TRANSPORTATION OPTIMIZATION MODELING FOR WASHINGTON STATE HAY SHIPMENTS: MODE AND COST IMPLICATIONS DUE TO LOSS OF CONTAINER SERVICES AT THE PORT OF PORTLAND

By

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of STEPHANIE MARIE MEENACH find it satisfactory and recommend that it be accepted.

Chair

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TRANSPORTATION OPTIMIZATION MODELING FOR WASHINGTON STATE HAY SHIPMENTS: MODE AND COST IMPLICATIONS DUE TO LOSS OF CONTAINER SERVICES AT THE PORT OF PORTLAND

General Abstract

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A recent issue impacting hay shipments in Washington State involves the reduction of container services at the Port of Portland. As a result, the Port of Seattle and Tacoma have experienced a considerable increase in hay shipments received by rail and truck since September of 2004. Prior to this date, containers filled with hay were shipped almost exclusively via barge on the Columbia River to the Port of Portland. After reaching Portland, the containers were then loaded onto one of three steamship lines: Hyundai, K-Line, or Hanjin. As of September 2004, Hanjin is the only carrier that calls on the Port of Portland. K-Line and Hyundai now require producers to haul their containers to the Ports of Tacoma or Seattle by either truck or rail. As a result, barge

shipments of containers out of the Port of Pasco decreased dramatically, while rail shipments to the Port of Tacoma and Seattle increased considerably.

The primary objective of this research is to collect firm level data on the production, transportation and marketing of hay in Washington and then apply this information to the development of a transportation model of hay movements. This included detailing the varied usage of transportation service by mode for producers and processors prior to September 2004. After establishing the regional hay transportation and marketing utilization prior to this date, this information is utilized to develop a model that can be used to evaluate many different alternative policy scenarios. One alternative evaluated in this study is determining industry shifts in transportation usage and modal choice in reaction to the transportation changes after September 2004. This study investigated the impacts on industry structure and operating practices as firms react to these changes in the market.

A cost minimization transportation optimization model is developed for hay shipments out of Washington that is used to investigate impacts to producers, brokers and ports. The results indicate that after all barge and hay shipments were eliminated into Portland, total transportation costs decrease initially overall, while some producers experience shipping cost increase. Both rail and truck volumes increase substantially in the absence of container shipments on barge. The total industry impact is a $6.3 million increase in transportation costs from the Base Scenario to Scenario 3. Also, once trucks rates are allowed to increase due to the shortage of trucks and the increased demand for truck services, the total transportation cost increased by $8.7 million.

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INTRODUCTION

The local and regional hay industry has experienced considerable growth over the past few years generating multiple economic benefits and multiplier effects throughout Washington's economy. Growth in this industry and continued success depend upon access to markets and an efficient multimodal transportation system to bridge production supply sources with destination demand markets. The value of hay to regional producers and the state's economy is substantially diminished without an efficient transportation system.

Hay producers and handlers in the State of Washington are able to take advantage of a multimodal transportation network of county and state roads, highways, railroads and the Snake and Columbia River in-land navigation system to effectively move large amounts of hay in a timely and economic manner. Dependence on the system is the result of the continual use of this infrastructure for movement of commodities. If there is an interruption or shift in the infrastructure, then there are certainly effects on producers, broker, exporters and consumers of hay. Current but changing modal choices generate many effects on a complex hay industry. The impacts on marketing strategies that occur because of the choices available in transportation modes reflect the decision process of a producer or processor. The modal choices that have been traditionally available to the hay industry are the use of rail, the use of trucks, barge and many combinations of these modes.

Data and Methods

In order to obtain more specific and detailed information on Washington Hay movements and transportation characteristics, a statewide survey of all producers and processors was conducted. The Washington State Hay Growers Association provided a list of producers throughout the state (WSHGA, 2004). Processing facilities were obtained similarly, based on interviews with area producers and industry experts. Mail surveys were sent to producers and processors in 18 Washington counties gathering transportation and shipment characteristic information for the statewide hay industry. The questionnaire asked producers and processors for the volume of inbound and outbound shipments, seasonality of shipments, local and state roads being used, vehicle type, and destination of shipments.

The questionnaires were mailed initially in the month of May 2004 with a secondary mailing and telephone contact made with those who had not provided a response. The final completed response rate of 48.1 percent (Table 1.1) provided excellent information regarding hay shipments, including which roads were predominately utilized, volume of shipments on those roads and highways, and primary destinations for hay shipments. King, Lincoln and Whitman counties were the only three counties where no responses were received. However, these counties represent a small fraction of statewide hay production and in those areas where hay production is heavily concentrated the response rate was above 40 percent.

