An Economic Evaluation of a Multimodal Transportation System: Grain Transportation in Eastern Washington

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

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AN ECONOMIC EVALUATION OF A MULTIMODAL TRANSPORTATION SYSTEM: GRAIN TRANSPORTATION IN EASTERN WASHINGTON

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DISCLAIMER

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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SUMMARY

The objective of this research is to determine how alternative marketing strategies and transportation policies affect the efficiency and performance of a multimodal transportation system.

A case study of eastern Washington grain transportation included modal use and marketing characteristics of farm producers and grain elevators, a mathematical spatial equilibrium model reflecting commodity flows, alternative model scenarios reflecting shipper strategies and policy changes, and an evaluation of the multimodal response and system performance under the alternative models.

The overriding conclusion is that this multimodal system--while essentially a duopoly at most shipping points--is quite competitive. This competitive environment is made possible by the intermodal complementary relationship of truck and barge in a single mode. Any decrease in truck-barge rates, even two cents, captures much of the wheat originally transshipped to multiple-car loading facilities. An eight cent and twelve cent reduction would eliminate three-car and multiple-car shipment, respectively.

The multimodal transportation system performance is directly affected by the operating structure of the industry utilizing that system. 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.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The overriding conclusion has to be that this multimodal system, while 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.

A second conclusion is that the multimodal transportation system performance is directly affected by the operating structure of the industry utilizing 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.

RECOMMENDATIONS

The study and policy recommendations from this study are to maintain availability of all modes in the existing multimodal system to decrease costs to the shipper, increase service to the shipper, and increase the overall mobility of freight and goods. Further study should incorporate differing storage costs over time and specific attention should be paid to the impact on roads of railline abandonment or river closure to barge transportation.

INTRODUCTION

The United States, and certainly the state of Washington, have experienced the development and enjoyed the benefits of a complete multimodal transportation system. This system has aided past and present economic development, increased financial returns to firms and decreased the costs of consumption items to Washington citizens and purchasers of Washington products. The fact that this system was, and is, multimodal--meaning the available transportation modes are rail, barge, truck and air--has been a major reason for the development of system transport efficiencies. Each mode has contributed in its own way, moving products in those origin-destination pairs in which its comparative advantage exists. These modes are also contributing individually now, and will be in the future, in the state's quest for continuing Washington and the U.S. achievements in increased international trade and, therefore, economic development. The overall efficiency of the total integrated transportation system depends on combining the special characteristics of each mode, supported by the port and trade services, so as to maximize the total efficiency and benefits to the overall system.

Recent situations are affecting the ability of the system to achieve these objectives. Truck efficiencies are potentially being negated by the overall condition of road infrastructure and congestion in heavy industrial or urban areas, including those around ports. Railroads have undertaken massive abandonments of branch lines, and are engaged in sales of marginally profitable lines to newly formed regional or short line railroads.

But, an important outcome of a balanced multimodal system has been the competitive environment existing between modes. This competition has kept rates down close to the costs of operation, improved efficiency and awarded innovation. There is an obvious benefit from competition and coordination among the modes.

The basic problem, then, is to identify how these changes will be incorporated into the transportation system supporting desired economic development. Where will these products be moving and what corridors will require reviews and possibly improvements? How can the many potential benefits of this integrated multimodal transportation system be maximized?

The problem being analyzed in this research report has not gone unnoticed by academic and government researchers and planners. Intermodal planning and policy analyses are significantly influenced by the changes in nature and intensity of the efficiencies and competition among modes. Past studies document the basis of historical efficiencies and resultant benefits of a multimodal, balanced transportation system. This research effort has built on that information, incorporating new policies, infrastructural situations, and relevant firm management information as appropriate.

Much work on the impact of grain transportation changes, especially railline abandonment and multiple-car rail rates, has previously been accomplished by this principal investigator for the Washington State Department of Transportation. Findings identified damage to roads of increased traffic, and how to predict damage prior to changes in marketing or railline abandonment. No specific analysis has been done on the shifting of competition among modes that results or the resultant shift in traffic patterns. Information related to the rail work has been the Palouse Empire Rail study, the Rail Development Commission reports and the Port of Whitman County short line analyses; all of these study analyses provided a base line from which to determine the feasibility of short line or regional railroads, with or without public investment or ownership,

No specific attention has been paid to the identification of traffic corridors or the review of the adequacy of the infrastructure in those corridors as these traffic changes occur. If motor carriers are able to efficiently divert traffic from railroads in the coming years, then future highway replacement and construction cost will be needed in certain corridors. Conversely, if railroads are able to capture an increased share of commodity movements, then future overall highway needs may decline and railroad improvements may be necessary. Therefore, specific corridor infrastructural needs need review and assessment relative to projected future utilization.

The grain industry in eastern Washington is a well-documented case study of the changes in the multimodal system. Infrastructure deterioration, changing mode availabilities and a new competitive environment for the modes suggest this area may well be seeing the benefits--and costs--of a multimodal system.

OBJECTIVES

The overall purpose of this study was to determine how to maximize the benefits and efficiencies available from the multimodal transportation system. Specific objectives were to:

1. Review the infrastructure of the transportation system in eastern Washington.
2. Select a study area where modal competitive environment was affecting the grain industry.
3. Survey elevators and farm producers in the study area as to modal use and marketing characteristics.

4. Develop a conceptual and mathematical spatial equilibrium model capable of reflecting commodity flows.

5. Review and construct alternative models reflecting current or potential mode and policy changes.

6. Determine multimodal performance under the alternative models.

7. Evaluate benefits from competition and coordination in the multimodal system.

STUDY APPROACH

The main tool of analysis of this study was a spatial equilibrium model, developed to evaluate and be sensitive to the intermodal competitiveness in the transportation system in eastern Washington. Supporting the mathematical model and giving realism to the analysis were two separate comprehensive surveys of grain producers/shippers and grain elevators in the chosen study region (Appendices A and B). Transportation rates and other coefficients were obtained from the shippers, carriers and elevator firms who are currently participating in grain marketing.

The study was conducted in a southern Spokane and northern Whitman County study area. This area was chosen based on the existing vigorous competitive environment among modes (see Logsdon, Casavant, Dooley).

Spokane County has an area of 1,764 square miles and is located in the Northeast District of Washington State. The topography of the county can be divided into three distinct areas. Northern Spokane County is dominated by the hilly and mountainous Okanogan Highland; it is an area of coniferous forest, broad valleys, highlands lakes and Mount Spokane. Much of the western portion of the county consists of channelled scablands, an evenly surfaced plateau on thin, stony glaciated soil interspersed with numerous lakes. Finally, the southeastern part of the county is comprised of the gently sloping Palouse Hills which contain highly fertile soil of significant agricultural value (Washington State Freight Rail Plan-Draft. Washington State Department of Transportation, 1991, pp. 5-35). The economy of Spokane County is based on agricultural production, manufacturing and trade.

Whitman County is located to the south of Spokane County, falling on the Washington-Idaho border, as does Spokane County. Whitman County has an area of 2,151 square miles. The northern part of the county is somewhat rocky, while the rest of the county is flatter with rolling hills (the Palouse Hills). The economy of Whitman County is resource based, producing mainly agricultural products and services. The government sector dominates the non-agricultural sectors largely because of Washington State University. The combined two segmented counties in the study region include strong grain-producing areas and a multimodal transportation system.

SURVEY RESPONSE AND STUDY AREA CHARACTERISTICS

Detailed information needed for the analytical model, and general descriptive information, was obtained by separate surveys of grain producers and grain elevator firms.

Grain Producer Survey

Procedure

An inclusive list of farmers in the two-county area was obtained from the data bases of the Agricultural Stabilization and Conservation Service (ASCS) offices in Spokane and Whitman Counties. A random sample of 621 farmers were then mailed questionnaires (Table 1). The first questionnaires were mailed on July 1, 1991. Following survey methods outlined by Dillman (1978), a reminder letter was sent 15 days later. On August 5, a second set of questionnaires was sent out to the 427 farmers that had not answered the first mailing. After the second mailing, a 49% (304) return was obtained. Of these 304 returned questionnaires, 226 (74%) stated that they were actually currently farming. These 226 responses were used to conduct the analysis presented here and to develop coefficients for the spatial equilibrium model.

Table 1. Survey Structure.

	Spokane Country			Whitman County			Total
	July 1	Aug. 5	Subtotal	July 1	Aug. 5	Subtotal	
Questionnaires Sent Out	371	260	371	250	167	250	621
Questionnaires Returned	111	77	188	83	33	116	304
Farming	84	37	121	79	26	105	226
Not Farming	27	40	67	4	7	11	78
Returned Responses	30%	30%	51%	33%	20%	46%	49%
Surveyed That Were Farming	76%	48%	64%	95%	79%	91%	74%

To determine if the sample obtained from the two mailing dates and the two counties was drawn from the same population of farmers and that responses reflected the overall population, two F-tests were applied to determine equality of variances in the data obtained by the survey. The first test was performed under the null hypothesis that total grain production between the first and second mailing dates had the same variance against the alternative hypothesis that they did not have equal variance. The results of this analysis for the survey sent to southern Spokane County are shown in Table 2. As with questionnaires received from Whitman County, the analysis revealed no significant differences between the variances. Thus, data from the two mailings were combined, treated as one population, and were felt to represent the overall population.

Table 2. Tests for Population Similarities and Differences.

Response to the Survey	Mean	Standard Deviation	Degrees of Freedom	F
	--------- Bu/Farm ---------			
(1) Ho = Response to July and August mailing in Spokane County have the same variance:				
Mailed on 7/1/91	35,434	30,124	82	1.11
Mailed on 8/5/91	35,429	31,795	34	
(2) Ho = Response in southern Spokane and northern Whitman Counties have the same variance.				
In Spokane County	35,433	30,629	120	2.19*
In Whitman County	71,558	45,372	104	

*Significative difference.

When an F-test was applied to compare variances between grain production in southern Spokane and northern Whitman Counties, results were significantly different. This indicates a significant difference in grain production of 35,433 bushels per farm in Spokane County compared to 71,558 bushels per farm in Whitman County. Based on these differences, the data coming from the survey in southern Spokane and northern Whitman Counties were analyzed and are presented separately.

Results

Specific information was sought from the farmers, information dealing with farm size, grain production, marketing strategies, use of country elevators, on-farm storage, road conditions and seasonal movement of grain.

As indicated in Table 3, Spokane County farms in the study area are significantly smaller in acreage than Whitman County respondents. Ninety-one percent of the farms in southern Spokane County were smaller than 2,000 acres compared to 80% in Whitman County. Conversely, 62% of Spokane farms were 1,000 acres or less, compared to 37% in Whitman County. For the entire study area, 50% of the farms were 1,000 acres or less.

Table 3. Farm Size Distribution, Southern Spokane and Northern Whitman Counties.

Farm Size (Acres)	------Spokane------		------Whitman------		-------Total-------	
	Number	Percent	Number	Percent	Number	Percent
1-500	35	29	13	12	48	21
501-1000	40	33	26	25	66	29
1001-1500	18	15	31	30	49	22
1501-2000	17	14	14	13	31	14
>2000	11	9	21	20	32	14
Total	121		105		226	

Most of the farms produce either wheat or wheat and barley; only 3% produced only barley and these were very small farms located in Spokane County (Table 4). The use of peas and lentils in an annual rotation is very evident, and more common in Whitman County than in Spokane, since around 50% of the larger farmers grow wheat, barley and other crops. Barley appears to be about one-third of the acreage when in a wheat-barley rotation and about one-fourth when in a wheat-barley-other rotation (Table 5). Wheat ranges from

59% to 67% of acreage. Also evident is that as farms grow in size, the number of crops that are annually grown increases. This multiple cropping characterization does increase the complexity of the marketing decisions by the individual producer and the complexity of the task assigned to the transportation system.

Table 4. Relative Frequencies of Wheat, Barley and Other Crops Grown.

Farm Size	Wheat Only	Barley Only	Wheat and Barley	Wheat and Other	Wheat, Barley and Other	Total
Acres	Percent					
Spokane						
1-500	47	6	32	3	12	100
501-1000	13	0	58	8	21	100
1001-1500	6	0	67	11	17	100
1501-2000	12	0	35	12	41	100
>2000	27	0	45	0	27	100
Whitman						
1-500	15	0	54	0	31	100
501-1000	4	0	35	19	42	100
1001-1500	10	0	23	16	52	100
1501-2000	0	0	36	14	50	100
>2000	19	0	29	19	33	100
Whole Study Area						
1-500	31	3	43	1	21	100
501-1000	9	0	46	14	32	100
1001-1500	8	0	45	14	34	100
1501-2000	6	0	36	13	46	100
>2000	23	0	37	10	30	100
Average	15	1	41	10	33	

Total grain production in the two counties increased an average of 26% and 4% for wheat and barley, respectively, from 1989 to 1990 (Table 6). This growth by respondents

Table 5. Proportion of Wheat, Barley and Other Crops Produced per Farm According to Rotation and Farm Size.

Farm Size	Wheat and Barley Rotation		Wheat, Barley and Other Crops Rotation		
	Wheat	Barley	Wheat	Barley	Other
Acres	Percent				
Spokane					
1-500	67	33	55	30	14
501-1000	63	37	59	29	13
1001-1500	65	35	44	45	11
1501-2000	73	27	62	18	20
>2000	84	16	74	9	17
Whitman					
1-500	60	40	44	41	15
501-1000	51	49	61	20	19
1001-1500	70	30	64	21	15
1501-2000	70	30	64	22	13
>2000	68	32	66	20	14
Whole Study Area					
1-500	64	36	50	36	14
501-1000	57	43	60	24	16
1001-1500	67	33	54	33	13
1501-2000	72	28	63	20	16
>2000	76	24	70	15	15
Average	67	33	59	26	15

was compared to the Washington Agricultural Statistics reports, with similar consistent results, thus reflecting our confidence in the results of the survey.

Agricultural producers have various marketing alternatives available to them. Each of these alternatives requires differing capital investments and puts differing demands at different times on the transportation system and its infrastructure. As indicated in Table 7

Table 6. Percentage Change in Wheat and Barley Production Between 1989 and 1990.

Farm Size	Wheat	Barley
Acres	---------------- Percent ----------------	
Spokane		
1-500	26	-0.3
501-1000	20	5
1001-1500	50	26
1501-2000	22	-7
>2000	31	19
Whitman		
1-500	20	-6
501-1000	21	2
1001-1500	20	6
1501-2000	29	-10
>2000	17	5
Whole Study Area		
1-500	23	-3
501-1000	21	3
1001-1500	35	16
1501-2000	26	-8
>2000	24	12
Average	26	4

and 8, there is a considerable difference as to what producers do with their wheat and barley, depending upon county of location and size of farm. About 43% of the farms overall moved their grain to the local elevator with Spokane farmers doing so much more often. Sixteen percent of the farms relied on on-farm storage only and they were predominantly located in Whitman County. Size of farm did not seem to affect the usage of on-farm storage. Those firms choosing to sell their grain immediately at harvest were mainly the smaller farms and this occurred in both counties. The larger farmers relied more on a combination of elevator and on-farm storage to move their wheat.

Table 7. Marketing Alternatives Utilized for Wheat by Farm Size.

Farm Size	Only Elevator	Only On-Farm Storage	Only Sold at Harvest	Elevator and On-Farm Storage	Elevator and Sold at Harvest	Elevator, On-Farm Storage and Sold at Harvest	Total
Acres	Percent						
Spokane							
1-500	47	21	21	9	3	0	100
501-1000	51	8	10	23	0	8	100
1001-1500	50	6	11	17	0	17	100
1501-2000	41	12	0	29	12	6	100
>2000	45	9	0	37	0	9	100
Whitman							
1-500	54	8	31	0	8	0	100
501-1000	50	23	4	4	12	8	100
1001-1500	39	26	0	17	10	9	100
1501-2000	36	29	0	21	0	14	100
>2000	14	24	5	43	5	10	100
Whole Study Area							
1-500	50	14	26	4	5	0	100
501-1000	51	15	7	13	6	8	100
1001-1500	44	16	6	17	5	13	100
1501-2000	38	20	0	25	6	10	100
>2000	30	16	2	40	2	10	100
Average	43	16	8	20	5	8	100

Barley movements on to the local elevator were even more pronounced than wheat, on-farm storage was used even less and selling at harvest was similar to wheat movements

Table 8. Marketing Alternatives Utilized for Barley by Farm Size.

Farm Size	Only Elevator	Only On-Farm Storage	Only Sold at Harvest	Elevator and On-Farm Storage	Elevator and Sold at Harvest	Elevator, On-Farm Storage and Sold at Harvest	Total
Acres				Percent			
Spokane							
1-500	55	10	25	10	0	0	100
501-1000	58	12	6	12	3	9	100
1001-1500	56	6	6	19	13	0	100
1501-2000	57	0	0	21	14	7	100
>2000	60	10	0	10	0	20	100
Whitman							
1-500	67	0	25	0	8	0	100
501-1000	50	14	14	0	18	5	100
1001-1500	54	19	4	8	12	4	100
1501-2000	50	25	0	17	8	0	100
>2000	24	35	12	24	6	0	100
Whole Study Area							
1-500	61	5	25	5	4	0	100
501-1000	54	13	10	6	11	7	100
1001-1500	55	13	5	13	12	2	100
1501-2000	54	13	0	19	11	4	100
>2000	42	23	6	17	3	10	100
Average	53	13	9	12	8	4	100

(Table 8). There was significantly fewer farmers who used the local elevator and on-farm storage combination and this was principally the larger farms.

It has been noticed in previous studies by this author that farmers seem to feel less responsibility to support and use their nearby local elevator and, as a result, miles traveled by farm trucks may be increasing. The farmers in this study in eastern Washington do, in fact, use more than one elevator but the majority by far still rely on only one elevator (Table 9). There is a significant difference between the two counties in the study area. Whitman farms are larger and the owner-operators of these farms seem quite willing to combine river terminal usage with more than one elevator. Further, especially in Whitman County, these farmers used the river terminal as their sole outlet for their on-farm storage. It should be noted that Whitman County has more than twice as many elevators as Spokane County. Also, the survey did not collect data regarding cooperative loyalty, contracts or other factors influencing elevator choice.

Table 9. Distribution Alternatives of Country Elevators and River Terminal.

Farmers Shipping Grain Farm to:	------ Spokane -----		----- Whitman -----		-------- Total --------	
	Number	Percent	Number	Percent	Number	Percent
One Elevator	82	68	30	29	112	50
One Elevator and River Terminal	11	9	9	9	20	9
Two Elevators	9	7	22	21	31	14
Two Elevators and River Terminal	4	3	7	7	11	5
Three Elevators	3	2	8	8	11	5
Three Elevators and River Terminal	1	1	0	0	1	0
Only River Terminal	11	9	29	28	40	18
Total	121		105		226	

The amount of on-farm storage has also been determined by previous studies to be increasing in the state of Washington. About 50% of these farms had some on-farm storage and this occurred evenly, over size, in Spokane County and more commonly on the larger-sized farms in Whitman County (Table 10).

Table 10. Percentage of Farms Having On-Farm Storage, by Size of Farms.

Farm Size	Percentage of the Total Number of Respondents		
	Spokane	Whitman	Whole Study Area
Acres	----------	Percent	----------
1-500	43	15	35
501-1000	43	31	38
1001-1500	50	48	49
1501-2000	47	64	55
>2000	55	81	72
Average	47	48	50

An integral part of efficiently marketing grain and having an effective multimodal system to support that movement is the condition of the roads serving the on-farm storage. As indicated earlier, on-farm storage is an active component of the marketing system. Farmers in the study area stated that 27% of the roads were in poor condition, 54% were in good condition and 8% felt the roads were very good (Table 11). All of the small farmers in Whitman felt the roads were either in good or very good condition. As the size of the farm increased, perceptions of increased problems with roads were evident in both Spokane and Whitman Counties. In both counties, the dominant comment (54%) was that road conditions were good.

The road conditions response had a split personality when evaluating the change in road conditions over the past five years. Forty percent felt there had been no significant changes in the condition of the roads leading to their on-farm storage. Twenty percent felt

Table 11. Road Conditions (According to Farm Size) Reported by Farmers Having On-Farm Storage.

Farm Size	Road Conditions				Change in Road Conditions Over the Past Five Years			
	Poor	Good	Very Good	No Comment	No Change	Improved	Deteri-orated	No Comment
Acres	Percent							
Spokane								
1-500	11	44	17	28	39	22	11	28
501-1000	24	71	0	5	62	10	29	0
1001-1500	11	56	11	22	33	33	22	6
1501-2000	55	18	0	27	18	9	45	17
>2000	25	63	0	13	25	25	25	11
Whitman								
1-500	0	50	50	0	50	50	0	0
501-1000	40	60	0	0	70	10	20	0
1001-1500	35	65	0	0	24	12	65	0
1501-2000	18	41	0	12	25	17	42	17
>2000	23	71	0	6	52	14	24	10
Study Area								
1-500	6	47	33	14	44	36	6	14
501-1000	32	66	0	2	66	10	24	0
1001-1500	23	60	6	11	28	23	43	3
1501-2000	36	30	0	20	22	13	44	17
>2000	36	67	0	9	39	20	24	10
Average	27	54	8	11	40	20	28	9

improvement had occurred and 28% felt the road had deteriorated. Whitman County farmers felt a little stronger than Spokane County farmers that road conditions had deteriorated. The smaller farmers again seemed to feel more positively about the present condition of the roadway.

The transportation system and the local feeder roads serving the grain industry must stand ready to move grain throughout the year because 49% of the farmers now move their grain throughout the year (Table 12). This marketing activity is more common on the roads of Whitman County and is directly related to the size of farm. The smaller farms move

60%-70% of the movements only during the harvest period, contrasted to 37% of the larger farmers.

Table 12. Timing of Wheat Movement.

Farm Size	Number of Farms Surveyed	Grain Shipped Only at Harvest	Grain Shipped Throughout the Year
Acres		------- Percent -------	
Spokane			
1-500	35	74	26
501-1000	40	60	40
1001-1500	18	67	33
1501-2000	17	59	41
>2000	11	45	55
Total	121		
Whitman			
1-500	13	85	15
501-1000	26	62	38
1001-1500	31	42	58
1501-2000	14	29	71
>2000	21	10	90
Total	105		
Whole Study Area			
1-500	48	77	23
501-1000	66	61	39
1001-1500	49	51	49
1501-2000	31	45	55
>2000	32	22	78
Total	226		
Average		51	49

The seasonal flow throughout the year also reflects the pressure and usage of local roads. As indicated in Table 13, the dominant time of movement to the elevator from farmers is the two-month July through August period when 45% of the movements occurred. It is evident that there is strong movement in other periods as well, with 26% moving during the four-month period of September through December and 24% moving during the January through April four-month period. Only May and June have low movements, about 5% of the total. Approximately 55% of the farm to elevator movements occur after the harvest period.

In summary, it is evident that farms in Whitman County are larger than those in Spokane County. Just under half of the wheat produced is stored for later sale rather than being sold immediately after harvest. County elevators are the most important form of wheat storage, although on-farm storage becomes more important as farm size increases.

Grain Elevator Survey

Procedure

Decisions made by grain elevator firms have a direct impact on the transportation system. Accordingly, a group of 45 elevators in the study area was identified from the list of licensed grain elevators published by the Washington State Department of Agriculture in 1991. A questionnaire was sent to each of these elevator firms (see Appendix B), followed by personal interviews, as necessary, to encourage completion of the questionnaire or to eliminate any item nonresponse. Forty-one elevators operated by eleven elevator firms completed the questionnaire, while four elevators were no longer in operation, so 100% complete coverage of the study area was accomplished (Table 14).

