Forward Shipping Options for Grain by Rail: A Strategic Risk Analysis

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In the late 1980s, grain-hauling railroads began offering alternatives that have made shipping decisions more strategic. Shippers now confront alternatives ranging from nearby and unguaranteed ordering to various durations of forward and guaranteed shipment. Each has varying penalties for cancellation and payments from the railroad for nonperformance, and differing risks and payoffs. Because of the configuration of choices, shippers confront a portfolio of shipping alternatives. A dynamic stochastic simulation model was developed to analyze alternative strategies. The model includes the effects of uncertainties in tariff rate changes, car premiums, basis levels, forward and spot grain purchases, and receiving railcars under each of three alternatives. Shipping demand is determined by inter-month commodity price differences, carrying costs, transport costs, and storage capacity. Considering these factors, the shipper chooses grain sales and shipping strategies that maximize net payoffs and confronts a tradeoff between expected profits and risk.

Key words: grain shipping, grain transportation, railcar allocation

Introduction

Chronic rail transportation problems have adversely affected those in the grain industry for some time (Norton). As a normal course of business, shippers buy cash grain, resulting in a short freight position, and assume risks associated with receiving cars and changes in rates. Before 1987, cars generally were allocated on a first-order/first-served basis. Rail rate and car supply guarantees usually were not offered, and shippers had few alternatives to manage railcar risks (rates and service), thereby increasing merchandising risks (Gelston and Greene). Shippers often inflated orders to secure railcars because of the absence of car cancellation penalties. "Phantom orders" were prevalent, and general car allocation mechanisms did little to address post-harvest shipping problems confronting the grain merchandising/transportation industry (W. Wilson 1989).

Railcar allocation strategies have evolved dramatically since the passage of the Staggers Rail Act. To induce more efficiency and meet the needs of logistically differentiated shippers, the railroads focused on providing more shipping options. These took the form of more innovative railcar allocation mechanisms which started to evolve in the late 1980s. Most important was the development of forward service options with

guarantees for railcar supplies that provide logistical alternatives to grain shippers. The Burlington Northern (BN) pioneered these efforts with the introduction of its Certificates of Transport (COTs) program in 1987. Under COTs, forward guarantees are offered to grain shippers using a bidding mechanism. Prepayments serve as cancellation penalties and have had the effect of discouraging "phantom orders." Different segments of shippers emerged with the advent of these mechanisms, and cars essentially were allocated according to shipping priorities. Since then, Canadian Pacific Rail Systems (CPRS), Union Pacific, CSX, and other major Class I railroads have adopted certain aspects of auction-based rate and car guarantee programs.[1]

In addition, following the merger of the BN and Santa Fe (BNSF) railroads, the BNSF adopted the BN programs for car allocation throughout their combined system. However, these have not been without controversy within the industry. The National Grain and Feed Association summarizes some of the issues in its December 1996 newsletter. Further, in late 1997, the Surface Transportation Board mandated that two of the carriers use alternative prioritization schemes, at least temporarily, and the U.S. Department of Agriculture (USDA) held listening sessions throughout the grain industry to address these problems (USDA).

Longer-term guaranteed freight programs were introduced in the early 1990s. These mechanisms allowed grain companies to enter longer-term contractual arrangements, typically one to three years in duration, where shipper-owned or -controlled railcars are leased to the carrier in return for a negotiated fee and a specified number of guaranteed loadings per month. Examples of long-term guaranteed programs include BN's SWAPs (commonly referred to as "guaranteed freight") and the CPRS's Guaranteed Equipment Exchange Program (GEEP). These rail equipment supply packages generally consist of an annual contract for a number of guaranteed car placements. The guaranteed freight programs also have cancellation penalties for carrier and shipper nonperformance. However, it is important that such penalties are generally less onerous than those for shorter-term guaranteed options. Shippers participating in pooling arrangements either redeem their obligations or sell them through secondary markets. Transferability of the instruments provides shippers flexibility and has resulted in informal secondary markets and transaction mechanisms for the underlying instruments to these shorter-term and longer-term programs.[2]

The advent of alternative forward guaranteed transportation services in grain merchandising has given shippers options for strategically integrating logistics and merchandising decisions.[3] Utilization of these programs by shippers can be viewed in a context similar to grain hedging strategies, with some exceptions and peculiarities. Shippers' cash grain positions typically are hedged in the futures or forward cash market. Once the cash grain position is established, the shipper becomes short freight and experiences uncertainties about both rate changes before shipment and car placements during the want period. These options provide alternatives from which the shipper can choose to manage risks. The configuration of discrete choices can be viewed

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[1] For a detailed explanation of these mechanisms, see Wilson and Priewe.

[2] Priewe and Wilson provide a detailed description of these mechanisms; Wilson and Dahl offer theoretical analysis and bidding strategies for these instruments.

[3] Others have indicated the need for strategic analysis of grain shipping decisions (e.g., Baumel and Van Der Kamp; Frost; Niedens; and Moser).

as choosing either a transaction-specific strategy, or a portfolio of alternatives. In either case, the importance of integrating grain merchandising and shipping decisions escalates dramatically with these mechanisms.

In contrast to hedging cash grains, however, there are some important complications. Each of the options has various penalties for shipper cancellation and payments for railroad nonperformance, as well as different costs. As a result, each option has differing risks and payoffs which must be an integral component of the decision analysis. Analyzing shipping decisions is further compounded by uncertainty in shipping demand and car requirements, and different premiums, durations, and obligations imbedded in each option. Shipping under general tariff has the greatest flexibility and incurs lower shipping costs, but has greater uncertainties of car placement and no guarantees. In contrast, longer-term and shorter-term guarantees are characterized by having greater flexibility, generally higher premiums, a narrower window of service, a higher probability of receiving cars within the window, and a higher penalty imposed on the railroad for nonperformance.

