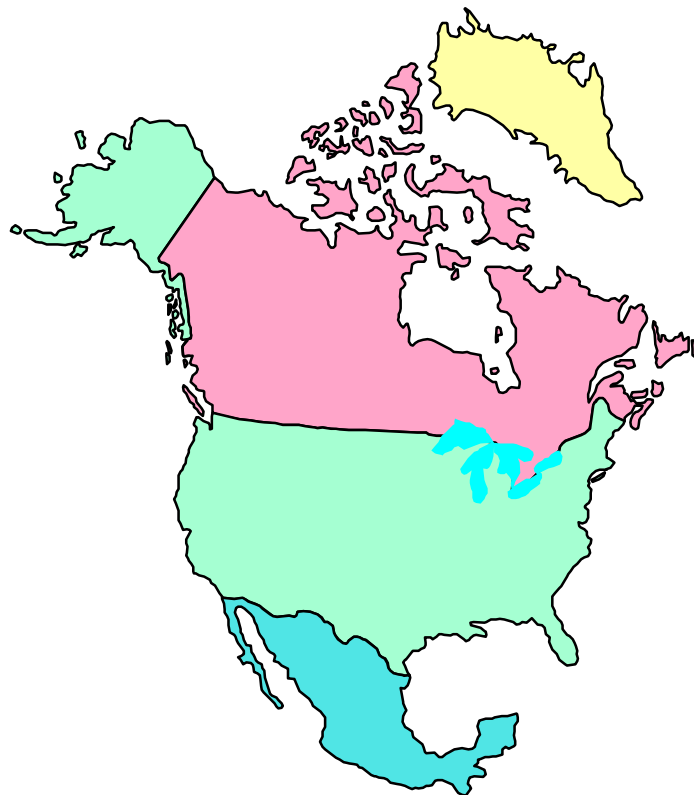Agricultural Economics Report No. 408   December 1998

Logistical Strategies and Risks in Canadian Grain Marketing

William W. Wilson
Bruce L. Dahl
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Acknowledgments

The research in this paper has benefitted from interactions with numerous individuals, both throughout the Canadian grain industry as well as my colleagues and students in discussions on how to model supply chains in grain marketing. I wish to thank in particular Mr. Bruce Dahl who was instrumental in the first round of model development and Mr. Don Carlson who subsequently ran numerous simulations. I wish to thank my colleagues who have provided very insightful ideas on the modeling and results, as well as their review of previous versions of this paper. These include Drs. William Nganje, Demcey Johnson and finally, Norma Ackerson assembled the many final versions of this manuscript. However, errors and omissions remain the responsibility of the authors.

NOTICE:

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Abstract

Supply chain management in grain marketing has become very important with the maturity of the industry. This is particularly important in the Canadian grain marketing system which has experienced disruptions for various reasons over many years. These problems have been the topic of numerous industry evaluations, have resulted in a complaint about service obligations and recently have been addressed by the Estey Commission. A detailed model of the supply chain in the Canadian grain logistics system was developed in this paper to evaluate factors that cause disruptions, as well as the effect of several important logistics and marketing strategies on system performance.

The results indicated that in a normal year there is sufficient randomness throughout the various elements of the system that it is expected that demurrage at the West Coast would be a major cost. However, the amount of service disruptions and demurrage are affected by several important factors including the distribution of tough and damp grains, mis-graded grain, and the level of exportable supplies. There are several important strategic variables that have important effects on system performance. These include the aggressiveness in selling relative to capacity, and the level of beginning port stocks.

Key Words: Grain Marketing, Transportation, Supply Chain Management, Logistics

Logistical Strategies and Risks
in Canadian Grain Marketing

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

1.   Introduction and Scope

There are a number of fundamental sources of logistical risks in grain marketing that result in unanticipated disruptions and ultimately unexpected costs to the system. In Canada, the challenge differs in that most firms are vertically integrated, but due to the administrative nature of grain marketing, operate without being able to exploit these efficiencies. Of particular interest is that there has been an increased frequency of interruptions in the grain market supply chain in the past decade. As evidence there has been what appears to be an escalation in demurrage costs, which are concurrent with shipments deferred from their planned shipping dates. Indeed, demurrage costs were one of the important sources of inefficiency cited recently by Carter, Loyns, and Berwald and their escalation in the 1996/97 crop year resulted in a complaint to the Canadian Transport Agency (CTA) about service obligations and performance. Not only are costs escalating for pool accounts, but customers are concerned about the logistical system and its operations in Canada (McKinsey).

In addition, there has been growing concern about the efficiency of the logistical system. For example, the recent McKinsey report indicated that "the Canadian grain logistics system does not perform adequately. It is costly, highly variable–unable to reliably get the right product to the right place at the right time" (McKinsey, p.1).[1] Further, though the Canadian Wheat Board (CWB) has extensive control over the system, "unneeded grain enters the system incurring unnecessary costs and 'plugging up' elevator storage space" (McKinsey, p.4). The CWB essentially plays a "coordinating role" throughout many aspects of the interior marketing system. This control has been drawn into question in the recent Estey Commission with suggestions that the CWB become a port buyer. However, the CWB has indicated they could not "effectively function as a single-desk marketer and provide our core service to farmers if we were buying at port" and have suggested that "confining the CWB to port would cost farmers money by increasing costs, increasing risk and reducing the CWB's ability to react to customer requirements." (CWB, p.2).

This report analyzes logistical strategies and risks in the Canadian grain marketing system. It emphasizes the supply chain and quantifies risks involved in managing grain marketing logistics. The critical elements in the Canadian grain marketing system that give rise to logistical risk are identified along with important characteristics of the 1996-97 crop marketing year. A dynamic stochastic simulation model was developed to quantify the logistical risks in the marketing system in a typical year, and the salient features of the 1996-97 crop year. This model was used for several purposes, most important of which was to identify variables and strategies that give rise to logistical disruption and demurrage costs.

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[1]Ballou (P.5) defines that "the mission of logistics is to get the right goods or services to the right place, at the right time, and in the desired condition, while making the greatest contribution to the firm.

2.   Critical Elements of Logistical System and Canadian Grain Marketing

Several characteristics of the West Coast grain handling system give rise to logistical performance problems and risks. These are highlighted below.

2.1   Characteristics of West Coast Grain Handling

West Coast Capacity Constraints. In very simple terms, West Coast exporting capacity is thought to be about 1.8 mmt per month (about 21.6 mmt per year) assuming that all elements of the system work efficiently, without interruption, and there is not unexpected underperformance by any component of the system. Any time sales are planned at or above that level the likelihood of meeting those levels diminishes. Each of the problems below are exacerbated by limited storage and the demands of movement of competing crops.

Increased Number of Grades.   There has been a rapid increase in the number of grains (wheat and barley) and grades exported during the past five years. This is critical, because at least for CWB grains it does not appear that any individual port terminal specializes in handling specific grades/grains. As a result, demands on terminal operations have increased. These observations are supported by recent proposals considered by the CWB and Canadian Grain Commission (CGC). Specifically, as concluded in a recent report prepared for the CWB and CGC, "as new classes of wheat have been developed, the number of segregations in the system has dramatically increased." (*Western Producer).* They cite that the number of segregations has increased from 12 in 1985 to 68 in 1995/96, which is seen as "a major factor limiting the efficient movement of grain from farm to port and increasing the costs incurred by grain handling companies."

Mis-grades and Tough and Damp Unloads. A related issue is that of tough and damp and mis-grades (i.e. grain received of different quality, grain or grade than ordered). The former was potentially a peculiarity in the 1996-97 crop which severely worsened terminal throughput and resulted in deferred shipments and demurrage. Mis-grades, or offgrades, are potentially the result of any number of effects. Nevertheless, the level of mis-grades that have been documented is startling and has a dramatic effect on deferred shipments and demurrage.

FOB Selling (vs. C&F). In contrast to most multinational grain companies, the vast majority of CWB sales are FOB, as opposed to C&F. This is important because for FOB sales the ocean shipping cost is paid directly by the buyer and placement of the vessel is the buyers' responsibility. It implies that the CWB has less control over a vessel arrival within the prescribed shipping window once contracted. As a result, this is a risk that is not easily controllable.

Compressed Market Season. In the past decade it appears there has been an increase in the number of years with inverted markets which has important implications on grain marketing. Essentially, sellers all try to accelerate their rate of sales in nearby months to capture premiums. However, in so doing, their logistical risks increase. In addition, buyers, try to defer purchases as much as possible to capture discounts. The latter does affect sellers, in that, if they reserve shipments for a buyer that defers purchases, they incur added risk and cost.

2.2   Important Characteristics of the 1996-97 Crop Year

Several characteristics of the 1996-97 marketing year had adverse impacts on the performance of the logistical system. These are critical and are used in the model and identified below.

The crop was larger than normal, resulting in a projected exportable supply of CWB grains of nearly 25 mmt. In addition, there were several critical sources of uncertainty. First, the level of carry-out stocks from the 1995/96 crop was large. This prior-year carry-out was an important source of risk due to the uncertainty about whether it would enter the marketing system during the fall of 1996. Second, the crop size was severely underestimated.[2] The cumulative impacts of these uncertainties on the logistical system (as demonstrated in the simulation results) is substantial. Third, the crop was harvested later than normal, resulting in later shipments to terminals. This was worsened due to Prince Rupert starting the marketing season with virtually no stocks. Fourth, the distribution of quality was greater than normal. In particular, the levels of tough and damp were far greater than normal. Finally, the market price inversion was very large, particularly for the period beginning in January/February. This provided an incentive to sell for nearby shipping periods rather than deferred periods.

2.3   Elements of Supply Chain Management and Canadian Grain Logistics

Supply chain management is a relatively recent concept addressed by grain industry participants. Given the importance of logistics in this industry, the concept of supply chain management is critical. Supply chain management has escalated in prominence in recent years both in the United States and Canada due to the evolving industries in each country. In particular, with industry and market maturity, there are continual efforts to reduce costs through managing the vertical market system. This has become an important problem in the United States grain industry as it becomes more vertically integrated. It is a unique challenge to the Canadian grain industry in that the firms are already vertically integrated, but have relatively little control over their own logistical functions.

Ultimately the goal in logistics management is to "get the right goods or services to the right place, at the right time, and in the desired condition, while making the greatest contribution to the firm" (Ballou, p. 5). However, important factors causing problems in supply chain management are randomness in demand, quality and supplier performance.[3] Several strategies can be used to manage uncertainties, but generally include either stockholding throughout the system, and/or contingent contractual relationships to induce forward planning and supplier performance.

Several methods for improving supply chain performance have applications to the Canadian grain industry (Davis, p. 45). These include: 1) information sharing; 2) reduced tolerances; 3) reduced product offerings and options; 4) formulation of delivery expectations; 5)

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[2]For reference CWB estimates for total wheat production increased from 25.8 in cwt on June 13, 1996 to 27.7 in September, (Canadian Wheat Board, June 13 to September 12), and Statistics Canada estimates increased further from 28.8 to 29.4 in mt between September and December (Statistics Canada). For perspective, these under estimates translate to 3.6 mmt or about 2 months worth of West Coast handling capacity.

[3]See Davis and Handfield and Nichols for a summary of recent developments in supply chain management, both analytically, as well as with applications to several industries.

development of buffer capacities; and others. However, the apparent evolution of the Canadian supply chain does not promote actions that would improve supply chain performance (McKinsey). Problems include: the escalation in the number of grains, grades, and segregations in the export system; tighter specification; inadequate buffer capacities at critical points in the system; and delivery expectations which do not account for risks in the marketing system.

