Multimodal Transportation and Impacts of Policy: Grain Transportation Model

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Multimodal systems offer efficiencies from complementary and competitive interactions. A least cost spatial equilibrium model is used to determine how alternative policies and firm decisions affect the performance of a multimodal grain transportation system. The system is found to be extremely competitive, and much of the competitive structure comes from intermodal movement via truck-barge. It is also found that the operating structure of the shipping firm using the system directly affects the performance.

The availability of a multimodal transportation system brings with it many benefits for shippers. The obvious benefit is the efficiencies achieved by allowing each mode to be used for the type of movement for which it is specifically suited. This is particularly evident in an intermodal movement where different segments or functions of the overall movement are performed by that mode with the comparative advantage for each segment. These efficiencies and system approach have led to TOFC, double-stack railcars, RoadRailer, truck-barge, truck-rail, and rail-barge intermodal movements throughout the United States and the world.

An additional benefit of a "complete" intermodal system, meaning availability of rail, truck, and barge modes, has been the competition among these modes. Competitively induced rates and competitively induced cost innovations and reductions have been the impetus for much of the economic development of the United States and have been the sustaining force in the competition for U.S. markets. Competition between the rail industry and truck-barge movements has left rail rates, as late as 1991, at 1936 levels.

The historical policies toward aiding each mode to develop, regulating each mode's economic decision making, and the shippers' use of the modes are currently undergoing significant change. Critical issues of rail line abandonment, potential rural road deterioration, and loss of barge movement due to salmon preservation efforts have received considerable attention from researchers and policymakers (*1–9*). The Pacific Northwest grain transportation serves as a good laboratory in which to evaluate the probable impacts of such changes on a multimodal system. It has a complete multimodal system with alternative management structures in shipping firms and a history of active rate and service competition as well as complementary activity among modes.

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OBJECTIVES

The overall purpose of this study is to determine how alternative marketing strategies and transportation policies affect the efficiency and performance of a multimodal transportation system. Specific objectives are to

1. Select a case study area where the modal competitive environment has affected the grain industry,
2. Determine modal use and marketing characteristics of farm producers and grain elevators,
3. Develop a conceptual and mathematical spatial equilibrium model capable of reflecting commodity flows,
4. Construct alternative model scenarios reflecting current or potential shipper marketing strategies and transportation policy changes, and
5. Determine multimodal response and system performance under the alternative models.

STUDY APPROACH

The primary tool of analysis for this study was a least cost spatial equilibrium model, developed to evaluate intermodal competitiveness in the transportation system in eastern Washington. Supporting the mathematical model and providing realistic borders for the analysis were two comprehensive surveys of grain producers and grain elevators in the study region. Transportation rates and other coefficients were obtained from shippers, carriers, and elevator firms currently participating in grain marketing.

An area including southern Spokane and northern Whitman counties in eastern Washington was chosen for this study (Figure 1). Wheat and barley are the major crops in this area, with natural geographic and political boundaries serving as effective barriers and minimizing grain inflows into the region. The area has 25/26-car rates available to it from the Burlington Northern and the Union Pacific railroads, as well as single- and 3-car rates. Proximity to the Snake River is an important