The characteristics and importance of chronic post-harvest logistical problems have been addressed in numerous agricultural marketing references (e.g., Baumel and Van Der Kamp; Frost; Gelston and Greene; Moser; Niedens; Norton; Pautsch, Lapan, and Baumel; Pedraza; Pautsch, McVey, and Baumel). The problems of car allocation have not been addressed in the agricultural economics literature, but the general problem of allocating fixed supplies and establishing priorities has become increasingly important in economics (e.g., R. Wilson 1993), as have the problems of bidding mechanisms for allocation (e.g., Crampton; McAfee and McMillan 1987, 1996a, b; Milgrom; R. Wilson 1992). Studies on logistics theory with applications to the rail industry have been applied generally, but have been limited in agriculture. These include studies on time reliability (Allen, Mahmoud, and McNeil), railroad service (Ainsworth), requirements planning (Bookbinder and Serenda), and modal selection (Sheffi, Eskandari, and Koutsopoulus).

Our research analyzes grain shipping and merchandising strategies that integrate these shipping options with merchandising strategies. The primary objectives are to: (a) develop a logistics model applicable to grain shippers that captures important operating and cost components, and (b) analyze a spectrum of logistical strategies representing varying degrees of forward commitment and their relationships with key elements of planning uncertainty for a typical grain shipper.

Model Description and Simulation Procedure

A dynamic stochastic simulation model was developed based on inventory management and scheduling theory to analyze the efficacy of these mechanisms for grain shippers. The model builds on the distribution and material requirements planning (DRP and MRP) techniques (see Ballou, pp. 532–45, for a description) commonly used in logistics management. It was applied to a shipper characterized by a single-origin elevator shipping to competing markets—in this case, either Minneapolis or Portland. The model is dynamic in the sense that grain selling, forward freight coverage, and shipping decisions are made through time, and residual inventories are stored.

Shipping demand is determined by evaluating inter-month price differentials, interest and transport costs, and storage capacity. The shipper evaluates shipping alternatives for each month and chooses those that maximize expected payoffs $[E(\pi)]$ (i.e., by shipping in the month and to the market with the highest net payoff). Revenues consist of receipts from grain sales and nonperformance payments from rail carriers. The latter occur infrequently and have a low priority, but to be complete, are included as a source of revenue. Costs include rail tariffs and car premiums, handling, carrying (including interest) costs, and car cancellation penalties incurred by shippers. The analysis is stochastic and captures uncertainties confronting shippers, including tariff rate changes, car premiums, basis, forward/spot purchases from farmers, and receipt of railcars under different shipping options.

The logistical model can be represented as:

$$(1) \qquad E(\pi) = \sum_{t=1}^{12} \text{Max}\left[\pi^1, \pi^2\right],$$

given

$$\pi^1 = Q^1\left[(F + B^1 - R^{o1}) + R_{NP} - (R^S G^S + R^L G^L)\right.$$
$$\left. - CC - TSCP - HC\right]$$

and

$$\pi^2 = Q^2\left[(F + B^2 - R^{o2}) + R_{NP} - (R^S G^S + R^L G^L)\right.$$
$$\left. - CC - TSCP - HC\right],$$

where

π^j	=	payoff for shipments to market j, Minneapolis and Pacific Northwest ports, respectively;
t	=	time duration for the month;
Q^j	=	volume shipped to market j;
F	=	Minneapolis futures price for month relevant for shipment in time duration t;
B^j	=	basis for wheat shipped to market j;
R^{oj}	=	rail shipping cost for shipment from origin o to market j;
R_{NP}	=	revenue from carrier for nonperformance;
R^S	=	premiums for shipments under short-term guarantees;
R^L	=	premiums for shipments under long-term guarantees;
G^S	=	quantity shipped under short-term guarantee options;
G^L	=	quantity shipped under long-term guarantee options;
HC	=	handling cost;
CC	=	carrying cost; and
$TSCP$	=	shipper cancellation penalties.

Variables were treated either as nonrandom or random. Distributions for the random variables were based on empirical data and/or industry observations. The type of distribution varied depending on the variable. In several cases, there also were correlations

Table 1. Nonrandom Input Variables

Parameter	Value
Elevator storage capacity	1.1 mil. bushels
Elevator turnover ratio	5
Carrying cost	9.25%
Handling cost	12¢/bushel
26-car tariff rate to Minneapolis	$2,063/car
26-car tariff rate to Pacific Northwest	$4,280/car
Forward purchase contract	25%
Spot purchase	75%
G^S carrier performance guarantee	$400/car
G^L carrier performance guarantee	$250/car
Shipper cancellation penalty	$250/car

among the random variables, the effect of which was imposed on the simulation. Specific treatments of each are discussed below.

The model was simulated for a number of different strategies. It converged within 1,000 iterations in the base case analysis. The random number generator was seeded using the same seed value for all simulations. This function is important in controlling the simulation environment to analyze the impact of parameter changes.

Data Sources

The nonrandom variables included in the model are train size, railcar capacity, tariff rate levels, carrier payments to the shipper for nonperformance under guaranteed movements, storage capacity, turnover ratio, handling, and annual carrying cost (interest rates). Values for these nonrandom input variables for the model are shown in table 1. Variables treated as random include tariff rate changes, wheat basis values at each market, premiums for guaranteed shipments, spot and forward contract purchases from producers, and railcar placements under different shipping options.

Market Prices

Market prices were based on futures prices and basis values in April 1996. Futures for different periods forward were nonrandom, assuming their value would be fixed through concurrent hedging of the commodity. Basis values for each month for hard red spring wheat (HRS) were derived for 1989–94 for each of the two destination markets (Flaskerud) and are treated as random variables with normal distributions. The basis reflects the randomness of the commodity market, which, combined with other effects, triggers shipping demand. The correlation between Minneapolis and Pacific Northwest (PNW) basis levels of .81 was incorporated into the model.