Logistical risks are inevitable and the challenge is to manage them. Consider the potential problems in coordinating grain logistics. Sales are made for a shipping period, but the timing of the vessel arrival is uncertain. The level of inventories of the right grain in port may be inadequate. Having too much grain in port positions involves an opportunity cost. Grain arriving at the terminals may be mis-graded for numerous reasons. Finally, the rate of rail car unloads is fraught with randomness that is affected by everything from car orders to strikes to farmer deliveries into the marketing system, problems in handling/loading the correct grain, and adverse weather. The point is that managing logistical risks is a very important function and challenge confronting grain marketing. Relative to other risks in grain marketing (i.e., price) the tools available for managing logistical risk are less easily adaptable.

An important theme in this analysis is that there are systemic risks in grain marketing and logistics management. Risks include (but are not limited to): 1) grain market (futures and basis) risk; 2) the timing of export sales and shipments; 3) rail car unloads and uncertainties; 4) vessel arrivals, which have some randomness due to FOB selling giving the option to the buyer for placement within shipping periods; 5) the level and randomness of tough and damp (or out of condition) grains, and unloads which do not conform with load orders. These factors represent logistical risks which vary through time. Logistical risks are also affected by the volume of export sales relative to normal rail car unloading capacity. As export sales increase relative to capacity, the potential for disruptions in the supply chain increases, as does risk.

There are two critically important elements of randomness in the logistics system. One is rail car unloads. The rate of unloads has some randomness and is affected by numerous factors. This is evidenced by examination of historical data between unloads and guidelines (Figures 1a - 1f). The second element of randomness is vessel arrivals, which in FOB transactions are essentially determined by the buyer, within a window which is negotiated in the purchase contract (normally being a 30 day window). Thus, there is risk as to which shipping week within the window a vessel arrives. Again, review of historical data supports that vessel arrival has some randomness which has the effect of increasing logistical risk.
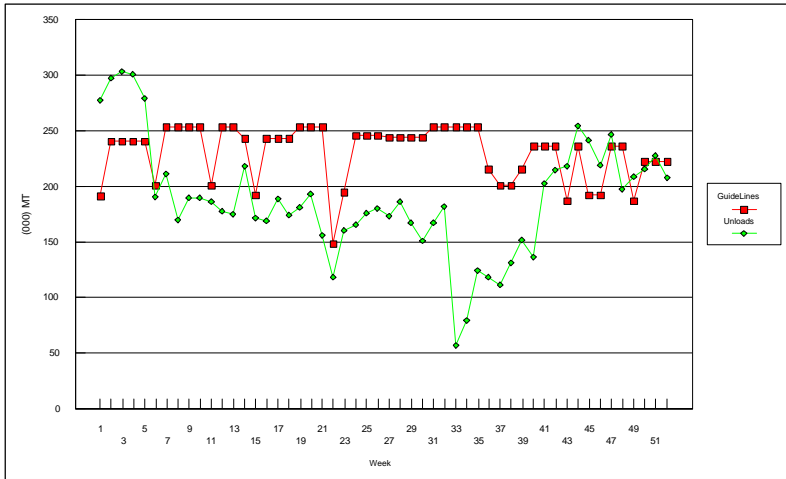
Figure 1a. CWB Unloads & Guidelines for Vancouver 1994/95
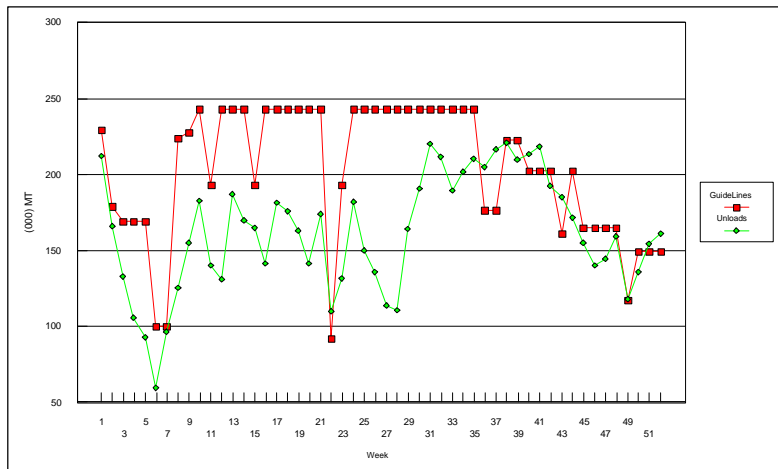
Figure 1b. CWB Unloads & Guidelines for Vancouver 1995/96
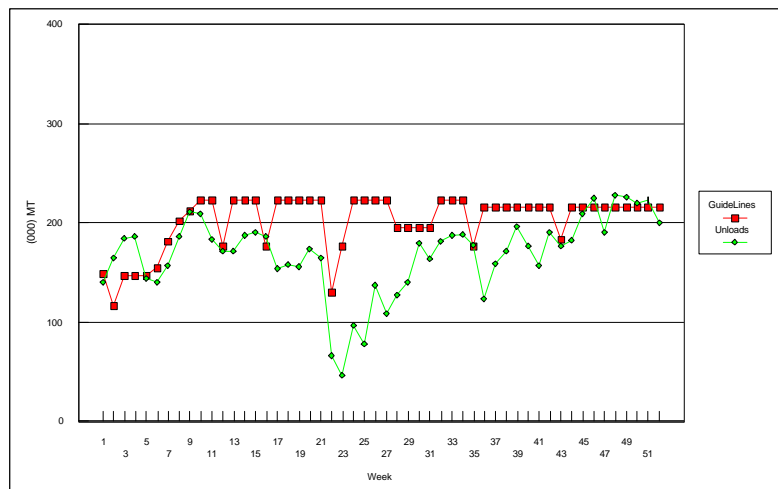
Figure 1c. CWB Unloads & Guidelines for Vancouver 1996/97
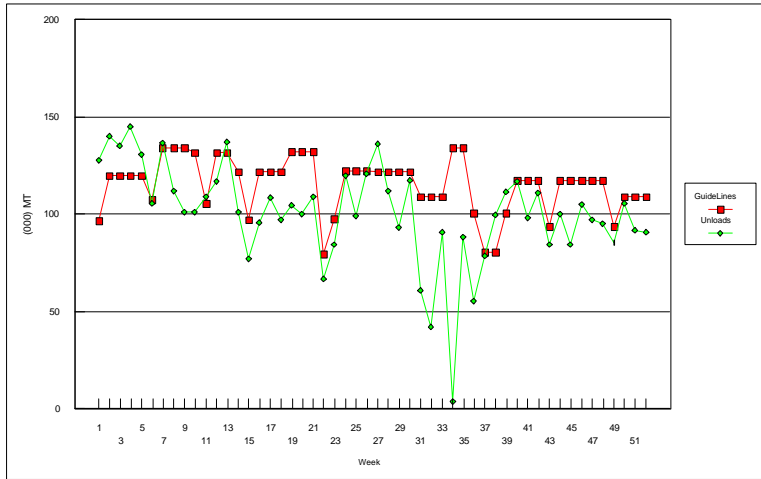
Figure 1d. CWB Unloads & Guidelines for Prince Rupert 1994/95
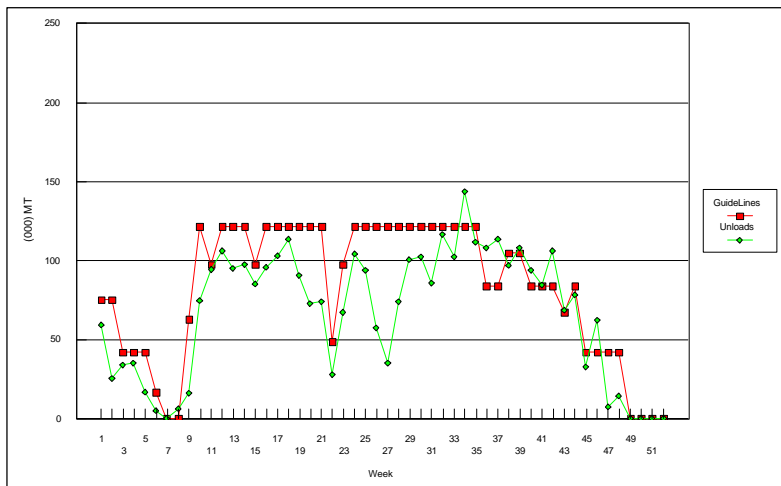
Figure 1e. CWB Unloads & Guidelines for Prince Rupert 1995/96
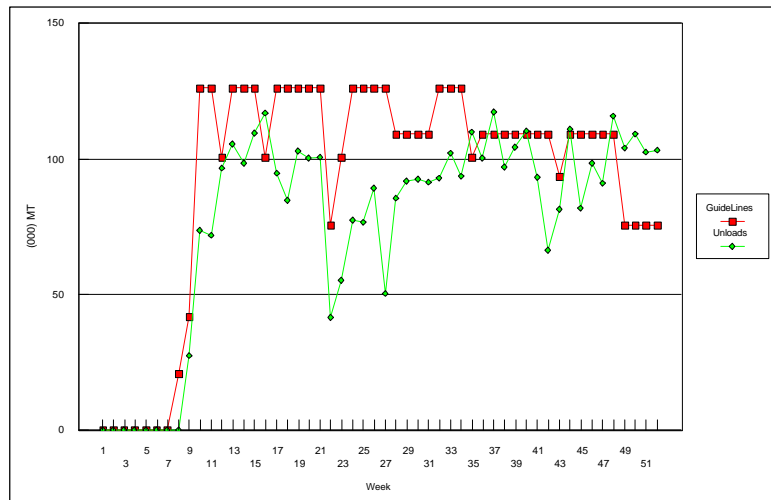
Figure 1f. CWB Unloads & Guidelines for Prince Rupert 1996/97

Tradeoffs exist in formulating marketing (sales) and logistical strategies. In general, conservative sales strategies relative to expected system performance may result in lost sales opportunities, but would minimize demurrage and other costs associated with system underperformance. In contrast, aggressive sales strategies relative to capacity would result in an escalation in logistical risks. These are not unique to the CWB or the Canadian marketing system, but in fact are a challenge to all grain exporters. The essential tradeoff is between additional sales opportunities and logistical costs, the latter including expected demurrage costs.

Unique circumstances in the 1996-97 crop marketing year exacerbated these risks as discussed above. The inversion in the market was particularly important. Given the terms of FOB sales, it may be optimal to sell in excess of capacity for nearby shipment in markets with large inversions. In this case, one would be taking a risk that system performance (i.e. unloads, vessel loadings, etc.) would exceed normal for purposes of capturing premiums associated with nearby shipments. The risk of course is that the system performs normally, or potentially underperforms, resulting in deferred shipments and demurrage accrual.

3.   Stochastic Simulation Analysis of West Coast Grain Logistics

An analytical model of the West Coast logistical system was developed to analyze factors affecting risk in the grain marketing system. The model was used to analyze logistical risks and tradeoffs, quantify demurrage costs, and evaluate the effect of critical variables and the effects of different strategic variables on the logistical system.

3.1   Model Overview and Assumptions

The analytical model was based on Materials Requirements Planning (MRP) which are normally analyzed in a non-stochastic framework.[4] However, due to the highly stochastic nature of many of the crucial variables, the model was formulated as a dynamic stochastic simulation model and analyzed using *@Risk* (Palisade).[5]

The model framework is based on a logistical position report, which is the tool used by grain traders to analyze and coordinate their logistical position. For purposes here, the logistical position report is expanded in two dimensions. Other functions of the supply chain are incorporated and stochastic variables within the logistical system are introduced explicitly.