The study area includes three major highways used to move the grain: State Highways 195, 27 and 23 (Figure 1). Highway 195 crosses Spokane and Whitman Counties

Table 13. Seasonal Distribution of Shipments of Wheat.

Farm Size	Number of Shipments	Shipments			
		July to August	September to December	January to April	May to June
Acres		Percent			
Spokane					
1-500	42	69	17	12	2
501-1000	56	55	20	20	5
1001-1500	25	56	20	20	4
1501-2000	25	52	8	36	4
>2000	26	38	31	27	4
Total	174				
Whitman					
1-500	14	79	21	0	0
501-1000	39	49	26	21	5
1001-1500	60	28	35	32	5
1501-2000	34	26	29	29	15
>2000	59	20	42	32	5
Total	206				
Whole Study Area					
1-500	56	71	18	9	2
501-1000	95	53	22	20	5
1001-1500	85	36	31	28	5
1501-2000	59	37	20	32	10
>2000	85	26	39	31	5
Total	380				
Average		45	26	24	5

from north to south, cutting the study area in two. Rosalia Producers, Inc., has its major elevators on this road at Spangle, Plaza and Rosalia. Whitman County Growers, Inc., also has its Thornton, Cashup, Steptoe and Colfax houses on Highway 195.

Table 14. Forty-One Grain Elevators Belonging to Eleven Warehouse Firms Surveyed in Southern Spokane, Northern Whitman and Eastern Lincoln Counties of Washington State, 1991.

Warehouse Company		Country Elevator	Location
Cheney Grain Growers, Inc.	1	Cheney	Spokane
	2	Rodna	Spokane
Fairfield Grain Growers, Inc.	3	Fairfield	Spokane
	4	Waverly	Spokane
Rockford Grain Growers, Inc.	5	Rockford	Spokane
	6	Freeman	Spokane
	7	Mt. Hope	Spokane
Rosalia Producers, Inc.	8	Plaza	Spokane
	9	Spangle	Spokane
	10	Spring Valley	Spokane
	11	Rosalia	Whitman
	12	Balder	Whitman
	13	McCoy	Whitman
	14	Pine City	Whitman
	15	Squaw Canyon	Whitman
Whitman County Growers, Inc.	16	Thornton	Whitman
	17	Cashup	Whitman
	18	Steptoe	Whitman
	19	Glenwood	Whitman
	20	Colfax	Whitman
Palouse Grain Growers, Inc.	21	Palouse	Whitman
The Garfield Union Warehouse Company	22	Garfield	Whitman
	23	Walters	Whitman
	24	Crabtree	Whitman
	25	Elberton	Whitman
Oakesdale Grain Growers, Inc.	26	Oakesdale	Whitman
	27	Farmington	Whitman
	28	Seltice	Whitman
	29	Warner	Whitman
	30	Fairbanks	Whitman
Lamont Grain Growers, Inc.	31	Lamont	Whitman
	32	Revere	Whitman
St. John Grain Growers, Inc.	33	St. John	Whitman
	34	Ewan	Whitman
	35	Juno	Whitman
	36	Sunset	Whitman
	37	Pleasant Valley	Whitman
United Grain Growers, Inc.	38	Edwall	Lincoln
	39	Waukon	Lincoln
	40	Edens	Lincoln
	41	Sprague	Lincoln

SOURCE: Public Grain Warehouses Licensed for 1990-91. State of Washington, Department of Agriculture, 1991.

Highway 27 runs parallel and to the right of Highway 195. Along Highway 27 Rockford Grain Growers, Inc., has two of its major houses, Freeman and Rockford;

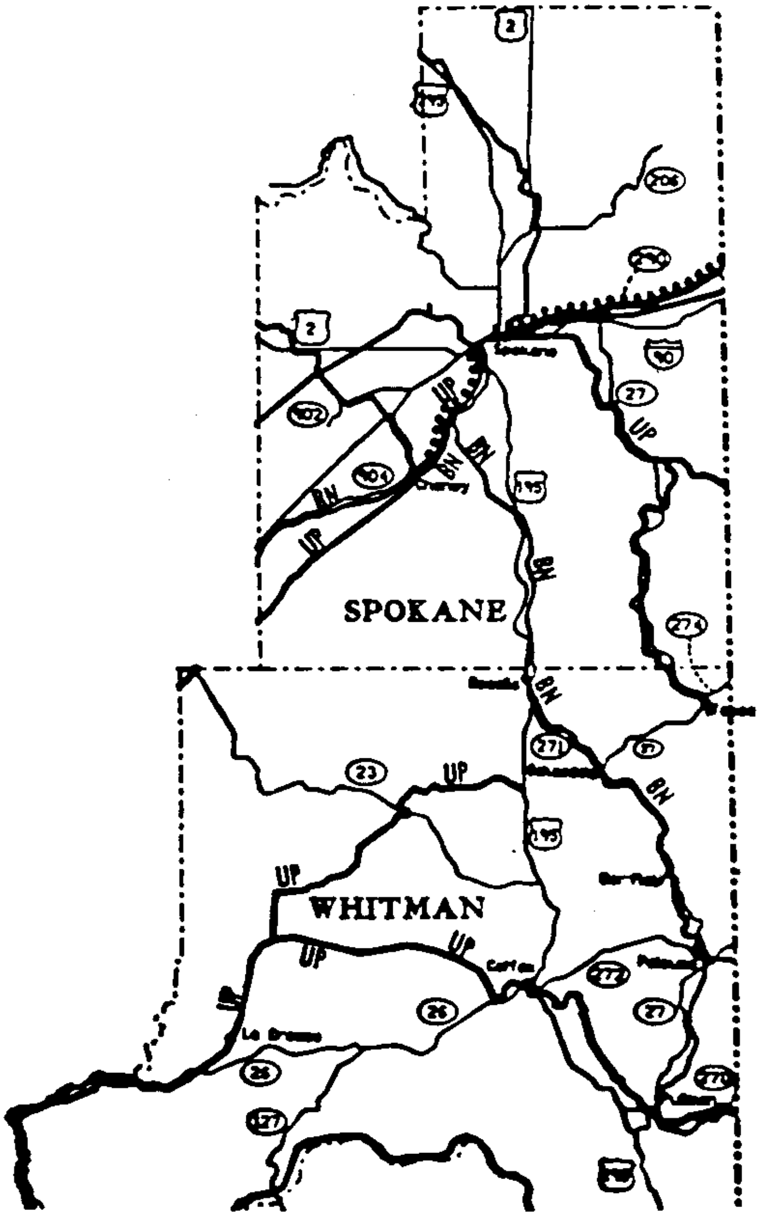

Figure 1. Major Highways (195, 27 and 23), and Burlington Northern (BN) and Union Pacific (UP) Raillines Running Across Spokane and Whitman Counties in Eastern Washington State.

SOURCE: Washington State Department of Transportation Geographic Services, Olympia, June 1990.

NOTE: The railroad lines on the map were modified to reflect the use of the railroad mode reported in the elevators' survey.

Oakesdale Grain Growers, Inc., and Garfield Union Warehouse Company have their major houses; and finally, Palouse Grain Growers, Inc., is based on Highway 27. Highway 27 joins Highway 195 in Pullman.

Highway 23 comes from the northwestern corner of Whitman County, running to the southeast and meeting Highway 195 south of Steptoe. St. John Grain Growers, Inc., is the main company on this road with its Ewan, St. John and Pleasant Valley elevators. In addition, Lamont Grain Growers, Inc., has its largest house on Highway 23.

United Grain Growers has a house at Sprague on Highway 23, but they reported that they use Highway 90, which runs to the west, as their major outlet. Cheney Grain Growers, Inc., was the only company surveyed without an elevator on one of the three major highways. However, its major house is located less than 20 miles from Spangle on Highway 195. Importantly, Cheney Grain Growers is the only company to have access to the two railroads that attend the area.

Burlington Northern and Union Pacific railroads are the major carriers in the area. Both have stations in Spokane and pass through Cheney on their way to west coast ports. After passing through Cheney, Union Pacific goes south to meet the Union Pacific branch line which carries grain from Thornton, Sunset, Juno, St. John and Willada, and a second branch line that comes from Colfax and Pullman. At the other end of the line, Union Pacific carries grain from Fairfield and goes north through Rockford and Freeman to join the mainline at Spokane.

Burlington Northern covers the area coming from Lewiston, going through Pullman to the north and joining the mainline at Marshall between Spokane and Cheney. Along the way, it collects grain from elevators in Palouse, Garfield, Oakesdale, McCoy, Rosalia, Plaza and Spangle.

Results

The proportion of wheat, barley, corn and legumes reported to be handled by the 41 elevators surveyed is presented in Table 15 and does approximate the crop history of the region. The volume of corn and feed crops is insignificant. Legumes are not handled in large volume either. Less than 15% of the elevators reported more than 20% of their total volume to be legumes. Legumes were never reported to make up more than 40% of the total volume.

Table 15. Proportion of Wheat, Barley, Corn and Legumes.

Percent Handled	Commodity Handled				
	Wheat	Barley	Corn	Feed Crops	Legumes
	Percent				
No Handling			98	88	44
< 10		5	2	10	29
10-19		5		2	12
20-29		41			10
30-39		29			5
40-49		20			
50-59	24				
60-69	54				
70-89	17				
90-100	5				
	100	100	100	100	100

Approximately 76% of the responding elevators handled 60% to 100% of their total volume in wheat, reflecting the fact Whitman and surrounding counties are some of the largest wheat-producing counties of the nation and world. Approximately the same proportion (70%) reported handling 20% to 40% barley, thus barley movements are a significant user of the transportation system.

Information was developed on the percentage of wheat shipped using each of the transportation modes available (Table 16). To summarize the results, elevators were grouped according to those having direct railroad access (14) or those who had no direct access (27), meaning they were not located on a railline. Truck-barge is the most commonly used transport mode for wheat, even for those elevators located on raillines. This can be related not only to economic (rate) factors, but also the effect of contracts and cooperative loyalty. Direct truck to market is not a popular option (the firm using it for 70% was only moving it three miles to a local mill) and there is almost no use of 1-car rates. Three-car rates are heavily used by the elevators that have this option (if they do not have 25/26-car rates) as are 25-car rates for those that have this option. Transshipments go from elevators without access to railroad lines (except for one firm) and are directed almost exclusively to 25-car rates.

Those firms having no railroad access do use direct truck to the market, but only for about 15% of their movements. Transshipment to another elevator is used almost over 70% of the time by over 50% of the firms. Truck-barge is used about the same amount as transshipment by these elevators not located on a railline.

When the grain production reported in the survey is carried to market, railroad carried 11.6 million bushels of wheat, 9.4 by multiple-car (25/26-car) units including 3.9 million bushels transshipped from elevators without railroad access. Truck-barge moved 4.9 million bushels, with 73% coming from elevators without railroad access. For barley

Table 16. Transportation Mode Choices for Wheat Shipments to Final Market.

Percentage Range	14 Elevators with Direct Railroad Access						27 Elevators with No Railroad Access		
	Direct Truck to Market	Truck Barge	Trans-shipment	Railroad			Direct Truck to Market	Truck Barge	Trans-shipment
				1-Car	3-Cars	25-Cars			
	Percent								
< 10	21	29		14	14		4		
10-19		29			14		15	11	7
20-29					7		4	7	4
30-39								11	
40-49			7				4		4
50-59					14	7			4
60-69								4	
70-79	7							4	15
80-89		7						7	7
90-99		21			29	21		30	30
Total Use	29	86	7	14	79	29	26	74	70
Do Not Use the Mode	71	14	93	86	21	71	74	26	30
	000,000 Bushels								
Wheat Moved	0.2	1.3	0.2	0.01	2.2	5.5	0.2	3.6	3.9

(Table 17) competition between the three modes is more active. No 25/26-car rates exist for barley. Again, the railroad is an important carrier with 1.38 million bushels (33,094 tons) with an additional 1.5 million bushel moving by transshipments from elevators with no direct access to railroad facilities. Direct truck to market carries 2.1 million bushels and includes barley going to many different feedlots at many different locations. Truck-barge carries 1.8 million bushels and, as with wheat, fills the quota set by the Central Ferry Terminal Association.[1]

[1]The Central Ferry Terminal Association is a cooperative organization that established grain quotas to be delivered by the elevators to the Snake River port with the purpose to assure a minimum amount of grain designed to assure the availability of the truck-barge mode whenever there are shortages of railroad cars. This is accomplished by the members, cooperative elevator firms, agreeing to a minimum quota of shipments each year to be moved through the river facility.

Table 17. Transportation Mode Choices for Barley Shipments to Final Market.

Percentage Range	14 Elevators with Direct Railroad Access					27 Elevators with No Railroad Access		
	Direct Truck to Market	Truck Barge	Trans-shipment	Railroad 1-Car	Railroad 3-Cars	Direct Truck to Market	Truck Barge	Trans-shipment
	Percent							
< 10	7	21		14	7			
10-19	7		7	7		7		
20-29	7		7	7		19	19	
30-39	14					11	4	7
40-49	7	7				11		7
50-59					14	11	7	4
60-69					7			
70-79		7			14			11
80-89		14			7	4	7	7
90-99	7	7			21	11	19	15
Total Use	50	57	14	29	71	74	56	52
Do Not Use the Mode	50	43	86	71	29	26	44	48
	000,000 Bushels							
Barley Moved	0.8	0.6	0.01	0.08	1.3	1.3	1.2	1.5

The survey showed that wheat is shipped almost exclusively to Portland (Table 18). Participating elevators reported receiving and shipping a total of 16.8 million bushels of wheat. In-state flour mills received only around 2% of the wheat shipped by the elevators. The local market is, however, important for specific elevators such as the Cheney Grain Growers' elevator in Cheney. Wheat is also sometimes shipped to feedlots as a result of sprouting following rainy harvests.

Ninety percent of the elevators reported shipping at least some barley to Portland or the lower Columbia River ports for exports (Table 19). Fifty-one percent of the elevators shipped over 70% of their barley to the Columbia River ports. A total of 86,550 tons of barley were shipped to Portland. Vancouver received 31,370 tons of malting barley from the surveyed elevators, and 41,650 tons were shipped to in-state feedlots. All of the elevators reported receiving most of their wheat (88%) within four months of harvest

Table 18. Shipping Destination for Wheat.

Percentage Range	Wheat Shipped To: Columbia River Ports	Puget Sound Ports	In-State Flour Mills	Feed Lots
	---------- Percent ----------			
< 10		2	2	2
10-19			5	2
20-29	2			2
40-49			2	
60-69	2			
70-79			2	
80-89	2			
90-99	93			
Total	100	2	12	7
To Another Destination	0	98	88	93
	---------- 000 Bushels ----------			
Wheat Shipped	16,803	15	350	45

(Table 20). Approximately 58% of the elevators reported that they receive all their wheat in July and August. Few firms received grain throughout the year and this was for only a small percentage of total receipts.

Wheat shipments, though, are a different picture (Table 21). In every period, 60% or more do some shipping of grain to final markets. However, the movement is strongest in September-October and November-December. Only in May and June is there a drastic slow down in shipments.

Most barley is moved to elevators during July and August (Table 22). Elevators reported receiving 142,000 tons of barley during these months. Only 18,465 tons were reportedly received during the rest of the year. Shipments of barley to market closely match the distribution of wheat shipments (Table 23). Approximately 70% of all barley is shipped

Table 19. Shipping Destinations for Barley.

Percentage Range	Barley Shipped To:			
	Columbia River Ports	Puget Sound Ports	Vancouver	Feed Lots
	Percent			
< 10	2		5	2
10-19		2		20
20-29	10			20
30-39	7		2	22
40-49	5			7
50-59	10		5	15
60-69	5			
70-79	12		15	
80-89	10		5	
90-99	29			2
Total	90	2	32	88
To Another Destination	10	98	68	12
	000 Bushels			
Barley Shipped	3,609	20	1,308	1,737

Table 20. Seasonal Distribution of Wheat Received.

Percentage Range	Receiving Period					
	July-August	Sept.-Oct.	Nov.-Dec.	Jan.-Feb.	March-April	May-June
	Percent					
< 10		27	2	5	2	2
10-19		22				
20-29	2	32	3	2	2	2
30-39			1			
40-49	2	2				
50-59	5	5				
60-69	3					
70-79	13					
80-89	17					
90-99	58					
Total	100	88	6	7	4	4
No Reception	0	12	94	93	96	96
	000,000 Bushels					
Wheat Received	12.3	2.77	0.77	0.70	0.34	0.34

Table 21. Seasonal Distribution of Wheat Shipped.

Percentage Range	Shipment Period					
	July-August	Sept.-Oct.	Nov.-Dec.	Jan.-Feb.	March-April	May-June
	Percent					
< 10	10	2		5	10	44
10-19	32	2	7	17	41	10
20-29	27	63	59	51	24	
30-39	15	7	15	12	2	2
40-49		7	12			
50-59	5	7				
60-69		5	5			
70-79						
80-89						2
90-99						
Total	88	95	98	85	78	59
No Shipment	12	5	2	15	22	41
	000,000 Bushels					
Wheat Shipped	2.99	3.77	3.88	3.13	2.45	0.99

between September and February. Only in the months March through June is the barley movement significantly less.

The above actual characteristics of the grain elevator and grain producer transportation users served to develop the analytical framework for the spatial equilibrium model in this study. Specific coefficients used were based on the actual survey findings.

THE EMPIRICAL MODEL

The purpose of the grain marketing system model is to represent the flow of wheat and barley from points of production origin to terminal markets and the resultant use of the multimodal transportation system. Because of the complex nature of the grain marketing

Table 22. Seasonal Distribution of Barley Received.

Percentage Range	Receiving Period					
	July-August	Sept.-Oct.	Nov.-Dec.	Jan.-Feb.	March-April	May-June
	Percent					
< 10		27	5	7	5	2
10-19		20				
20-29		22				
30-39						
40-49	7					
50-59						
60-69		7				
70-79	17					
80-89	15					
90-99	61					
Total	100	76	5	7	5	2
No Reception	0	24	95	93	95	98
	000,000 Bushels					
Barley Received	5.91	0.68	0.03	0.02	0.03	0.01

Table 23. Seasonal Distribution of Barley Shipped.

Percentage Range	Shipment Period					
	July-August	Sept.-Oct.	Nov.-Dec.	Jan.-Feb.	March-April	May-June
	Percent					
< 10	20	2	2	2	10	51
10-19	29	12	7	20	49	10
20-29	22	37	46	41	17	
30-39	12	22	29	15		2
40-49		12	12			
50-59	5	5	2	5		
60-69		5				
70-79						
80-89		2				
90-99						
Total	88	98	100	83	76	63
No Shipment	12	2	0	17	24	37
	000,000 Bushels					
Barley Shipped	1.02	1.62	1.63	1.45	0.63	0.33

industry, assumptions were introduced to reduce the size and scope of the model. Although somewhat restrictive, these assumptions are necessary to develop a workable and interpretable economic model.

The Study Area

The area including southern Spokane and northern Whitman Counties (the Spokane-Whitman supply region), as described earlier, was chosen for the study (Figure 2). The following six factors were specifically considered in the determination of the regional supply area:

1. The number of field crops produced.
2. Natural geographic and political boundaries.
3. Rail and truck-barge rates.
4. River proximity.
5. Elevators' size distribution.
6. Close rate competition among modes.

As revealed by the survey data, wheat and barley are by far the major crops in the Spokane-Whitman supply region. On this basis, the empirical model is simplified by assuming that the supply region produces only these two crops. Because local demand for wheat and barley in the study area is minimal relative to production, it is further assumed that producers rely on the grain marketing system to move their crop from farm to distant international and domestic markets.

Natural geographic and political boundaries serve as effective barriers and minimize inflows of grain to the supply region (Dooley, 1986). This study area goes from the southern

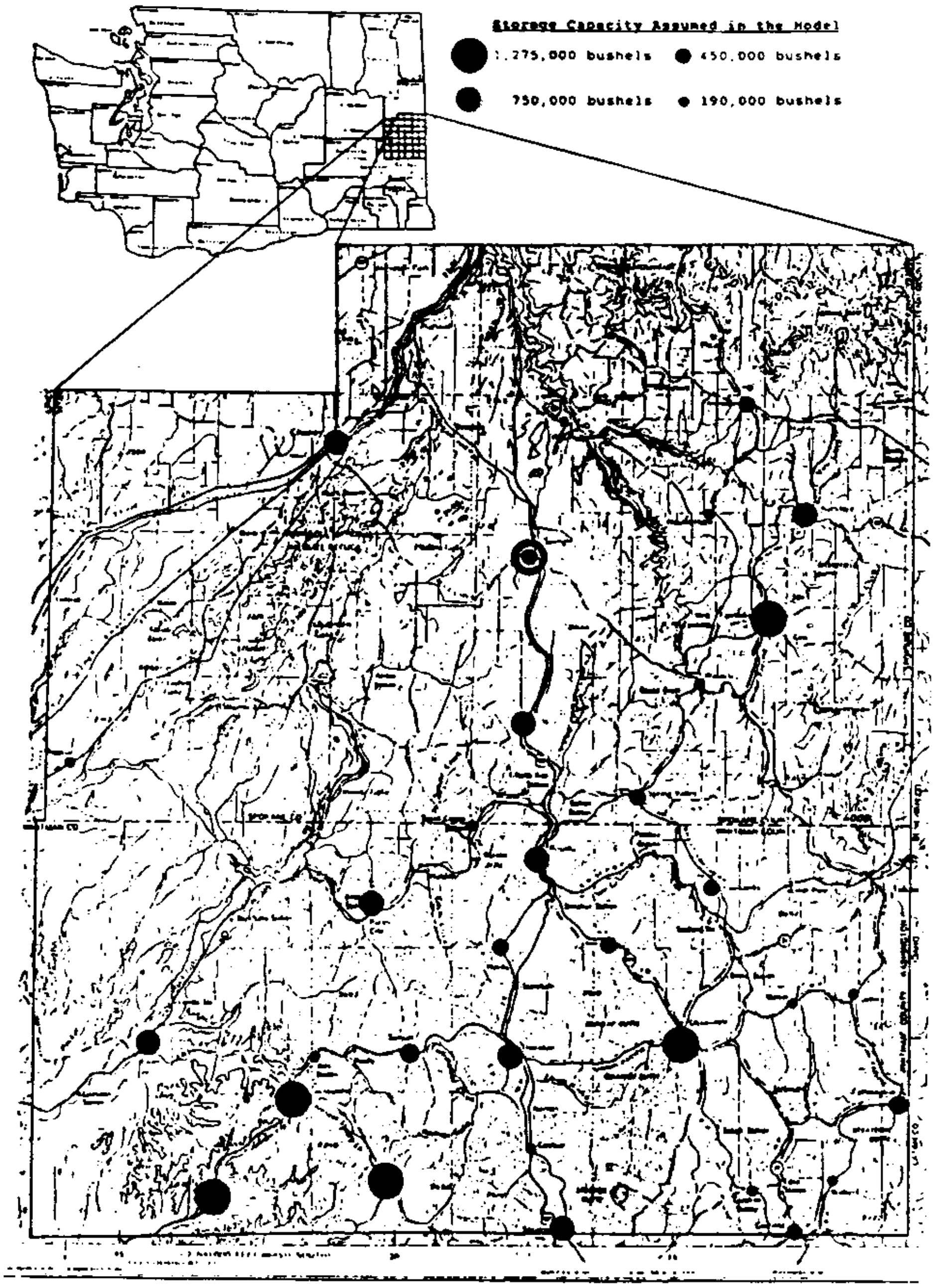

Figure 2. Location of the Study Area and the Thirty-Three County Elevators Identified for the Development of a Grain Transportation Cost Minimization Model for Southern Spokane and Northern Whitman Counties in Washington State.