Grain Purchases

Estimates of grain purchases were derived to reflect a typical single-origin shipper in North Dakota. Estimates for forward and spot deliveries were obtained from several sources. First, the average annual shipment volume of a typical North Dakota elevator was derived. A typical elevator storage capacity and an average turnover ratio were used to derive shipment volume (Gelston and Greene; Anderson and Vachal). The percentage of crop year totals sold by producers (North Dakota Agricultural Statistics Service), and therefore purchased by elevators, was applied to determine monthly purchases by elevators. Monthly purchases consisted of both spot and forward transactions, each with different levels of uncertainty. The split between forward and spot delivery transactions (forward/spot delivery ratios) was 25% and 75%, respectively (Stearns).[4] Spot deliveries were treated as a random variable with a normal distribution. Monthly averages and standard deviations for this parameter were calculated using historical data (1991–95) from the North Dakota Agricultural Statistics Service.

Forward purchases were derived similarly. The volume purchased under forward contracts was assumed to have substantially less uncertainty than spot purchases due to their obligatory nature. However, uncertainty about forward purchases increases in more distant months. Standard deviations for forward purchases were established around the fixed level of forward contracts based on interviews with grain shippers. The standard deviations applied were 5% for one to four months forward, 10% for five to nine months forward, and 15% for 10 to 12 months forward. These distributions were included to reflect that there is less uncertainty about shipping demand for grain bought under forward contracts in contrast to spot purchases, and to reflect the increased uncertainty shippers confront during the post-harvest season.

Shipping Costs

Shipping costs are comprised of three elements: the current tariff rate level, changes in tariffs, and premiums for guaranteed service. The first is treated as nonrandom; the latter two are random variables. The 26-car tariff rate from Devils Lake, North Dakota, to Minneapolis and Pacific Northwest markets was used as of April 1, 1996 (Burlington Northern Tariff ICC-BN-4022 H-I, 1990–94).

Tariff Rate Changes. Shippers confront the risk that tariff rail rates may increase. To capture this risk, tariff rate changes were treated as random variables using a procedure of "variation around a fixed trend" (Palisade Corp., pp. 5–13). Monthly average tariff rate changes were derived for 1990–94. Estimates were obtained with a method used to measure volatility in commodity markets (Cox and Rubenstein, p. 257). Simply, the logarithm of monthly rate ratios [i.e., $\ln(R_t^{oj}/R_{t-1}^{oj})$] was computed; the square root of the natural logarithm of this ratio was derived and its standard deviation calculated for each month. These were used to derive levels of uncertainty for tariff rate changes. Results suggest a greater likelihood of rate changes for some months than for others. The Minneapolis and PNW tariff rates had a correlation of .82 for 1990–94, and this was imposed on the simulation.

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[4] These were rounded from 34% forward and 66% spot to simplify later sensitivity analyses.
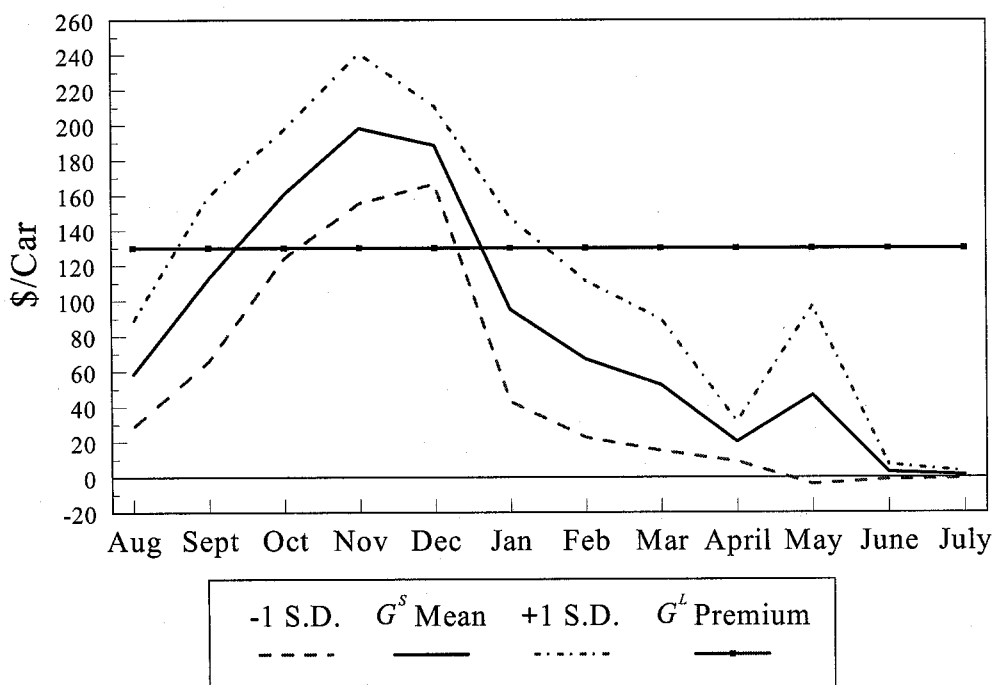
Figure 1. Short-term and long-term guarantee premiums (discounts)

Short-Term Guarantee Premiums (Discounts). Shippers confront both tariff rate changes and premium uncertainties. Premium levels are identical for the Minneapolis and PNW movements, and rate differences between the two markets are captured in the tariff rates. Figure 1 summarizes the monthly averages. Of particular importance is the seasonal behavior which, combined with the seasonal basis values, affects the timing of shipping demand. All guarantees are assumed to be purchased through the primary market. The standard deviation for the short-term guarantee (R^S) premium was derived from monthly BN COTs values for 1993–95 (W. Wilson 1996). A normal distribution was assumed, but the mean was centered on values in the spring of 1996 to more accurately reflect the market situation concurrent with the base case.

Long-Term Guarantee Premiums. Long-term guarantee (R^L) premiums are treated as a nonrandom variable to reflect the contracted nature of the instrument. R^L rates were obtained from Harvest States Cooperatives' transportation packages for spring 1996. These premiums are fixed, but the rate level is subject to the tariff rate at the time of shipment. While G^L instruments have only tariff rate uncertainty, G^S instruments have both tariff rate and premium uncertainties until the instrument is acquired.