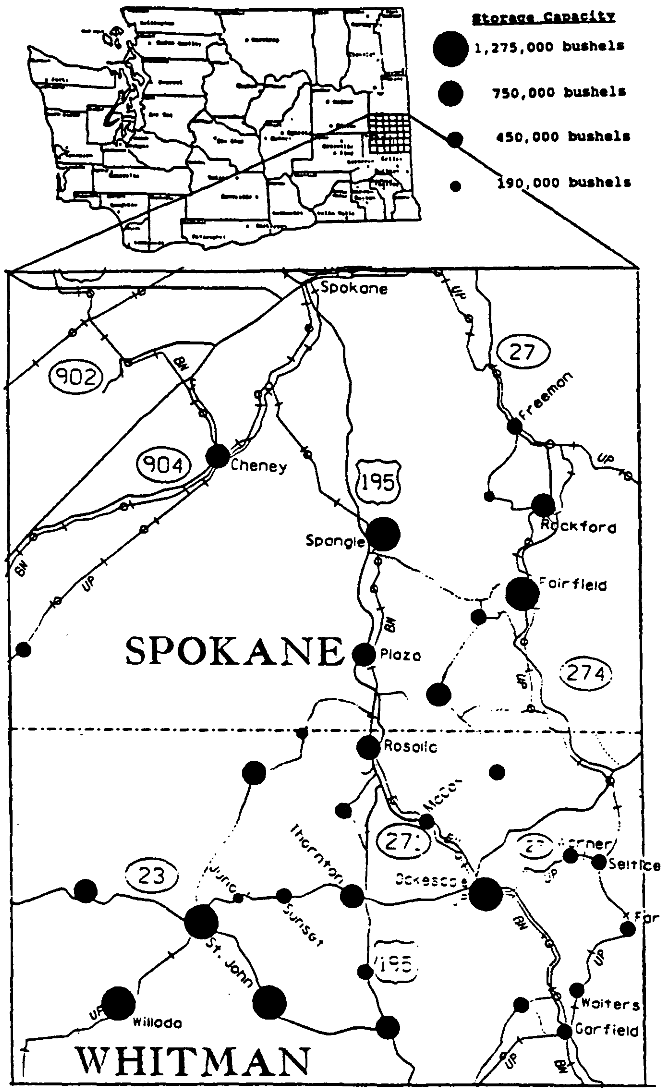

FIGURE 1 Location of the study area and the 33 county elevators identified for the development of a grain transportation cost minimization model for southern Spokane and northern Whitman counties in Washington State (adapted from *Washington Agricultural Statistics 1989–1990* and the U.S. Geological Survey, 1965).

determinant of whether grain is shipped by truck to river barges or sent by rail (*10*).

It has been hypothesized that the introduction of multiple-car rail rates will hasten the demise of smaller country elevators (*4*). To test the potential effect of such impacts from multimodal competition, the study area chosen had to have a representative size distribution of elevators by licensed capacity. The 33 elevators, belonging to 12 firms existing in the study area, represent that desired size distribution (Figure 1).

The difficulty of allocating accounting costs to programming cost coefficients was reduced using information provided by two sources. The first was a seminal work conducted in a similar geographic area by Dooley in 1986 (*4*), where cost coefficients were approximated by nonlinear cost functions using mixed integer programming. Second, estimates were developed from the two surveys and from direct telephone consultation with the elevator managers and personnel of Burlington Northern and Union Pacific railroad companies.

SURVEY RESPONSES IN STUDY AREA

Producers were surveyed to develop an appropriate operating framework and coefficients for the analytical model. [An in-depth review of survey findings and a copy of the survey forms are given elsewhere (*11*).] Agricultural producers had various marketing alternatives available to them. Depending on location and size of farm, considerable differences were found in what producers did with their grain. Almost half of producers moved their grain first to local elevators, with country elevators being the most important form of wheat storage. On-farm storage was used by fewer than 20 percent of the surveyed farms, but more frequently by larger producers.

Farm size and seasonal timing of marketing activity influenced perceived road conditions. Larger farms moving grain during the winter months on local roads more frequently reported problems with roads. For all producers in the area, the dominant perception was that road conditions were good but deteriorating.

More than half of the farm-to-elevator movement occurred just after the harvest period. These findings were used to define realistic coefficients for the model. Most of the grain was moved to elevators during the 4 months following harvest (July through October). Shipments from elevators to markets occurred throughout the year.

Since decisions made by grain elevators have a direct impact on the transportation system, such analysis was of primary importance. The breakdown of wheat and barley handled by the elevators is consistent with proportions reported by grain producers (an approximately 7:3 wheat:barley relation). Wheat is shipped almost exclusively (98 percent) to Portland. Three-car and 25/26-car are the common railroad methods used. Direct truck-to-market shipments were not used by the producers or elevators surveyed. Transshipments go from elevators without direct railroad access to the 25/26 multiple-car loading facilities within the same firm.

Because barley is not a homogeneous product like wheat, its transport is more specialized. Malting barley was transported by rail to Vancouver. Barley went to in-state feedlots by truck. Barley for export was moved by train and truck-barge.

MATHEMATICAL MODEL

A traditional linear programming model was used to find the least cost optimal solution to the transportation cost problem. The model considered the following costs: (*a*) assembly costs, the costs of moving 1 bushel of grain from the supply regions (farms) to the elevators; (*b*) elevation costs, cents per bushel elevator operating costs; and (*c*) shipment costs, cents per bushel transportation and handling costs from the elevator to the final destination.