A base case model was formulated representing the marketing characteristics of a typical year. This was used to calibrate the model, to demonstrate results, and conduct sensitivities. The model was then adapted to the peculiar characteristics of the 1996-97 crop marketing year to permit a comparison with what would be considered normal logistical flows and risks. The model is that of the logistical system, including most of the major functions. The focus is on sales,

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[4]The model used here builds on the distribution and material requirements planning (DRP and MRP) techniques (see Ballou pp. 532-545 for a description) commonly used in logistics management and the recent work by Wilson, Priewe, and Dahl which applies these techniques to rail car ordering strategies.

[5]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 1972), requirements planning (Bookbinder and Serenda 1987) and modal selection (Sheffi, Eskandari, and Koutsopoulus).

inventories and port unloads. The model and statistical distributions are described in detail in Appendix A. Following is a brief description of the logic of the model:

- *Sales by Shipping Week.* The timing of sales and shipments are made as follows based on expected prices, which are evaluated for each month forward based on current expected prices and ranges. These are evaluated relative to interest costs (i.e., the opportunity cost of holding grain) to determine if it is optimal to sell or store.[6] If it is optimal to sell, sales are made for specific shipping months. These are made subject to two constraints. One is that shipments in a given week cannot exceed λG_t where G_t is the CWB share of the unload guidelines for week t, and λ is a strategic variable indicating the portion of guidelines to which sales are made (i.e., λ in CWB sales as a fraction of unload guidelines) . In all cases $\lambda=1$, but given it is an important strategic variable, sensitivities are made on λ. Second, if it is not optimal to sell, then a minimum amount is shipped for each shipping week.

- *Vessel Arrivals.* Vessels are assumed to arrive within a shipping period, according to FOB terms, to match the allocation of temporal sales. However, given the exact timing of arrival is the buyers option in FOB contracts, a probability distribution is used to schedule arrivals within the shipping month.

- *Unloads.* Car unloads are used as a measure of system performance and is an important stochastic variable. A statistical relationship was estimated to reflect expected unloads.

- *Tough & Damp and Mis-grade.* Grain unloaded which was not of adequate quality was treated as not being readily available for export loadings. Specifically, probability distributions for Tough & Damp unloads were derived using CGC data for each week and port. Unloads exceeding Tough & Damp limits were dried subject to port drying capacity. In some cases, if the amount of Tough & Damp were large, the drying system was backlogged and inventories ready for shipment were reduced.

- *Mis-grade shipments.* Mis-grade shipments are those not conforming to intended quality specifications, or grain other than that ordered to be loaded in the country. Mis-graded grain poses important adverse effects on the logistical system. However, in contrast to Tough & Damp, it was not possible to estimate probability distributions of mis-grades, nor the natural disposition of the grain. In base case simulations, mis-grades were assumed equal to zero. However, because of the importance of this problem, sensitivities were simulated to demonstrate the impact of off-grade unloads.

- *Inventory.* Inventories were defined simply as beginning port inventories of CWB grains, plus unloads, less export loadings.

- *Demurrage/deferred Shipments.* Any time inventories were inadequate to fill arriving vessels, shipments were deferred 1 period (one week). In this case a demurrage cost was assessed.

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[6]This is similar to the temporal demand for grain shipments used by Wilson and Priewe.

The model is dynamic and stochastic because decisions and allocations are made dynamically throughout the marketing year. Stochastic variables include the following: grain prices which determine the timing of sales and shipping periods; car unloads which are based on orders to correspond with sales by shipping week (expectations about unload) are formulated based on statistical relations based on historical data. Vessel arrivals, which correspond to sales for each shipping period, but occur randomly within the shipping month; off-grade and Tough and Damp grain.

Three important logistical strategic (or decision) variables affect the supply chain and logistical risk: 1) beginning port inventories; 2) the amount of minimum weekly sales, which is intended to reflect the effect of on-going sales throughout the market season and contractual relations; and 3) the extent that sales are made relative to Unload Guidelines (i.e., λ). As sales increase relative to guidelines (i.e., λ increases) the likelihood of unloads meeting sales diminishes, inventories are depleted, shipments are deferred and demurrage accrues. This is induced by inverted grain markets, and problems are exacerbated by expanded exportable supplies, and an increase in *Tough & Damp* and *Off-Grade* unloads. The effects of these factors on logistical risks and costs are evaluated through model simulations.

A number of simplifying assumptions were made in the design of the model. These were made due to data constraints. Only West Coast ports were modeled, with separate treatment of Vancouver and Prince Rupert. Only CWB grains were included and were treated as an aggregate. However, it should be recognized that the proliferation of grades would exacerbate logistical risks. Lead time and variability of lead-time uncertainty with respect to the time between ordering the rail car and its placement at port, are not included.[7]

3.2   Results: Base Case Year

A base case was specified to typify the logistical marketing conditions of a typical marketing year. For purposes here, important characteristics of the base case include: 1) Exportable supplies of CWB grains were based on an average over the years 1993-1995; 2) Normal price relationships, reflecting typical carrying charges and volatility; 3) Normal levels of Tough & Damp; and 4) Normal levels of Beginning Port Inventories.

Some of the output from the base case model are presented for validation purposes (See Figures 2 and 3). Exports distributed among Vancouver and Prince Rupert, are generally consistent with historical values. Unloads and exports are highly linked as would be expected. Note that unloads would typically peak in about week 20 (i.e. of the shipping calender where week 1 is the first week of the crop year) and decline gradually thereafter. This is in part due to the fact that exportable supplies for West Coast shipment are generally less than system capacity. Exports generally follow a similar pattern. The probability of ship arrivals exceeding inventories increases from nil to about 12% in the case of Vancouver, and up to about 25% in the case of Prince Rupert.

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[7]In fact, there is substantial lead time and variability therewith. Other studies (Allen) have demonstrated that lead-time variability increases logistical risks. Thus, by ignoring this effect, the risks in the system are understated.
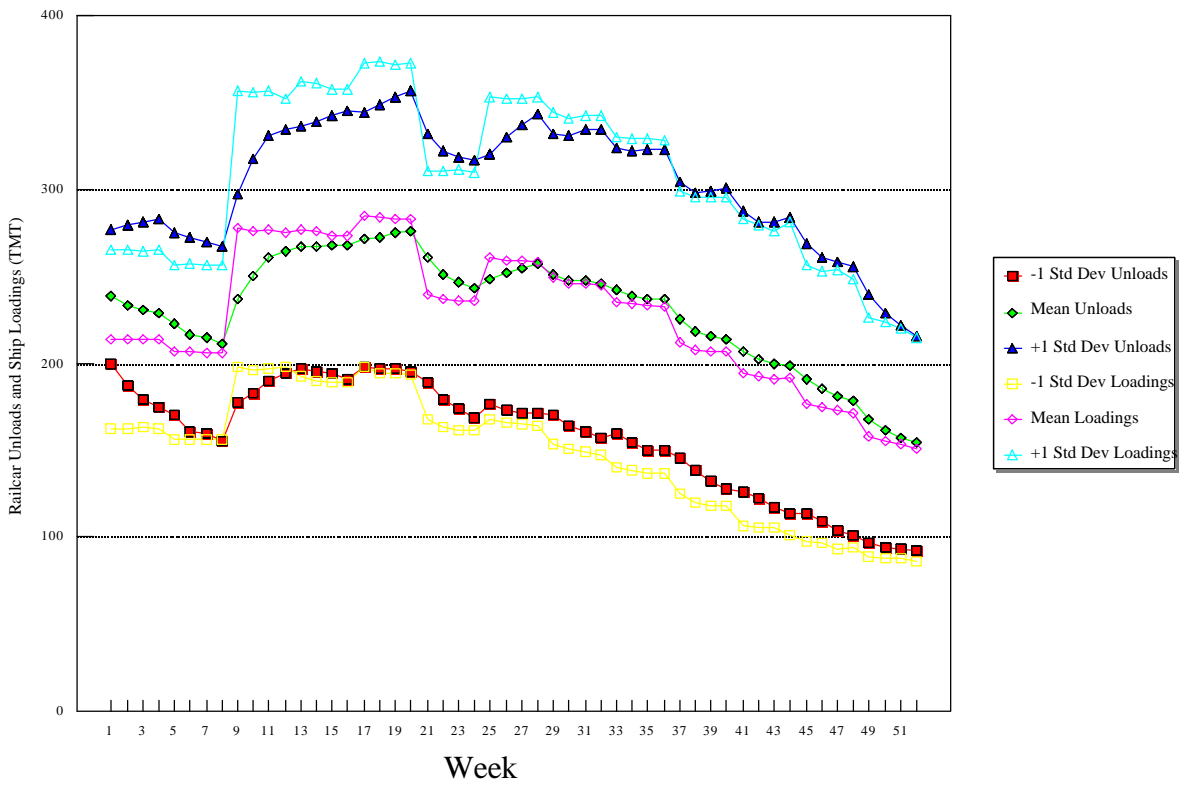
Figure 2 Distribution of West Coast CWB Railcar Unloads and Ship Loadings, by Week (Base Case).
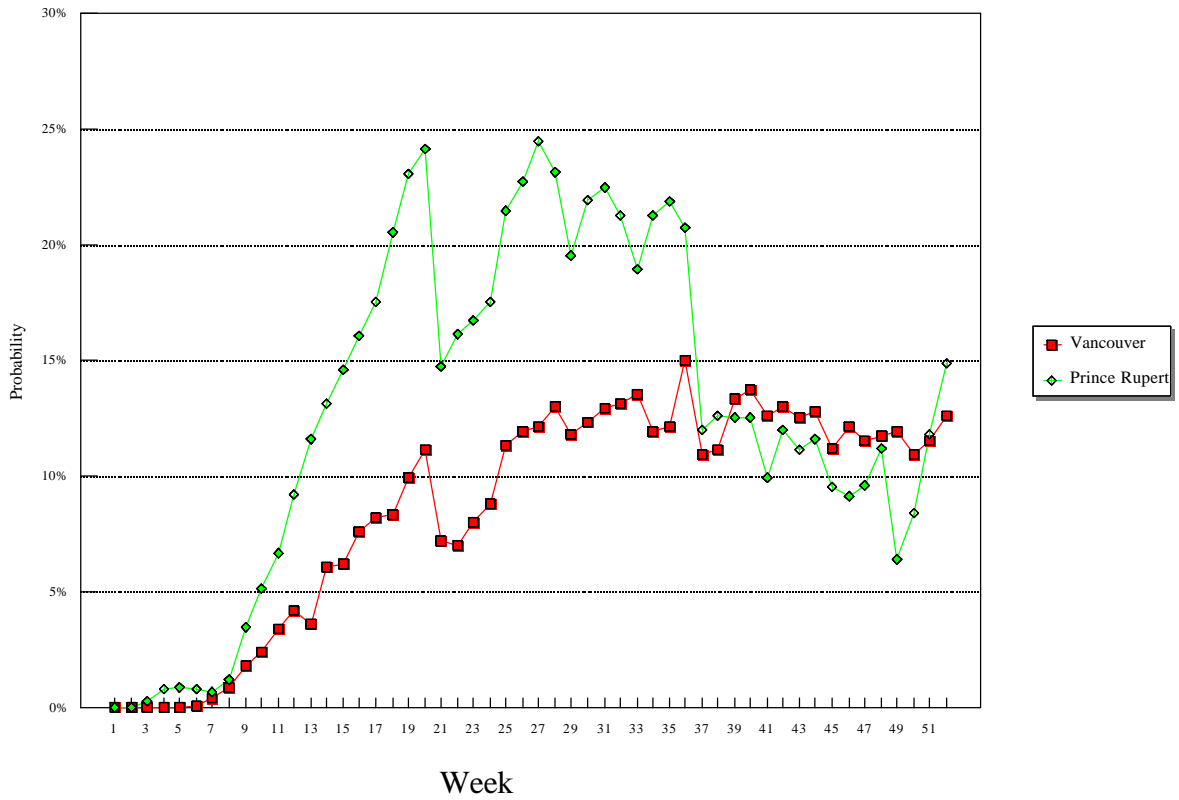
Figure 3. Probability of Ship Arrivals Greater than Grain Inventories, by Week (Base Case).