Railcar Placements

Allocation mechanisms have differing degrees of reliability. Service differentials between rail logistical options were included in the model for general tariff and nontariff allocation mechanisms.
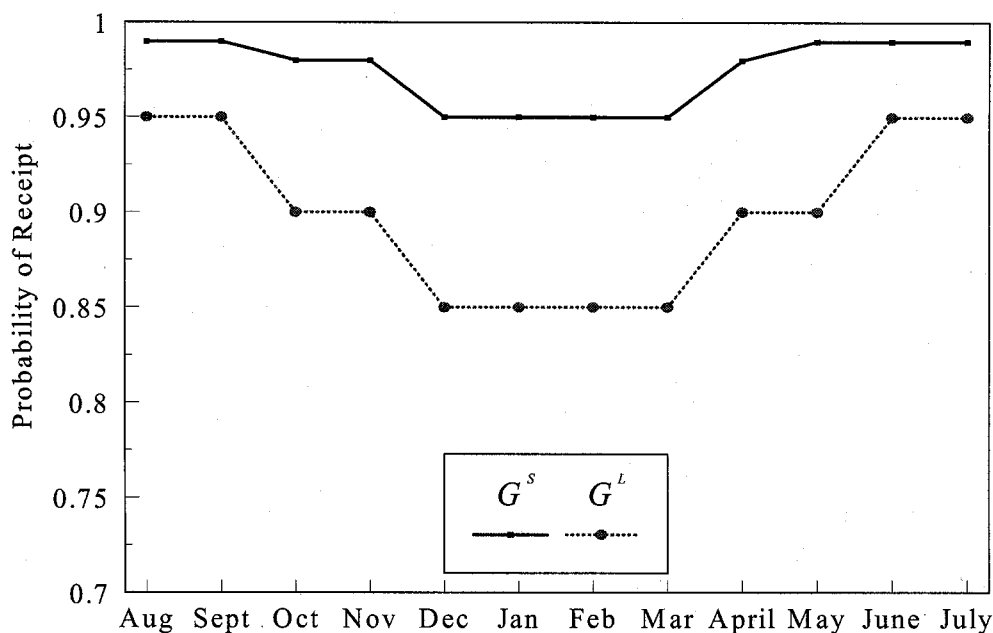
Figure 2. Probability of receipt for short-term (G^S) and long-term (G^L) guarantees

Guaranteed Service Options. Service parameters for short-term and long-term guarantees were established as discrete probabilities. The probability of receipt was defined as one minus the likelihood of carrier default. Estimates of the probabilities of receiving cars within the shipping period were obtained through interviews with rail and grain industry contacts (Wood; Strege). These probabilities are shown in figure 2. Both sources noted a higher performance level for shorter-term than for longer-term guarantees due to the carrier performance incentives associated with the former.

Car Allocation for General Tariff Services. Similar data were not available for car placement under general tariff services. Thus, an algorithm was developed encompassing the distributions for the supply and demand for railcars to approximate the probability of receiving general tariff cars. These values were subjected to the logic of the general tariff allocation mechanisms to determine the likelihood of receiving cars under this option.

Monthly railcar supply and demand estimates were calculated for North Dakota. Demand estimates were derived from several sources. First, average production levels for 1990–94 were computed for wheat, barley, sunflower, oats, soybeans, flaxseed, and corn from historic estimates of principal crops harvested in North Dakota (North Dakota Agricultural Statistics Service). Trucking shares of the average annual production (tons) were netted out, assuming an average (1990–94) rail-truck ratio derived from various "North Dakota Grain and Oilseed Transportation Statistics" publications (i.e., Busch and Vachal 1992, 1993; Anderson, Young, and Vachal; Anderson and Vachal). Rail shares of annual production were converted to car units, using load factors for each

commodity (Burlington Northern Railroad Co.). Average total monthly grain and oilseed market sales were computed by multiplying derived average percentages of crop year totals sold in open market for 1990–94 (North Dakota Agricultural Statistics Service). This total served as the railcar demand estimate for North Dakota.[5]

Railcar supply estimates for North Dakota were derived using several sources. North Dakota grain movement served as the basis for these estimates (Anderson, Young, and Vachal; Anderson and Vachal). First, three-year average monthly totals were computed for wheat, barley, sunflowers, oats, flaxseed, and corn. These totals were converted into cars using 1993 BN load factors (Burlington Northern Railroad Co.). Nontariff movements were subtracted from these totals, assuming a fixed annual percentage of tariff movements (Vachal). This total served as the residual railcar supply estimate for North Dakota. The estimates of both railcar supply and demand were treated as random variables.

An algorithm was developed to simulate the general tariff allocation procedures used by the BN (Burlington Northern Tariff ICC-BN-4022 H-I, 1990–94). If car supply exceeded car demand, the shipper would receive one train for that month; otherwise, a random draw from a uniform distribution was used to determine whether cars would be received during that month. If the shipper won, it was awarded one 26-car unit-train. Otherwise, the elevator received no general tariff cars for the month. A uniform distribution between zero and one assures that each shipper has an equal likelihood of receiving a train. Residual supplies, if present, are also randomly allocated. This procedure exactly replicates that used by the BN in allocation of its general tariff cars.

Shipping Demand

Shipping demand was determined stochastically by evaluating variables within the model that determine the expected net payoff of storing versus shipping grain. The shipper is assumed hedged in the futures market for its commodity risk, thereby making futures price, F, a nonrandom variable. Variables included in this evaluation are: (a) inter-month price differences, i.e., the "carry" in the commodity market from time period t to $t + z$ is defined as $[(F + B)_{t+z} - (F + B)_t]$, where F is the commodity futures price, and B is the basis at the destination market in the respective periods $t + z$ and t; (b) interest cost of storage (i); (c) transport costs (T), which are comprised of the current tariff plus expected change in tariff and premium costs (i.e., $T = R^{oj} + E\Delta R^{oj} + R^S$); and (d) storage capacity.