The mathematical model took into account the total cost of assembly, elevation, shipping, and transshipment, subject to specified constraints imposed on the grain marketing industry of the area. The specified objective function was as follows:

$$\text{Minimize } z = \sum_{j}\sum_{i}\sum_{n}\sum_{t} (c_g)_{ij}^{tn} G_{ij}^{tn} + \sum_{j}\sum_{n}\sum_{t} (c_e)_j^{tn} E_j^{tn}$$

$$+ \sum_{j'}\sum_{j}\sum_{t} (c_t)_{jj'}^{t1} T_{jj'}^{t1} + \sum_{p}\sum_{j}\sum_{n}\sum_{t} (c_s)_{jp}^{tn} S_{jp}^{tn} \qquad (1)$$

The c coefficients in parentheses in Equation 1 indicate the cost per unit of the variable they precede. The superscripts, subscripts, and activities in this objective function are defined as follows:

- t = time period (1 for July–August, 2 for September–October, 3 for November–February, and 4 for March–June).
- n = type of grain (1 for wheat and 2 for barley).
- i = crop origin supply point; each origin supply point is a township ($i = 1, 2, \ldots, 40$).
- j = elevator ($j = 1, 2, \ldots, 33$).
- j' = elevator with multiple-car loading facilities (the j''s are a subset of the j's; $j' = 1, 2, \ldots, 17$).
- p = mode used to transport the grain from elevators to final market [1 for truck-barge of wheat and barley to Portland, 2 for three-car unit trains of wheat to Portland and for barley to Portland or Vancouver (since the rates are the same), 3 for 25/26-car unit trains of wheat to Portland, and 4 to indicate that barley goes to in-state feedlots].
- G_{ij}^{tn} = is the quantity of the nth grain assembled from origin supply point i to elevator j in time period t.
- E_j^{tn} = quantity of the nth grain received at the j elevator during time period t, stored, and subsequently shipped.
- $T_{jj'}^{t1}$ = level of wheat transshipment activities, shipping wheat from elevator j to an elevator with multiple-car loading facilities j' in time period t ($j \neq j'$).
- S_{jp}^{tn} = quantity of the nth grain shipped from elevator j by the mode and destination p in time period t.

The equation is minimized subject to empirical conditions relating to grain production, assembly coefficients, elevator capacities, shipping coefficients, and minimum storage use of elevator's capacity.

Four elevator capacities were used in a multiplant grain firm structure. Multiple-car loading facilities were identified as central gathering points for subsequent lower-cost outbound shipments. The base model outlined below is a close approximation, compared with survey results, of what actually happens in the grain marketing system in the study region.

Linear programming models, as used in this study, are constrained representations of the actual marketing system. Competitive reaction to price changes, handling costs related to volume put through an elevator, and capacity changes over time are the types of changes that are held constant in this type of model.

MODEL SCENARIOS

Seven models were evaluated; each model tested a marketing strategy or policy change within the multimodal transportation system. The first four models evaluated alternative shipper marketing strategies of grain firms, and the final three deal specifically with potential carrier policy changes in the transportation sector. The base model reflects the existing grain transportation system and actual usage of that system in eastern Washington. Elevators are organized into multiplant firms, as in the actual situation, where an average cost of operation for the entire firm, rather than for each elevator, is charged per bushel handled. A critical feature of this base model is the minimum amount of grain forced into each elevator, determined by the elevator survey.

The shipping of grain from the elevator to final market is a function of the type of grain and the transportation modes available. Two general transportation modes compete for wheat shipping to this port: railroad, which offers 3-car and 25/26-car rates, and truck-barge, which takes the wheat by truck to the Central Ferry Port on the Snake River and then to Portland by barge. Wheat is also transshipped from elevators without access to those with access to 25/26-car rates, but only within the same firm. No seasonal variation in rates occurs in the study area.

The second model, the least cost model, relaxes the assumption of minimum storage constraint. Thus, grain was allowed to flow without any restriction of using all elevators through the path with the lowest total transportation cost.

The third and fourth models were run on a single firm basis with every elevator operating as an independent firm; there were no multiplant firms. Single Firm Model A allowed no transshipments, and 25/26-car rates were only available to multiple-car loading facilities. Single Firm Model B eliminated 25/26-car rates by assuming that even elevators with multiple-car loading facilities could not put together enough grain to meet the requirements of filling 25/26-car trains in 24 hr.

A virtue of linear programming is the flexibility it offers to change specific parameters, maintaining the rest of the economical setting unchanged, and predicting the effects of the changes made. This allowed the last three models to evaluate the impact of actual issues confronting eastern Washington shippers.

The first policy model examined the impact on grain flow of closing the Snake River during the early summer in an attempt to save the salmon recently listed under the Endangered Species Act. This was accomplished by closing the time period in the base model from March to June (time period 4).

A second policy model sought to examine the effect on wheat movement and rail revenue if the Burlington Northern were to adopt a competitive or aggressive rate policy. Burlington Northern rail lines cross the study area as a vertical column from south to north, with 3 elevators on its lines being multiple-car loading facilities and 11 other elevators having transshipment connections to multiple-car loading facilities.