The distribution of demurrage is shown in Figure 4. It is important that normal demurrage cost for the West Coast would be about $6.2 million per year. However, the results show that demurrage could exceed $11.5 million with probability of .20. The strict interpretation of this is that given the characteristics of the Canadian grain logistical system, demurrage can vary substantially. In a normal year, there is a probability of .80 that demurrage costs would be less than $11.5 million.

Sensitivity/Simulations on Random Variables: The model was used to conduct simulations of some of the important random variables that affect logistical risks. These are summarized below. In the base case the annual average level of Tough and Damp ranged from 3.1% to 4.1% at Vancouver and was 5.5% at Prince Rupert, though it varied weekly according to a probability distribution. As the level of Tough and Damp increases (Figure 5), the expected level of demurrage increases sharply. Note that if the level of Tough and Damp is 300% of normal (on an annual average basis), expected demurrage would increase to over $19 million.

Mis-grades were assumed to be nil in the base case. However since mis-grades affect the ability to load specific shiploads, a simulation was run where mis-grades were assumed to average 5% per week of ship arrivals. To do so, ships were deferred in amounts equal to the mis-grade for a period of one to four weeks. The period of the delay was assumed to be equally likely for each week. Ships were retained in port during the delay period and charged demurrage. When the delay period was over, ships were loaded. Grain arriving as mis-grade were unloaded and assumed to be available for placement on other vessel shipments of the specified grade. The results, are shown in (Figure 6), and should be viewed as explorative because the disposition of mis-graded grain is unclear. However, if persistent mis-grading occurs of the magnitude assumed here, prospective costs to the system would increase demurrage to over $19 million.

The level of exportable supplies of CWB grains available for export through the West Coast has an important effect on demurrage. In the base case this value was 12 mmt. This relationship typifies the expected increase in costs associated with increased exports. As exportable supplies increase, the expected demurrage increases (Figure 7). This results in an increase in the likelihood of numerous specific risks, all manifested in an increased probability of short inventories in port position for export shipment.

The model was used to identify the random variables that had the greatest impact of the demurrage costs. Specifically, results from model simulations were retained and correlations were derived among the values of the random variables and demurrage costs. Results indicated that the most important variable affecting demurrage costs was the quantity of the exportable supplies. This was followed in order by unload performance, Tough and Damp, vessel arrivals and prices.
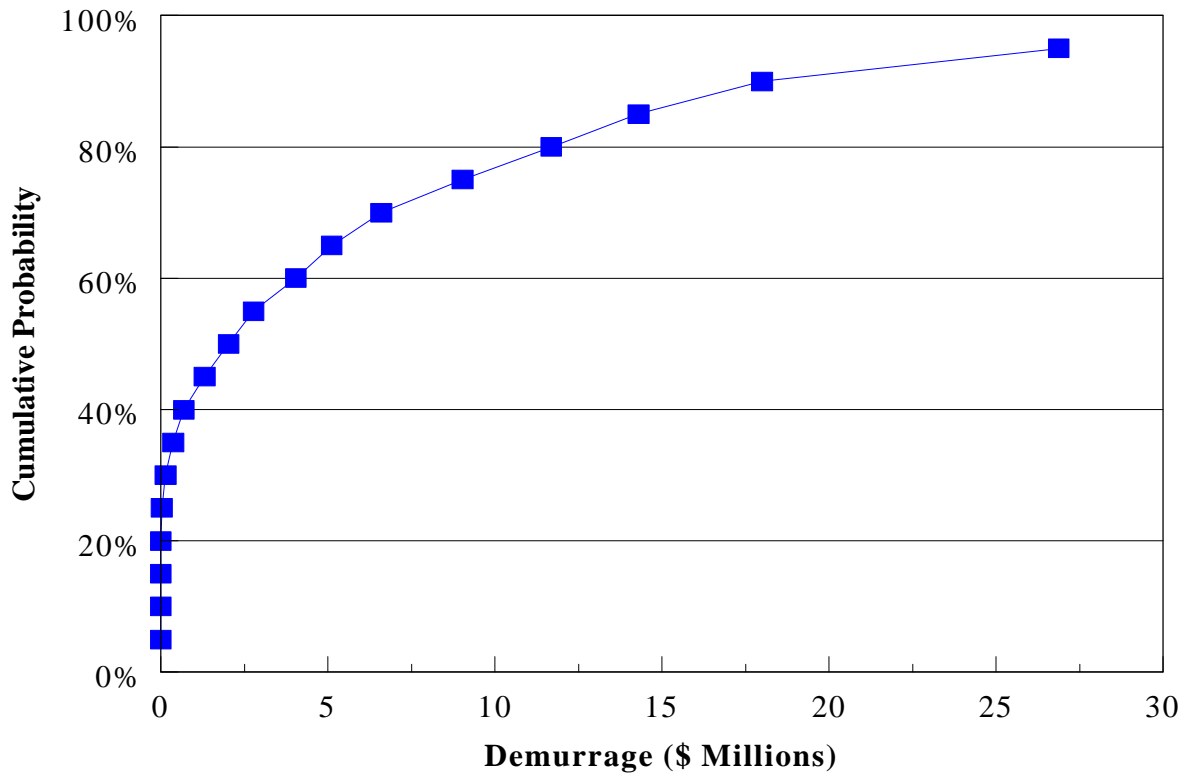
Figure 4. Distribution for Demurrage Costs (per year), Base Case.
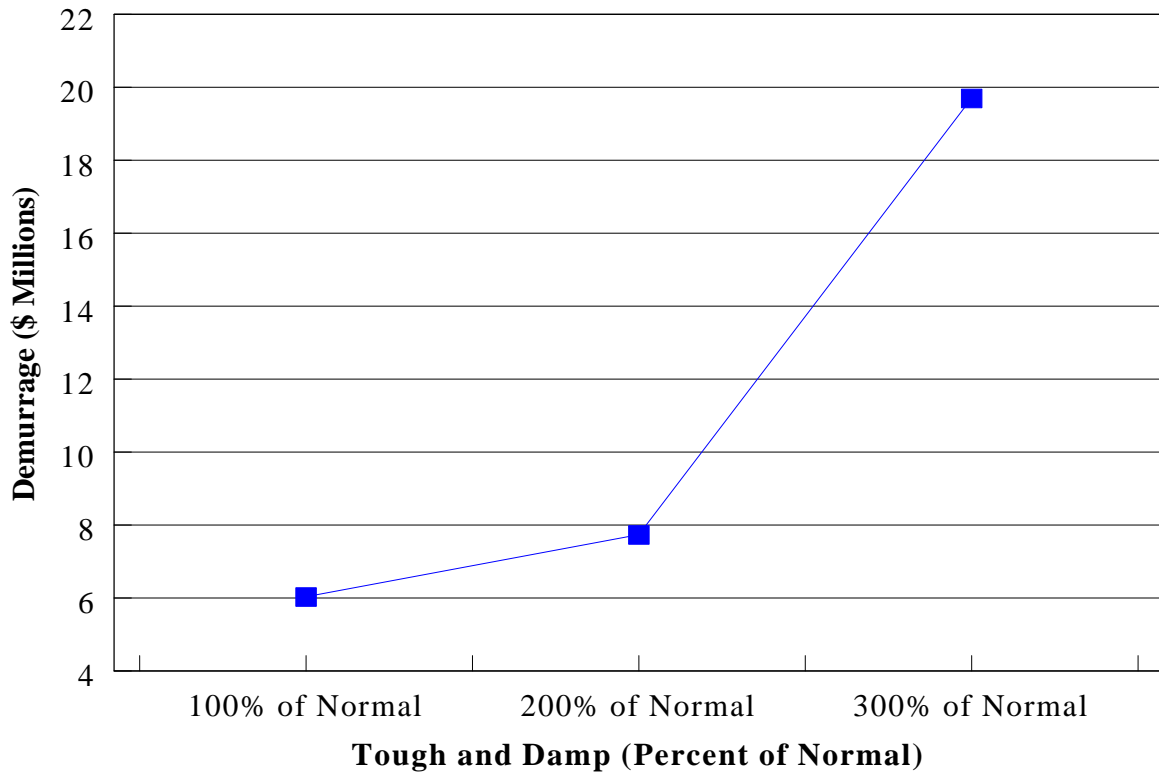
Figure 5. Average Demurrage: Effect of Tough and Damp.
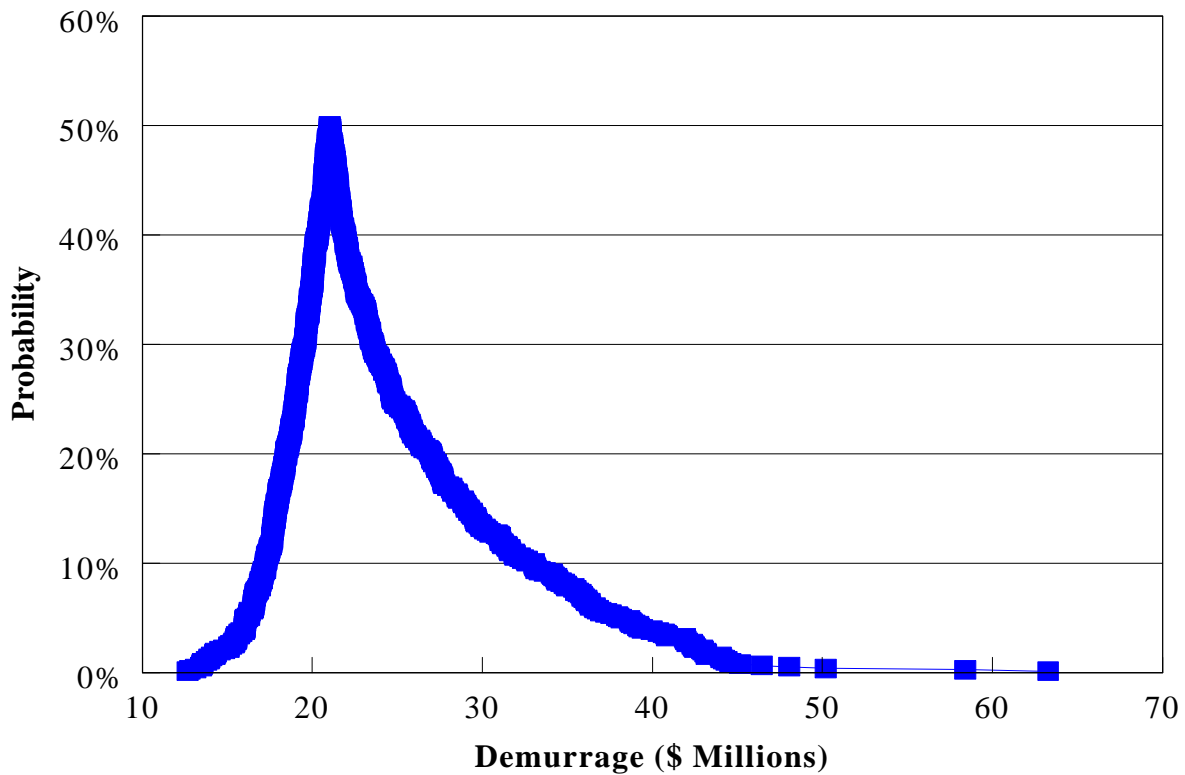
Figure 6. Probability of Demurrage: Effect of Off-Grade (Off Grade=5 Percent Per Week), Base Case.