SOURCE: Washington Agricultural Statistics 1989-90, Olympia, WA, Sept. 1990, p. 13; and the U.S. Geological Survey, 1965.

border of the city of Spokane and the valley metropolitan area in Spokane County, at the north, to the south of Willada, Steptoe and Garfield (southern boundary of township T.18 N. and ranges from R.39 E. to R.45 E.) in Whitman County to the south. The borderline between Idaho and Washington determines the eastern border and the Lincoln County line sets the western border.

As Dooley (1986) points out, the availability of various rail rates, particularly 25/26-car rates, is desirable since it is believed that these rates may be a cause of any market restructuring and changing modal competition. The two most important railroad companies in the region, the Burlington Northern and the Union Pacific, have stations in this area and offer 1-car, 3-car and 25/26-car rates.

River proximity refers to truck-barge distances to Columbia River barge terminals. This truck-barge option, for the study area, is centered at the Port of Central Ferry on the Snake River. Proximity to the Snake River is an important determinant of whether grain is shipped by truck to river barges or sent by rail. The location of the study area represents a point where railroad and truck-barge modes compete to transport the grain produced in the region. Modal use predominantly seems to be determined by the distance from the elevator to the river port compared to its proximity to a multiple-car loading facility for the railroad.

It also appears that grain elevators are willing to pay a premium to insure the availability of truck-barge transportation whenever there are shortages or lack of railroad. To assure this, such elevators have contracts with the Central Ferry Terminal Association, contracts guaranteeing a minimum of grain shipments by each house to maintain the terminal in operation. Finally, it has been hypothesized that the introduction of multiple-car rail rates will hasten the demise of smaller country elevators (Dooley, 1986, p. 170), thereby affecting use of alternative modes. To analyze this hypothesis, it is desirable that the study region have a representative size distribution of elevators by licensed storage capacity. The 33 elevators, belonging to 12 firms established in the study area, represent a good size distribution of elevators for testing this hypothesis (Table 24).

Assumptions

The following assumptions (taken from Dooley, 1986, pp. 172-74) apply throughout the analysis:

1. The study area was subdivided into a finite number of production regions.

2. The supply of wheat and barley in each production region and the demand for wheat and barley at the terminal markets were assumed to be known, i.e., the 1989 production level, and fixed.

3. All grain moved from the points of origin to the elevator or multiple-car loading facility in a single-axle farm truck.

4. All grain produced in the crop year was delivered from the origin point to any country elevator within 18 miles of the origin point or to any multiple-car loading facility within the same firm (multiplant firm).

5. The model was developed for one crop year. The crop year was divided into four time periods, July-August (T1), September-October (T2), November-February (T3), and March-June (T4).

6. All grain delivered to multiple-car loading facilities or elevators was shipped to terminal markets; there was no long-term storage of grain considered.

7. Country elevators and multiple-car loading facilities had predetermined receiving, storage, and shipping capacities.

8. All wheat collected and handled in the Spokane-Whitman region was shipped to Portland, Oregon, while all barley was delivered to either Portland, Oregon, Vancouver, Washington, or in-state feedlots.

9. No existing railroad line in the region was subject to abandonment.

Table 24. Licensed Storage Capacity for Thirty-Three Country Elevators Belonging to Nine Warehouse Firms Study Area.

Warehouse Firm	Elevator Location	License Storage Capacity	
		Elevator's	Whole Firm
		------------ Bushels ------------	
Cheney Grain Growers, Inc.	Cheney	757,000	
	Rodna	215,000	972,000
Fairfield Grain Growers, Inc.	Fairfield	1,580,000	
	Waverly	252,000	1,832,000
Rockford Grain Growers, Inc.	Rockford	901,000	
	Freeman	381,000	
	Mt. Hope	160,000	1,442,000
Inland Empire Pea Growers Association, Inc.	Spangle I	1,235,000	1,235,000
Rosalia Producers, Inc.	Plaza	836,000	
	Spangle II	477,000	
	Spring Valley	540,000	
	Rosalia	697,000	
	Balder	448,000	
	McCoy	376,000	
	Pine City	773,000	
	Squaw Canyon	98,000	4,245,000
Whitman County Growers, Inc.	Thornton	537,000	
	Cashup	216,000	
	Steptoe	888,000	1,641,000
The Garfield Union Warehouse Company	Garfield	309,000	
	Walters	216,000	
	Crabtree	238,000	763,000
Oakesdale Grain Growers, Inc.	Oakesdale	1,426,000	
	Farmington	394,000	
	Seltice	206,000	
	Warner	146,000	
	Fairbanks	453,000	2,625,000
St. John Grain Growers, Inc.	St. John	1,133,000	
	Ewan	672,000	
	Willada	2,030,000	
	Juno	142,000	
	Sunset	366,000	
	Pleasant Valley	1,077,000	5,420,000
Total			20,175,000

SOURCE: Public Grain Warehouse 1990-91, State of Washington, Department of Agriculture.

Except for the assumption about long-term storage, these assumptions realistically depict the study area.

The Mathematical Model

A linear programming model was used to find the optimal solution to the transportation cost problem. The model considered the following costs: (1) assembly costs, the cents per bushel costs of moving one bushel of grain from the farms (supply regions) to the elevators; (2) elevation costs, the cents per bushel elevator operating costs; and (3) shipment costs, the cents per bushel transportation and handling costs from the elevator to the final destination. The mathematical model was a cost minimization model. It took into account the total cost of assembly, handling and storage, transshipment and shipping, subject to specified constraints imposed on the grain marketing industry of the area. The specified objective function was:

$$(1) \qquad \text{Minimize } z = \sum_j \sum_i \sum_n \sum_t (c_g)_{ij}^{tn} G_{ij}^{tn} + \sum_j \sum_n \sum_t (c_e)_j^{tn} E_j^{tn} + \sum_{j'} \sum_j \sum_t (c_t)_{jj'}^{t1} T_{jj'}^{t1} + \sum_p \sum_j \sum_n \sum_t (c_s)_{jp}^{tn} S_{jp}^{tn}$$

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 = 1, 2, 3, 4, and denotes the time period; T1 for July-August, T2 for September-October, T3 for November-February and T4 for March-June.

n = 1, 2, and represents the type of grain; n equals 1 for wheat and 2 for barley.

i = 1, 2, . . . , 40, where the values of i denote the crop origin supply points; each origin supply point is a township in Figure 2.

j = 1, 2, . . . , 33, and represents the 33 elevators considered in the model; they are identified in Table 24.

j' = 1, 2, . . . , 17, where j' is a subset of j and represent the transshipment of wheat to elevators with multiple-car loading facilities; the transshipments considered in the model are presented in Table 25.

p = 1, 2, 3, 4, where the values of p denote the mode used to transport the grain from elevators to final market; p equals 1 for truck-barge of wheat and barley to Portland, equals 2 for 3-car unit trains of wheat to Portland and for barley to Portland or Vancouver (since the rates are the same), equals 3 for 25/26-car unit trains of wheat to Portland, and equals 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 the elevator j in time period t.

E_j^{tn} is the quantity of the nth grain received at the j elevator during time period t, stored, and subsequently shipped.

$T_{jj'}^{t1}$ is the level of wheat transshipment activities, shipping wheat from the elevator j to an elevator with multiple-car loading facilities j' in time period t($j \neq j'$).

S_{jp}^{tn} is the quantity of the nth grain shipped from the elevator j by the mode and destination p in time period t.

Equation (1) is minimized subject to conditions (2) through (7) below. There are five general constraints in the model: (1) grain production; (2) assembly transfer rows; (3) elevator operating capacity constraints; (4) shipping transfer rows; (5) minimum storage use of elevators' capacity; and (6) barley allocations.

Grain Production

Total shipments of grain n from the ith origin supply point in time period t must satisfy:

$$(2) \qquad \sum_j G_{ij}^{tn} \geq P_i^{tn} \text{ for all i, t, and n.}$$

Equation (2) requires that the amount of grain available at the origin supply points, i.e., the farms, must be shipped to elevators. The right-hand side P_i^{tn}, specifies the amount of grain

Table 25. Transshipments to 25/26-Car Unit Trains from Origin Houses Without Multiple-Car Loading Facilities (MCLF), Within the Same Firm.

Multiplant Firm	Station Elevator Origin	Destination (MCLF)
Fairfield Grain Growers, Inc.	Waverly	Fairfield
Rosalia Producers, Inc.	Spangle	Plaza
	Spring Valley	Plaza
	Rosalia	Plaza
	Balder	Plaza
	McCoy	Plaza
	Pine City	Plaza
	Squaw Canyon	Plaza
Oakesdale Grain Growers, Inc.	Farmington	Oakesdale
	Seltice	Oakesdale
	Warner	Oakesdale
	Fairbanks	Oakesdale
St. John Grain Growers, Inc.	St. John	Willada
	Ewan	Willada
	Juno	Willada
	Sunset	Willada
	Pleasant Valley	Willada

n available at the ith origin supply point in each time period. During the harvest season (T1), it is assumed that grain is trucked directly to the elevator. During the rest of the year, (T2 through T4), it is assumed that the grain originates from on-farm storage.

Assembly Transfer Rows

For each grain n, the total production level must equal the level of grain received at the j elevators,

(3a) $\sum_i G_{ij}^{t1} = E_j^{t1} + T_{jj'}^{t1}$ for all t and j.

(3b) $\sum_i G_{ij}^{t2} = F_j^{t2}$ for all t and j.

Equation (3a) represents the assembly transfer rows for wheat while (3b) is the equation for assembly transfer rows for barley. The assembly transfer rows for wheat include transshipment activities $T_{jj'}^{t1}$. These activities differ from the elevation activities, E_j^{t1}, in that the transshipment activities permit wheat to be first received at station elevators in a multiplant firm, before subsequently being transshipped to the multiple-car loading facility owned by the multiplant firm. The transshipment activities are not used for those houses which have the multiple-car loading facilities, thus preventing an elevator from shipping wheat to itself.

There are three restrictions on the transshipment activities in the model. First, wheat is the only grain which may be transshipped. Second, wheat may be transshipped only during time periods T2 to T4. During T1, both elevators and the multiple-car loading facilities are preoccupied with the harvest and are unable to transship wheat. Finally, for purposes of model simplification and based on the surveyed response of the 12 companies included in the model, the potential transshipment pairs are limited to the 17 pairs of elevators in which both the origin station elevator and the elevator with the multiple-car loading facility are owned by the same firm. The station elevator origin, the multiple-car loading facility destination and the multiplant firm for all transshipments considered in the model are identified in Table 25.

Elevator Storage Capacity Constraints

The quantity of grain stored in an elevator is constrained by the level of storage capacity.

(4) $\sum_{q<t} \sum_{n} \beta_j^{qn} E_j^{qn} + \sum_{q<t} \gamma_{jj'}^{q} T_{jj'}^{q1} \leq R_j^t$ for all t and j.

The right-hand side values for the elevator storage capacity constraints R_j^t in equation (4) are the physical storage capacity constraints for all the j elevators. They represent the differences in the operating capacities for the various sized elevators.

Transshipment activities are present in the storage capacity constraints of both the elevators where the transshipment comes from and the elevators with the multiple-car loading facility. This is an outbound movement of wheat for the origin elevator and an inbound movement of wheat at the elevator with the multiple-car loading facility. Thus, transshipment activities are required for both storage capacity constraints because, if transshipment occurs between any transshipment pair, storage capacity is utilized at both the destination elevator with the multiple-car loading facility and the transshipment origin elevator.

During the harvest period (T1), it is assumed that all elevators, including the ones with multiple-car loading facilities, can fill their respective storage to capacity. Since grain, which is received at the elevator during harvest, is shipped from storage throughout the crop year, technical coefficients (Greek symbols) are introduced in the elevation and transshipment activities for harvest time (T1) to reduce the available storage capacity in later time periods. The technical coefficients are expressed as percentages indicating the amount of grain received in T1 which remains in storage in T2 through T4. Thus, the technical coefficients which specify a merchandising pattern for grain received at elevators during T2 through T4 are equal to 1.0 for the time period when grain is received and zero elsewhere since this grain is assumed to be directly shipped to the terminal market. This merchandising pattern exactly matches the pattern identified by the two surveys of grain producers and elevator firms.

Shipping Transfer Rows

The total quantity of grain handled at the various elevators and multiple-car loading facilities must equal the level of shipments.

(5) $\sum_{q<t} E_j^{qn} + \sum_{q<t} T_{jj'}^{q1} = \sum_{p} S_{jp}^{tn}$ for all t, n, j, and p.

Equation (5) is the mathematical representation of the shipping transfer rows for all grain. This equation constrains the amount of grain shipped from all the elevators j (or activity E_j^{qn}) plus all the transshipments (if $T_{jj'}^{q1}$ applies), to be equal to the grain shipped by the transportation mode p in activity S_{jp}^{tn} for the time period $q < t$. The transshipment activities $T_{jj'}^{q1}$ represent the receipt of wheat at multiple-car loading facilities that come from station elevators j′ at time period $q < t$.

Minimum Storage Constraint

The minimum storage constraints are stated as:

(6) $\sum_{t} E_j^{tn} + \sum_{t} T_{jj'}^{t1} \geq Q_{jp}^{tn}$ for all t, n, j, and p.

It is assumed that all elevators and multiple-car loading facilities must have handled a Q_{jp}^{tn} amount of wheat and barley (n equals 1 and 2, respectively) at the end of the fourth period (t goes from 1 to 4). This constraint is necessary to initially insure that all elevators are used and, also, that grain does not go to storage based only on minimum cost, but will consider other factors (i.e., contracts, loyalty) that are incurred for the grain marketing system to represent actual shipments in 1991.

Barley Allocation

The barley allocation constraints are:

(7) $$\sum_j E_{jp}^{t2} \geq X_p^{t2} \text{ for all t and p = 1, 2, and 4.}$$

The quantity of barley shipped from the various elevators must equal the demand, X_p^{t2}, for exports transported by truck-barge (p equals 1), 3-car unit train (p equals 2) and feedlot barley (p equals 4). A wheat allocation constraint is unnecessary since it is assumed that all wheat is shipped to one destination.

Estimation of Model Coefficients

To implement the mathematical programming model developed above, coefficients and parameters of the model were determined. The validity of the mathematical programming model largely depends on the accuracy and relevancy of the data used to generate the coefficients. As Dooley (1986, p. 194-95) pointed out, there are three major data limitations potentially associated with plant location models. First, location models require extensive amounts of data, which are expensive to collect and maintain. Second, much of the information solicited, especially cost data, is proprietary to the firm which may be reluctant to provide complete and detailed information and it is, therefore, difficult to verify the accuracy of proprietary data. Third, cost data requirements for a mathematical programming model differ substantially from cost accounting records generally maintained by firms.

The potential effects of these problems were minimized in the study in the following manner: first, the Washington State Department of Transportation contract provided funds to cover the considerable cost of collecting the primary data used to calculate the model's coefficients. Second, farmers, grain elevator managers and industry officials were extremely helpful and cooperative in providing data of a proprietary nature.

The difficulty of allocating accounting costs to programming cost coefficients was reduced using information provided by two sources. The first was a similar work conducted in a similar area by F. Dooley in 1986, where costs coefficients were approximated by nonlinear cost functions using mixed integer programming. Second, estimates were drawn from the two surveys conducted and from direct telephone consultation with the elevator managers and personnel of Burlington Northern and Union Pacific railroad companies. Accordingly, the coefficients used in the model are believed to be realistic.

Grain Origin Regions

The study area included 40 townships (Figure 2). Each township was defined as a grain origin region. Twenty-two origin regions lie in southern Spokane County and 18 in northern Whitman County. A grain-producing area was assigned to each grain origin region based on land use maps (Spokane County Data Atlas, 1981, p. 9; The Whitman Conservation District Washington, Long Range Resource Program, 1978; Land Use Map).

Within each grain origin region, a point of origin producing wheat and barley was located. This point was assumed to be the furthest corner of the township related to a given elevator. This provided opportunity for the farms furthest away to still use the elevator. Some error is introduced with this practice giving more marketing alternatives to farms further from the center of each township. However, since this distance was only a maximum of four miles this bias was considered minimal.

Grain Supply

Grain supply is the product of acres harvested multiplied by the average yield per acre. Table 26 shows wheat and barley production for Spokane and Whitman Counties, and an estimate of the production area and wheat and barley supply assumed in the model. These data agree quite well with the results of the two surveys. The area harvested in Whitman County is more than three times the area harvested in Spokane County. In addition, per acre yields are higher in Whitman County. Overall, however, the relation between area harvested and production of wheat and barley is very similar.

Table 26. Area Harvested, Yield and Grain Production for Spokane and Whitman Counties in 1989, and Area and Production Proportions for Wheat and Barley Assumed in the Model.

	Area		Yield	Production	
	Harvested	Proportion		Grain	Proportion
	000 Ac	Percent	Bu/Ac	000 Bu	Percent
Spokane					
Wheat	126	71	54	6,757	68
Barley	52	29	63	3,282	32
Total	178	100		10,039	100
60% of County's Production Assumed in Model				6,023	
Whitman					
Wheat	401	71	59	23,710	68
Barley	164	29	64	10,496	32
Total	565	100		34,206	100
30% of County's Production Assumed in the Model				11,402	

SOURCE: Washington Agricultural Statistics 1989-90, Spokane County Data Atlas, 1981. Long Range Resource Program, Whitman Conservation District, Washington. Soil Conservation Service, 1978.

NOTE: Percentage of grain production assumed was based on Land Use Maps and expert opinion from WSU Cooperative Extension, Agricultural Stabilization and Conservation Service, and Soil Conservation Service personnel.

Grain production per origin region for the study area is presented in Table 27. Here, production per origin region is based on Table 26 and the estimated area harvested from land use maps for Spokane and Whitman counties. The total production of wheat and barley assumed in the model was 17,922,00 bushels. The total licensed storage capacity for the elevators in the study area in 1991 was 20,175,000 bushels (Table 24). Therefore, considering some carryover stocks, the assumed grain supply for the study area appears to be a reliable estimate of actual production.

Time Frame

Grain marketing creates seasonal assembly, storage, and shipping patterns. To reflect this seasonality in the models, the crop year was divided into four time periods. The first time period, T1, was the July-August harvest season. The rest of the year was divided into time periods T2, T3, and T4, which represent September-October, November-February, and March-June, respectively. Grain was brought into the elevators in each of the four periods. An average of 45% of wheat shipments from the farm was during harvest (Table 13).

Over the remainder of the year, shipments were distributed, according to the producer survey, with 26% in T2, 24% in T3 and 5% in T4 (Table 28). These figures are supported by the fact that approximately 50% of the producers surveyed utilize on-farm storage in that pattern (Table 10).

Grain received during harvest was stored at the elevator and shipped to the terminal market over the course of the year (Dooley, 1986, pp. 199-200). With grain in storage, elevators were physically constrained as to the volume of grain which could be received during the rest of the crop year. The coefficients used for these constraints were directly

Table 27. Assumed Acreage and Estimated Wheat and Barley Production by Grain Origin Region in the Study Area.

Grain Origin Region	Acres Harvested	Grain Production		
		Wheat	Barley	Total
	Acres	000 Bu	000 Bu	000 Bu
Southern Spokane				
1	3,840	147	69	216
2	4,480	172	81	253
3	4,480	172	81	253
4	3,840	147	69	216
5	3,840	147	69	216
6	4,480	172	81	253
7	3,840	147	69	216
8	4,480	172	81	253
9	5,120	196	92	289
10	6,400	245	115	361
11	3,840	147	69	216
12	3,840	147	69	216
13	4,480	172	81	253
14	5,760	221	104	325
15	7,680	339	160	499
16	6,400	245	115	361
17	5,120	196	92	289
18	6,400	245	115	361
19	5,120	196	92	289
20	7,680	339	160	499
21	6,400	245	115	361
22	5,120	196	92	289
Northern Whitman				
23	9,600	424	200	624
24	5,120	226	106	333
25	5,120	226	106	333
26	7,680	339	160	499
27	7,680	339	160	499
28	9,600	424	200	624
29	7,680	339	160	499
30	7,680	339	160	499
31	9,600	424	200	624
32	11,520	509	240	749
33	14,080	622	293	915
34	9,600	424	200	624
35	7,680	339	160	499
36	9,600	424	200	624
37	14,080	622	293	915
38	14,080	622	293	915
39	11,520	509	240	749
40	14,080	622	293	915
Total	288,640	12,187	5,735	17,922

Table 28. Assumed Assembly Pattern for Study Area.

Time Period	Months	Assembly Pattern (%)
T1	July/August	45
T2	September/October	26
T3	November/February	24
T4	March/June	5
Total		100

SOURCE: Table 12 from the Farmers' Survey, 1991.

taken from the Dooley study since it was based on a similar geographical region. These coefficients were 0.6 for T2, 0.4 for T3 and 0.1 for T4. For the transshipment activities they were 0.5 for T2, 0.3 for T3 and 0.2 for T4. Grain received from on-farm storage, i.e., grain assembled at elevators during time periods T2 through T4, is assumed to move directly through the elevators to the terminal markets.

Elevator Location and Capacity

The plant location decision of a firm is considerably more complex than can be depicted in a mathematical programming model. Factors such as the available transportation modes and network, local tax structure, labor availability and wages, zoning restrictions, and state or local governmental incentives may exist, complicating the decision (Dooley, 1986, p. 200).

The existing 33 elevators in the Spokane-Whitman study area were chosen as the plant locations for all models (Figure 2) based on the licensed building storage capacity and the elevator survey conducted in the area. Each elevator was grouped into one of the following sizes: 190,000; 425,000; 750,000 or 1,275,000 bushels (Table 29).

Table 29. Elevators' Nine Firms, Thirty-Three Locations, Code Names, State Licensed Storage Capacity, Grain Elevator's Survey Handling Report and the Model's Assumed Storage Capacity, Located in Southern Spokane and Northern Whitman Counties in Washington State, 1991.

Warehouse Firm	Elevator Location	Code Name	Licensed Storage Capacity	Survey Handling Reported	Model Assumed Storage
			----------- 000 Bu/House	-----------	
Cheney Grain Growers, Inc.	Cheney	CHE	757	500	750
	Rodna	CRD	215	150	190
Fairfield Grain Growers, Inc.	Fairfield	FFI	1,580	1,425	1,275
	Waverly	FWA	252	360	190
Rockford Grain Growers, Inc.	Rockford	ROC	901	650	750
	Freeman	RFR	381	575	425
	Mt. Hope	RMH	160	159	190
Inland Empire Pea Growers Association, Inc.	Spangle I	SPA	1,235	814	1,275
Rosalia Producers, Inc.	Plaza	PLR	836	770	750
	Spangle II	SPR	477	435	425
	Spring Valley	SVR	540	500	425
	Rosalia	ROS	697	816	750
	Balder	BAR	448	411	425
	McCoy	MCR	376	340	425
	Pine City	PCR	773	730	750
	Squaw Canyon	SCR	98	92	190
Whitman County Growers, Inc.	Thornton	THW	537	467	750
	Cashup	CAW	216	257	190
	Steptoe	STW	888	617	750
The Garfield Union Warehouse Company	Garfield	GAR	309	220	425
	Walters	WAG	216	83	190
	Crabtree	CRG	238	75	190
Oakesdale Grain Growers, Inc.	Oakesdale	OAK	1,426	1,000	1,275
	Farmington	FAO	394	300	425
	Seltice	SEO	206	225	190
	Warner	WAO	146	160	190
	Fairbanks	FBO	453	900	425
St. John Grain Growers, Inc.	St. John	STJ	1,133	900	1,275
	Ewan	EWS	672	850	750
	Willada	WIS	2,030	1,000	1,275
	Juno	JUS	142	250	190
	Sunset	SUS	366	350	425
	Pleasant Valley	PVS	1,077	850	1,275
Total			20,175	17,230	19,375

No outside storage was included in the model elevators because it is generally used for long-term storage. Since the models depict the grain flow for a single cropping year, long-term storage was also not considered. For the study area, the total level of storage capacity in the models (19,375,000 bushels) is less than the licensed storage capacity (20,175,000 bushels), but more than the assumed grain production (17,922,000 bushels in Table 27). This results in a turnover ratio (bushels storage capacity divided into bushels handled) of 0.9.