The final policy model evaluated the potential result if a recently abandoned (but not yet salvaged) line (the Arrow Line) were to be purchased and operated as a regional or short line railroad. If this line were to be successfully resurrected, it would have to offer lower rates to draw traffic. To test the effect of such changes, both Burlington Northern and Union Pacific rates were decreased to determine the impact on rail movement. Several other permutations of the rates gave information on the elasticities of demand for transportation modes.

ANALYTICAL RESULTS

The results of the first model are indicated in Table 1. It is evident that many of the smaller elevators, as forced by the assumptions, collect grain, but then quickly transship the grain to multiple-car loading elevators. Since these elevators fill only about 40 percent of their capacity, their long-term life is suspect.

Three factors explain these results and give a better understanding of the industry's use of the multimodal system. First is the organization of elevators into multiplant firms and the average firm cost scheme they use. Essentially, a firm's share of the grain market is more important than any one elevator's share. Therefore, small elevators serve as grain collection units into the overall firm volume.

Dooley (*4*) found that larger elevators could increase their market share if they could build additional storage capacity when individual elevators are operating as firms. Another fact favoring the association of individual firms into multiplant firms, rather than the buildup of large individual elevators, was discussed by Hays (*12*). He found that because of severe time constraints, especially during harvest, grain producers choose the closest elevator available.

The modal split of the grain shipments for the base model indicates that wheat is moved by truck-barge only if the elevator does not have access to multiple-car loading facilities (12 percent of total wheat transported) or if the distance to the Snake River port is short enough to allow competition between truck-barge and rail rates.

Three-car rates were used by elevators with access to them except in the case of the elevators with on-site multiple-car loading facilities. This option is well suited to firms that do not have the operational volume required for the implementation of multiple-car loading facilities (21 percent).

There are five multiple-car loading facilities in the model, each belonging to a different multiplant firm and being located at the largest elevator of the firm. All the multiple-car loading facilities have transshipment connections with the other elevators within the firm. For the base model, 67 percent of the wheat delivered to Portland was shipped by this means. Of the 67 percent, 41 percent came directly into elevators from farms, and 26 percent was the product of transshipments.

System costs for the base model are presented in Table 2. The total bill for transportation of 12.184 million bushels of wheat and 5.733 million bushels of barley from the producing areas of southern Spokane and northern Whitman counties

TABLE 1 Modal Split of Grain Transportation for Base Model

Elevator	Wheat							Barley			
			MCLF (25/26-Car Rail)								
				Transship							
	Truck-Barge	3-Car Rail	At Elevator	From	To	Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
	000 Bushels										
Cheney	0	391					391	0	261	0	261
Rodna	100						100	0		50	50
Fairfield	0	0	845		88	933	933	0	585	0	585
Waverly	0			88	Fairfield		0	0		83	83
Rockford	0	600					600	0	50	0	50
Freeman	0	333					333	0	81	0	81
Mt. Hope	150						150	0		9	9
Spangle I	0		891			891	891		523	0	523
Plaza	0	0	473		1,070	1,543	1,543	0	202	0	202
Spangle II	0	268		0	Plaza		268	0	114	0	114
Spring Valley	0			268	Plaza		0	0		115	115
Rosalia	0	472		0	Plaza		472	0	203	0	203
Balder	0			266	Plaza		0	0		116	116
McCoy	0	240		0	Plaza		240	0	100	0	100
Pine City	0			472	Plaza		0	0		203	203
Squaw Canyon	0			64	Plaza		0	0		28	28
Thornton	0	303					303	0	477	0	477
Cashup	120						120	0		51	51
Steptoe	380						380	0		237	237
Garfield	200						200	0		20	20
Walters	75						75	0		8	8
Crabtree	60						60	0		15	15
Oakesdale	0		1,543		669	2,212	2,212	0	200	0	200
Farmington	0			200	Oakesdale		0	0		100	100
Seltice	0			114	Oakesdale		0	0		57	57
Warner	0			100	Oakesdale		0	0		60	60
Fairbanks	0			255	Oakesdale		0	10		118	128
St. John	37			412	Willada		37	221		229	450
Ewan	56			381	Willada		56	238		0	238
Willada	0		1,225		1,367	2,592	2,592	0	400	0	400
Juno	88			14	Willada		88	4		64	68
Sunset	59			141	Willada		59	150		0	150
Pleasant Valley	82			418	Willada		82	195		155	350
Total	1,407	2,606	4,977		3,193	8,171	12,184	818	3,196	1,719	5,733
Percent	12	21	41		26	67	100	14	56	30	100