Sensitivities/Simulations of Strategic Variables. The model was used to simulate the effects of the strategic variables on logistical risks and demurrage costs. Major conclusions are summarized below. In the base case, beginning inventories (i.e., week 1) at Vancouver and Prince Rupert were equal to historical averages. As those stocks decrease, the expected level of demurrage escalates quite radically (Figure 8). For example, inventories at 75% of normal increases expected demurrage to $8 million, an increase of $2 million.

The base case assumes that maximum weekly sales of CWB grains would be 1.0 times the CWB share of guideline unloads (i.e. λ=1). To evaluate the effect of deviations from this strategy, the model was simulated from λ=.80 to λ=1.20. As λ increases, the expected level of demurrage increases (Figure 9). It is notable that for λ<.9 (i.e., CWB are 90% of guidelines), demurrage is about $4 million. However, it increases sharply thereafter. The reason is that as sales increase relative to capacity, the likelihood of unload shortages relative to ship arrivals escalates, resulting in increased demurrage costs to the system. For example, in the base case model if the CWB sells at a rate of 1.2 times guidelines, expected demurrage would be $11 million.

The results were also simulated to evaluate the effects on pool returns. The CWB's logistical capacity was determined as the CWB's share of guideline unloads (λ = 1). Simulations representing a range of sales from λ=.6 to λ = 2.0 were run and in the base case the carry was
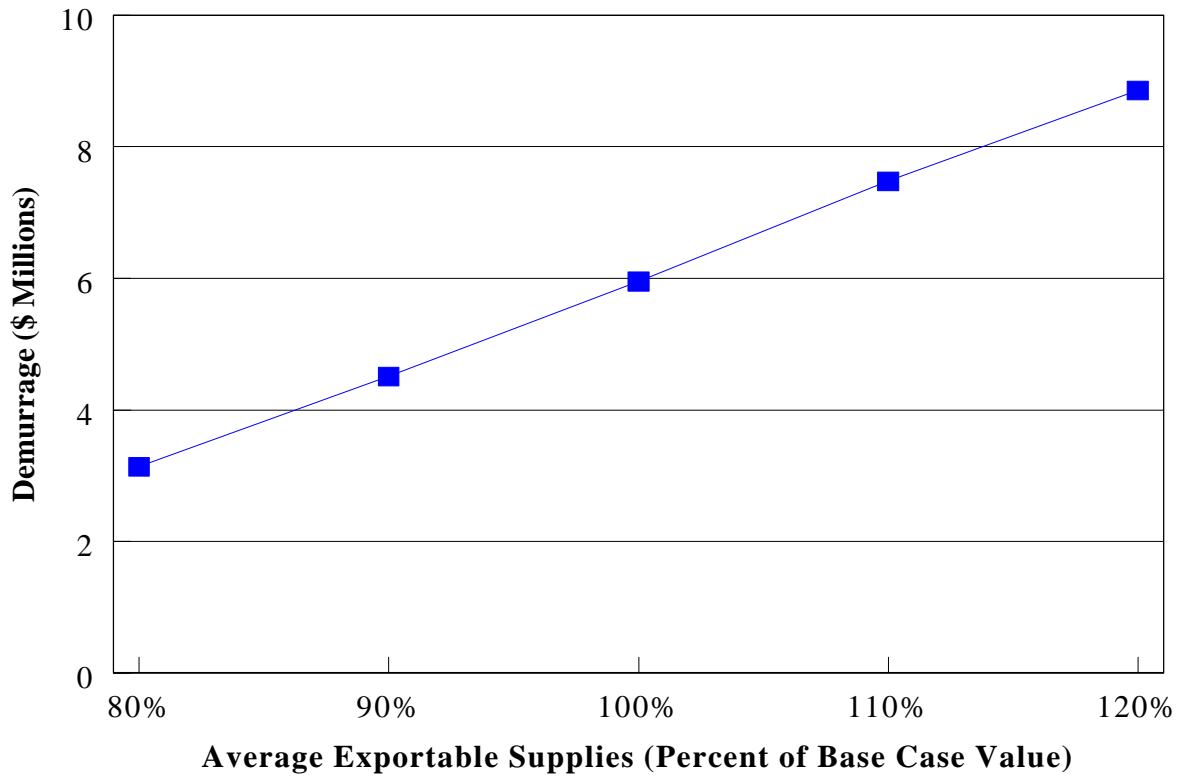
Figure 7. Average Demurrage: Effect of Exportable Supplies
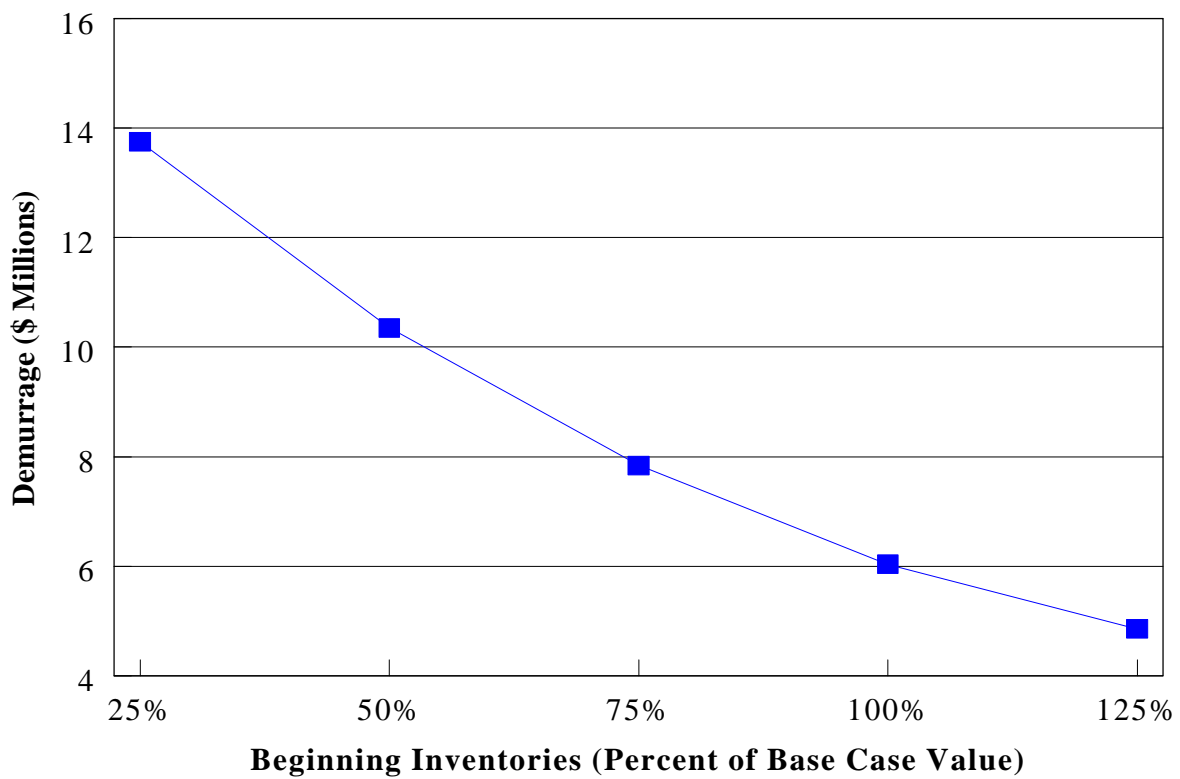
Figure 8. Average Demurrage: Effect of Beginning Port Inventories.

Figure 9. Average Demurrage: Effect of Scale Factor on Sales.

$1/mt/month. Payoffs are defined as revenue minus interest and demurrage costs: $\pi = (P \times W) - D - i$ where: P = Price 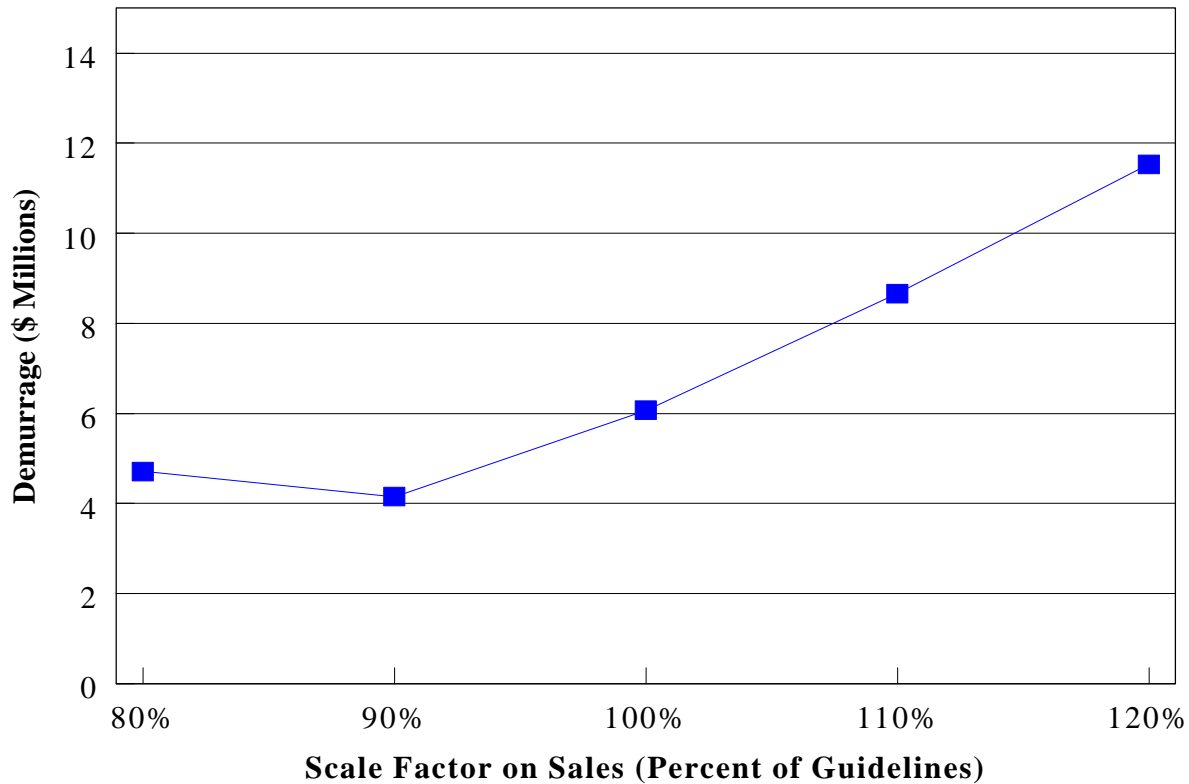in $/mt, W = Wheat sales in mt up to λG_t,[8] D = Demurrage cost and i = Interest cost. Payoffs for the pool are maximized (Figure 10) at about $\lambda=1.17$, indicating that it would be optimal to oversell logistical capacity by 20%.

These results indicate that in a normal market situation (i.e., with a mean carrying charge of +1$/mt/month) there are incentives to oversell the logistical position. For sales strategies greater than (less than) $\lambda=1.17$, the expected additional revenue from sales is less (greater than) than the expected additional interest and demurrage costs. Thus, for sales strategies greater than $\lambda=1.17$, though revenue from accelerated sales would increase, that would be offset by an increase in expected demurrage costs. Of course, this result is highly dependent on the carry in the commodity market. In market situations with a large carry, the optimal level of sales (relative to guidelines) would be less, and in fact may result in $\lambda<1.0$. In contrast, with inverses in the commodity market, the optimal level of λ increases. In this case the implication would be that the expected revenue due to selling in the more nearby shipping positions (which would be sold at a premium relative to the deferred) would exceed the expected additional demurrage which as demonstrated in Figure 10 would be increasing.