To reflect the storage handling pattern reported by the elevators' survey, the model was constrained as to the amount of wheat and barley handled by each of the elevators individually (Table 30). These proportions were reported to be a three-year average; however, they were adjusted to represent less than 90% of total elevator capacity.

Destination

Columbia River ports are the most common destination for wheat, receiving more than 97% of the wheat shipped from the study area (Table 18). There are three major markets for barley produced in the area. Over 50% of the barley is reportedly shipped to Columbia River ports (Table 19), approximately 20% goes to Vancouver and the remaining 30% is shipped to feedlots throughout the study area.

In the model, all wheat is assumed to be shipped to Portland, Oregon. For the base model, 70% of all barley produced is assumed to be shipped to Portland and Vancouver and 30% to be shipped to feedlots. Since the railroad companies use blanket rates for Vancouver and Portland, the two destinations are essentially treated as a single destination.

Table 30. Minimum Wheat and Barley Assumed to be Handled by Each One of the Thirty-Three Elevators Considered in the Model.

Elevator	Grain Handled		
	Wheat	Barley	Total
	Bushels		
Cheney	300,000	200,000	500,000
Rodna	100,000	50,000	150,000
Fairfield	845,526	301,974	1,147,500
Waverly	87,875	83,125	171,000
Rockford	600,000	50,000	650,000
Freeman	332,609	49,891	382,500
Mt. Hope	150,000	8,900	158,900
Spangle I	500,000	310,000	810,000
Plaza	473,377	201,623	675,000
Spangle II	268,190	114,310	382,500
Spring Valley	267,750	114,750	382,500
Rosalia	471,762	203,238	675,000
Balder	266,168	116,332	382,500
McCoy	240,000	100,000	340,000
Pine City	471,575	203,425	675,000
Squaw Canyon	64,000	28,000	92,000
Thornton	303,000	164,000	467,000
Cashup	119,767	51,233	171,000
Steptoe	380,000	237,000	617,000
Garfield	200,000	20,000	220,000
Walters	75,000	8,000	83,000
Crabtree	60,000	15,000	75,000
Oakesdale	800,000	200,000	1,000,000
Farmington	200,000	100,000	300,000
Seltice	114,000	57,000	171,000
Warner	100,000	60,000	160,000
Fairbanks	255,000	127,500	382,500
St. John	450,000	450,000	900,000
Ewan	436,765	238,235	675,000
Willada	600,000	400,000	1,000,000
Juno	102,600	68,400	171,000
Sunset	200,000	150,000	350,000
Pleasant Valley	500,000	350,000	850,000
Total	10,334,962	4,831,938	15,166,900

SOURCE: Grain Elevators' survey, August 1991.

Costs

Assembly Costs

Assembly cost in the analytical model is the cost of hauling grain from the farm to the elevator. As Dooley (1986, p. 205) points out, these costs should be included in a minimum cost study for three reasons. First, assembly costs theoretically may be an important factor in "limiting plant size, even in cases where plant diseconomies of scale are absent" (French, 1977, p. 118). Second, assembly costs may be overlooked by elevator management in expansion decisions because they are paid by farmers. This does not, however, eliminate these costs. When the focus is placed on the total cost to the system, all costs should be considered, regardless of the incidence of costs (Araji and Walsh, 1969, p. 37). Finally, in cases of cooperative elevators, the goals of the firm are usually stated in terms of benefits to farmer-patron. Thus, cooperative management should consider the effect of assembly costs as well as plant costs in determining the optimum plant size, location and transport mode used (Araji and Walsh, 1969, p. 36).

Assembly costs were calculated based on the discussion and estimation done by Dooley (1986, pp. 206-14). In his analysis, Dooley started by supporting the appropriateness of his method in comparison to French's circular supply region method, where the entire volume of grain for a supply region goes to only one centrally-located elevator. Dooley argues that farmers may market their grain through more than one elevator and, to take advantage of low rates on multiple-car unit trains, they can bypass the closest elevator. As in Dooley's case, the Spokane-Whitman farm survey indicated that it is not uncommon for farmers to market grain through more than one elevator (Table 9). Approximately 50% of the respondents indicated that they used more than one elevator. Also, the existence of on-farm storage (Table 10) and the availability of multiple-car unit trains give farmers additional flexibility to bypass the closest elevator. However, as the elevator survey revealed, elevators in the area are organized as multiplant firms, and use this organization to transship grain to their multiple-car loading facilities.

Based on the assumption that farmers will continue to ship grain to the nearest location when elevators are organized as multiplant firms, the Dooley's method states:

1. Subdivide the study region into various production or supply regions.
2. Randomly locate a point of origin in each production area.
3. Estimate the cost per bushel per mile of farm trucking.
4. Generate cost coefficients for feasible origin point to elevator movements.

This method is more flexible and realistic because it does not pre-specify a volume of grain to be assembled at each elevator and also permits the bypassing of the nearest elevator. For the Spokane-Whitman study, data collected from the elevators indicated the volume of grain assembled at each elevator. Therefore, the base model for this Spokane-Whitman study is constrained by a pre-specified volume of grain at each elevator. A least-cost model, holding Dooley's assumptions, is then used to compare the costs and/or benefits of this greater range of choices of elevators.

It was assumed that single-axle trucks are the only type of farm truck available. Dooley shows enough evidence to support this choice. To estimate the variable costs of operating single-axle farm trucks the economic-engineering approach was followed. As Griffin, Wilson, and Casavant (1984, p. 37) and Dooley (1986, p. 209) indicated, variable costs for farm trucks include tires, fuel, maintenance and repairs, and driver's wages.

Tire Cost

As Dooley determined, single-axle farm trucks are equipped with two 900/20-inch bias highway tires and four 900/20-inch bias traction tires. Table 31 shows the calculations used to obtain the weighted average per mile cost of tires for a single-axle farm truck ($0.0577 per mile per truck), inflated from Dooley's figures to reflect 1991 prices. New tires are more expensive than recaps. However, the cost per mile is lower because they have longer estimated useful life.

Table 31. Farm Truck Tire Costs.

Type	Cost Per Tire	Cost Per Truck	Estimated Useful Life	Cost Per Mile
	($)	($)	(Miles)	($)
Highway, New	210.89	421.77		
Traction, New	240.34	961.34	____	____
Total New		1,383.11	25,000	0.0553
Highway, Recap	165.63	331.27		
Traction, Recap	166.99	667.96	____	____
Total Recap		999.22	17,000	0.0588
Weighted Average[1]				0.0577

SOURCE: Dooley, Frank J. "The Theory and Economics of Multiplant Firms Applied to Washington Grain Elevators." Ph.D. dissertation, Dept. of Agr. Econ., Wash. State U., Pullman, 1986 (p. 211).

NOTE: Costs inflated by the Consumer Price Index, less food (1982-84 = 100 and May 1991 = 135.4). Table 6. Agricultural Outlook, Economic Research Service, U.S. Department of Agriculture, August 1991 (p. 39).

[1]Weighted by tire dealer's estimates of 30% new and 70% recap rate of single-axle farm truck tires purchases.

Dooley indicates that the estimated useful life for tires is less than that suggested by manufacturers for two reasons. First, most farm truck tires are replaced because of age rather than mileage. Second, much of the farm truck mileage is on poorly maintained roads or in fields and not under ideal highway conditions.

Labor Cost

Labor cost per mile is the hourly average wage rate for farm truck drivers divided by the average speed (equation 9) (Dooley, 1986, p. 212).

$$(9) \qquad \text{Labor Cost per Mile} = \frac{\text{Average Wage per Hour}}{\text{Average Speed per Hour}}$$

Assuming an average speed of 30 miles per hour and a wage of $9.89 per hour, the dollar per mile labor cost is $0.3296.[2]

Fuel Cost

All single-axle farm trucks are assumed to be gasoline powered with an estimated fuel efficiency of 6.89 miles per gallon. The average cost of gasoline was $1.64 per gallon.[3] Fuel cost is determined as follows:

$$(10) \qquad \text{Fuel Cost per Mile} = \frac{\text{Fuel Cost per Gallon}}{\text{Fuel Mileage per Gallon}}$$

Therefore, the per mile cost of gasoline for a single-axle farm truck is $0.2380 per mile per truck.

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[2]The drivers hourly wage was inflated from Dooley (1986, p. 212) by the Consumer Price Index (1982-84 = 100 - 1991 = 135.4). Agricultural Outlook, August 1991. Waiting time in line at the elevator is reflected by less average speed than reported in other truck costing studies (Dooley, 1986, p. 212; Payne, Baumel, and Moser, 1978).

[3]Even if gasoline prices are affected by other than inflation factors, to be consistent and allow for comparison, Dooley's 1984 gasoline price is inflated by 1.354. Current prices suggest this is overstated by 25%-30%. However, the difference causes less than 0.5¢ per bushel.

Truck Maintenance and Repair Cost

Maintenance and repair costs include lubricants, tune-ups, engine overhauls, and general repair. Reliable per-mile estimates of these costs are difficult to establish since most of these costs arise sporadically (Dooley, 1986, p. 213). Miller and Kenyon (1974) estimated annual maintenance and repair costs to be 2.5% of the truck's original purchase price. The average purchase price of a single-axle farm truck in Washington is $9,407.[4] This represents an estimated annual maintenance and repair cost of $235.17. The per-mile maintenance and repair cost is then calculated as:

$$(11) \qquad \begin{array}{c}\text{Maintenance and}\\ \text{Repair Cost per Mile}\end{array} = \frac{\begin{array}{c}\text{Annual Maintenance}\\ \text{and Repair Cost}\end{array}}{\text{Annual Mileage}}$$

For a single-axle farm truck, the dollar per mile per truck maintenance and repair cost is $0.1026.[5]

Total Variable Assembly Cost

Total variable costs per mile are calculated by combining the items identified above (Table 32). With an average payload of a single-axle farm truck of 255.6 bushels per truck (Dooley, 1986, p. 214), the variable assembly cost per mile per bushel of grain transported is $0.002848.

Since fixed costs are canceled out in the linear programming optimization process and most farms use a truck in their production activities, this figure when multiplied by the distance from the farm to the elevator, generates the coefficients to evaluate assembly costs.

[4]This cost has been updated with the inflation factor 1.354 from Dooley's figure of 1984.

[5]Ibid.

Table 32. Total Variable Cost for Single-Axle Farm Trucks, 1991.

Cost Item	Cost Per Mile	Cost Per Mile Per Bushel
	Dollars	
Tires	0.0577	0.000226
Labor	0.3296	0.001289
Fuel	0.2380	0.000931
Maintenance and Repair	0.1026	0.000401
Total Variable Costs	0.7279	0.002848

Since little or no backhaul is available to farms, the assembly cost was assessed for both the trip to and from the elevator.

Elevators' Operating Cost

The estimation of elevators' operating costs relies on conscientious work done by Dooley (1986, pp. 214-20) in Lincoln County. The following reasons validate this choice: both areas are similar and adjacent; wheat and barley are the main crops in both. There are also similarities in the size of the elevators, the same organization of elevators in multiplant firms, the similar commodities handled by elevators in both places, the existence of multiple-car loading facilities in both places, and the possibility to compare the results from both studies. Items used in estimating operating costs for the elevators in this study included management and labor, electricity, maintenance and repair, insurance on inventory, sampling and inspection fees, grain conditioning, and interest on working capital.

Management and Labor Cost

Management and labor costs consist of salary and wages of the manager, assistant manager, clerical staff (secretarial and bookkeeping), full-time labor, and seasonal labor.

The annual full-time salary for management and wages for labor is estimated in Table 33. These factor prices were assumed to be constant for the various size model elevators and were estimated assuming a turnover ratio of 1.0 (Dooley, 1986, pp. 215-16).

Table 33. Estimated Annual Salary for Staff and Wages for Labor for a Typical Country Elevator.

Position	Salary[1]
Manager	$40,620
Assistant Manager	$33,850
Clerical	$20,310
Labor	$23,830
Seasonal Labor	$ 2,980

SOURCE: Dooley, Frank J. "The Theory and Economics of Multi-plant Firms Applied to Washington Grain Elevators." Ph.D. dissertation, Dept. of Agr. Econ., Wash. State U., Pullman, 1986 (p. 217).

[1]Inflated by the Consumer Price Index, (82 - 84 = 1 - May 1991 = 1.354). Agricultural Outlook, Table 6. Economic Research Service, U.S. Dept. of Agriculture. August 1991 (p. 39).

These costs were allocated to each of the four sizes of elevators considered in the model. According to grain elevator managers, individuals working in country elevators commonly have joint management, clerical, and/or labor responsibilities. The involvement of each of the positions in the operations of the elevators was allocated in terms of full-time equivalent proportions (Table 34) (Dooley, 1986, pp. 215-16).

Electricity Cost

The estimated electricity cost per bushel for receiving, storing, and shipping grain was determined as the product of kilowatt hours required per bushel times the per kilowatt hour charge. The estimated kilowatt hours required per bushel were 0.055; 0.050; 0.045 and

Table 34. Staffing Allocation in Full-Time Equivalents for Model Elevators.

Position	Model Elevator (in Bushels)			
	190,000	425,000	750,000	1,275,000
	Full-Time Equivalents			
Manager	0.25	0.50	0.50	1.00
Assistant Manager	0.00	0.00	0.25	0.25
Clerical	0.25	0.25	0.50	0.75
Labor	0.50	1.25	1.75	3.00
Seasonal Labor	1.00	1.00	2.00	2.00

SOURCE: Dooley, Frank J. "The Theory and Economics of Multiplant Firms Applied to Washington Grain Elevators." Ph.D. dissertation, Dept. of Agr. Econ., Wash. State U., Pullman, 1986 (p. 217).

0.042, for the 190,000; 425,000; 750,000 and 1,275,000 bushel model elevators, respectively. The rate used to estimate the electrical cost was 4.87¢ per kilowatt hour (1991, adjusted for inflation from U.S. Dept. of Agriculture, 1984, p. 37).

Other Maintenance and Repair Costs

Maintenance and repair costs include costs arising as a result of usage (such as replacing equipment parts which have failed) and time (such as painting which is the result of weathering). As with farm truck costs, the method of determining elevator maintenance and repair costs is not well-defined. These costs were developed from secondary sources. First, plant and equipment investment costs were estimated (Table 35), and then a percentage of this cost was assumed as the bill for maintenance and repair costs.

The model elevator structure is comprised of grain storage bins, receiving pits, the office building, and equipment structural supports. Elevator machinery includes a truck scale, receiving and shipping legs, load-out spouts, and an aeration system. "Equipment

Table 35. Plant and Equipment Investment Costs for Model Elevators.

Elevator Cost Item[1]	Model Elevator (in Bushels)			
	190,000	425,000	750,000	1,275,000
	Dollars			
Structure	630,287	1,352,308	2,284,875	3,711,653
Equipment	595,760	771,780	1,015,500	1,394,620
Rail Track	0	0	121,860	121,860
Total	1,226,047	2,124,088	3,422,235	5,228,133

SOURCE: Dooley, Frank J. "The Theory and Economics of Multiplant Firms Applied to Washington Grain Elevators." Ph.D. dissertation, Dept. of Agr. Econ., Wash. State U., Pullman, 1986 (p. 218).

[1]Costs inflated by the Consumer Price Index, (1982 - 84 = 100 and May 1991 = 135.4). Agricultural Outlook, Table 6. Economic Research Service, U.S. Dept. Agriculture, August 1991 (p. 39).

investment generally declines percentage-wise as the size of the model elevator increases" (Schnake and Stevens, 1983, p. 15). To access multiple-car shipments, it is assumed that the largest model elevators incur railroad trackage costs which include the installation of a rail shipping scale and 1,000 feet of rail trackage at a cost of $80 per linear foot. Based on Schnake and Stevens (1983), and Van Ausdle and Oldenstadt (1969), the annual estimated maintenance and repair costs for the model elevators was computed at 0.7% of the assumed plant and equipment investment cost (Dooley, 1986, pp. 217-19).

Insurance on Inventory Cost

The average inventory value times the insurance rate determines insurance on grain in storage. The average inventory value was computed using 70% of the storage capacity of the model elevator times $4.01, the seasonal weighted average wheat/barley price (1991 adjusted for inflation from U.S. Dept. of Agriculture, 1984, p. 24). The insurance rate was assumed to be 21.9¢ per $100 of inventory value (Schnake and Stevens, 1983, p.15). The per bushel insurance on inventory cost of 0.46¢ is the same for all four sizes of the model elevators.

Sampling and Inspection Fees

A sample is taken from each lot of grain received at the elevator for grading and inspection by either state or federal inspection services. The cost estimate for this service was obtained from the Lincoln County country elevator survey. The adjusted sampling and inspection fee was 0.20¢ per bushel.

Grain Conditioning Cost

All grain received is assumed to require fumigation and aeration. The per bushel cost estimate for grain conditioning of $1.08 was adjusted for inflation. This cost did not vary by size of the model elevator.

Interest on Working Capital

Working capital requirements for the model elevators were assumed to be the sum of costs of one month's salary and wages, electricity, and the value of inventory on hand (Schnake and Stevens, 1983, p. 22). Based on the typical storage pattern obtained from the country elevator survey, the average inventory level for the month is assumed to be 40% of the assumed volume storage capacity of the model elevator. An interest rate of 12% was assumed.

Total Elevator Operating Cost

Total elevator operating costs per bushel for the four sizes of model elevators are identified in Table 36. These costs are 25.32¢, 21.92¢, 19.25¢ and 18.48¢ per bushel at the 190,000; 425,000; 750,000 and 1,275,000 bushel model elevator, respectively. These operating costs per bushel decrease as the size of the elevator increases because of economies of size.

Table 36. Estimated Operating Costs per Bushel for Model Elevators Operating at a 1.0 Turnover Ratio, 1991.

Cost Item	Model Elevator (in Bushels)			
	190,000	425,000	750,000	1,275,000
	Cents per Bushel			
Management	8.02	5.97	5.19	5.05
Labor	7.84	7.70	6.35	6.08
Electricity	0.27	0.24	0.22	0.20
Maintenance and Repairs	4.51	3.49	3.18	2.87
Insurance on Inventory	0.46	0.46	0.46	0.46
Sampling and Inspection	0.20	0.20	0.20	0.20
Grain Conditioning	1.08	1.08	1.08	1.08
Interest on Working Capital	2.94	2.76	2.57	2.53
Total	25.32	21.92	19.25	18.48

Management, labor, electricity, maintenance and interest on working capital are variable costs in the traditional economic interpretation. Insurance on inventory, sampling (grading) and inspection, and grain conditioning are assumed to be rigid variable costs and may remain constant unless significant changes in output occur (Zink, 1982, p. 8).

Multiplant Firm Average Elevator Operating Costs

Theoretically, the operation of a multiplant firm may offer cost savings in management, labor, and interest on working capital. Even if multiplant firm managers receive higher salaries, at the per bushel basis these costs will be spread among the various elevators in the firm resulting in lower average costs. Labor will represent a savings because there is an opportunity for better utilization of the full-time labor force by moving laborers among various elevators. Multiplant firms view working capital requirements as a common cost to the firm. Moreover, the multiplant firm probably has a steadier cash flow and, therefore, less need to borrow working capital (Dooley, 1986, pp. 225-28). These arguments indicate that average operating costs for the multiplant firm will be lower than for individual elevator.

Elevators in the Spokane-Whitman study area charge, to all clients, an average cost for all the elevators in a firm. A weighted average cost per bushel, per firm, was calculated to reflect this practice. These costs were checked and calibrated with each one of the firms in the study area and used in the model as the elevators charge for elevation.

Grain Handling Costs

The grain handling costs, insurance on inventory, grading and inspection fees, and grain conditioning are linear operating costs. They do not vary regardless of the size of the elevator or the organization of the firm. Nevertheless, when transshipping grain, a multiplant firm experiences a cost savings with these cost items relative to an individual elevator. When grain is transshipped between individual elevators, each incurs a cost for insurance, grading, and inspection. However, these costs occur only once when grain is transhipped between elevators of the same multiplant firm.

Shipping Costs

Based on the country elevator survey, three modes were assumed for the transport of wheat to the market (Table 16). Direct truck to market and one-car railroad rates for wheat were not considered in the model because their use was not found to be significant.

All the elevators had the option to send wheat by truck to Central Ferry (the Snake River port) and, from there, ship by barge to the terminal market ports on the Columbia River (Table 18). Truck-barge rates were collected from direct individual interviews with each of the elevators. The truck-barge rate was composed of a barge rate of 15¢ per bushel, a put-through charge of 5¢ per bushel, and the truck transportation cost was dependent on the distance from the elevator to the Central Ferry Port in the Snake River (Table 37).

Railroad rates were obtained directly from the two companies involved in this transport. Burlington Northern Railroad publishes rates applicable to each one of its stations with the destination to Portland, Oregon or Vancouver, Washington (Burlington Northern Railroad Co., 1991). Union Pacific Railroad has an 800 telephone number for rates from specific locations to the west coast ports. Barley shipments, reported in the elevator survey, used truck to send barley to feedlots, truck-barge mode for export to Portland, Oregon, and 3-car train units to send barley to Portland for exports and/or to Vancouver, Washington, for malting (Tables 17 and 19). The rates for the three modes used in the model are presented in Table 38.

Table 37. Truck-Barge, Three-Cars and 25/26-Cars Train Unit Rates for Wheat.

Elevator	Code Name	Truck-Barge Rate	3-Cars Rate	25/26-Cars Rate
		----------------------	Cents/Bushel	----------------------
Cheney	CHE	40.00	33.50	
Rodna	CRD	40.00		
Fairfield	FFI	40.00	34.30	28.10
Waverly	FWA	40.00		
Rockford	ROC	40.00	34.30	
Freeman	RFR	40.00	35.00	
Mt. Hope	RMH	40.00		
Spangle I	SPA	38.00	31.10	27.40
Plaza	PLR	38.00	31.10	27.40
Spangle II	SPR	38.00	31.10	
Spring Valley	SVR	38.00		
Rosalia	ROS	36.00	31.00	
Balder	BAR	36.00		
McCoy	MCR	36.00	31.00	
Pine City	PCR	36.00		
Squaw Canyon	SCR	36.00		
Thornton	THW	35.50	33.00	
Cashup	CAW	34.00		
Steptoe	STW	33.50		
Garfield	GAR	34.00		
Walters	WAG	34.00		
Crabtree	CRG	34.00		
Oakesdale	OAK	34.00	31.10	28.00
Farmington	FAO	34.00		
Seltice	SEO	34.00		
Warner	WAO	34.00		
Fairbanks	FBO	34.00		
St. John	STJ	34.00		
Ewan	EWS	34.00		
Willada	WIS	34.00	32.10	25.00
Juno	JUS	34.00		
Sunset	SUS	34.00		
Pleasant Valley	PVS	34.00		

Table 38. Truck-Barge, Three-Cars Train Unit and Feedlot Rates for Barley.