TABLE 2 Transportation System Costs for Base Model

Item	Wheat	Barley	Total	Percent	Grain Shipped
	---------- 000 Dollars ----------				---- 000 Bu ----
Assembly	297	148	445	5	
Elevation	2,453	1,138	3,591	40	
Shipping	3,705	1,215	4,920	55	
Wheat	3,705		3,705	0.41	12,184
Truck-Barge	492				1,407
3-Car Rates	857				2,606
25-Car Rates	2,196				8,171
Transshipments	160				3,193
Barley		1,215	1,215	0.14	5,733
To Portland-Vancouver		1,001			4,014
Truck-Barge		275			818
3-Car Rates		726			3,196
To Feedlots		214			1,719
Total Costs			8,956	100	

TABLE 3 Modal Split of Grain Transportation for Least Cost Model

Elevator	Wheat							Barley			
			MCLF (25/26-Car Rail)								
	Truck-Barge	3-Car Rail	At Elevator	Transship From	Transship To	Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
	000 Bushels										
Cheney	0	491					491	0	313	0	313
Rodna	0						0	0		92	92
Fairfield	0	0	1,418		0	1,418	1,418	0	760	0	760
Waverly	0			0	Fairfield		0	0		0	0
Rockford	0	0					0	0	0	0	0
Freeman	0	0					0	0	81	0	81
Mt. Hope	0						0	0		0	0
Spangle I	0		1,898			1,898	1,898		545	0	545
Plaza	0	0	599		430	1,029	1,029	0	282	0	282
Spangle II	0	0		0	Plaza		0	0	0	0	0
Spring Valley	0			0	Plaza		0	0		0	0
Rosalia	0	582		0	Plaza		582	0	193	0	193
Balder	0			0	Plaza		0	0		0	0
McCoy	0	633		0	Plaza		633	0	93	0	93
Pine City	0			430	Plaza		0	0		0	0
Squaw Canyon	0			0	Plaza		0	0		0	0
Thornton	0	0					0	0	1,539	0	1,539
Cashup	373						373	0		0	0
Steptoe	219						219	0		0	0
Garfield	0						0	0		0	0
Walters	0						0	0		0	0
Crabtree	0						0	0		0	0
Oakesdale	0		2,550		0	2,550	2,550	0	78	0	78
Farmington	0			0	Oakesdale		0	0		224	224
Seltice	0			0	Oakesdale		0	0		135	135
Warner	0			0	Oakesdale		0	0		138	138
Fairbanks	0			0	Oakesdale		0	0		52	52
St. John	0			0	Willada		0	0		142	142
Ewan	110			314	Willada		110	0		571	571
Willada	0		2,064		613	2,677	2,677	0	130	0	130
Juno	0			23	Willada		0	0		157	157
Sunset	205			245	Willada		205	0		0	0
Pleasant Valley	0			31	Willada		0	0		208	208
Total	906	1,705	8,530		1,042	9,573	12,184	0	4,014	1,719	5,733
Percent	7	14	70		9	79	100	0	70	30	100

to the final markets was $8.956 million. This compares closely with a total estimated transportation bill of $9.200 million developed from the elevator surveys.

LEAST COST MODEL

In this model, the assumption of minimum storage constraint was relaxed. Thus, grain was allowed to flow, without any restriction, through the path with the lowest cost of assembly, elevation, and shipping to the market.

This environment of greater competition with no minimum storage constraints would result in the complete elimination of 10 elevators from the system (Table 3). The underused elevators identified in the base model are, in fact, now forced to exit the industry under the competitive conditions of this model. Grain would be concentrated around the multiple-car loading facilities and transshipments would be almost completely eliminated. Truck-barge would be completely eliminated as a barley transportation mode, and only four elevators would use truck-barge for wheat.

Compared with the base model, total transportation costs in the least cost model decreased from $8.956 million to $8.643 million (approximately 3.6 percent; see Table 4). This savings was realized mainly in the shipment of grain from elevators to the final market.

The increase in use of 25/26-car train units was accompanied by a reduction in transshipments to multiple-car loading facilities. Handling costs of loading and unloading were avoided by directly assembling the grain over longer distances instead of transshipping it as in the base model case.

SINGLE FIRM MODEL A (WITH MULTIPLE-CAR RATES)

The results of this scenario (Table 5) differ little from the base model results in Tables 1 and 2, although a 2 percent increase in the total transport bill occurred. This similarity arises largely because the supply of grain from farms closely matches the storage capacity of the elevators or the minimum amount of grain handled.

Once transshipments are eliminated, all of the wheat, previously transshipped to multiple-car loading facilities for movement by 25/26-car unit trains, makes its way to Portland through the truck-barge mode (Table 6). The truck-barge activity increased from 12 to 38 percent when transshipments were eliminated. However, the three-car rail rates were still a more economically efficient option than truck-barge for moving some wheat to Portland.