Shipping demand is determined as follows. If $[(F + B)_{t+z} - (F + B)_t] < [i + E(\Delta T)]$, grain is shipped; otherwise it is stored. Literally, if the inter-month price spread $[(F + B)_{t+z} - (F + B)_t]$ is greater than the estimated marginal cost of storage (i) and the expected change in transport $[E(\Delta T)]$, then grain is stored. Grain stocks are not shipped and are stored if $[(F + B)_{t+z} - (F + B)_t] > [i + E(\Delta T)]$. The evaluation also compares grain supplies to storage capacity as follows. If the total monthly grain supplies (TGS) exceed the storage capacity (SC), shipping demand is equal to the excess inventory.

When there is a carry in the market, i.e., when $[(F + B)_{t+z} - (F + B)_t] > [i + E(\Delta T)]$, and total monthly grain supplies are less than storage capacity, shipping demand is zero. If

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[5] Shippers are assumed to prefer to move grain with lower-cost tariff cars if possible. For this reason, the summation of the monthly car totals for each commodity serves as the proxy for the total monthly general tariff demand.

Table 2. Alternative Shipping Strategies Considered in the Analysis

Strategy	G^L		General Tariff	G^S
	Trains/ Month	% Annual Vol. Under G^L [a]		
G^S Intensive (0-G^L)	0	0	Random	*
G^S Mix (2-G^L)	2	33	Random	*
G^L Mix (4-G^L)	4	67	Random	*
G^L Intensive (6-G^L)	6	100	Random	*

*Determined dynamically within the model. Specifically, each shipping strategy consists of a given G^L position, with general tariff and G^S cars filling residual shipping demand, when present.
[a]Derived as the expected value of car placement under longer-term guarantees. These represent the actual percentage times the probability of car placement under that service option.

the inter-month price spread is less than the cost of storage and transport, the shipping demand is total monthly grain supply. Ultimately, random movements in the inter-month spreads and basis levels generate shipping demand in the model.

Car-Ordering Strategies

Shipping demand is the basis for implementing sales and car-ordering strategies. In the model, railcars are ordered using each of the three options. The hierarchy of use of these mechanisms is as follows. First, general tariff cars are always used to meet monthly shipping demand, but both shipping demand and cars received under general tariff are random. Second, varying positions in G^L are assumed. Finally, the residual not met using either of these mechanisms is shipped on shorter-term guarantees (G^S).

Specifically, general tariff orders are ordered monthly whenever shipping demand is positive, accepting them if they are awarded through the allocation process. Cars also are ordered using long-term commitments (G^L), ranging from 0–6 trains per month. This is an important strategic variable and is analyzed in different simulations. Monthly shipping demands not met with G^L and general tariff cars are shipped using short-term guarantees (G^S) which can be purchased on a monthly basis. Alternative shipping strategies considered in the analysis are presented in table 2.

Simulation Scenarios and Results

The base case scenario is presented first, followed by simulations of changes in key variables affecting uncertainty. In the simulation, car-ordering strategies were varied while holding all other parameters and distributions fixed.

Base Case Results

A fundamental element of strategy for all shippers is the portion of shipment made under longer-term guarantees versus shorter-term options. This decision is complicated

by numerous sources of uncertainties; the most important are shipping demand, price spreads, etc., and varying penalties and requirements of the different shipping mechanisms. The simulations seek to capture these effects and evaluate tradeoffs and illustrate differences.

The maximum $E(\pi)$ was \$582,085 with a shipping strategy of zero G^Ls (i.e., G^S intensive). Under this strategy, the shipper supplements all of the remainder of shipping demand with G^S. Longer-term guarantees are not used in this strategy (i.e., $G^L = 0$). Increased use of longer-term guarantees results in lower payoffs, and the $E(\pi)$ decreases at an increasing rate. The $E(\pi)$ declines to -\$248,335 with a G^L strategy of six unit-trains per month and no short-term guarantees. Results show a \$541,880 reduction in revenues on grain sales going from the $E(\pi)$ maximizing strategy to 100% coverage with longer-term guarantees. Total revenues on grain sales are affected by grain prices and the quantity shipped in a given month.

The relationship between $E(\pi)$ and shipping strategy is a result of several factors. Of particular importance is that G^Ls remove marketing flexibility, forcing shipments in otherwise suboptimal shipping periods. As the number of G^Ls increases, shipping patterns are governed less by market spreads and more by railcar positions and associated obligations.

A second factor is that shipper cancellation penalties are more frequent with greater use of G^L, increasing from nil with the G^S intensive strategy to \$48,428 with the G^L intensive strategy (figure 3). Uncertainties in grain supplies generate a greater frequency of being in an excess car position with more fixed shipping strategies. Declining carrying costs reflect the lower levels of grain stocks. G^S strategies enable shippers to better target months with favorable prices and to avoid cancellation penalties when grain stocks, and therefore shipping demand, are nil.

As the shipper's strategy becomes more long-term intensive, the standard deviation of $E(\pi)$ diminishes and reaches a minimum at 5-G^Ls, increasing thereafter.[6] Lower risk levels reflect the stability in the shipping patterns realized with such commitments, and reduced risk of changes in shipping costs and storage.

Tradeoffs between $E(\pi)$ and risks are illustrated in figure 4, typifying a conventional tradeoff relationship. Generally, increased profits can be attained with different strategies, but only by incurring greater risks. Here, risks for the shipper would be reduced with a longer-term car guarantee strategy of 4–5 trains per month, or generally covering from 66–83% of annual shipping requirements using longer-term guarantees. The residual would be covered, using service either under shorter-term guarantees or general tariffs. Profits increase with less use of longer-term guarantees and increased use of shorter-term guarantees. By only using tariffs and shorter-term guarantees, profits would increase by 56%, but risk also would increase from the minimum risk strategy. Ultimately, the selection of a shipping strategy depends on the risk preferences of the decision maker.