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[8]This allows for sales to be below the maximum allowed per month: minimum sales $\leq W \leq$ maximum sales.
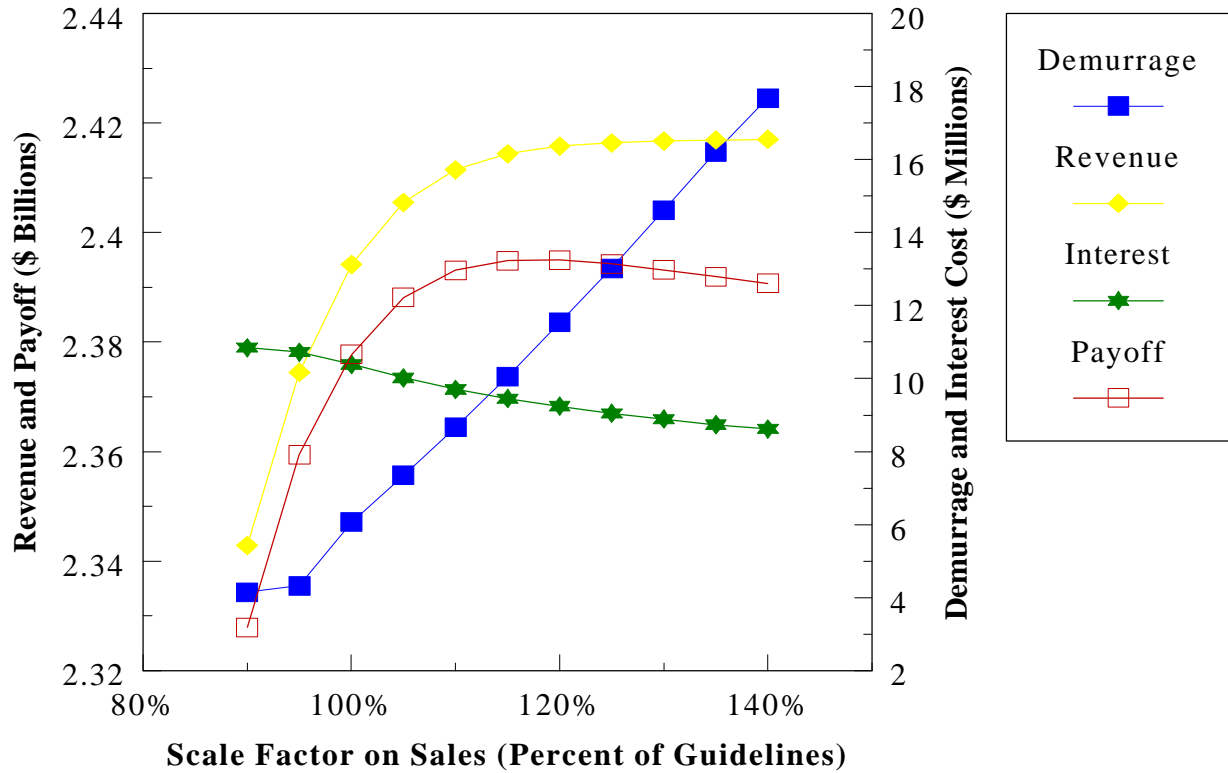
Figure 10. Pool Payoff as λ Changes.

3.3   Results and Sensitivities: 1996-97

Several characteristics of the 1996-97 crop year had a critical impact on the logistical system and risk. There were three of particular importance. First, there was a large exportable supply of CWB grains, due to a large carry over from the previous crop year and, a large 1996 crop of CWB grains. Second, the grain market was highly volatile with a very severe price inverse, peaking earlier than normal. Figure 11 shows the temporal structure of world prices at different dates.[9] The effect is to induce sales for shipments early in the market year to capture premiums associated with sales prior to February. Third, relative to previous years for which data were available, Tough & Damp was a major problem at both ports, but particularly at Prince Rupert. Seasonal average Tough & Damp unloads in 1996-97 were 7-10% at Vancouver and 10% at Prince Rupert compared to 3-5% in the earlier years. Finally, the weather was abnormal in western North America, causing disruptions in rail operations.

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[9]Prices in Figure 11 are from *Tradewest* (a prominent cash grain brokerage firm in Portland, Oregon and distributes its prices widely amongst the domestic and international grain firms) and were derived as futures plus basis for each respective forward shipping month.
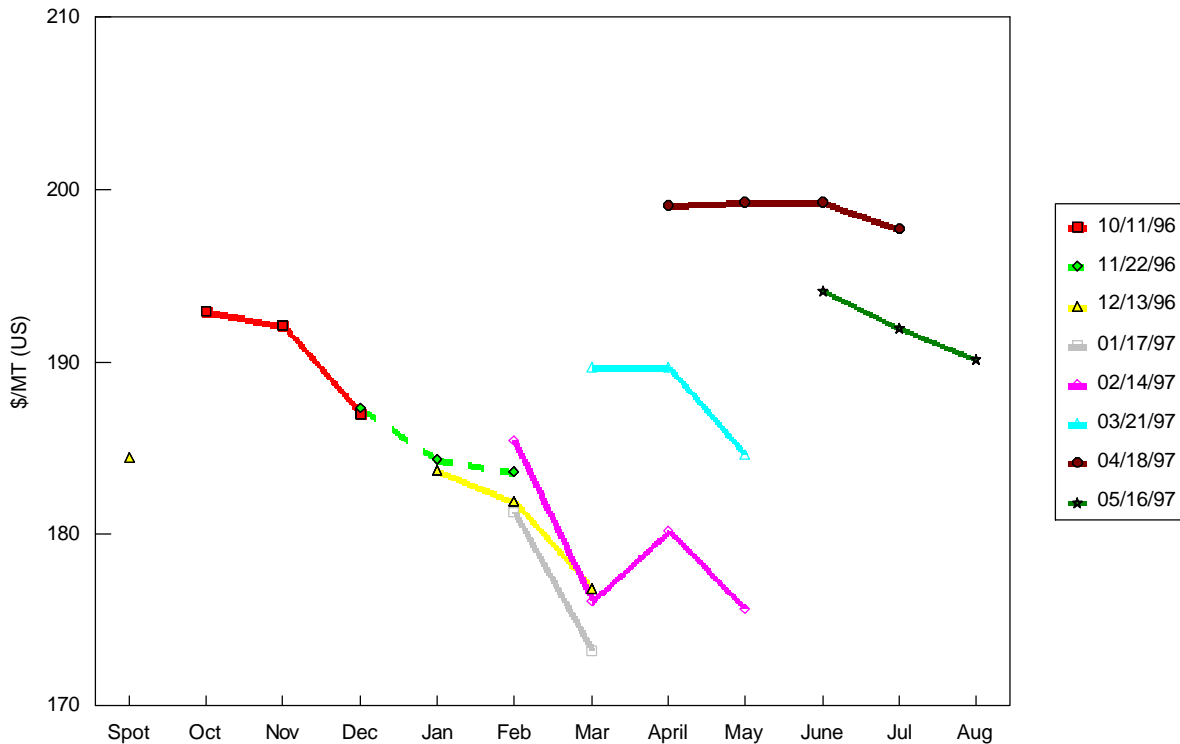
Figure 11. Nearby and Forward Price Spreads for PNW HRS FOB, on Selected Dates

Some of the summary data are shown in (Figures 12 and 13). First, weekly unloads and exports are maintained at just under 300 mt/week throughout the marketing year, rather than gradually reduced after about week number 21 as in the base case. Second, in comparison to the base case, the distribution of expected demurrage has shifted upwards. Specifically, expected demurrage (evaluated at a probability of .50) was about $18 million (Figure 13). Note that these expectations of demurrage are based on the parameters of the model chosen to be representative of the 1996-97 crop year, with the exception of λ which was maintained at 1.0.

The base case assumed that maximum weekly sales CWB grains would be 1.0 times the CWB share of guaranteed cars (i.e. $\lambda=1$). The effect of this strategy was evaluated by stimulating the model from $\lambda=.80$ to $\lambda=1.20$ (Figure 14). However, the rate of increase for sales above 100% of guidelines is much more radical due to the multitude of other factors in 1996-97 that exacerbated logistical risks. In particular, so long as the expected deferral of shipment is less than about 7 weeks, there would be incentives for the CWB to sell for more nearby shipping positions.[10]

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[10]For example, during 1996/97, the added premium for selling in November versus January was about $12.50/mt. Thus, the payoff of selling nearby versus deferred would be: $\pi=12.50-D\cdot E(Z)$ where D is the demurrage rate (in this case $1.75/mt/week) and E(Z) is the expected period over which the shipment is deferred. $\pi>0$ in this case so long as $(12.50/D)>E(Z)$.

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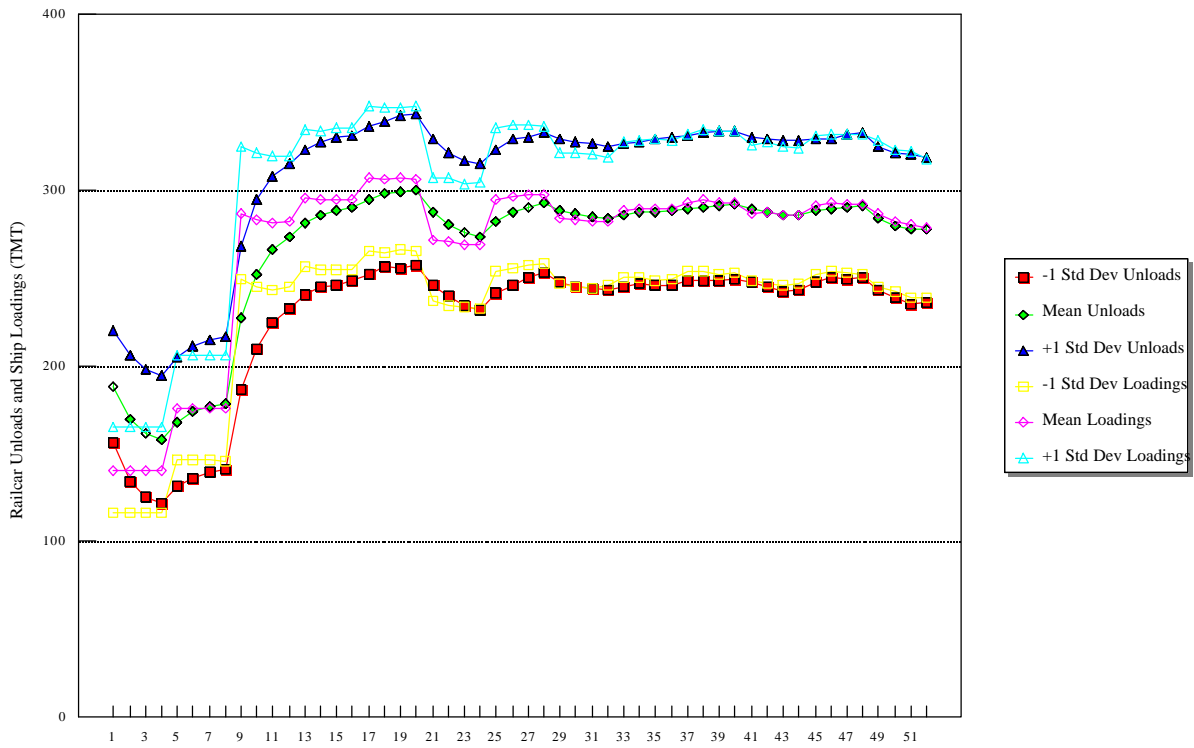
Figure 12. Distribution of West Coast CWB Railcar Unloads and Ship Loadings, by Week, 1996-97.
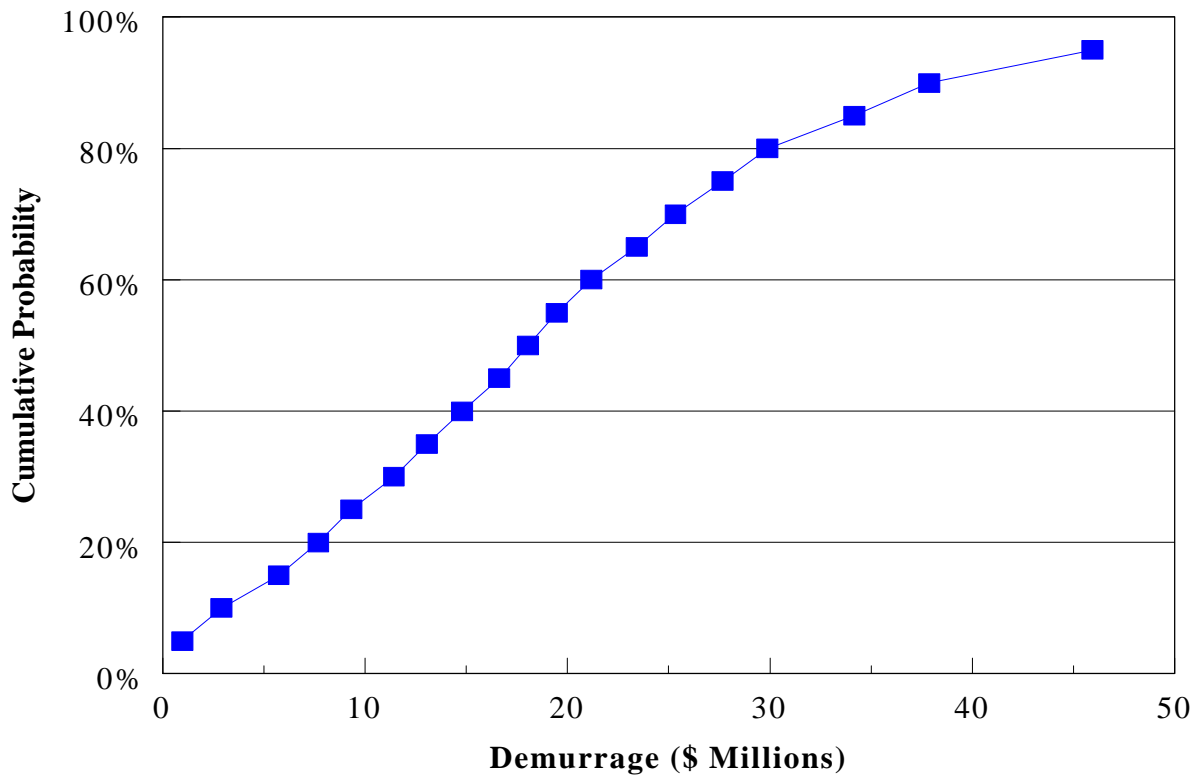
Figure 13. Distribution of Demurrage, 1996-97.