SINGLE FIRM MODEL B (NO MULTIPLE-CAR RATES)

With 25/26-car unit trains eliminated, 3-car rail rates remain a more economically efficient option than truck-barge for moving wheat to Portland (Figure 2). Without 25/26-car unit trains, all the rail-moved wheat would be moved by 3-car train units. However, because these rates were not as low as the 25/26-car rates, they did not lead to the pooling of grain from as far as multiple-car loading facilities had done.

Total transportation costs went up by $253,000 when multiple-car loading facilities were eliminated. This represents cost savings from moving almost 5 million bushels of wheat by 25/26-car train units. This comparison underscores the importance of the lower rates for 25/26-car rail.

A comparison of the shipping costs (Table 7) and total cost components (Figure 3) reveals little variation in assembly, elevation, and barley shipping costs. The cost of shipping wheat causes most of the variation.

RIVER CLOSURE MODEL

As previously discussed, one potential impact of salmon being listed under the Endangered Species Act is the drawdown of the river below levels that would allow barge traffic to continue. Results of the analysis indicate that the grain that would normally go by barge in the fourth period, after closure, sim-

TABLE 4 Transportation System Costs for Least Cost Model

Item	Wheat	Barley	Total	Percent	Grain Shipped
	----------- 000 Dollars		----------		---- 000 Bu ----
Assembly	333	152	485	6	
Elevation	2,421	1,137	3,557	41	
Shipping	3,484	1,117	4,601	53	
Wheat	3,484		3,848	0.40	12,184
Truck-Barge	307				906
3-Car Rates	541				1,705
25-Car Rates	2,584				9,573
Transshipments	52				1,042
Barley		1,117	1,117	0.13	5,733
To Portland-Vancouver		902			4,014
Truck-Barge		0			0
3-Car Rates		902			4,014
To Feedlots		214			1,719
Total Costs			8,643	100	

TABLE 5 Modal Split of Grain Transportation for Single Firm Model A

Elevator	Wheat							Barley			
			MCLF (25/26-Car Rail)								
	Truck-Barge	3-Car Rail	At Elevator	Transship From	Transship To	Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
	000 Bushels										
Cheney	0	391		NA	NA		391	0	391	0	391
Rodna	100			NA	NA		100	0		50	50
Fairfield	0	0	845	NA	NA	845	845	0	451	0	451
Waverly	88			NA	NA		88	0		83	83
Rockford	0	600		NA	NA		600	0	216	0	216
Freeman	0	333		NA	NA		333	0	50	0	50
Mt. Hope	150			NA	NA		150	0		9	9
Spangle I	0	0	770	NA	NA	770	770	0	310	0	310
Plaza	0	0	594	NA	NA	594	594	0	285	0	285
Spangle II	0	268		NA	NA		268	0	114	0	114
Spring Valley	268			NA	NA		268	0		115	115
Rosalia	0	472		NA	NA		472	0	203	0	203
Balder	266			NA	NA		266	0		116	116
McCoy	0	240		NA	NA		240	0	100	0	100
Pine City	472			NA	NA		472	0		203	203
Squaw Canyon	64			NA	NA		64	0		28	28
Thornton	0	303		NA	NA		303	0	164	0	164
Cashup	120			NA	NA		120	0		51	51
Steptoe	380			NA	NA		380	0		237	237
Garfield	200			NA	NA		200	0		20	20
Walters	75			NA	NA		75	0		8	8
Crabtree	60			NA	NA		60	0		15	15
Oakesdale	0	0	1,049	NA	NA	1,049	1,049	0	513	0	513
Farmington	200			NA	NA		200	0		100	100
Seltice	114			NA	NA		114	0		57	57
Warner	100			NA	NA		100	0		60	60
Fairbanks	255			NA	NA		255	0		128	128
St. John	450			NA	NA		450	370		80	450
Ewan	437			NA	NA		437	238		0	238
Willada	0	0	1,719	NA	NA	1,719	1,719	0	400	0	400
Juno	103			NA	NA		103	0		68	68
Sunset	200			NA	NA		200	0		150	150
Pleasant Valley	500			NA	NA		500	209		141	350
Total	4,601	2,606	4,977			4,977	12,184	818	3,196	1,719	5,733
Percent	38	21	41			41	100	14	56	30	100