For perspective, the model also was run assuming 0-G^L and 0-G^S, implying that the shipping strategy was 100% on the general tariff option. Simulations show that the $E(\pi)$

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[6] Absolute risk (standard deviation) is minimized somewhere between the 4-G^L and 5-G^L strategies. A strategy of 5-G^Ls results in an $E(\pi)$ of \$132,595 and a standard deviation of \$1.831 million; the 4-G^L strategy results in an $E(\pi)$ of \$254,275 and standard deviation of \$1.835 million. An additional \$121,680 could be added to the $E(\pi)$ by accepting a \$3,894 increase in risk with the 4-G^L strategy.
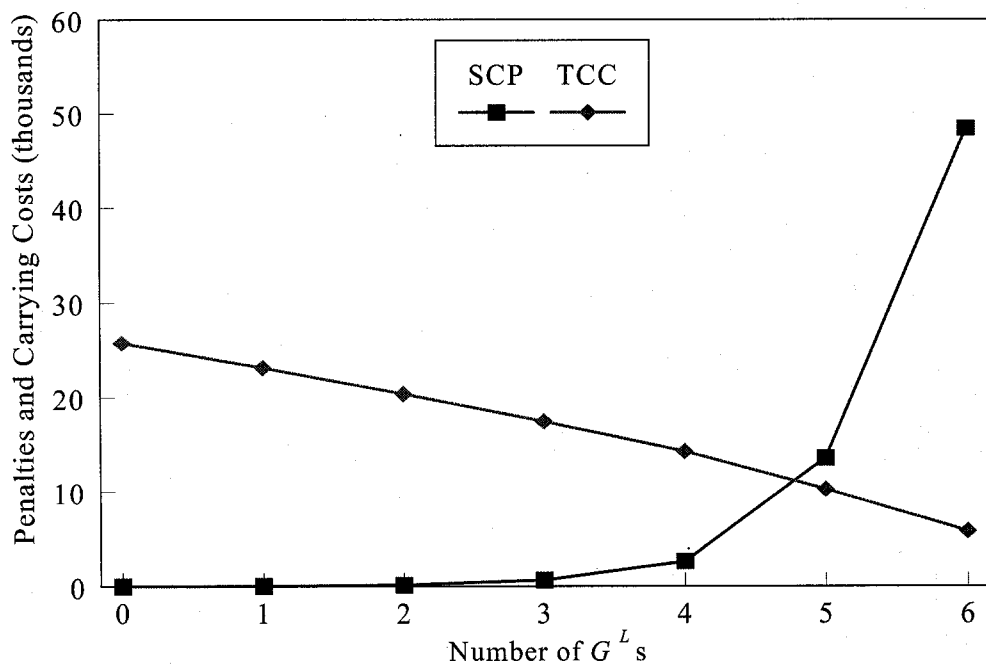
Figure 3. Relationships among shipper cancellation penalties (SCPs), total carrying cost (TCC), and shipping strategy
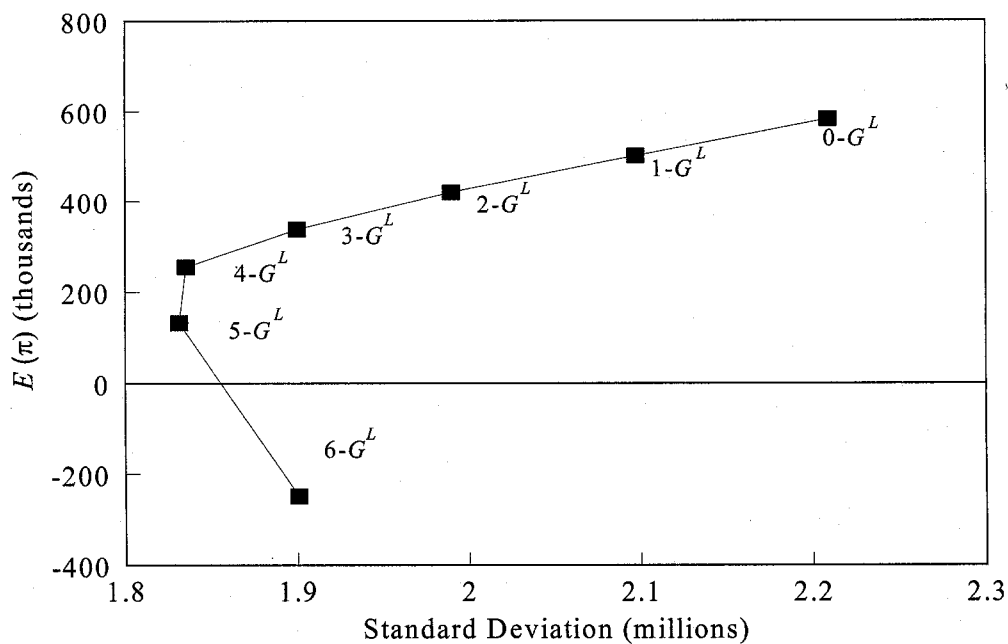

Figure 4. Shipper tradeoffs for alternative strategies

Table 3. Summary of the Simulation Results: Percentage Change from the Base Case

Description	Expected Annual Net Payoff by Shipping Strategy (G^Ls)				Std. Dev. of Expected Annual Net Payoff by Shipping Strategy (G^Ls)			
	0	2	4	6	0	2	4	6
150% tariff service reliability	16.2	22.1	26.9	28.8	−0.1	0.0	0.6	0.6
50% tariff service reliability	−14.0	−19.3	−27.6	−31.1	−0.4	−0.3	−0.3	−0.5
150% forward/spot ratio	0.1	0.2	2.3	11.8	−8.4	−10.7	−13.0	−13.8
50% forward/spot ratio	−0.2	−0.4	−4.1	−14.4	9.3	11.7	14.0	14.6
150% G^L premium	0.0	−8.7	−28.8	−44.3	0.0	0.0	0.0	0.0
50% G^L premium	0.0	8.7	28.8	44.3	0.0	0.0	0.0	0.0
150% G^S premium	−13.0	−12.1	−9.9	−2.1	−0.1	−0.2	−0.2	−0.1
50% G^S premium	12.4	11.3	9.0	1.7	0.2	0.2	0.2	0.1
150% carrying cost	−1.1	2.2	−3.3	−4.0	−0.4	−0.2	−0.1	−0.1
50% carrying cost	−4.4	−3.5	0.0	4.1	1.1	0.6	0.1	0.1

was negative, and excess grain stocks routinely exceeded the storage capacity. Effectively, these results illustrate an inability to meet annual shipping requirements and the need to expand storage capacity if the shipper relied solely on general tariff cars.