Figure 14. Average Demurrage by Scale Factor for Sales, 1996-97

A separate econometric model of rail car unloads was run including discrete dummy variables for shipping weeks 22-28 in Vancouver and 23-31 in Prince Rupert. These were included to allow for a shift in the unload behavior as a result of the adverse weather and system underperformance during those periods. The simulation model was then rerun assuming these values. Results are shown in (Figure 15). The results indicate that expected demurrage costs increased by $4.9 million (from about $19.9 to about $24.8 million), or 25%.   This is the amount of increase in demurrage that can be attributable to system performance.
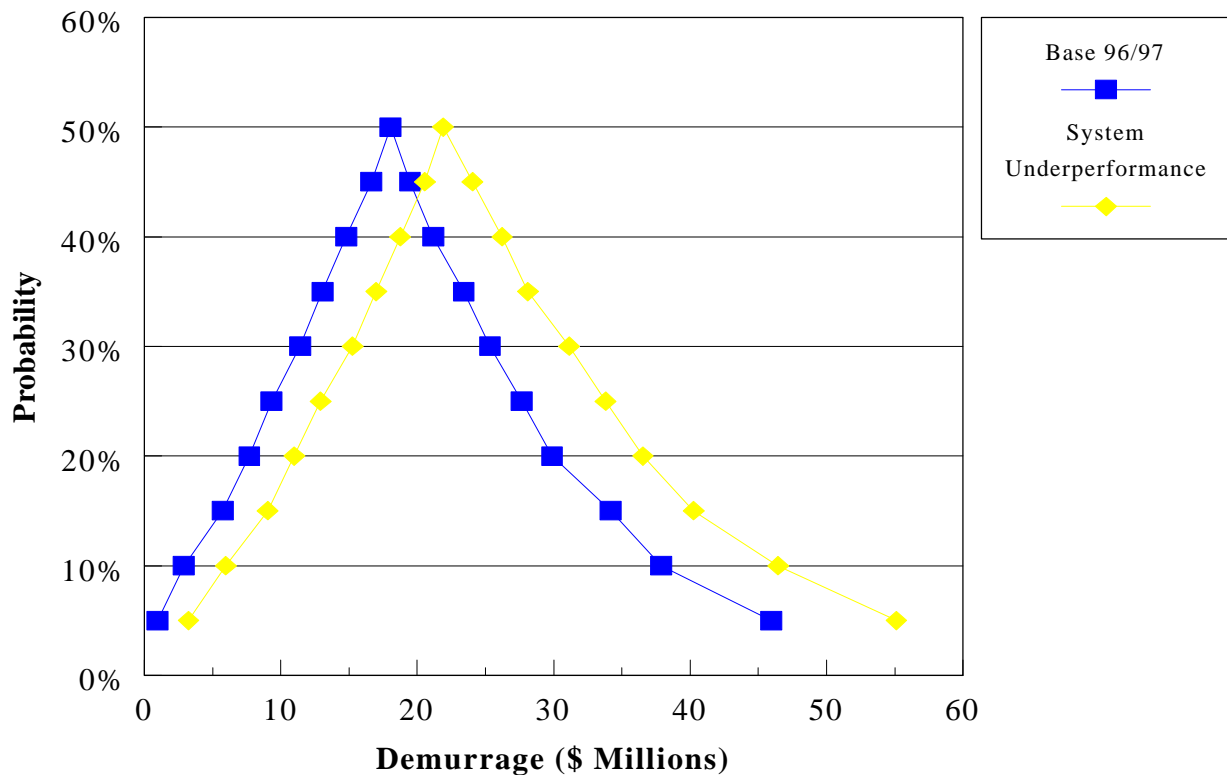
Figure 15. Comparison of Demurrage Base 1996-97 to System Underperformance.

4.   Summary and Implications

Many questions have been raised about logistical efficiency in the Canadian grain marketing system.   First, demurrage costs have persisted over time and appear to have been increasing during the 1990s. Second, during the 1996/97 crop year there was severe system under-performance due to adverse weather conditions and numerous other factors. Third, there has been continuing debate about the role of the CWB in managing and coordinating interior marketing functions in western Canada. Some of the important questions being addressed by the Estey Commission concern the logistical efficiency and controls in the Canadian grain marketing system. Finally, aside from the public issues in western Canada, handling firms confront challenges in improving their own logistical strategies.

This paper presents a model of the West Coast logistical system which was used to analyze effects of stochastic and strategic variables on risks and costs. The results presented are useful in understanding the logistical risks and factors that contribute to the logistical performance of the Canadian grain marketing system.

Demurrage is a Cost of Doing Business in Grain Marketing: Demurrage occurs due to the cumulative impacts of numerous factors that are not easily controllable. These include uncertainties due to tough and damp grains, ship arrivals, rail car unloads, and the rate of sales relative to guidelines. In a typical grain marketing year, demurrage costs would be expected to be about $6.2 million.

Logistical Risk Is Affected by Several Important Factors: Both exogenous factors and strategic variables affect logistics risk. Results indicate that in a normal year demurrage costs escalate with increases in tough and damp grain, mis-graded grain, the level of exportable supplies and unload performance. These statistical results indicate there is not a 1:1 relationship, nor a simultaneous relationship between unloads and vessel loadings. This suggests there are important dynamic adjustments that occur in the system, but they are fairly random. It is important that unloads are affected by a multitude of forces including sales, car allocation, car ordering, farmer deliveries, handler operating performance, and weather.

Results from these analysis indicate that the most important variable affecting demurrage costs was the quantity of exportable supplies. This was followed in order by unload performance, Tough and Damp, vessel arrivals and prices.

Logistical Strategies in Grain Marketing: Strategic variables that have an important effect on demurrage costs include: 1) the aggressiveness in CWB selling relative to guidelines; and 2) the level of beginning port stocks. Amongst numerous strategic variables, these have the greatest impact on logistical risks and demurrage costs.

1996-97: There were some extremely abnormal conditions in 1996-97 that adversely affected logistical risks. Most notable were: 1) large exportable surplus of CWB grains, which was severely underestimated until half-way through the marketing season; 2) a late crop which had greater heterogeneity in quality than normal; 3) a large proportion of tough & damp which slowed movement through the port; 4) grain markets with an extreme inversion, resulting in incentives to sell grain for shipment prior to the beginning of the southern hemisphere harvest; and 5) a lower than normal level of beginning CWB inventories at Prince Rupert.

Results indicated that given these conditions, expected demurrage costs increased to about $19.9 million, versus $6.2 million in a more normal year. This estimate reflects the cumulative impact of the conditions described above. The results indicated that there was a significant shift in system performance during part of this year.

Incentives for Over-Selling Capacity in Inverted Markets: Market inversions induce sellers to increase sales relative to expected capacity for purposes of trying to capture premiums for nearby sales, even if they have to incur added logistical costs to do so. The latter include either added demurrage costs, and/or costs of shipping through more expensive channels (e.g., through the United States, or shifting ports). It is important that inversions persisted throughout each month of the 1996-97 marketing year until about April (Figure 11). In each of these months, prices for more nearby shipments exceeded those for deferred shipments. Second, conventional terms of most FOB contracts do not explicitly penalize sellers for late shipment. Such contracts give the buyer some options and requires the seller to pay demurrage. In these situations there are incentives to sell above system capacity in more nearby periods to capture nearby premiums, on the risk that if inventories are inadequate, shipments may be deferred and demurrage would accrue. The point is that given conventional FOB contracts, incentives exist to sell excessively in more nearby positions, during crop years with price inversion.

References

Ainsworth, Don P. "Implications of Inconsistent Railroad Service." In *Proceedings - Thirteenth Annual Meeting of the Transportation Research Forum* 13(1):489-503, 1972.

Allen, W. Bruce, Mohamed M. Mahmoud, and Douglas McNeil. "The Importance of Time in Transit and Reliability of Transit Time for Shippers, Receivers, and Carriers." *Transportation Research. Part B: Methodological* 19B(5):447-456, 1985.

Ballou, Ronald H. *Business Logistics Management*. Englewood Cliffs, NJ: Prentice Hall, 1992. Bookbinder, James H., and Noreen Serenda. "A DRP-Approach to the Management of Rail Car Inventories." *Logistics and Transportation Review* 23(3): 265-280, 1987.

Canadian Wheat Board (July 6, 1995). "How the performance of the current handling and transportation system affects the CWB's ability to market grain." Winnipeg.

Canadian Wheat Board (June 13 and September 12, 1996) "Grain Industry Briefing." Winnipeg.

Canadian Wheat Board (September 21, 1998). "Role in Transportation Critical, CWB Advises Estey", *CWI News Release*, Winnipeg.

Carter, C., R.M.A. Loyns and D. Berwald,   "Domestic Costs of the Canadian Wheat Board" *American Journal of Agricultural Economics*, (May 1998): Vol 80(2).

Davis, T. "Effective Supply Chain Management." *Sloan Management Review* (Summer 1993): 35-46.