TABLE 6 Transportation System Costs for Single Firm Model A

Item	Wheat	Barley	Total	Percent	Grain Shipped
	000 Dollars				000 Bu
Assembly	306	139	445	5	
Elevation	2,447	1,145	3,593	40	
Shipping	3,801	1,221	5,022	55	
Wheat	3,801		3,801	0.42	12,184
Truck-Barge	1,609				4,601
3-Car Rates	857				2,606
25-Car Rates	1,335				4,977
Transshipments	0				0
Barley		1,221	1,221	0.13	5,733
To Portland-Vancouver		1,006			4,014
Truck-Barge		275			818
3-Car Rates		732			3,196
To Feedlots		214			1,719
Total Costs			9,060	100	

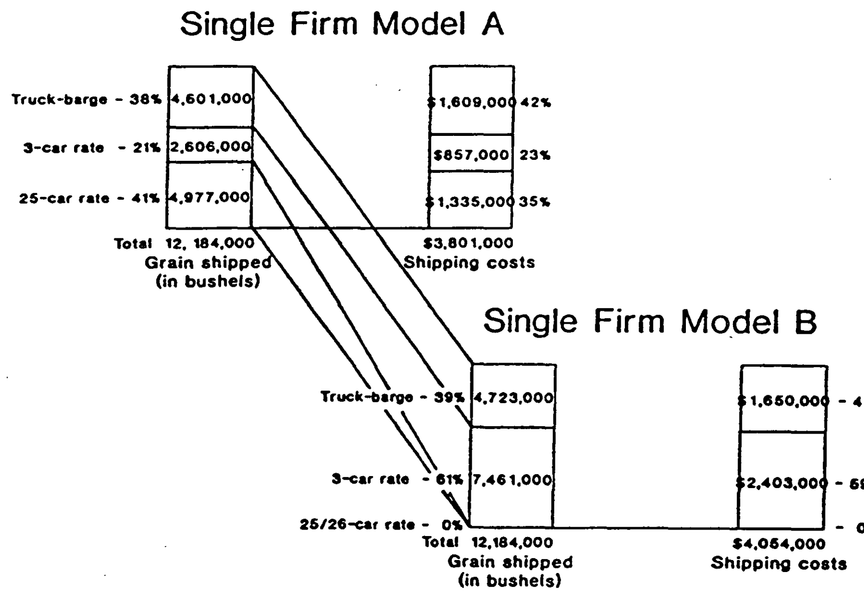

FIGURE 2 Comparison among the three shipping options (25/26-car, 3-car, and truck-barge) used in Single Firm Models A and B to ship wheat produced in southern Spokane and northern Whitman counties to Portland, Oregon.

TABLE 7 Shipping Costs for the Four Broad Base Models

County	Shipping Costs			
	Base Model	Least Cost Model	Single Firm Model A	Single Firm Model B
	000 Dollars			
Spokane	1,566	1,365	1,385	1,488
Whitman	1,979	2,067	2,416	2,566
Total	3,545	3,432	3,801	4,054

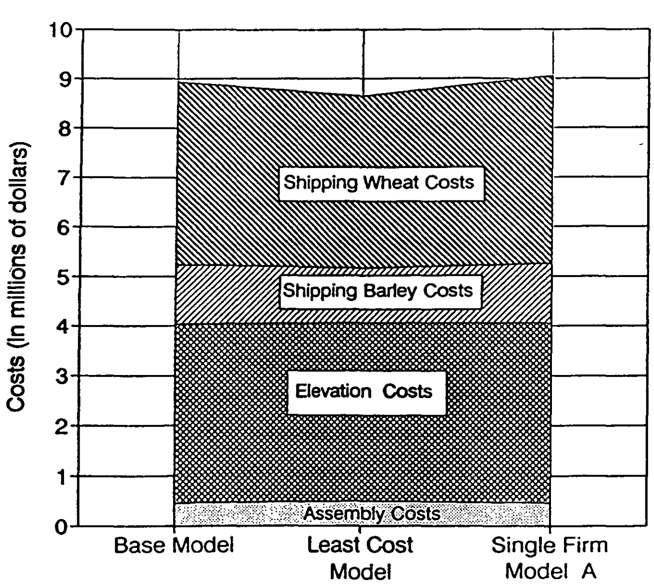

FIGURE 3 Comparison of component and total costs for three models.

ply shifted to another time period. The model did not specifically price the storage and shipping during the fourth period by adding on a storage penalty; thus the mathematical solution was simply another shipping pattern. If such a penalty were assigned, total costs would increase. No change in costs, storage, or modal choice occurred.

The shipper could sell before closure, hold until after the closure period, or sell during closure but move the grain via a different mode. The first alternative saves storage costs but makes shippers dependent on existing market price, the second causes increased storage cost and some price dependency, and the third entails higher transport costs. The actual response by shippers to a river closure would be driven by market demand conditions, financial needs of producers, rate reactions by other modes, and capacity needs in the elevator and storage sector.