Sensitivity Analysis

Simulations were conducted to evaluate effects of sources of uncertainty on a spectrum of shipping strategies. Elements of uncertainty selected for analysis were (*a*) reliability of general tariff service; (*b*) premiums for guaranteed service, R^S and R^L; and (*c*) uncertainty in the ratio of forward to spot grain purchases. To accomplish this and to simplify the presentation, sensitivities were conducted assuming differences of ±50% from base case values and were demonstrated for each of the strategy combinations from 0–6 trains per month of longer-term guarantees (G^L), the residual being from tariff cars and shorter-term guarantees. A summary of results from sensitivity analyses on key elements is presented in table 3. Effects of these variables on $E(\pi)$ and risks are discussed below with respect to the G^L and G^S intensive strategies.

Reliability of General Tariff Service. Reliability in car placement under general tariff shipments is an important problem for grain shippers. The likelihood of receipt of general tariff cars depends on the distribution of the supply/demand ratio, and thus whether cars are randomly allocated. Simulations were conducted on the supply and demand variables that affect the probability of receiving general tariff cars.

Reliability of general tariff service affects shipping strategies that depend more on shorter-term commitments. $E(\pi)$ is positively affected by changes in general tariff service reliability. Increases in service reliability increase profit from the base case levels for each strategy, ranging from 16% (0-G^L) to 29% (6-G^L). Decreases in service reliability result in negative changes ranging from −14% (0-G^L) to −31% (6-G^L).

Improvements in the service reliability lead to less uncertainty in tariff car receipts and vice versa. The impact of service reliability has a greater effect on $E(\pi)$ for shipping strategies that are more G^L intensive. Shipping strategies that rely more on shorter-term guarantees (G^S) are less affected by changes in tariff service reliability. The more fixed G^L intensive strategies incur fewer shipper cancellation penalties with higher service reliability on tariff cars. Essentially, greater service reliability for tariff cars enhances the value of longer-term guarantee mechanisms because there is less uncertainty regarding residual shipping demand (i.e., that not met from tariff cars).

The standard deviation was unaffected by changes in the tariff service reliability. This is likely due to the general tariff allocation logic that depends on a random draw and the limited percentage of total shipments made with the tariff option.

Uncertainty in Forward Grain Purchases. The timing of grain purchases from farmers results in a great source of uncertainty for shippers. During preharvest, producers—and therefore shippers—have a high degree of uncertainty due to growing season risk. In the post-harvest period, uncertainty also exists around farmer delivery patterns. Grain purchased under forward contracts has less uncertainty, resulting in a greater ability to plan logistics requirements. Uncertainties about farmer sales patterns result in uncertainty in shipping demand, and thus risks associated with railcar strategies. These effects are an important part of the model. To evaluate this effect, simulations were conducted on a ±50% change in grain purchases under forward contracts which also affect the level of spot purchases, since these two comprise total purchases. This relationship is denoted the forward/spot (F/S) ratio (i.e., the portion of the crop purchased under a forward contract versus spots) in table 3.

$E(\pi)$ has a positive relationship with changes in the percentage of forward purchases. Increases in the level of forward contracted deliveries increase the expected payoffs across strategies. Increases in forward deliveries result in increases from base case levels for each strategy, ranging from zero to 12% for the 0-G^L and 6-G^L strategies, respectively. Decreases result in negative changes ranging from zero to -14% (table 3). The G^L intensive strategy is affected the most by changes in the forward/spot delivery ratio.

Forward purchases have the largest impact on risk across strategies. Sensitivities show an inverse relationship between changes in the level of forward contracts and the standard deviation of $E(\pi)$. Greater use of purchases under forward contracts results in less risk. Forward contract purchases are more important as the strategy becomes more G^L intensive (see table 3). The strategic implication of this is important: an increase in grain purchased under forward contracts reduces uncertainty in shipping demand, making forward shipping alternatives more effective and lessening the risk of cancellation penalties.

G^S and G^L Premiums. G^S and G^L premiums vary with grain transportation market conditions. Shippers can take positions as far forward as six months before the shipping period with certain G^S programs. However, premiums tend to be seasonal, and volatile annual production levels can result in unanticipated shifts in G^S premiums (W. Wilson 1995). Positions and premiums for G^L instruments can be made one to three years in advance at fixed premiums through forward contracts. Uncertainty also exists over the actual future value of the G^L instrument. Thus, the relationship between G^S premiums

(which are random) and G^L premiums (which can be locked for extended periods) is critical. Volatility in G^S premiums was represented in the model by a random normally distributed variable based on monthly BN COTs data from 1993–95 (W. Wilson 1996). G^L premiums were fixed at their April 1996 value of $130 per car to reflect their contractual nature. Simulations were conducted at ±50% deviations in each of these premiums for each of the shipping strategies.

The G^S premium level had an inverse relationship with $E(\pi)$. Higher premiums result in reduced profits from base case levels for each strategy, ranging from -2% to -13%, consequently making G^L intensive strategies more attractive. As expected, the G^S intensive strategy was the most sensitive to changes in premiums.

Changes in G^L premiums had the greatest impact on $E(\pi)$ for strategies with more longer-term coverage (table 3). This parameter had an inverse relationship with the $E(\pi)$.[7] Increases in G^L premiums resulted in a decrease from the base case levels for the G^S mix (-9%), G^L mix (-29%), and G^L intensive (-44%) strategies. Decreases in G^L premiums increased from the base case levels for the G^S mix (9%), G^L mix (29%), and G^L intensive (44%) strategies.

Summary of Simulation Results

These simulation results provide insight into effects of changes in key elements of uncertainty and the relationships between G^S and G^L shipping strategies. First, reliability of general tariff service has the greatest impact on expected payoff levels for the G^S intensive and G^S mix strategies. The discrete and random nature of the general allocation mechanism leads to large changes in $E(\pi)$. Second, G^L premium changes have the greatest impact on the more G^L intensive strategies. The fixity of the forward rate becomes more critical than the general tariff reliability as the shipping strategy becomes more long-term intensive. Third, grain purchases on forward contracts increase in importance as the shipper becomes more G^L oriented in strategy. Uncertainty in spot purchases results in greater risk of being understocked. Securing stocks through forward contracts leads to greater $E(\pi)$ and lower risk. Finally, G^S premiums become less important as the shipping strategy becomes more long term.