Hadfield, R. and E. Nichols, *Introduction to Supply Chain Management*, Prentice Hall, 1999.

McKinsey & Company. *Improving the Western Grain Logistics System,* special study for the Western Canadian Provinces, July 29, 1998.

Palisade Corp. *@RISK: Risk Analysis for Spreadsheets*. Newfield, NJ: Palisade Corporation, 1994.

Statistics Canada. (October 8, 1996). "September Estimate of Production of Principal Field Crops." Ottawa.

Statistics Canada (December 5, 1996) "November Results of Production of Principal Field Crops." Ottawa.

Western Producer. "Wheat Grades could be based on protein." *Western Producer* March 12, 1998, p. 13.

Wilson, William W., and B. Dahl. *Bidding on Railcars: A Strategic Analysis.* Agricultural Economics Report No. 376, Department of Agricultural Economics, North Dakota State University, Fargo, 1997.

Wilson, William W., and S. Priewe. *Railcar Allocation Mechanisms for Grain: A Comparison Among U.S. Class I Railroads,* (forthcoming). Department of Agricultural Economics, North Dakota State University, Fargo, 1997.

Wilson, W., S. Priewe, and B. Dahl. "Forward Shipping Options for Grain by Rail: A Strategic Analysis, *Journal of Agricultural and Resource Economics*, December 1998, and Agricultural Economics Report No. 372, North Dakota State University, Fargo.

Winston, Wayne L. *Simulation Modeling Using @RISK.* New York: Duxbury Press, 1996.

Appendix A: Detailed Model Elements

Model Logic: The logistical system is modeled based on a dynamic MRP representative of the salient features of the Canadian West Coast grain logistical system. Distribution for the stochastic variables were either taken from known industry information, or estimated using *Best Fit* to identify that which was most appropriate. In total there were 391 probability distributions contained in the model. In distribution for The basic elements of the model and its logic are described below and statistical parameters are summarized in tables A1-A3.

Sales/Shipments (S_t): Sales are evaluated and determined on a monthly basis. Sales are made based on an evaluation of expected prices in nearby versus deferred shipping positions relative to interest costs. The shipping volume is based on weekly unload guidelines, G_t . An evaluation is made about which shipping month (*m*) is the most advantageous to sell, and then sales are based on expected guidelines.

Sales decision. Price expectations for different forward periods are the basis for determining the shipping period for forward sales. Specifically, an evaluation of payoffs for sales during different periods is made. The difference, P^*_{m+k} $-P_m$ where P^*_{m+k} and P_m are expected prices for k periods (months) forward, was derived. This difference was compared to the interest cost of holding the commodity from m to m+k, which can be interpreted as the margin from holding the grain, $\pi= P^*_{m+k}$ $-P_m- i_{m,m+k}$. If π is negative, sales for that period are limited to the minimum weekly sales. If $\pi \geq 0$, sales are made for that shipping period equal to G_t. If it is not profitable to defer sales, based on changes in expected prices relative to interest costs, sales were made for that month.

Expected prices were defined based on mean prices at m period of \$194/mt with monthly price changes defined as P with a base case distribution of $N(1,2)$. These were used to generate random realizations of monthly prices. A base price of \$194 was used and it was assumed these prices followed a normal distribution of: $P_{t+1}=P_t+$ P where $P=N(1,2)$. Price data were taken from *Tradewest*, a Portland based Brokerage Company and used to calibrate the distributions.

Sales are made subject to the following restrictions: 1) *Minimum Restriction*: A minimum weekly volume is assumed exported every week; 2) *Maximum Restriction*: If sales are made for a week, the maximum that can be sold is the CWB share of guideline unloads, G_t ; and 3) *Marketing Year Requirements*: A restriction is imposed such that the most that can be exported throughout the year is the exportable crop year supplies, defined as carrying plus exportable supplies of CWB grains.

Sales Strategy, λ. An important element of strategy affecting logistics is the rate of selling for each period relative to unload guidelines. To capture this effect, λG_t was introduced where λ is a factor which in the base case is assumed to equal 1. However, to evaluate the effects of this strategic variable, the system was simulated for a range of λ values.

Vessel Arrivals. Sales are made for a shipping month, m. Vessels are assumed to arrive within the shipping month (for contracting purposes). Monthly sales/shipments are then allocated to individual shipping weeks (t) using a binomial distribution with parameters [100,.25] with the residual being allocated to the last week of the shipping month. Weeks 1-3 of

Table A1: Values of Constants (West Coast)				
Parameter	**Base Case**		**1996/97**	
	Vancouver	**Prince Rupert**	**Vancouver**	**Prince Rupert**
Beginning Port Inventories (000 mt)	399	84	406	23
Drying Capacity (mt/wk) (from industry statistics)	25,200	12,600	25,200	12,600
Maximum Port Storage Capacity (from industry statistics)		210,000 mt		210,000 mt
Minimum Weekly Shipments:	101,250 mt/week. Derived from historical CGC unload data as 125,000 mt * .81 (CWB share)			
Exports as % of Exportable Supplies	61% Based on industry statistics			
Interest Cost	10%/year converted to a per week rate			

Table A2: Values of Variables Used in Simulation		
Parameter	**Base Case Value**	**1996/97**
Exportable Supplies	Normally distributed with mean 19.7 mmt and Std of 2.4 mmt	A fixed value was assumed equal to 24.8 mmt
Unloads	Expected unloads estimated from regression. Separate models estimated for each port using weekly unload data from 1994/95-1996-97 crops years	Expected unloads estimated from regression with dummy variables for selected weeks. Separate models estimated for each port for CWB grains using weekly unload data from 1994/95-1996-97 crop years
Tough and Damp	A Triangular distribution was used with a minimum, most likely and maximum value. Separate distributions for each shipping week and each railroad/port	Uniform distribution utilized using minimum, maximum of parameter values for 1996-97. Separate distributions for each shipping week and each railroad/port.
Off-Grade Shipments	Maintained value of 0; Simulated values at 5%	Off-grade not explicitly included in 1996-97
Export Prices	Base price of $194 was used and assumed to follow a distribution of: $P_{t+1}=P_t+ \Delta P$ where $\Delta P=N(1,2)$.	ΔP was defined with a distribution of $N(-.5,4)$ reflecting the inverse and more volatility during 1996/97 versus the base case.
Ship Arrival	Binomial distributions were used with parameters of [100, 25]. Ships arrive within 4 week window encompassing sales; weekly arrivals determined using binomial distribution.	Same as base case .

each consecutive month were treated as binomial distributions [100, .25], with the remainder allocated to the 4th week. This means 25% of the ships are expected to arrive each week in a particular month, but the exact time of their arrival is random. Thus, vessel arrival within the 30-day period is a random variable when viewed from the seller's perspective.

Rail Car Unloads. Supplies available for export were defined as beginning exportable inventories plus unloads:

$$A^*_t = U^*_t + I_{t-1}$$

Where, A^*_t is expected exportable supplies in week t, U^*_t is expected rail car unloads in week t, and I_{t-1} is the carryover inventory from week t-1. Note that * is used to indicate an expectation of a random variable.

An econometric model was developed and estimated to determine U^*_t. Specifically, for each port, a partial adjustment first-order autoregressive model was specified and estimated using autoregressive techniques. The logic to the model is:

$$U^*_t = f(S_t)$$

where U^*_t is desired unloads in week t, and S_t is weekly export sales for week t. This follows the conventional econometric formulations of dynamic partial adjustment models. Specifically, there is a desired level of unloads, U^*_t, necessary to facilitate the planned loadings of vessels, S_t, for week t. The unobserved variable U^*_t reflects the cumulative effects of car ordering to correspond with expected loadings, as well as the effect of system performance.

Since U^*_t is not observed it is not possible to estimate the above equation. Instead, a transformation (a first-order partial adjustment model) was developed following Nerlove, resulting in:

$$U_t = \quad + \quad _1 \cdot U_{t-1} + \quad _2 \cdot S_t + \quad _t$$

where $_t$ is the error term and used to derive the probability distribution. The model was estimated as a first order autoregressive process where $_t$ was allowed to vary through time. Finally, several other variables were added. S_t^2 was added to allow for a non-linear relationship between loadings and unloads. The purpose was to capture the effect of reduced unload efficiency as the level of exports escalates. In addition, U_t^V was defined as unloads at Vancouver. This variable was added to the equation for Prince Rupert to capture the interrelationship between these ports. (i.e., specifically that Prince Rupert is a residual port to Vancouver).

Results are shown in Table A3. There are several points of interest. Econometrically the equations explain 75% and 79% of the variability in unloads at Vancouver and Prince Rupert, respectively. The fact that $_1 \neq 0$ and $_2 \neq 1$ indicates that: 1) response within the logistical system is not simultaneous--i.e., there is a lag between export shipments and desired unloads; and 2) there is less than a 1:1 correspondence between export shipments and unloads. The partial adjustment parameter, .62 and .52 respectively, indicates that the system does not respond instantaneously. It takes about two periods for a change in desired unloads to accrue. As the level of export increase,

the level of unloads increases, but at a decreasing rate. This reflects the reduced capacity as loadings increase. As the level of unloads at Vancouver increases, the level of unloads at Prince Rupert also increase. This likely reflects the fact that the latter is more of a residual port.

The model was re-estimated including a binary dummy variables, D96, for selected shipping weeks during the 1996-97 marketing year. Specifically, statistical tests were conducted to determine during which weeks within this crop year was there a statistically different unload behavior. Results indicated these were weeks 22-28 in Vancouver and 23-31 in Prince Rupert. These dummies were included to capture the effects the adverse weather during that year which affected unloads. In each case there was a negative effect on unloads during these periods. In the case of Vancouver it was simply on the intercept, whereas at Prince Rupert, it affected both the intercept and slope.

Vessel Demurrage. Demurrage rates and rules were applied assuming FOB sales. Seven days free (1 week, or 1 period) were allowed. The demurrage rate per metric tonne was 1.75 $/mt, based on discussion with shippers.

Rail Demurrage: Demurrage on rail cars was not applied following trade practices.

Tough & Damp: Uniform with a minimum and maximum based on observed values.[12]

Exportable surplus: Normally distributed with mean 19.8 mmt, std 2.4 and derived from prior years data (1993 to 1995) of CWB exports.

Data Sources: The primary source of data was from a data set prepared by the Canada Grain Commission for the CN and CP Railroads. Data included weekly observations at each port for the following variables: CWB Unloads; CWB vessel loadings; Port inventories; and tough and damp grains.

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[12]Attempts were made to estimate the parameters of this distribution, but of 35 different distributions, none were acceptable. Thus, a uniform was assumed with the above limits.

Table A3: Regression Parameters for Models of Railcar Unloads by Port				
	Base Case		**1996/1997**	
Variable	**Vancouver**	**Prince Rupert**	**Vancouver**	**Prince Rupert**
Constant	11,636 (5894)	-7,511 (3666)	15,729 (6177)	-8,191 (3699)
Ship Loadings	0.307 (0.03)	0.510 (0.02)	0.309 (0.04)	0.550 (0.02)
Ship Loadings P.R.		.704 (0.08)		0.715 (0.08)
Ship Loadings^2 P.R.		-0.000002 (-4.2E-7)		-0.000002 (-4.2E-7)
Railcar Unloadings Previous Period	0.621 (0.04)	0.52 (0.04)	0.599 (0.04)	0.50 (0.04)
Intercept Dummy (Selected Weeks)			-18,728 (9,109)	22,472 (11,597)
Interaction between Dummy and Ship Loadings (P.R.)				-0.25 (.13)
R^2	0.74	0.79	0.75	0.80
RMSE	25,779	17,312	25,716	17,231

*Value in ( ) is the standard error.