Elevator	Code Name	Truck-Barge Rate	3-Cars Rate	Feedlots Rate
		Cents/Bushel		
Cheney	CHE	39.00	23.60	9.00
Rodna	CRD	39.00		9.00
Fairfield	FFI	39.00	22.60	9.00
Waverly	FWA	39.00		9.00
Rockford	ROC	39.00	22.60	9.00
Freeman	RFR	39.00	23.10	9.00
Mt. Hope	RMH	39.00		9.00
Spangle I	SPA	36.00	23.30	9.00
Plaza	PLR	36.00	23.30	9.00
Spangle II	SPR	36.00	23.30	9.00
Spring Valley	SVR	36.00		9.00
Rosalia	ROS	33.60	23.30	9.00
Balder	BAR	33.60		9.00
McCoy	MCR	33.60	23.30	9.00
Pine City	PCR	33.60		9.00
Squaw Canyon	SCR	33.60		9.00
Thornton	THW	33.60	21.60	9.00
Cashup	CAW	33.60		9.00
Steptoe	STW	33.60		9.00
Garfield	GAR	33.60		9.00
Walters	WAG	33.60		9.00
Crabtree	CRG	33.60		9.00
Oakesdale	OAK	33.60	23.30	9.00
Farmington	FAO	33.60		9.00
Seltice	SEO	33.60		9.00
Warner	WAO	33.60		9.00
Fairbanks	FBO	33.60		9.00
St. John	STJ	33.60		9.00
Ewan	EWS	33.60		9.00
Willada	WIS	33.60	21.60	9.00
Juno	JUS	33.60		9.00
Sunset	SUS	33.60		9.00
Pleasant Valley	PVS	33.60		9.00

In the model, no difference was made between the transportation of barley for export versus malting barley because the railroad rate was the same to Portland (export barley destination) or Vancouver (malting barley destination). Moreover, malting barley sent to Vancouver goes exclusively by train. The commercial trucking (semi-truck) cost is assumed to be $1.39 per mile (inflated from Casavant and Dooley, 1983, pp. 26 and 40). Assuming a typical payload of 1,062 bushels of barley, the per bushel per mile commercial trucking cost was $0.0013.

Transshipment Costs

Transshipment is the movement of grain between country elevators. Smaller elevators may decide to transship grain to multiple-car loading facilities rather than ship it directly to the terminal market. Both elevators may benefit from these practice. The smaller elevator gains access to lower multiple-car freight rates available to multiple-car loading facilities, while the multiple-car loading facilities are able to increase their plant utilization.

The cost of transshipment considered by the decisionmaker is the trucking cost from one elevator to another destination elevator. Based on survey results transshipments were considered only for wheat and only between members of the same multiplant firm.

There is only a single handling charge for transshipment in a multiplant firm. There is, also, a single charge of insurance, grading, inspection, and interest on working capital because the grain remains within the firm. In addition, there is a single charge for management, labor, electricity, and maintenance and repair because the multiplant firm probably views its operation at a firm-wide level rather than at a plant-specific level (Dooley, 1986, pp. 229-34).

Transshipment cost in the model includes the average firm elevation cost and a two-way commercial trucking cost (Table 39). Assuming a typical payload of 850 bushels of wheat, the per bushel per mile commercial trucking cost was $0.0016 (Dooley, 1986, p. 234).

Table 39. Elevation Cost Plus Transshipments to 25/26-Car Unit Train from Houses Without Multicar Loading Facilities Within the Same Firm.

Company	Origin	Destination	Cost (Cents/Bu)
Fairfield Grain Growers, Inc.	Waverly	Fairfield	24.37
Rosalia Producers, Inc.	Spangle	Plaza	25.63
	Spring Valley	Plaza	25.63
	Rosalia	Plaza	25.63
	Balder	Plaza	25.63
	McCoy	Plaza	25.63
	Pine City	Plaza	25.63
	Squaw Canyon	Plaza	25.63
Oakesdale Grain Growers, Inc.	Farmington	Oakesdale	25.68
	Seltice	Oakesdale	25.68
	Warner	Oakesdale	25.68
	Fairbanks	Oakesdale	25.68
St. John Grain Growers, Inc.	St. John	Willada	24.12
	Ewan	Willada	24.12
	Juno	Willada	24.12
	Sunset	Willada	24.12
	Pleasant Valley	Willada	24.12

ANALYTICAL RESULTS

This section presents and discusses the results for all the simulation models run. It is divided into three parts. First, four broad base models of the study region are presented. Then, some alternative scenarios of present issues of economic interest for the region are presented. Finally, the concept of elasticity and elasticity coefficients are used to evaluate the performance of this multimodal transportation system.

The discussion of each model is presented by including: (1) a description of the competitive situation being analyzed, (2) a report on the system grain flow results and the associated cost structure of the marketing model, and (3) a summary and discussion of the economic implications of the findings for each particular model. In addition, results of the models in each section are summarized and compared to analyze the effect of the assumptions included in each model upon grain flow, mode usage and marketing system costs for the study region.

Broad Base Models

Base Model

The empirical model developed earlier serves as the base model for this analysis. This model was developed largely to portray the existing grain transportation system and actual usage of that system in eastern Washington. Supported by the findings of the two surveys conducted for this research project, and the data collected for the estimation of parameters and coefficients previously discussed in detail, this model is considered the best approximation of the actual transportation system and usage.

The base model is a cost-minimization, linear-programming model that considers the costs of assembly, elevation, and shipping of wheat and barley from the production areas of southern Spokane and northern Whitman Counties to final markets. Grain supply, demand, and storage capacity are assumed to be exogenous to the model and therefore constant. The assembly costs are a direct function of the distance to elevators.

Elevators are organized into multiplant firms, as in the actual situation, where an average cost of operation for the entire firm is charged per bushel of grain handled. A critical feature particular to this base model is the minimum amount of grain handled by each elevator, determined by the survey of elevators. Wheat is an homogeneous commodity. Barley, on the other hand, is differentiated by fixed proportions into barley for exports and malting that is shipped to Portland, Oregon, and Vancouver, Washington, and feeding barley that goes to feedlots around the state.

The shipping of grain from the elevator to final market is a function of the type of grain and the transportation modes available. Wheat is assumed to go for export to Portland, Oregon. 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 to Portland by barge. Wheat is transshipped, from elevators without access, to those which have access, to 25/26-car rail rates, but only within the same firm.

The solution to the optimization base model shows grain receipts at each one of the elevators (Table 40). This solution is constrained to allow a minimum amount of wheat and barley to be received by each elevator, again to reflect the elevator survey handling report results (Table 30).

Results from the base model show turnover ratios greater than one for all the largest elevators (Table 40). For the smallest elevators, grain receipts are less than half of their capacity, raising the question of how small elevators survive in the long run if they do not fill even half of their usable capacity.

Table 40. Grain Receipts and Turnover Ratios for Base Model.

Elevator	Grain Received			Storage Assumed	Turn-Over Ratio
	Wheat	Barley	Total		
	---------- 000 Bushels ----------				
Cheney	391	262	652	750	0.9
Rodna	100	50	150	190	0.8
Fairfield	846	585	1,431	1,275	1.1
Waverly	88	83	171	190	0.9
Rockford	600	50	650	750	0.9
Freeman	333	81	413	425	1.0
Mt. Hope	150	9	159	190	0.8
Spangle I	891	523	1,414	1,275	1.1
Plaza	473	202	675	750	0.9
Spangle II	268	114	383	425	0.9
Spring Valley	268	115	383	425	0.9
Rosalia	472	203	675	750	0.9
Balder	266	116	382	425	0.9
McCoy	240	100	340	425	0.8
Pine City	472	203	675	750	0.9
Squaw Canyon	64	28	92	190	0.5
Thornton	303	477	780	750	1.0
Cashup	120	51	171	190	0.9
Steptoe	380	237	617	750	0.8
Garfield	200	20	220	425	0.5
Walters	75	8	83	190	0.4
Crabtree	60	15	75	190	0.4
Oakesdale	1,543	200	1,743	1,275	1.4
Farmington	200	100	300	425	0.7
Seltice	114	57	171	190	0.9
Warner	100	60	160	190	0.8
Fairbanks	255	128	383	425	0.9
St. John	450	450	900	1,275	0.7
Ewan	437	238	675	750	0.9
Willada	1,225	400	1,625	1,275	1.3
Juno	103	68	171	190	0.9
Sunset	200	150	350	425	0.8
Pleasant Valley	500	350	850	1,275	0.7
Total	12,184	5,733	17,917	19,375	0.9

There are three factors that explain these results and give a better understanding of the industry's use of the multimodal system. The first point is the organization of elevators into multiplant firms, and the average firm cost pricing they use. Essentially, a firm's share of the grain market is more important than any one individual elevator's share. Therefore, small elevators serve as grain collection units into the overall firm volume.

Dooley, in earlier research, found that larger elevators could increase their market share if they could build additional storage capacity when individual elevators are operating as firms. The same result is achieved here by the association of these individual firms into multiplant firms, rather than building additional storage capacity at one location.

The second factor favoring the association of individual firms into multiplant firms rather than the build up of large individual elevators was discussed by Hays in 1986 (p. 150). Because of severe time constraints, especially during harvest, grain producers choose the closest elevator available. His survey in Washington showed that over 86% of the grain received, by the 622 elevators surveyed, originated within 10 miles of the elevator, and over 98% within 20 miles.

An additional factor is the importance of the availability of multiple-car loading facilities and transshipments at the firm level (Table 41). Results indicate that the transportation mode used greatly affects the producers' choice of elevator's storage. Together, these factors seem to indicate that, in the future, the merger of smaller firms around multiple-car loading facilities can be expected.

The modal split of grain shipments for the base model is summarized in Table 41. In this situation, wheat is moved by truck-barge only if the elevator does not have access to multiple-car loading facilities (12% of total wheat transported), as in the case of Rodna, Mt.

Table 41. Modal Split of Grain Transportation for Base Model.

Elevator	Wheat							Barley			
			MCLF (25/26-Car Rail)								
	Truck-Barge	3-Car Rail	At Elevator	Tranship		Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
				From	To						
	000 Bushels							000 Bushels			
CHE	0	391					391	0	261	0	261
CRD	100						100	0		50	50
FFI	0	0	845		88	933	933	0	585	0	585
FWA	0			88	FFI		0	0		83	83
ROC	0	600					600	0	50	0	50
RFR	0	333					333	0	81	0	81
RMH	150						150	0		9	9
SPA	0		891			891	891		523	0	523
PLR	0	0	473		1,070	1,543	1,543	0	202	0	202
SPR	0	268		0	PLR		268	0	114	0	114
SVR	0			268	PLR		0	0		115	115
ROS	0	472		0	PLR		472	0	203	0	203
BAR	0			266	PLR		0	0		116	116
MCR	0	240		0	PLR		240	0	100	0	100
PCR	0			472	PLR		0	0		203	203
SCR	0			64	PLR		0	0		28	28
THW	0	303					303	0	477	0	477
CAW	120						120	0		51	51
STW	380						380	0		237	237
GAR	200						200	0		20	20
WAG	75						75	0		8	8
CRG	60						60	0		15	15
OAK	0		1,543		669	2,212	2,212	0	200	0	200
FAO	0			200	OAK		0	0		100	100
SEO	0			114	OAK		0	0		57	57
WAO	0			100	OAK		0	0		60	60
FBO	0			255	OAK		0	10		118	128
STJ	37			412	WIS		37	221		229	450
EWS	56			381	WIS		56	238		0	238
WIS	0		1,225		1,367	2,592	2,592	0	400	0	400
JUS	88			14	WIS		88	4		64	68
SUS	59			141	WIS		59	150		0	150
PVS	82			418	WIS		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

Hope and the elevators of the Whitman County Growers, Inc. firm, or if the distance to the Snake River port is short enough to allow competition between truck-barge and rail rates, as is the case of St. John Grain Growers, Inc.

Three-car rates were used by elevators with access to them, except in the case of 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. As shown in Table 41, three-car rates were a better option than transshipments to multiple-car loading facilities for elevators at Spangle, Rosalia and McCoy from the Rosalia Producers, Inc. firm. Approximately 21% of the wheat shipped to Portland went by three-car rail rates.

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. With the exception of the Spangle house of the Inland Empire Pea Growers Association, Inc., all the multiple-car loading facilities have transshipment connections with the other elevators within the firm. For the base model, 67% of the wheat delivered to Portland was shipped by this means. Of this 67%, 41% came directly into elevators from farmers and 26% was the product of transshipments.

For this particular model, 25/26-car rates is the variable which had the greatest affect on outcome. In reality, however, 25/26-car train units (and the cars to support them) are not always available and this creates car shortage uncertainty. To cope with this uncertainty, some warehouse firms have developed specific strategy.

Formation of the Central Ferry Terminal Association guaranties the availability of barge transportation when railroad cars are unavailable by establishing quotas of grain to be furnished, by the elevator firms, to the Central Ferry Terminal on the Snake River. With these quotas, enough grain is secured to maintain the truck-barge operation.

In summary, wheat, in the base model, goes to Portland mainly from the multiple-car loading facilities in the area. Truck-barge is an alternative that, while in total is not as efficient, it does supplement transportation whenever the 25/26-car units are not available. Given these relationships, any effort to control the movement of grain on the Snake River must consider the availability of alternate modes of transportation, especially 25/26-car rates.

For barley, the 3-car railroad was the most frequently used mode of transport, 56% (Table 41). The model was forced to ship 70% of the barley produced and stored to Portland and Vancouver to reflect the actual usage determined in the elevator survey. Again, the use of truck-barge seems directly related to the distance from the river. Barley, too, is included in the Central Ferry Terminal Association quotas. However, due to lack of data, this feature was not implemented in this modeling.

System costs for the base model are presented in two tables. Table 42 presents the system costs for the entire system and its components while Appendix Table A.1 presents the system costs broken down by county. The total bill for transportation of the 12.184 million bushels of wheat and 5.733 million bushels of barley from the producing areas of southern Spokane and northern Whitman Counties to the final markets was $8,956 million. The results of this base model are consistent with the findings of other grain elevator cost studies, such as the one conducted in neighboring Grant-Lincoln Counties by Dooley (1986).

Table 42. 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	

Shipping, the movement from elevator to final market, made up approximately 55% of the total cost, with wheat shipping representing two-thirds and barley shipping one-third of that cost. Elevation made up 40% and the assembly of grain, from the farm to the elevators, represented only 5% of the total cost.

Least Cost Model

In this model, the minimum storage constraint at any one elevator assumption is relaxed. Thus, grain will flow to the lowest cost elevator and transportation mode, eliminating some elevators in this competitive process.

An environment of full independent competition would completely eliminate 10 elevators (Table 43), and reduce wheat storage from 33 to 15 elevators, and barley from 33 to 19. Grain would be concentrated around the multiple-car loading facilities (Tables 43 and 44) 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 (see Appendix Table A.2 for county depictions).

This scenario shows the importance of 25/26-car train units for the transport of wheat to Portland. But, more than that, it indicates that the availability of cars for this transportation mode is essential for an efficient and effective marketing of the wheat produced in the area.

Turnover ratios went up to more than 1.7 in 7 of the 15 elevators still in use (Table 43). Capacity concerns play an important role in maintaining the actual turnover ratios in the study area. The least cost solution would depend on elevators large enough to maintain such high turnover ratios and producers not needing or desiring local available elevators.

Compared with the base model (Table 42), total transportation costs in the least cost model decreased from $8,956 to $8,643 million, around 3.6% (Table 45). This savings was realized mainly in the shipment of grain from elevators to the final market (Table 45). Assembly costs, going longer distances, increased slightly by $40,000, elevation costs decreased slightly from more efficient larger elevators by $34,000, and it was the reduction in shipping costs from the 25/26-car facilities that really made the difference, a savings of around 1.78¢ per bushel of grain shipped.

Table 43. Grain Receipts and Turnover Ratios for Least Cost Model.

Elevator	Grain Received			Storage Assumed	Turnover Ratio
	Wheat	Barley	Total		
	------------------------ 000 Bushels		------------------------		
Cheney	491	313	804	750	1.1
Rodna	0	92	92	190	0.5
Fairfield	1,418	760	2,178	1,275	1.7
Waverly	0	0	0	190	0.0
Rockford	0	0	0	750	0.0
Freeman	0	81	81	425	0.2
Mt. Hope	0	0	0	190	0.0
Spangle I	1,899	545	2,444	1,275	1.9
Plaza	599	282	881	750	1.2
Spangle II	0	0	0	425	0.0
Spring Valley	0	0	0	425	0.0
Rosalia	582	193	775	750	1.0
Balder	0	0	0	425	0.0
McCoy	633	93	726	425	1.7
Pine City	430	0	430	750	0.6
Squaw Canyon	0	0	0	190	0.0
Thornton	0	1,539	1,539	750	2.1
Cashup	373	0	373	190	2.0
Steptoe	219	0	219	750	0.3
Garfield	0	0	0	425	0.0
Walters	0	0	0	190	0.0
Crabtree	0	0	0	190	0.0
Oakesdale	2,550	78	2,628	1,275	2.1
Farmington	0	224	224	425	0.5
Seltice	0	135	135	190	0.7
Warner	0	138	138	190	0.7
Fairbanks	0	52	52	425	0.1
St. John	0	142	142	1,275	0.1
Ewan	424	571	995	750	1.3
Willada	2,064	130	2,194	1,275	1.7
Juno	23	157	180	190	0.9
Sunset	450	0	450	425	1.1
Pleasant Valley	31	208	239	1,275	0.2
Total	12,184	5,733	17,917	19,375	0.9

Table 44. Modal Split of Grain Transportation for Least Cost Model.

Elevator	Wheat							Barley			
			MCLF (25/26-Car Rail)								
	Truck-Barge	3-Car Rail	At Elevator	Tranship From	Tranship To	Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
	000 Bushels							000 Bushels			
CHE	0	491					491	0	313	0	313
CRD	0						0	0		92	92
FFI	0	0	1,418		0	1,418	1,418	0	760	0	760
FWA	0			0	FFI		0	0		0	0
ROC	0	0					0	0	0	0	0
RFR	0	0					0	0	81	0	81
RMH	0						0	0		0	0
SPA	0		1,898			1,898	1,898		545	0	545
PLR	0	0	599		430	1,029	1,029	0	282	0	282
SPR	0	0		0	PLR		0	0	0	0	0
SVR	0			0	PLR		0	0		0	0
ROS	0	582		0	PLR		582	0	193	0	193
BAR	0			0	PLR		0	0		0	0
MCR	0	633		0	PLR		633	0	93	0	93
PCR	0			430	PLR		0	0		0	0
SCR	0			0	PLR		0	0		0	0
THW	0	0					0	0	1,539	0	1,539
CAW	373						373	0		0	0
STW	219						219	0		0	0
GAR	0						0	0		0	0
WAG	0						0	0		0	0
CRG	0						0	0		0	0
OAK	0		2,550		0	2,550	2,550	0	78	0	78
FAO	0			0	OAK		0	0		224	224
SEO	0			0	OAK		0	0		135	135
WAO	0			0	OAK		0	0		138	138
FBO	0			0	OAK		0	0		52	52
STJ	0			0	WIS		0	0		142	142
EWS	110			314	WIS		110	0		571	571
WIS	0		2,064		613	2,677	2,677	0	130	0	130
JUS	0			23	WIS		0	0		157	157
SUS	205			245	WIS		205	0		0	0
PVS	0			31	WIS		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

Table 45. 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	

The increase in the 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.

In summary, making the economic setting of the transportation system more competitive and less service oriented will reduce total grain transportation cost, would increase the use of local roads to assemble grain at more distant elevators, and would result in a reduction of transshipment activities and the subsequent use of roads between elevators. In addition, it would reduce truck-barge shipping and travel on roads to the river as well as the number of elevators in operation. However, availability of 25/26-car train units (and car supply) on a consistent basis is necessary for that system to operate reliably.

Single Firm Models

Two models were run under this scenario. These models assumed that all the elevators operated as single firms;there simply were no multiplant firms. Elevation costs for grain were charged according to an elevator's capacity (Table 36). Economies of size gave lower costs per bushel to elevators with larger capacities.

The assumption that a minimum amount of grain is handled by each elevator was maintained from the base model. This reflects the reality of elevators' operations identified in the elevator survey. It also permits better comparisons with the base model, and underscores the influence and benefits of transshipments and the 25/26-car unit train option on the transportation system, even when elevators operate as independent units.

Single firm model A, the first single firm model, follows the assumptions stated above. Only single firms operate and there are no transshipments and thereby 25/26-car rates no longer are available to those elevators who do not have multiple-car loading facilities. However, the elevators which actually have multiple-car loading facilities maintain these advantageous rate positions. This model was designed to investigate any benefits of the multiplant firm structure. It also shows any importance of transshipments in taking advantage of lower multiple-car loading facility rates.

Single firm model B, the second single firm model, adds to the above scenario the assumption that the elevators with multiple-car loading facilities can not put together enough grain to meet the requirements of filling 25/26 cars in less than 24 hours. Consequently, they will not be able to take advantage of this option. This model is specifically designed to test the influence of the multiple-car unit train option on the multimodal transportation system.

The results for firm model A, shown in Table 46 (and Appendix Table A.3), differ little from the base model results in Table 40. The similarity arises largely because the supply of grain from farms closely matches the storage capacity of the elevators and, also, the minimum amount of grain handled. However, it is possible to see the influence of lower storage costs charged by larger elevators. Figures for the smallest elevators (190,000 bushels of capacity) did not change from the base model because they are already at the local margin. The largest elevators, however, did seem to draw more grain, increasing their turnover ratios. For example, Willada went from a 1.3 to a 1.7 turnover ratio, thus taking advantage of lower competitive elevation costs.

Once transshipments are eliminated, all of the wheat, previously transshipped to multiple-car loading facilities for movement by 25/26-car unit trains, now makes its way to Portland through the truck-barge mode (Table 47). The truck-barge activity increased from 12%, when transshipments were present, to 38%, when they were eliminated. The 3-car rail rates were still a more economically efficient option than truck-barge for moving some wheat to Portland.

Barley shipments did not show much change, even though the activity at the elevators showed some variation (Table 47 compared to Table 41, and Table 46 compared to Table 40). This indicates that, for the present structure of the model, the differences in the modal shipping rates are the dominant variable rather than the differences of elevation costs

Table 46. Grain Receipts and Turnover Ratios for Single Firm Model A.

