (Rustebakke). Other concerns included the non-operation of the grain industry on weekends. In addition, grain companies are unable to provide billing instructions and the Federal Grain Inspection Service (FGIS) is unable to provide official grades (NGFA 1997). It demonstrates the interdependence of industry players on one another and their policies.

Canadian Pacific. There are four items or ways outlined in the tariff publication for grain shippers to incur demurrage penalties.[14] The first item is a car held for loading. Second is a car held for unloading. Third is a car held for other reasons. Fourth is a car loaded with export grain held for unloading in Duluth, MN or Superior, WI. Each item has slightly different specifications for tenders, releases, demurrage charges, credits, and demurrage charge computations.

Covered hopper cars for loading are considered tendered after actual or constructive placement by the railroad. Cars are released once forwarding instructions are presented to the CP, provided they are loaded to the proper weight, placed in the correct position, and are not being held for an official grade and inspection. Cars tendered before their order date have demurrage begin on the order date and not the tender date. Each car receives two demurrage

[14] The CP publishes its demurrage policies for U.S. grain in Tariff CPRS 6510.

credits and has eight U.S. holidays and Sundays as demurrage exempt days. Time begins for shippers 00.01 hours after cars are tendered. Charges are calculated on a monthly basis with credits being subtracted from debits. Debits in excess of credits result in a $60 per day per car charge assessed to them.

Specifications for covered hopper cars for unloading are similar to those at loading. Two notable differences exist between the two items. First, release is when shippers notify the railroad the car is empty. Second, it makes no mention of reloading other than to indicate the car must be released before reloading or demurrage charges will occur until car is forwarded. In other words, once the cars are released the specifications for loading go into effect.

Criteria for cars held for other reasons include cars waiting for disposition information, conditions related to actions of cosignors and cosignees, cars deemed unfit and rejected. Disposition information, such as forwarding instructions and notification of empty cars, allows the railroad to move cars. Tender and release definitions remain unchanged. Demurrage charges are computed from the first 00:01 after tender on cars which are diverted, ordered and not used, partially unloaded, reconsigned, reshipped, and stopped in transit. Special provisions exist for private cars on public tracks, refused loaded cars, and cars placed by other railroads. Cars are allowed two free days and are exempted from eight U.S. holidays. However, there are no free days for cars not used, loaded private cars on public track, and cars interchanging with other railroads. Charges are $30 per day per car on demurrage days after free days are subtracted.

Cars with export grain filled in Duluth, MN and Superior, WI have a unique system of demurrage charges. Sundays and eight U.S. holidays are demurrage-exempt days. Charges are calculated on the basis of average days per car. This average encompasses all cars unloaded for the month at each of these two facilities. There is no demurrage charge for an average of less than three days. In addition the CP pays a despatch incentive of $15 per car for an average of less than a day and $10 per car for an average between one and two days.

The CP Rail allows demurrage relief due to railroad error, strike interference, and weather interference. Railroad error is not defined, except to state runaround is not railroad error. During strike interference demurrage charges are 50% of published rate. This is contingent on the strike lasting seven straight days in one month and the CP being notified in the first 48 hours of the strike. Demurrage relief is not granted when waybills are dated more than four days after the strike begins and when cars are ordered for loading after the strike began and before the strike ends. Weather interferences must cause greater than 48 hours disruption to be eligible for total demurrage relief.

Union Pacific. Tariff rates[15] are applicable for all domestic and import traffic, as well as grain and grain products for export through California, Oregon, or Washington. All demurrage calculations begin at 12:00 midnight after placement or release of a car. Section 1 outlines railcars covered under this publication and whether or not they are part of the early release incentive (ERI) plan. Cars not part of the ERI plan are cars using intraplant switching

[15] The UP railroad publishes its general car demurrage rules and charges in Freight Tariff UP 6004. It is organized by sections and those pertinent to this discussion are presented in that manner.

service, reconsigned cars, diverted cars, reshipped cars, cars held for grain inspection, unused cars, and cars from other railroads. Private cars cannot receive credits, but credits can be used to offset debits earned by private cars on public track. All other cars can earn ERI credits by releasing cars before their first 24-hour day of free time is over. Only one credit can be earned per car. These credits offset debits, but only on cars used for the same function, such as loading.

Free time and exceptions to free time are outlined in Section 4. In general, shippers receive 48 hours free time for complete unloading and 24 hours free time for all other activities for which free time is allowed. Sundays and 11 U.S. holidays are exempt from demurrage charges. No free time is allowed on cars which are ordered and not used. Other special circumstances regarding free time such as overloaded cars, cars unloaded and loaded again, and cars received from other railroads are also outlined in this section.

Shippers are responsible for demurrage during loading. Loading commences upon car placement and is complete when the UP is provided with car forwarding instructions. Shippers are also responsible for cars and demurrage penalties upon placement of cars on their tracks or notification of placement on a holding track. Unloading is completed upon advice to the UP of the empty car.

Cars intended for loading or unloading which are reconsigned, diverted, reshipped, or released empty later are subject to the provisions in Section 8. Demurrage charges are the responsibility of the consignor or consignee depending on who makes the request. Cars held in transit have similar responsibilities. Grain held in transit for inspection has a free day beginning at 12:00 midnight the first day after placement and ending at 6:00 p.m. the following day. Thus, a demurrage day is a 24 hour period beginning at 6:00 p.m.

The UP grants demurrage relief for strike interference, bunching, run around, weather, delayed mail instructions, and railroad error. Cars held from the start until the finish of a strike are excluded from demurrage charges. Demurrage charges are $7 per car per day on cars delayed before and after a strike. Cars ordered following the start of a strike and before the ending of a strike are charged $11 per car per day. Bunching is receiving accumulated cars when they were scheduled through orders and tenders to arrive at separate times, while run around is receiving more recent car orders before previously ordered cars are placed. Extreme weather such as floods, earthquakes, and hurricanes cancels demurrage charges. Potentially damaging weather to the freight allows for a 24-hour loading and 48-hour unloading extension. Railroad error involves the railroad canceling demurrage charges calculated incorrectly. (See Table A1 for a summary comparison of Class I railroad demurrage policies.)

Table A1. Class I Railroad Demurrage Policy Comparison

Feature/Railroad	**BNSF**	**CP**	**UP**
Demurrage Rate	$50/day/car	$60/day/car	$50/day/car
Loading Free Days	2	2	1
Unloading Free Days	2	2	2
Exempt Demurrage Days	Sundays and 12 U.S. Holidays	Sundays and 8 U.S. Holidays	Sundays and 11 U.S. Holidays
Special Allowances	Bunching, Weather Occurrences, and Striking	Railroad Error, Strike Interference, and Weather Interference	Strike Interference, Bunching, Weather, Delayed Mail Instructions, and Railroad Error