The G^S intensive (i.e., $0\text{-}G^L$) strategy consistently provided the highest $E(\pi)$ and the greatest risk. Carrying cost, G^S premiums, and tariff service reliability had little impact on the standard deviation of risk. The ratio of forward to spot purchases (F/S ratio) had the most influence on risk for each strategy. However, such changes only have a significant impact on $E(\pi)$ with the G^L intensive strategy. Integration of G^Ls into a shipping strategy results in less risk.

Conclusions

Railcar market allocation has evolved dramatically since the passage of the Staggers Rail Act. Railroads have addressed chronic problems with the introduction of several innovative market-based allocation and ordering mechanisms. Because of these

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[7] The G^S intensive strategy was unaffected by G^L premium changes since this strategy does not use the G^L instrument.

innovations, grain marketing participants are confronted with three logistical options: (a) general tariff, (b) short-term guarantees (G^S), and (c) long-term guarantees (G^L). Forward guarantees are attractive to shippers because of seasonal fluctuations in railcar demand. Shippers must consider among different combinations of these strategies to maximize expected profits, recognizing that each strategy has different risks and obligations.

In this study we have evaluated rail and logistical options confronting grain shippers. Results illustrate that annual profits and risks increase for shipping strategies making greater use of short-term guarantees (G^S intensive strategies). Second, reliability of general tariff service has an important impact on the expected payoff levels. In addition, the portion of grain purchases made on forward contracts versus spot affects risk. Changes in the portion of purchases under forward contracts, however, have greater effects on shipping strategies using longer-term guarantees. Therefore, lower risk is achieved by integrating G^L into a shipping strategy and contracting forward purchases. However, shippers must coordinate their forward car and grain positions.

Results from this dynamic stochastic simulation model can put perspective on the importance of the variables in this system. This study illustrates the role of car-ordering strategies and their relationships to uncertainties in deliveries, premium levels, carrying costs, and tariff reliability. Some implications are identified below for shippers, railroads, and public policy.

Implications for Shippers

In any period, shippers must develop forward strategies that integrate grain trading and logistics strategies. These findings illustrate that grain merchandising decisions which are not integrated with forward shipping strategies are highly risky, and payoffs would be much less. In the extreme, the 100% general tariff shipping strategy would result in negative expected profits and the need to expand storage capacity. Coordination of expected grain purchases, sales, and shipping requirements increases profits. In doing so, managers must integrate grain marketing and transportation decision planning.

Implementing forward car-ordering strategies affects shipping patterns. First, as G^L use increases, shipping patterns become less governed by market spreads and more by railcar commitments. Such strategies remove a degree of market speculation and may induce shipments in otherwise "suboptimal" shipping demand periods compared to the more flexible G^S strategies. As use of G^Ss increases, shipping decisions become more governed by grain market conditions. The value of G^S rests with the strategic flexibility of this instrument to target peak demand shipping periods.

Shipping a portion of shipments on long-term guarantees (G^Ls) increases stability in shipping patterns and reduces risk, up to a point. As the shipper's strategy depends more on G^Ls, risk diminishes, reaches a minimum, and then increases. Results suggest that longer-term freight positions of 66–83% of annual shipments would minimize risk for a shipper with logistical characteristics similar to a typical North Dakota shipper. Fixed G^L strategies may be viewed as risk-reducing tools when used with the more flexible G^Ss. Success of such efforts, however, ultimately depends on the accuracy of shipping demand projections. Since logistical options are taken over a year in advance, shippers' projections of monthly shipping demands are critical.

The importance of forward contracts for grain purchases escalates as shippers integrate grain merchandising and transportation strategies. Increased use of forward contracts reduces uncertainty about forward shipping demand, making longer-term shipping options more attractive and less risky. Shipping strategies with longer-term guarantees require more planning and scheduling of grain flows. In this analysis, the portion of grain purchases under a forward contract has a great impact on expected payoff levels and risk, particularly for G^L intensive strategies. Greater certainty in monthly grain stock levels through forward contracts creates an assurance that reduces shipper cancellation penalties.

Transferability of the forward instruments has led to the development of informal secondary markets. The emergence of transportation brokers and packages put together by grain trading firms has created more options for grain shippers. Secondary markets can serve to adjust the size of railcar positions. Shippers with greater uncertainty in shipping needs can defer positions until demand becomes more apparent and then purchase instruments on the secondary market. Risk-averse shippers also can reduce uncertainty in primary market positions by purchasing instruments closer to the delivery period.

Implications for Railroads

Railroads must closely monitor the effectiveness of the design of these instruments. Objectives should be to develop and offer options for shippers. Optimal levels of shipper cancellation and carrier default penalties must be derived and implemented to ensure appropriate incentives are present.

Market-based allocation mechanisms have led to greater sophistication of logistical decision making. These systems are likely to result in productivity gains that will benefit carriers. Most obvious is that the forward dimension of the shipping options provides incentives for shippers to even out seasonal demands, and concurrently provides less uncertainty and variability in forward shipping demand for the carrier. Ultimately, the challenge for railroads is to integrate this information into operations and capacity planning.

Implications for Public Policy

Guaranteed rail transportation services have generated many public policy concerns. As an example, in late 1997, with alleged car allocation inequities, the Surface Transportation Board superceded the prioritization system of two western carriers. This study shows demand exists for forward guarantee mechanisms in the grain industry. Shippers who develop integrated logistical strategies can reduce merchandising risk using these mechanisms. Forward guarantee mechanisms also encourage greater sophistication of grain marketing decisions. Forward guarantee mechanisms ration demand during peak demand periods and level out shipping patterns. Such developments generate improvements in grain transportation efficiency which benefit shippers and carriers.

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