Elevator	Grain Received			Storage Assumed	Turnover Ratio
	Wheat	Barley	Total		
	---------- 000 Bushels ----------				
Cheney	391	391	782	750	1.0
Rodna	100	50	150	190	0.8
Fairfield	846	451	1,296	1,275	1.0
Waverly	88	83	171	190	0.9
Rockford	600	216	816	750	1.1
Freeman	333	50	382	425	0.9
Mt. Hope	150	9	159	190	0.8
Spangle I	770	310	1,080	1,275	0.8
Plaza	594	285	879	750	1.2
Spangle II	268	114	383	425	0.9
Spring Valley	268	115	383	425	0.9
Rosalia	472	203	675	750	0.9
Balder	266	116	382	425	0.9
McCoy	240	100	340	425	0.8
Pine City	472	203	675	750	0.9
Squaw Canyon	64	28	92	190	0.5
Thornton	303	164	467	750	0.6
Cashup	120	51	171	190	0.9
Steptoe	380	237	617	750	0.8
Garfield	200	20	220	425	0.5
Walters	75	8	83	190	0.4
Crabtree	60	15	75	190	0.4
Oakesdale	1,049	513	1,562	1,275	1.2
Farmington	200	100	300	425	0.7
Seltice	114	57	171	190	0.9
Warner	100	60	160	190	0.8
Fairbanks	255	128	383	425	0.9
St. John	450	450	900	1,275	0.7
Ewan	437	238	675	750	0.9
Willada	1,719	400	2,119	1,275	1.7
Juno	103	68	171	190	0.9
Sunset	200	150	350	425	0.8
Pleasant Valley	500	350	850	1,275	0.7
Total	12,184	5,733	17,917	19,375	0.9

Table 47. 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	Tranship From	Tranship To	Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
	000 Bushels							000 Bushels			
CHE	0	391		NA	NA		391	0	391	0	391
CRD	100			NA	NA		100	0		50	50
FFI	0	0	845	NA	NA	845	845	0	451	0	451
FWA	88			NA	NA		88	0		83	83
ROC	0	600		NA	NA		600	0	216	0	216
RFR	0	333		NA	NA		333	0	50	0	50
RMH	150			NA	NA		150	0		9	9
SPA	0	0	770	NA	NA	770	770	0	310	0	310
PLR	0	0	594	NA	NA	594	594	0	285	0	285
SPR	0	268		NA	NA		268	0	114	0	114
SVR	268			NA	NA		268	0		115	115
ROS	0	472		NA	NA		472	0	203	0	203
BAR	266			NA	NA		266	0		116	116
MCR	0	240		NA	NA		240	0	100	0	100
PCR	472			NA	NA		472	0		203	203
SCR	64			NA	NA		64	0		28	28
THW	0	303		NA	NA		303	0	164	0	164
CAW	120			NA	NA		120	0		51	51
STW	380			NA	NA		380	0		237	237
GAR	200			NA	NA		200	0		20	20
WAG	75			NA	NA		75	0		8	8
CRG	60			NA	NA		60	0		15	15
OAK	0	0	1,049	NA	NA	1,049	1,049	0	513	0	513
FAO	200			NA	NA		200	0		100	100
SEO	114			NA	NA		114	0		57	57
WAO	100			NA	NA		100	0		60	60
FBO	255			NA	NA		255	0		128	128
STJ	450			NA	NA		450	370		80	450
EWS	437			NA	NA		437	238		0	238
WIS	0	0	1,719	NA	NA	1,719	1,719	0	400	0	400
JUS	103			NA	NA		103	0		68	68
SUS	200			NA	NA		200	0		150	150
PVS	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

attributed to elevator size. It does appear, then, that having multiplant firms does save the producers in the area of $69,000 for shipping.

Assembly and elevation costs did not vary much (Table 48). But the change in shipping cost increased the total cost figure from $3,705,000 to $3,801,000.

Table 48. 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	

The competitive costs of the transportation system in the area allows the shifting of transportation modes from 25/26-car rates to truck-barge for more than three million bushels. However, this system cost does not consider road damage or/and other externalities that eventually might have to be taken into account to make a better comparison. In summary, single firm pricing of the elevation activity did not show much impact compared to firm average elevation costs. Shipping costs are what really affects the total system.

Single firm model B assumes the elimination of all multiple-car loading facilities in a single firm elevator environment. Grain receipts and turnover ratios, for the 32 elevators considered in the model (Table 49, Table 50 and Appendix Table A.3), were similar to the single firm model A. Assembly and elevation costs were similar too, indicating again that the rigidity of the model constraints the overall solution to a turnover ratio of 0.9. regardless of variation in price that producers incur for these services (Table 51).

Because the major difference between the two models is in shipping wheat, analysis was concentrated at this function. The comparison of the modal split and shipping costs for both models is illustrated in Figure 3. 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. Without 25/26-car unit trains, all the railroad 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 did.

Total transportation costs went up by $253,000 when multiple-car loading facilities were eliminated. This represents cost savings of moving almost five million bushels of wheat by 25/26-car train units. This comparison underscores the importance of the lower rates for 25/26-car rail on the entire transport system in southern Spokane and northern Whitman Counties.

Although a breakdown of the transportation system costs and grain shipments in each county involved in the study is difficult, an attempt was made to present these data for the four models included in this analysis (Appendix Tables A.1, A.2, A.3 and A.4). The

Table 49. Grain Receipts and Turnover Ratios for Single Firm Model B.

Elevator	Grain Received			Storage Assumed	Turnover Ratio
	Wheat	Barley	Total		
	------------------------ 000 Bushels ------------------------				
Cheney	391	391	782	750	1.0
Rodna	100	50	150	190	0.8
Fairfield	846	451	1,296	1,275	1.0
Waverly	88	83	171	190	0.9
Rockford	600	216	816	750	1.1
Freeman	333	50	382	425	0.9
Mt. Hope	150	9	159	190	0.8
Spangle I	816	310	1,126	1,275	0.9
Plaza	548	285	833	750	1.1
Spangle II	268	114	383	425	0.9
Spring Valley	268	115	383	425	0.9
Rosalia	472	203	675	750	0.9
Balder	266	116	382	425	0.9
McCoy	240	100	340	425	0.8
Pine City	472	203	675	750	0.9
Squaw Canyon	64	28	92	190	0.5
Thornton	303	164	467	750	0.6
Cashup	120	51	171	190	0.9
Steptoe	502	237	739	750	1.0
Garfield	200	20	220	425	0.5
Walters	75	8	83	190	0.4
Crabtree	60	15	75	190	0.4
Oakesdale	1,697	513	2,210	1,275	1.7
Farmington	200	100	300	425	0.7
Seltice	114	57	171	190	0.9
Warner	100	60	160	190	0.8
Fairbanks	255	128	383	425	0.9
St. John	450	450	900	1,275	0.7
Ewan	437	238	675	750	0.9
Willada	948	400	1,348	1,275	1.1
Juno	103	68	171	190	0.9
Sunset	200	150	350	425	0.8
Pleasant Valley	500	350	850	1,275	0.7
Total	12,184	5,733	17,917	19,375	0.9

Table 50. Modal Split of Grain Transportation for Single Firm Model B.

Elevator	Wheat							Barley			
			MCLF (25/26-Car Rail)								
	Truck-Barge	3-Car Rail	At Elevator	Tranship From	Tranship To	Total 25/26-Car	Total Shipped	Truck-Barge	3-Car Rail	Truck to Feedlots	Total Shipped
	000 Bushels							000 Bushels			
CHE	0	391	NA	NA	NA	NA	391	0	391	0	391
CRD	100		NA	NA	NA	NA	100	0		50	50
FFI	0	845	NA	NA	NA	NA	845	0	451	0	451
FWA	88		NA	NA	NA	NA	88	0		83	83
ROC	0	600	NA	NA	NA	NA	600	0	216	0	216
RFR	0	333	NA	NA	NA	NA	333	0	50	0	50
RMH	150		NA	NA	NA	NA	150	0		9	9
SPA	0	816	NA	NA	NA	NA	816		310	0	310
PLR	0	548	NA	NA	NA	NA	548	0	285	0	285
SPR	0	268	NA	NA	NA	NA	268	0	114	0	114
SVR	268		NA	NA	NA	NA	268	0		115	115
ROS	0	472	NA	NA	NA	NA	472	0	203	0	203
BAR	266		NA	NA	NA	NA	266	0		116	116
MCR	0	240	NA	NA	NA	NA	240	0	100	0	100
PCR	472		NA	NA	NA	NA	472	0		203	203
SCR	64		NA	NA	NA	NA	64	0		28	28
THW	0	303	NA	NA	NA	NA	303	0	164	0	164
CAW	120		NA	NA	NA	NA	120	0		51	51
STW	502		NA	NA	NA	NA	502	0		237	237
GAR	200		NA	NA	NA	NA	200	0		20	20
WAG	75		NA	NA	NA	NA	75	0		8	8
CRG	60		NA	NA	NA	NA	60	0		15	15
OAK	0	1,697	NA	NA	NA	NA	1,697	0	513	0	513
FAO	200		NA	NA	NA	NA	200	0		100	100
SEO	114		NA	NA	NA	NA	114	52		5	57
WAO	100		NA	NA	NA	NA	100	0		60	60
FBO	255		NA	NA	NA	NA	255	38		90	128
STJ	450		NA	NA	NA	NA	450	280		169	450
EWS	437	948	NA	NA	NA	NA	437	238		0	238
WIS	0		NA	NA	NA	NA	948	0	400	0	400
JUS	103		NA	NA	NA	NA	103	0		68	68
SUS	200		NA	NA	NA	NA	200	0		150	150
PVS	500		NA	NA	NA	NA	500	210		140	350
Total	4,723	7,461					12,184	818	3,196	1,719	5,733
Percent	39	61					100	14	56	30	100

Table 51. Transportation System Costs for Single Firm Model B.

Item	Wheat	Barley	Total	Percent	Grain Shipped
	------- 000 Dollars ------				000 Bu
Assembly	292	139	431	5	
Elevation	2,424	1,135	3,558	38	
Shipping	4,054	1,221	5,275	57	
Wheat	4,054		4,054	0.44	12,184
Truck-Barge	1,650				4,723
3-Car Rates	2,403				7,461
25-Car Rates	0				0
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			9,264	100	

differences arose mainly because political boundaries do not coincide with the organization of multiplant firms. A comparison of wheat shipping and costs for the four models is presented in Table 52, broken into Spokane and Whitman Counties.

Summary of the Broad Base Models

Transportation system total costs for the base model, the least cost model and single firm model A are presented in Figure 4. As shown, assembly, elevation and barley shipping costs did not vary much among the three models. The cost of shipping wheat is the major difference.

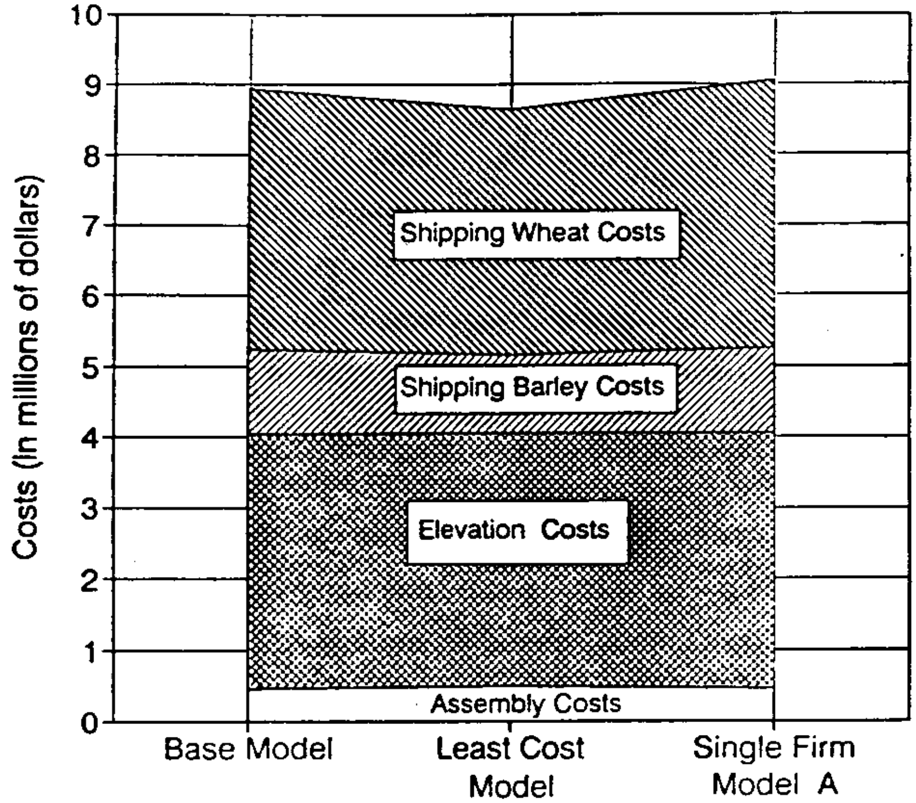

Figure 3. Comparison of Component and Total Costs for Three Models.

Table 52. Shipping Costs and Grain Shipped for Four Models Separated for Southern Spokane and Northern Whitman Counties.

	Shipping Costs				Grain Shipped			
	Base Model	Cost Model	Single Firm Model A	Single Firm Model B	Base Model	Cost Model	Single Firm Model A	Single Firm Model B
	000 Dollars				000 Bushels			
Spokane	1,566	1,365	1,385	1,488	5,208	4,836	4,407	4,407
Whitman	1,979	2,067	2,416	2,566	6,976	7,348	7,777	7,777
Whitman County Proportion	79%	66%	57%	58%	75%	66%	57%	57%

Consistent with economic theory, wheat shipping costs are lower as more competitiveness is allowed in the system. Given that the supply of grain is constant, under

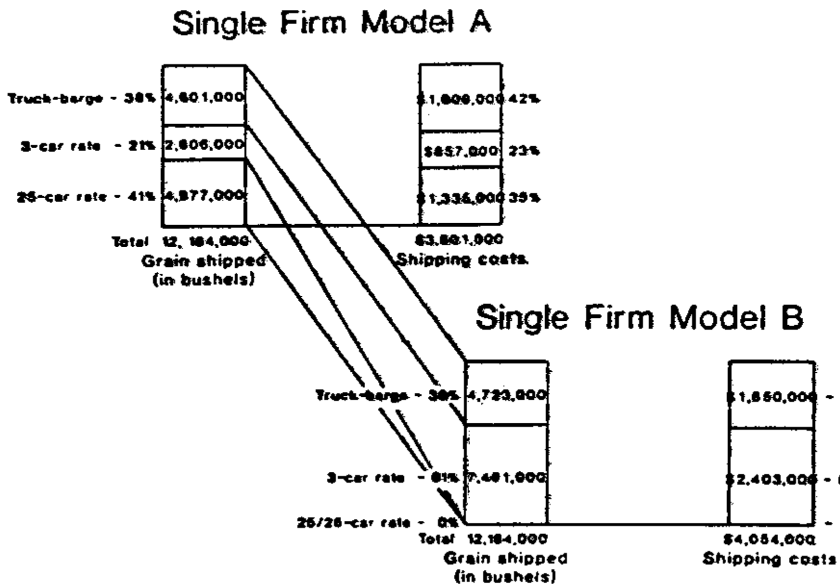

Figure 4. Comparison Between the Three Shipping Options (25/26-Car, 3-Car and Truck-Barge) Used in Single Firm Models A and B to Ship Wheat Produced in Southern Spokane and Northern Whitman Counties to Portland, Oregon.

the assumed economic setting, and relating wheat shipping costs to the degree of competitiveness in the transportation system, the fewer restrictions imposed on the system, the more efficient the transportation system will be. Here, restrictions refer to the availability of train unit cars when needed and sufficient demand to absorb the supply produced.

Comparing shipping options for wheat to Portland, Figure 5 shows the amount of wheat shipped, shipping costs, and the share of 25/26-car rates, 3-car rates and truck-barge transportation modes for the three models. As seen, the higher the share of 25/26-car rates, the lower shipping costs; the higher the share of 3-car rates and truck-barge, the higher are the shipping costs.

Concerns about the grain transportation systems in the area will continue to grow. What is the future of the railroad mode? Will abandonments continue? Are railroad

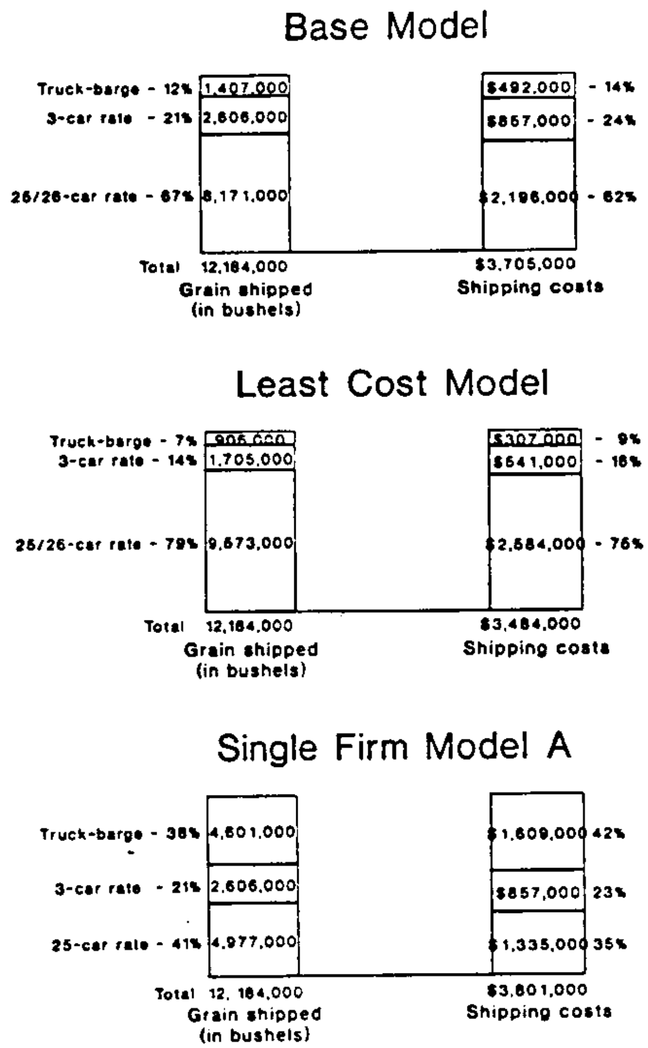

Figure 5. Comparison Between the Three Shipping Options (25/26-Car, 3-Car and Truck-Barge) Used in the Three Transportation Models (Base Model, Least Cost Model and Single Firm Model).

companies going to concentrate only on multiple-car units? What effect will the use of the truck-barge mode have on salmon survival? Or, what effect will salmon survival projects have on this multimodal system and its performance? Finally, is the trucking mode an option for grain transport to markets, or will it remain only viable as an assembly, transshipment and barge intermediate-transportation provider?

Alternative Scenarios

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 effect(s) of the changes made. Without the special data handling capabilities of a computerized spreadsheet, this would be a very difficult task. Given a tableau with 1100 rows and 2400 variables, as in the model, changing parameters in the input file and having the same changes produced in the summary tables extracted from the output solutions, becomes a bit of an art as well as a science.

However, the results of such computerized evaluation can reveal effects and trends important for predicting economic outcomes. This is the purpose of the analysis presented here. Three scenarios were run representative of actual issues confronting the multimodal transportation system of Eastern Washington.

River Closure Model

As previously discussed, one potential impact of various species of salmon being listed under the Endangered Species Act is the drawdown of the river below levels that would allow barge traffic to continue. This model analyzes the effect on grain flow of closing the river during early summer. The time frame closed in the base model was March to June.

Results from the analysis indicate that the grain that would normally go by barge in the fourth period, after closure, would simply shift to another time-period. The model did not specifically price the shipping during the fourth period by putting a storage penalty, the model simply chose another shipping pattern. No change in costs, storage or modal choice occurred.

Burlington Northern Rate Competition

Burlington Northern railroads cross the area as a vertebral column from south to north collecting grain from elevators in Oakesdale, McCoy, Rosalia, Plaza, Spangle and Cheney (Figure 1). Three of these elevators (Oakesdale, Plaza and Spangle) have multiple-car loading facilities; six can load 3-car units (McCoy, Rosalia, Spangle of Rosalia Growers; Spangle of Inland Empire Pea Growers; Plaza; and, also, Cheney), and the other eleven elevators have transshipment connections with two of the three multiple-car loading facilities (Spangle, Spring Valley, Rosalia, Balder, McCoy, Pine City and Squaw Canyon of Rosalia Growers can transship to Plaza; and Farmington, Selice, Warner and Fairbanks of Oakesdale can transship grain to Oakesdale). Since BN is so important in the multimodal system, it was decided to test to see if BN could affect their total revenue by adopting a competitive or aggressive rate policy.

Results from the base model (Table 41) indicate that almost 50% of the 12.184 million bushels of wheat shipped from the study area went to Portland on Burlington Northern cars. Union Pacific moved around 39% and the remaining 11% went by truck-barge (zero base rate in Table 53 and Figure 6). Reducing BN rates did not have much effect on the modal share distribution of wheat shipments, suggesting there is little incentive for BN to decrease rates since they do not gain traffic.

If BN rates are increased, the first 6¢ increment in increase in all Burlington Northern rates (3-car and 25/26-car rates) were critical in changing the modal share for

Table 53. Modal Split of Wheat Shipments as a Function of Burlington Northern Rates from Base Model.

Change in Rates	Truck-Barge	All 3-Car Rail	At Elevator	Trans-shipped	Total 25/26-Car	Total Shipped	Burlington Northern All NB	Burlington Northern 3-Car	Burlington Northern 25-Car Elevator	Burlington Northern Trans-shipped	All UP	Total Shipped by Train	All NB	Truck-Barge	All UP
Cents	Million Bushels												Percent		
-10	1.085	2.818	4.747	3.534	8.281	12.184	6.641	1.583	3.302	1.757	4.458	11.099	55	9	37
-8	1.085	2.673	4.911	3.516	8.426	12.184	6.477	1.437	3.302	1.739	4.622	11.099	53	9	38
-6	1.085	2.645	4.939	3.516	8.455	12.184	6.439	1.409	3.292	1.739	4.660	11.099	53	9	38
-4	1.104	2.606	4.977	3.497	8.474	12.184	6.354	1.371	3.244	1.738	4.727	11.080	52	9	39
-2	1.350	2.606	4.977	3.251	8.228	12.184	6.082	1.371	2.972	1.739	4.752	10.834	50	11	39
0	1.407	2.606	4.977	3.193	8.171	12.184	6.016	1.371	2.907	1.739	4.761	10.777	49	12	39
2	2.150	2.606	4.977	2.451	7.428	12.184	5.278	1.371	2.838	1.069	4.757	10.034	43	18	39
4	3.709	2.516	4.977	0.982	5.960	12.184	3.478	1.280	1.930	0.268	4.997	8.475	29	30	41
6	5.632	1.804	4.145	0.604	4.748	12.184	1.573	0.568	1.004	0.000	4.979	6.552	13	46	41
8	6.223	1.236	4.069	0.657	4.726	12.184	0.973	0.000	0.973	0.000	4.988	5.961	8	51	41
10	6.231	1.236	4.114	0.604	4.717	12.184	0.973	0.000	0.973	0.000	4.979	5.953	8	51	41

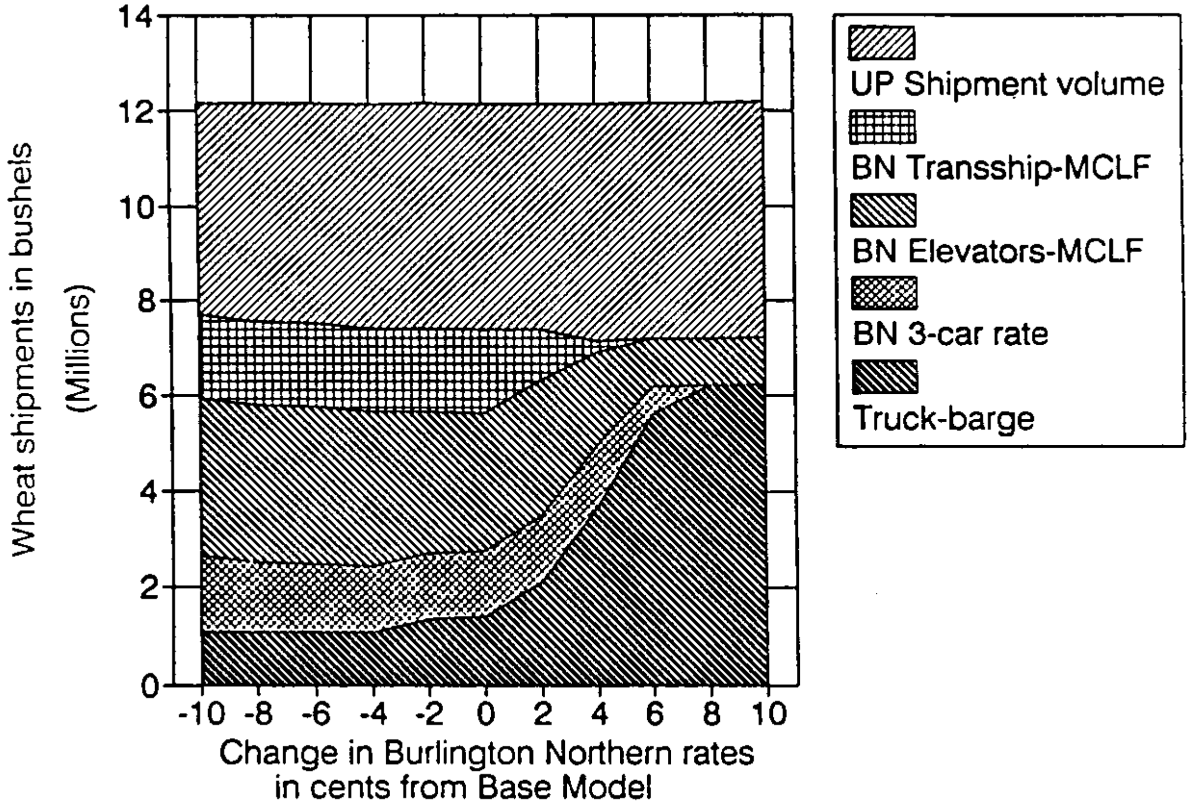

Figure 6. Modal Share of Wheat Shipments as a Function of Burlington Northern Rates.

wheat movement to Portland. A 4¢ rate increase reduced the Burlington Northern share from almost 50% to 29% (almost eliminating 3-car rates and transshipments to multiple-car loading facilities), in favor of an increase in the truck-barge share from 10% to 30%. Union Pacific gained only 2% of the shipping share.