BURLINGTON NORTHERN COMPETITIVE MODEL

Results from the base model indicated that almost 50 percent of the 12.184 million bushels of wheat shipped from the study area went to Portland, Oregon, on Burlington Northern cars. Union Pacific moved around 39 percent, and the remaining 11 percent went by truck-barge. Reducing Burlington Northern rates did not have a great effect on the modal share distribution of wheat shipments (Figure 4), suggesting that there is little incentive for Burlington Northern to decrease rates since they do not gain traffic.

If all Burlington Northern rates were increased (the 3-car and 25/26-car rates), the first 6-cent range increase would be critical in changing the modal share for wheat movement to Portland, Oregon. A 4-cent rate increase reduced the Burlington Northern share from almost 50 to 29 percent (almost eliminating three-car rates and transshipments to multiple-car loading facilities), in favor of an increase in the truck-barge share from 10 to 30 percent. Union Pacific gained only 2 percent of the shipping share.

This reduction assumes availability of barge capacity on the river system. In the peak year of grain movement on the river, 1985, almost twice as much moved on the river as the volume used in this analysis; thus, barge capacity appears to be available.

These results reflect the intense competition that exists in the transportation system in eastern Washington since the rates per ton-mile are very similar among model alternatives. Union Pacific did not gain a bigger share because of the proximity of Willada (its busiest station) to the Snake River. Another factor that influenced this result is the loyalty of wheat producers to specific elevators, thus preventing the low Union Pacific rates from drawing more grain to its stations. This loyalty was expressed by the minimum amount of grain handled per elevator that constrained the linear programming model.

ARROW LINE ALTERNATIVE MODEL

The assumed reduction in rates from the new Arrow Line did not have much effect on modal share since in the base model truck-barge rates were already at a rate disadvantage compared with railroad rates. Yet, if the new Arrow rail line configuration were able to offer a 2-cent reduction, an increase of 159,000 bushels would occur; this shift would be captured by wheat that was previously transshipped or moved by 25/26-car units. A further 2 cents per bushel decrease (a total of 4 cents) would move an additional 163,000 bushels by transshipment and 25/26-car movements.

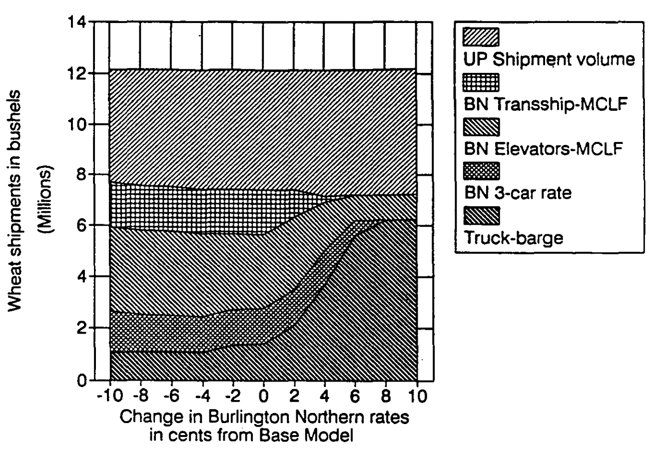

FIGURE 4 Modal share of wheat shipments as a function of Burlington Northern rates.

CONCLUSIONS

The overriding conclusion is that this multimodal system, essentially a duopoly at most shipping points, is quite competitive. Analysis of the modal share shifts in response to rate changes reveals the high elasticity of demand, in economics commonly associated with competition. It is also evident that the competitive environment is made possible by the intermodal complementary relationship of truck and barge in an integrated mode. Any competitive advantage held by the railroads has already been introduced into the market place by multiple-car rates. Little, if any, further monopoly power remains with the railroads.

Any decrease in truck-barge rates, even 2 cents, captures much of the wheat originally transshipped to multiple-car loading facilities. Eight- and 12-cent reductions would eliminate three-car mode and multiple-car shipments, respectively.

A second conclusion is that the multimodal transportation system performance is directly affected by the operating structure of the industry using that system. Maintaining all elevators, even the small, is costly to the transportation system. However, small elevators provide service to local producers during harvest and serve as collection sites whenever transshipments are available. Cooperatives or other multiple-plant firms can take advantage of multiple-car rates using transshipment between elevators in a firm to accumulate the required volume. Costs can then be averaged and spread out among elevators in a firm, allowing the survival of smaller elevators.

It is also evident that a decrease in availability of any mode in the existing complete multimodal system results in increased costs to the shipper, a decrease in the service received by the shipper, and a decrease in the overall mobility of freight and goods. The existing multimodal system seems to offer a competitive and efficient package of rates and service.

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