These results reflect the intense competition that exists in the transportation system in western Washington. 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 to draw more grain to its stations. This loyalty was expressed by the minimum amount of grain handled per elevator that constrained the linear programming model.

Costs were directly proportional to the changes in Burlington Northern rates. The distribution of costs presented in Table 54 and Figure 7 shows the increased competitive position that the truck-barge mode acquires as Burlington Northern rates increase. It also suggests the probable change in volume if truck-barge were to lower their rates in an aggressive fashion.

Table 54. Transportation System Costs as a Function of Burlington Northern Rates.

Change in Rates	Assembly	Elevation	Truck-Barge	3-Car Rate	25/26-Car Rates			Total Shipping	Total Transport Wheat	Total Transport Costs
					At Elevator	Transshipped	Total			
Cents	Million Dollars									
-10	0.303	2.463	0.382	0.765	1.730	0.177	1.907	3.054	5.819	8.041
-8	0.300	2.460	0.382	0.763	1.869	0.176	2.045	3.189	5.950	8.233
-6	0.300	2.460	0.382	0.784	1.977	0.176	2.153	3.319	6.080	8.424
-4	0.300	2.458	0.388	0.802	2.083	0.175	2.258	3.449	6.208	8.613
-2	0.297	2.454	0.472	0.830	2.118	0.163	2.281	3.583	6.334	8.796
0	0.297	2.453	0.492	0.857	2.196	0.160	2.356	3.705	6.455	8.956
2	0.298	2.452	0.744	0.885	2.067	0.123	2.189	3.818	6.568	9.099
4	0.314	2.445	1.296	0.878	1.677	0.049	1.726	3.900	6.659	9.217
6	0.316	2.443	1.974	0.640	1.313	0.030	1.343	3.957	6.717	9.303
8	0.316	2.443	2.204	0.422	1.324	0.033	1.357	3.983	6.742	9.353
10	0.316	2.443	2.207	0.422	1.341	0.030	1.371	4.000	6.760	9.399

A 10¢ increase in all Burlington Northern rates represented only a 5% increase in total transportation costs for wheat, revealing the shifts in movement to truck-barge. On the other hand, a 10¢ reduction results in a 10% reduction in total transportation costs without any significant modal share shifts.

Arrow Line Alternative

The Arrow Line to Lewiston on BN has been under discussion as a potential reorganization for a short line. If this line were resurrected, it would have to offer lower rates to draw traffic in the new direction. To see the effect of such changes, both Burlington

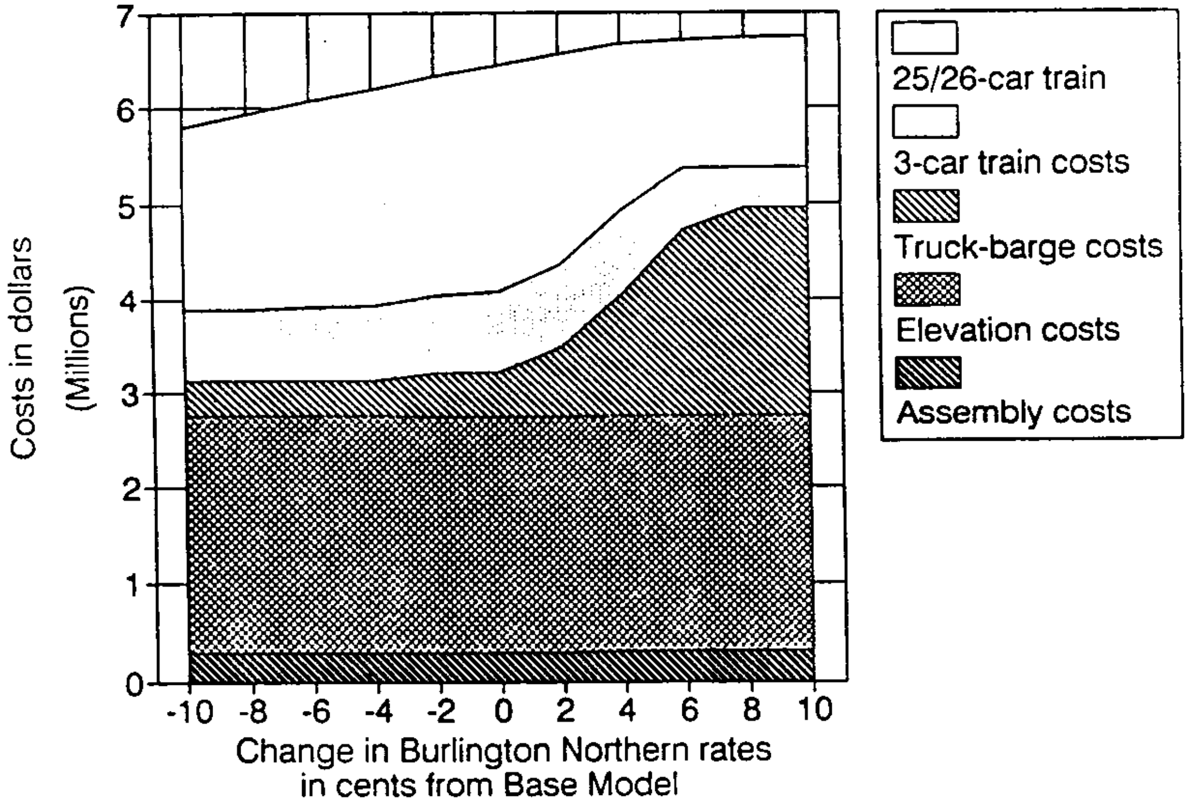

Figure 7. Assembly, Elevation and Modal Shipping Costs for Wheat Transportation as a Function of Burlington Northern Rates.

Northern and United Pacific rates were first decreased at 2¢ intervals five times and increased also at intervals of 2¢ until 10¢ was added to the base model rates. The effect of these changes on the modal share of wheat shipments are shown in Figure 8 and Table 55.

The reduction in rates did not have much effect on modal share since in the base model truck-barge rates were already at a rate disadvantage in comparison to all railroad rates. Yet if the new Arrow railline configuration were able to offer a 2¢ reduction an increase of 159,000 bushels would occur; the shift would be captured by wheat that is transshipped and/or moved by 25/26-car units. An additional 2¢ per bushel decrease (a total of 4¢) would move an additional 163,000 bushels by transshipment and 25/26-car movements.

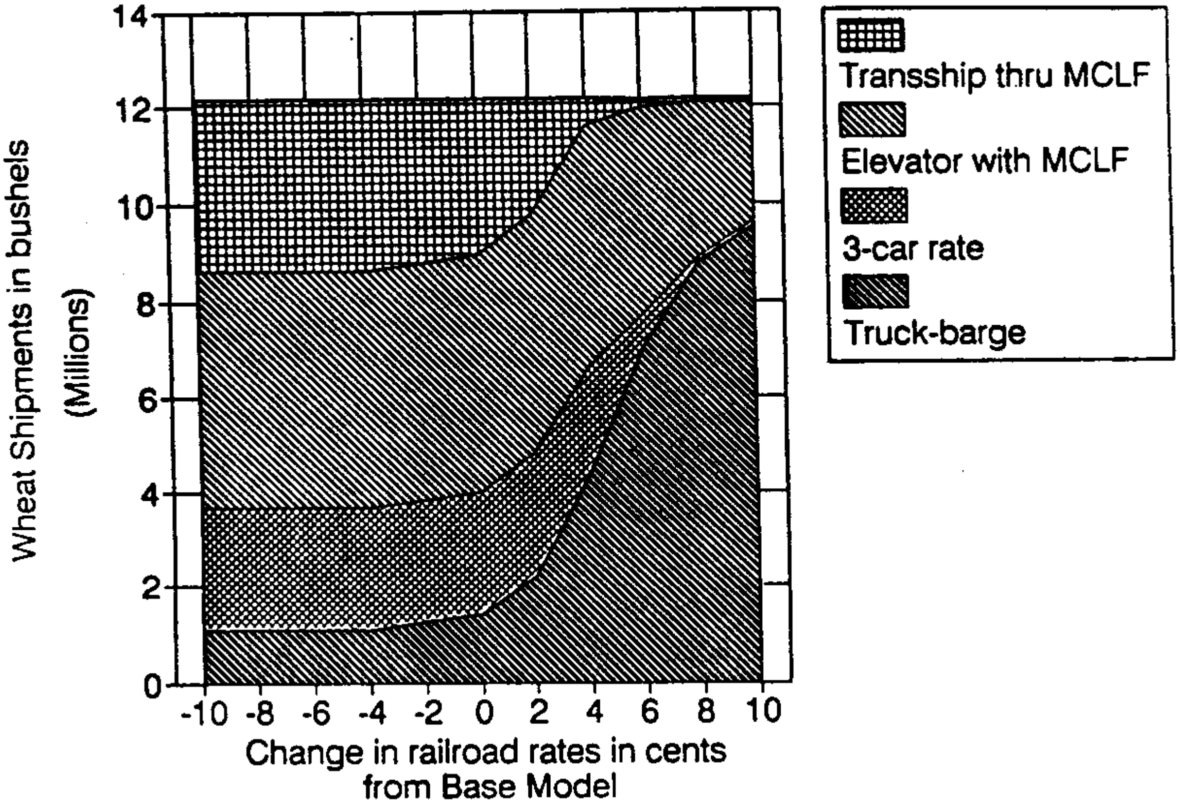

Figure 8. Modal Share of Wheat Shipments as a Function of All Railroad Rate Changes.

The first gain in truck-barge competitive position happens at 2¢ increase when some 163,000 bushels went by river instead of being transshipped to a multiple-car loading facility. From that point, any further increase in the railroad rates resulted in more wheat going to the river. At the 6¢ increase, transshipments were almost eliminated. Between 6¢ and 8¢ increases, truck-barge would capture almost all of the 3-car train share.

Even with a 10¢ increase, truck-barge takes a share of almost 80% of the wheat shipped and continues gaining volume as rates rise. This picture shows, one more time, how disruptive any change in the rate structure of the transportation system will be, if the actual rate structure is considered in equilibrium. It also indicates the importance of performing

Table 55. Modal Split of Wheat Shipments as a Function of All Railroad Rates (Arrow Line).

Change in Rates	Truck-Barge	All 3-Car Rail	At Elevator	Transshipped	Total 25/26-Car	Total Shipped
Cents	Million Bushels					
-10	1.085	2.606	4.977	3.516	8.493	12.184
-8	1.085	2.606	4.977	3.516	8.493	12.184
-6	1.085	2.606	4.977	3.516	8.493	12.184
-4	1.085	2.606	4.977	3.516	8.493	12.184
-2	1.248	2.606	4.977	3.353	8.330	12.184
0	1.407	2.606	4.977	3.193	8.171	12.184
2	2.220	2.606	4.977	2.380	7.358	12.184
4	4.401	2.217	4.977	0.589	5.566	12.184
6	7.084	0.672	4.244	0.184	4.428	12.184
8	8.836	0.084	3.168	0.096	3.264	12.184
10	9.561	0.084	2.443	0.096	2.539	12.184

more economic and behavioral analysis of the system in order to establish policy or direct the future economic transportation developments of the area.

Even if there were only minimal changes in the modal share of wheat shipments when all railroad rates are dropped, the total cost of transportation of wheat is reduced by $1,105,000 when railroad rates are dropped by 10¢ (Figure 9 and Table 56). This reduction becomes $1,502,000 considering both wheat and barley transportation. A 10¢ increase would not be as dramatic as the reduction, but will result in an additional $667,000 for the transportation of wheat from the farm to Portland.

Another final competitive scenario evaluated was the situation when railroad rates were increased and also truck-barge rates, taking advantage of the higher competitive rate ceiling, raise their rates at the same time (Table 57). A 10¢ increase in all rates resulted

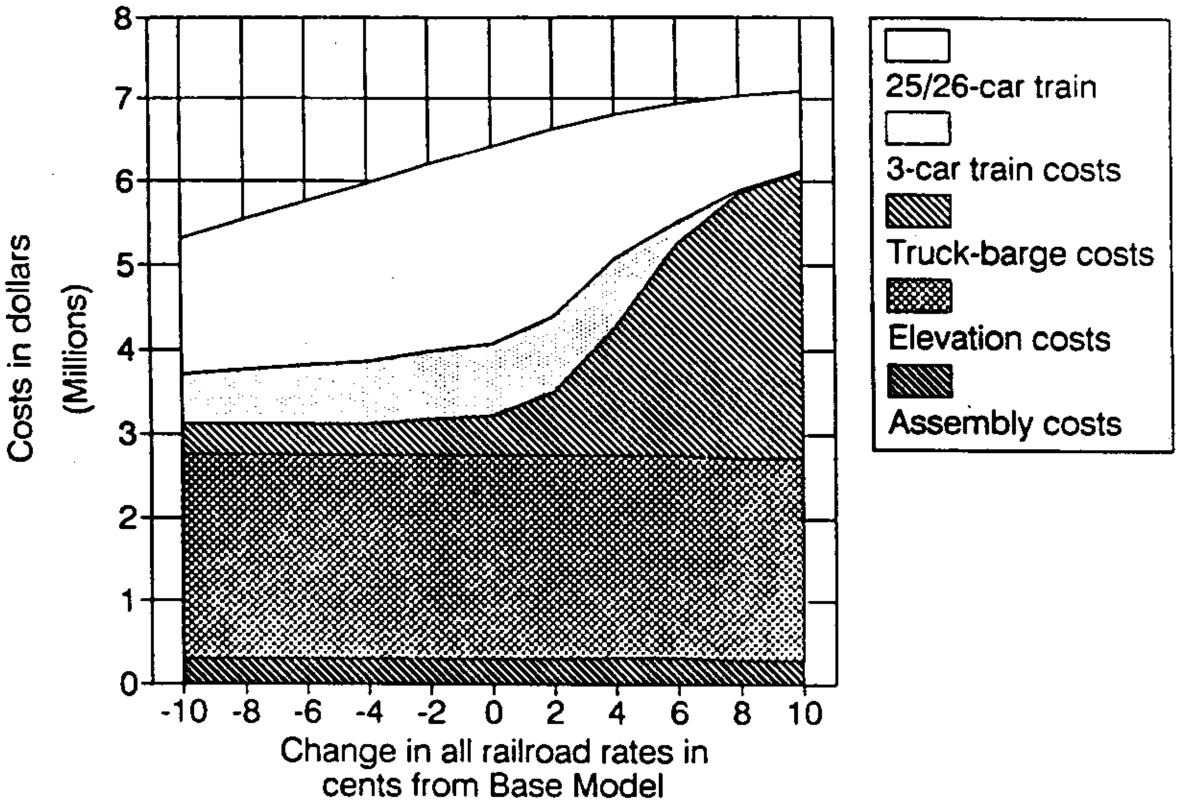

Figure 9. Costs as a Function of All Railroad Rate (Arrow Line) Changes.

Table 56. Transportation System Costs as a Function of All Railroad Rates (Arrow Line).

Change in Rates	Assembly	Elevation	Truck-Barge	3-Car Rate	25/26-Car Rates: At Elevator	25/26-Car Rates: Trans-shipped	25/26-Car Rates: Total	Total Shipping	Total Transport Wheat	Total Transport Costs
Cents	Million Dollars									
-10	0.303	2.457	0.382	0.596	1.435	0.176	1.611	2.590	5.350	7.454
-8	0.303	2.457	0.382	0.649	1.605	0.176	1.781	2.812	5.572	7.757
-6	0.303	2.457	0.382	0.701	1.775	0.176	1.951	3.034	5.794	8.059
-4	0.303	2.457	0.382	0.753	1.945	0.176	2.121	3.256	6.016	8.361
-2	0.300	2.455	0.437	0.805	2.073	0.168	2.240	3.483	6.237	8.662
0	0.297	2.453	0.492	0.857	2.196	0.160	2.356	3.705	6.455	8.956
2	0.298	2.451	0.768	0.909	2.117	0.119	2.236	3.913	6.662	9.227
4	0.310	2.443	1.535	0.817	1.709	0.029	1.738	4.090	6.842	9.471
6	0.310	2.443	2.524	0.258	1.439	0.009	1.448	4.230	6.983	9.675
8	0.282	2.449	3.153	0.033	1.141	0.005	1.145	4.332	7.063	9.819
10	0.281	2.449	3.400	0.035	0.952	0.005	0.957	4.392	7.122	9.940

in a cost increase of $1,218,000 (19%) for the total wheat transport and $1,620,00 (18%) for total transportation system costs, including barley transport. Modal shares did not vary appreciably under this scenario.

Table 57. Costs as Rail and Truck-Barge Rates are Increased.

Change in Rates	Assembly	Elevation	Truck-Barge	3-Car Rate	25/26-Car Rates At Elevator	25/26-Car Rates Trans-shipped	25/26-Car Rates Total	Total Shipping	Total Transport Wheat	Total Transport Costs
Cents	Million Dollars									
0	0.297	2.453	0.492	0.857	2.196	0.160	2.356	3.705	6.455	8.956
2	0.297	2.453	0.523	0.909	2.358	0.159	2.517	3.949	6.699	9.280
4	0.297	2.453	0.547	0.961	2.524	0.160	2.684	4.192	6.942	9.604
6	0.297	2.453	0.575	1.013	2.688	0.160	2.847	4.436	7.186	9.928
8	0.297	2.453	0.604	1.066	2.850	0.160	3.010	4.679	7.430	10.252
10	0.297	2.453	0.633	1.118	3.013	0.160	3.173	4.923	7.673	10.576

Elasticities and Competition

Elasticity, unlike changes in demand itself, is purely a price phenomenon relating quantity demanded of a transportation mode's service to changes in either its rate or a competitor's rate. Modal demand is directly related to intermodal competition (Sampson, Farris and Shock, 1985, p. 187). Hence, a more elastic (responsive) modal demand (more competitive) is expected with more modes available for transportation. The study area can be considered of having as many modes as rates exist (Table 37). Therefore, it can be assumed that even between Burlington Northern rates, 3-car rates compete with 25/26-car rates for grain shipments to Portland.

Consideration should be directly given to the effect of changes in truck-barge rates on modal share or demand, costs and elasticities. The base model was the starting scenario and the truck-barge rates were lowered until truck-barge took all the wheat shipped to

Portland (Figure 10). The truck-barge mode first took the wheat that was transshipped to multiple-car loading facilities, then, with an 8¢ rate reduction for truck-barge, the 3-car mode was eliminated by the competitive power of truck-barge rates. When the reduction in rates was 12¢, the multiple-car loading facilities were completely eliminated.

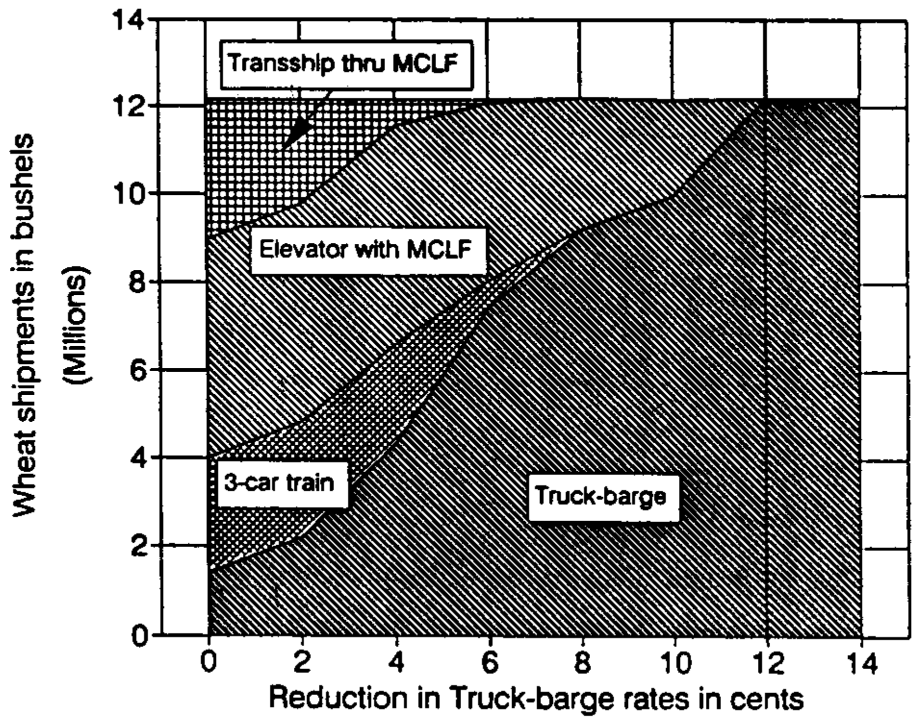

Figure 10. Modal Share of Wheat Shipments as a Function of Truck-Barge Rates.

Total shipping costs reduced by $1,200,000 as the truck-barge rates were decreased by 14¢ (Figure 11). These figures can be translated in demand terms, which show the relationship between rates and amount of transportation demanded (Figure 12). The estimation of elasticities along the demand schedule indicates that the demand for the truck-barge mode is elastic (especially at the base model rate where it is -16), and that any small reduction in the truck-barge rate would result in increased revenues for the truck-barge mode. The responsiveness to a given percentage change in rate is greater at the higher rates than at a lower truck-barge rate. The average own price elasticity is -9 over the range of prices.

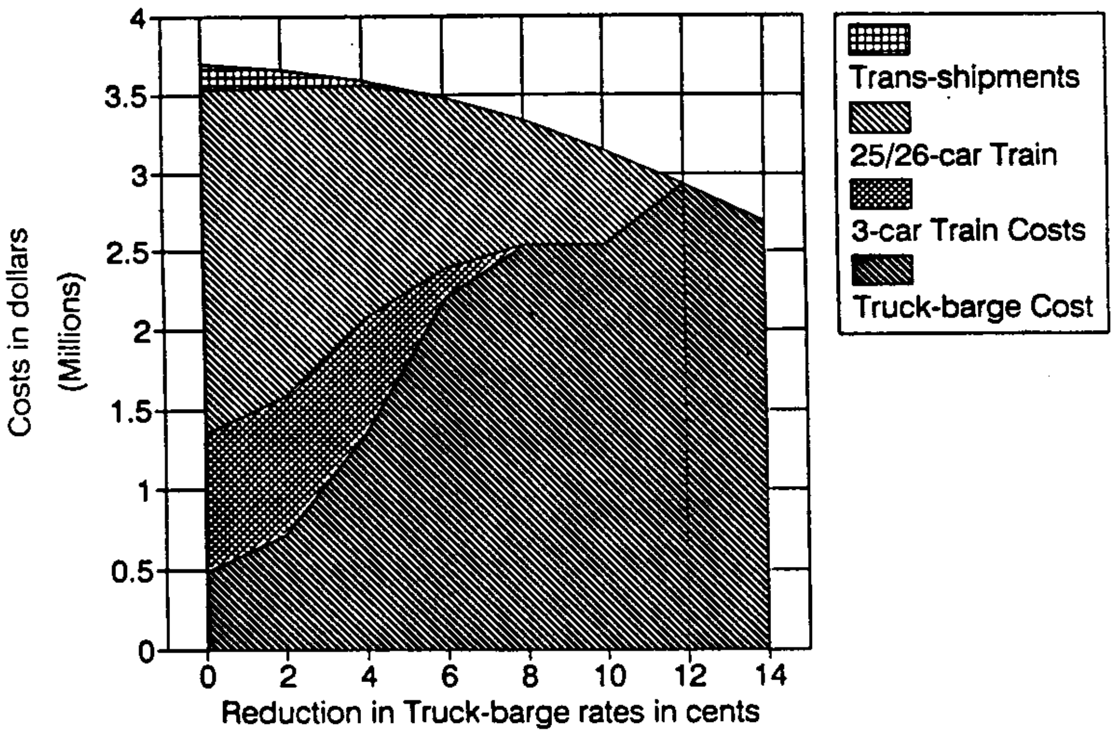

Figure 11. Wheat Shipping Costs as a Function of Truck-Barge Rates (From Base Model).

The positive cross price elasticities of the effect of truck-barge rates on demand for multiple-car loading facilities, indicated in Figure 13, reveal that as truck-barge rates increase, wheat traffic will shift from truck-barge to the multiple-car loading facilities. In summary, to increase revenues to the truck-barge mode, their rates should be lowered. If multiple-car loading facility rates do not change, in reaction to such a truck-barge rate change an increase of quantity demanded for the truck-barge shipping mode will occur until truck-barge mode hypothetically takes all the wheat produced. Elasticities are positive since an increase in truck-barge rates will cause an increase in rail movement.

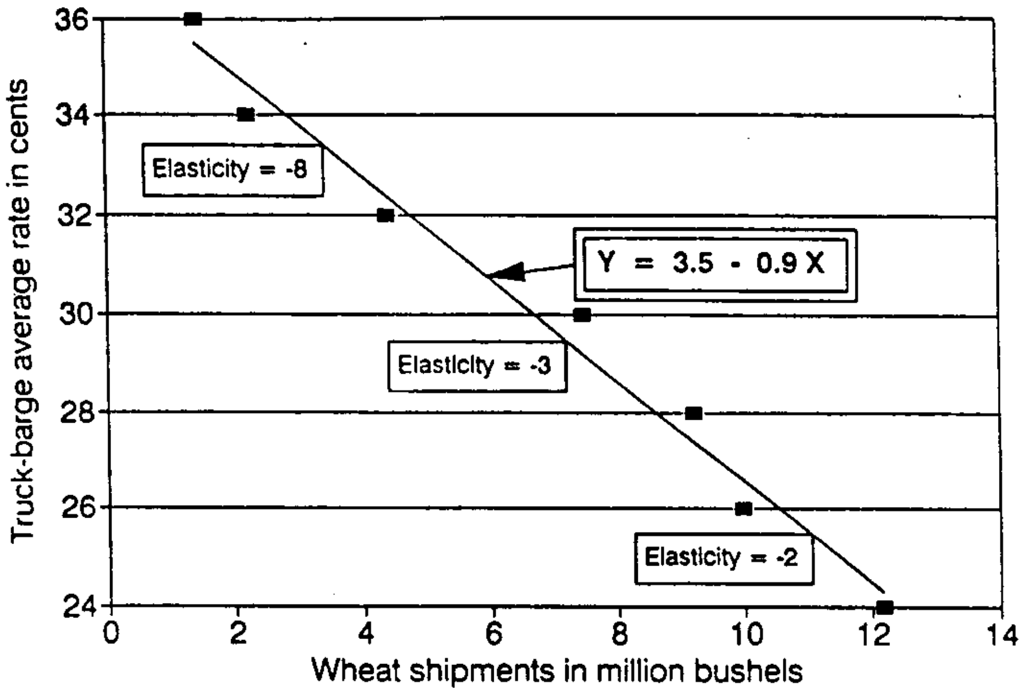

Figure 12. Demand of Truck-Barge Mode and Own Price Elasticities.

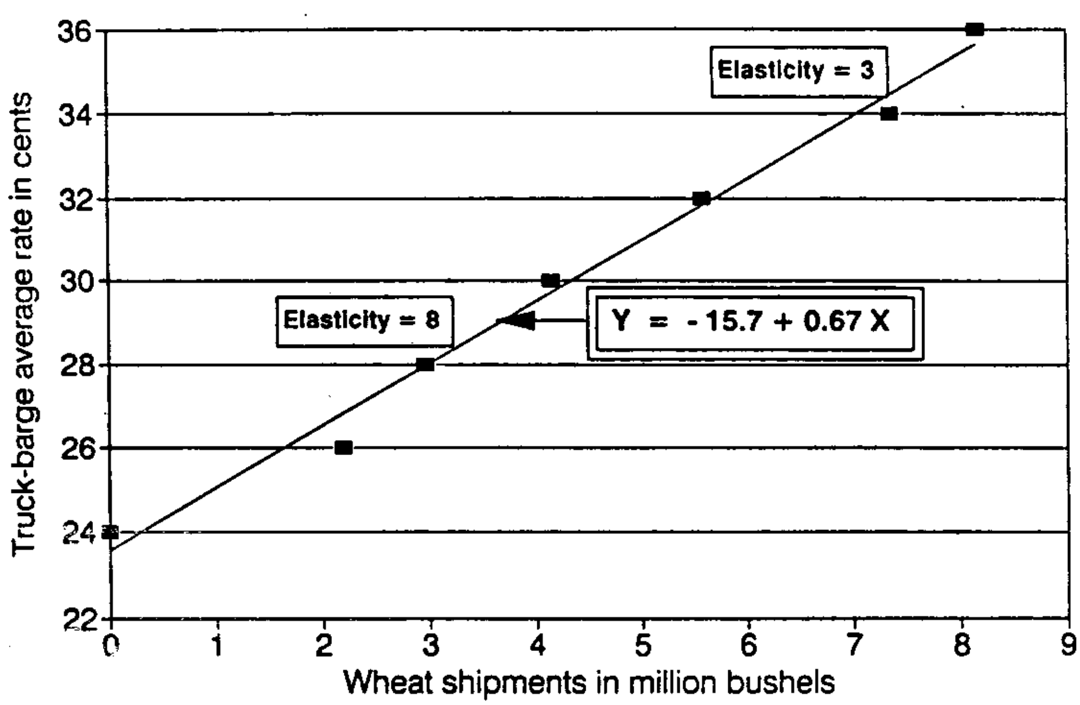

Figure 13. Truck-Barge Rate Effect on 25/26-Car Train Demand and Cross Price Elasticities.

These findings point out, one more time, the highly competitive nature of the multimodal transportation industry that exists in Western Washington. Any change in the marketing environment that causes rates to change will have a profound effect on the costs incurred and performance realized by this multimodal transportation system. The findings also allow us to project general usage of road infrastructure in various areas as this competitive multimodal system operates.

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APPENDIX A

ADDITIONAL TABLES

Appendix Table A.1. Transportation System Costs Broken Down by County for Base Model.

Item	Wheat	Barley	Total	Percent	Grain Shipped
	------- 000 Dollars ------				000 Bu
Assembly	297	148	445	5	
Spokane	122	57	179		
Whitman	175	91	266		
Elevation	2,453	1,138	3,591	40	
Spokane	888	412	1,300		
Whitman	1,566	726	2,292		
Shipping	3,705	1,215	4,920	55	
Wheat	3,705		3,705	0.41	12,184
Spokane	1,566		1,566		5,208
Truck-Barge	100				250
3-Car Rates	536				1,591
25-Car Rates	929				3,367
Whitman	1,979		1,979		6,976
Truck-Barge	392				1,157
3-Car Rates	321				1,015
25-Car Rates	1,267				4,804
Transshipments	160		160		3,193
Barley		1,215	1,215	0.14	5,733
To Portland-Vancouver		1,001	1,001		4,014
Spokane		419	419		1,817
Truck-Barge		0			0
3-Car Rates		419			1,817
Whitman		581	581		2,198
Truck-Barge		275			818
3-Car Rates		307			1,380
To Feedlots		214	214		1,719
Spokane		32			257
Whitman		182			1,462
Total Costs			8,956	100	

Appendix Table A.2. Transportation System Costs Broken Down by County for Least Cost Model.

Item	Wheat	Barley	Total	Percent	Grain Shipped
	------- 000 Dollars ------				000 Bu
Assembly	333	152	485	6	
Spokane	134	55	190		
Whitman	198	96	295		
Elevation	2,421	1,137	3,557	41	
Spokane	864	410	1,275		
Whitman	1,556	726	2,283		
Shipping	3,484	1,117	4,601	53	
Wheat	3,484		3,484	0.40	12,184
Spokane	1,365		1,365		4,836
Truck-Barge	0				0
3-Car Rates	164				491
25-Car Rates	1,201				4,346
Whitman	2,067		2,067		7,348
Truck-Barge	307				906
3-Car Rates	377				1,215
25-Car Rates	1,383				5,227
Transshipments	52		52		1,042
Barley		1,117	1,117	0.13	5,733
To Portland-Vancouver		902	902		4,014
Spokane		457	457		1,981
Truck-Barge		0			0
3-Car Rates		457			1,981
Whitman		445	445		2,033
Truck-Barge		0			0
3-Car Rates		445			2,033
To Feedlots		214	214		1,719
Spokane		12			92
Whitman		203			1,627
Total Costs			8,643	100	

Appendix Table A.3. Transportation System Costs Broken Down by County for Single Firm Model A.

Item	Wheat	Barley	Total	Percent	Grain Shipped
	------- 000 Dollars -----				000 Bu
Assembly	306	139	445	5	
Spokane	121	53	174		
Whitman	185	86	271		
Elevation	2,447	1,145	3,593	40	
Spokane	889	417	1,306		
Whitman	1,558	729	2,286		
Shipping	3,801	1,221	5,022	55	
Wheat	3,801		3,801	0.42	12,184
Spokane	1,385		1,385		4,407
Truck-Barge	237				606
3-Car Rates	536				1,591
25-Car Rates	611				2,210
Whitman	2,416		2,416		7,777
Truck-Barge	1,372				3,995
3-Car Rates	321				1,015
25-Car Rates	723				2,768
Transshipments	0		0		0
Barley		1,221	1,221	0.13	5,733
To Portland-Vancouver		1,006	1,006		4,014
Spokane		420	420		1,817
Truck-Barge		0			0
3-Car Rates		420			1,817
Whitman		587	587		2,198
Truck-Barge		275			818
3-Car Rates		312			1,380
To Feedlots		214	214		1,719
Spokane		32			257
Whitman		182			1,462
Total Costs			9,060	100	

Appendix Table A.4. Transportation System Costs Broken Down by County for Single Firm Model B.

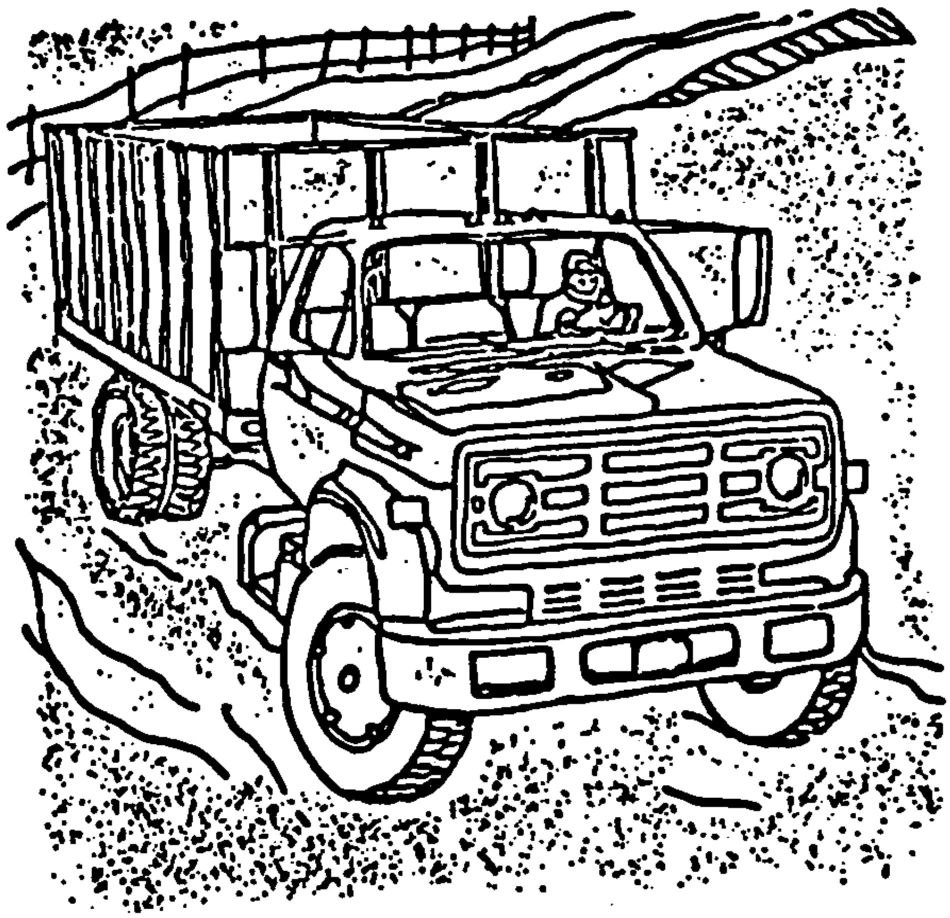
Item	Wheat	Barley	Total	Percent	Grain Shipped
	------- 000 Dollars ------				000 Bu
Assembly	292	139	431	5	
Spokane	121	53	174		
Whitman	171	86	257		
Elevation	2,424	1,135	3,558	38	
Spokane	879	409	1,289		
Whitman	1,544	725	2,270		
Shipping	4,054	1,221	5,275	57	
Wheat	4,054		4,054	0.44	12,184
Spokane	1,488		1,488		4,407
Truck-Barge	237				606
3-Car Rates	1,251				3,801
25-Car Rates	0				0
Whitman	2,566		2,566		7,777
Truck-Barge	1,413				4,117
3-Car Rates	1,153				3,660
25-Car Rates	0				0
Transshipments	0		0		0
Barley		1,221	1,221	0.13	5,733
To Portland-Vancouver		1,006	1,006		4,014
Spokane		420	420		1,817
Truck-Barge		0			0
3-Car Rates		420			1,817
Whitman		587	587		2,198
Truck-Barge		275			818
3-Car Rates		312			1,380
To Feedlots		214	214		1,719
Spokane		32			257
Whitman		182			1,462
Total Costs			9,264	100	

APPENDIX B

QUESTIONNAIRES

PLANNING FOR IMPROVED RURAL ROADS

Grain Transportation Survey



Washington State University
Cooperative Extension
Spokane County

and

The Washington State Department
of Transportation
(D.O.T)

1991

(All responses are confidential)

Q. 1 What is the total cropland that you farm, both owned and rented?

(please circle one)

a. 1 - 500 acres

b. 501 - 1000 acres

c. 1001 - 1500 acres

b. 1501 - 2000 acres

d. over 2001 acres

Q. 2 To evaluate the amount of grain that moves through our area, please give your best estimate of the crop production on your farm for the last TWO years.

	TOTAL PRODUCTION (in bushels) for 1990	for 1989
Wheat	______	______
Barley	______	______
Other ______	______	______
Total	______	______

Q. 3 On the average over the past three years, how did you store your grain at harvest?

	Wheat	Barley
Country elevator (you retain ownership)	_____ %	_____ %
On-farm storage	_____ %	_____ %
Sold immediately after harvest	_____ %	_____ %
Total crop	100 %	100 %

Q. 4 To help us identify needs for road maintenance please specify the roads and distance to the elevator. Give an estimate of the typical percentage of wheat shipped from your farm to each one of the elevators you used.

No.	Name of Elevator	Distance from your farm (miles)	Average percent shipped	Name or description of the roads used
1	______	______	____	______
2	______	______	____	______
3	______	______	____	______
4	______	______	____	______
River port	______	______	____	______
		Total	100 %	

Give an estimate of the typical percentage of <u>barley</u> shipped from your farm to each one of the elevators:

No.	Name of Elevator or Feedlot	Distance from your farm (miles)	Average percent shipped	Name or description of the roads used
1	______	______	____	______
2	______	______	____	______
3	______	______	____	______
River port	______	______	____	______
		Total	100 %	

Q. 5 To help us understand the volume of grain shipped on individual roads, please identify the location and storage capacity of your on-farm storage.

<u>Location A.</u> ___ Section ___ Township ___ Range __ __ Quarter section

-Total volume at location A: _______ bu.

-County or State road providing immediate access to your on-farm storage: ______________________

-Condition of the road. __ Poor __ Good __ Excellent

-Has the condition of this road changed in the past five years: ___ no ___ Improved ___ Deteriorated

<u>Location B.</u> ___ Section ___ Township ___ Range __ __ Quarter section

-Total volume at location B: _______ bu.

-County or State road providing immediate access to your on-farm storage: ______________________

-Condition of this road. __ Poor __ Good __ Excellent

-Has the condition of this road changed in the past five years: ___ no ___ Improved ___ Deteriorated

Do you plan to build additional farm storage in the next two years? ___ yes ___ no

If yes, how much additional capacity _______ bushels

and where? ______________________

Q. 6 To identify seasonal problems with roads, please estimate the approximate percentage of grain shipped from your farm to market during a typical year.

	Wheat	Barley		Wheat	Barley
July-Aug.	___ %	___ %	Jan.-Feb.	___ %	___ %
Sep.-Oct.	___ %	___ %	Mar.-April	___ %	___ %
Nov.-Dec.	___ %	___ %	May-June	___ %	___ %
			Totals	100 %	100 %

If you have any other comments about your roads, marketing, transportation, costs, or other thoughts, please feel free to add them below. We appreciate your input and we will try to incorporate your concerns into our report.

If you would like a copy of the results of the survey, Please write your name below. Thank you.

____

Washington State University Cooperative Extension programs are available to all without discrimination

ELEVATOR QUESTIONNAIRE

NAME OF THE FIRM:

LOCATION
or HOUSE:

We are interested in the location of your houses; the type of transportation services available (truck, rail and truck-barge); and the flow of WHEAT and BARLEY in and out of each location. We have included a questionnaire for each location. Please feel free to make address corrections or include other locations.

Q. 1 What are the ACCESS ROADS to this location?
(use numbers or local names) ______________________
____
____

Q. 2 Do you have RAIL ACCESS at this location?
___ Yes ___ No

If not, please indicate the NAME, DISTANCE and ACCESS ROADS (that you use) to the CLOSEST RAIL LOADING FACILITY:

NAME ______________________ DISTANCE ____________

ACCESS ROADS ______________________
____
____

Q. 3 Please indicate the NAME and DISTANCE to the RIVER PORT FACILITY that you use (or would use if you did go to the river):

NAME ______________________ DISTANCE ____________

ACCESS ROADS ______________________
____
____

Q. 5 On the average, of all commodities handled in this location, what percentage of total volume is:

Wheat	___ %
Barley	___ %
Corn	___ %
Other Feed Crops	___ %
Legumes	___ %
Oilseeds	___ %
Other ________	___ %
TOTAL	100 %

Q. 5 Please estimate the average annual volume (past three years) of WHEAT and BARLEY received at this location.

WHEAT	BARLEY
____ bu.	____ bu.

Q. 6 Please estimate the approximate percentage (average over three years) of WHEAT shipped by each one of the following transportation modes from this location.

	PERCENT AVERAGE SHIPPED
Transhipment via Truck to othes Houses	____ %
Direct Truck to Final Market	____ %
Truck-Barge	____ %
Single Car Rail	____ %
3-Car Rail	____ %
25 or 26-Car Rail	____ %
Other (please specify)	
____________________	____ %
TOTAL	100 %

Q. 7 Please estimate the average annual percentage of WHEAT shipped to each of the following destinations from this location.

	WHEAT
Columbia River Ports	____ %
Puget Sound Ports	____ %
In-State Flour Mills	____ %
Transshipment to other Houses	____ %
Other, (please specify)	
______________	____ %
TOTAL	100 %

Q. 8 Please estimate the approximate percentage (average over three years) of BARLEY shipped by each one of the following transportation modes from this location.

	PERCENT AVERAGE SHIPPED
Transhipment via Truck to othes Houses	____ %
Direct Truck to Final Market	____ %
Truck-Barge	____ %
Single Car Rail	____ %
Other (please specify)	
______________	____ %
TOTAL	100 %

Q. 9 Please estimate the average annual percentage of **BARLEY** shipped to each of the following destinations from this location.

	BARLEY
Columbia River Ports	___ %
Puget Sound Ports	___ %
Vancouver, WA	___ %
Feed Lots	___ %
Transshipment to other Houses	___ %
Other (please specify)	
______________	___ %
TOTAL	_100 %

Q.10 We are interested in the seasonality of shipping grain into this location during the whole year. Please estimate how much grain is received during a typical average year:

	WHEAT	BARLEY
July-August	___ %	___ %
September-October	___ %	___ %
November-December	___ %	___ %
January-February	___ %	___ %
March-April	___ %	___ %
May-June	___ %	___ %
TOTAL	_100 %	_100 %

Q.11 To determine the seasonality of shipping from this location, please estimate how much grain is shipped in a typical average year:

	WHEAT	BARLEY
July-August	___ %	___ %
September-October	___ %	___ %
November-December	___ %	___ %
January-February	___ %	___ %
March-April	___ %	___ %
May-June	___ %	___ %
TOTAL	_100 %	_100 %