Table 1.1. Response Rates by County

County	County Totals		
	Number Mailed	Number of Responses	Response Rate
Okanogan	1	1	100.0%
Pend Oreille	1	1	100.0%
Douglas	1	1	100.0%
Benton	3	3	100.0%
Grays Harbor	1	1	100.0%
Stevens	11	8	72.7%
Spokane	10	7	70.0%
Whatcom	3	2	66.7%
Klickitat	7	4	57.1%
Walla Walla	12	6	50.0%
Franklin	35	17	48.6%
Kittitas	7	3	42.9%
Yakima	14	6	42.9%
Grant	64	26	40.6%
Adams	8	1	12.5%
Lincoln	1	0	0.0%
Whitman	1	0	0.0%
King	1	0	0.0%
Total	181	87	48.1%

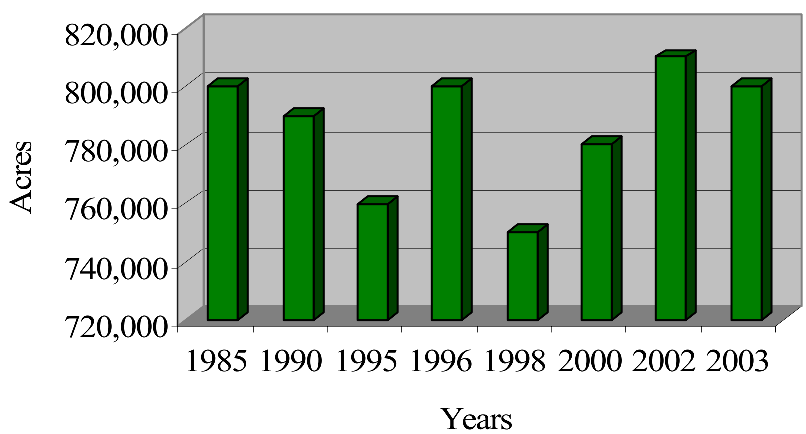
Background

The Washington hay market has had a steady increase in value over the past five years. The value of production for hay currently ranks sixth in Washington among the Top 40 Agricultural commodities (NASS). When looking at Washington's rank in the Nation's agriculture, hay is ranked seventh among all states. In 2003, the value of production for hay in Washington was $414 million, an increase of 1.5 percent from 2002. Alfalfa hay totaled over half of Washington's value in hay at about $289 million (Woodward).

Land Allocation to Hay Production

The area of land allocated to hay production within the state of Washington has also followed a similar pattern as the U.S.; fluctuating considerably over the past 20 years. For the specific years of 1985 and 2003, the number of acres allocated to hay production was the same at 800 thousand, with fluctuations from 10 to 40 thousand acres between these years. Alfalfa acreage remained the same in the state at 490 thousand acres, while all hay acreage decreased slightly from 810 thousands acres in 2002 to 800 thousand acres in 2003 (Figure 1.1). Similar to U.S. hay production, 1995 marked the year with the lowest hay acreage and 2002 the year with the largest hay acreage (NASS).

Figure 1.1. Washington Hay Acreage



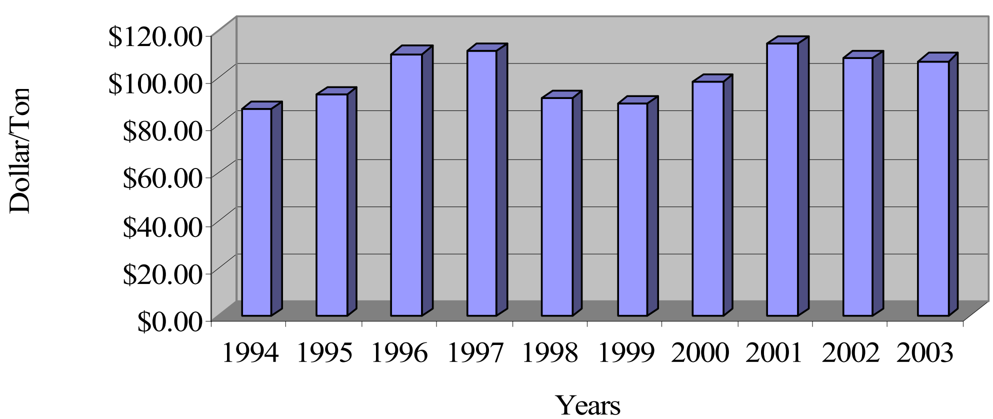
Source: National Agriculture Statistics Service (2004)

Hay Prices

Washington hay prices generally peak during the months of May, June and July. The typical trend for hay prices is to be strong and constant through June and then level off for the remainder of the year. This trend has been consistent from 1996 through 1998 but may not continue into 2004 due to the sharp drop in prices towards the end of the 2003 year (NASS) (Figure 1.2). This drop in prices may prompt a change in quantity supplied as area producers alter production plans, switching to more profitable crops.

A large percentage of hay is being distributed locally (Table 1.2), consequently the need for rail has diminished, whereas, trucking services continue to provide efficient, collection/assembly from producers to brokers in addition to providing access to many demand markets in Western Washington.

Figure 1.2. Washington Alfalfa Average Price



Source: 2004 Hay Market and Export Report, William T. W. Woodward

Annual Hay Tonnage by County

Washington hay is grown in several different counties, but the heavy concentration of production is predominantly in two central counties. Grant and Franklin counties together total 43 percent of the total tons produced in Washington (Table 1.2). The information in Table 1.2, also shown in Figure 1.4, represents the total amount of tonnage per county that was produced in Washington in 2003. The collected data clearly illustrates the dominance that Franklin and Grant County has in hay production. Figure 1.3 represents the number of acres allocated to the production of hay for each county in the state. The number of acres for production per county and the total amount of tonnage (Figure 1.4) per county naturally coincide with each other.

Table 1.2. 2003 Total Annual Hay Tonnages by County

County	Tons
Grant	1,036,000
Franklin	678,000
Adams	269,000
Kittitas	244,000
Yakima	213,000
Walla Walla	118,000
Spokane	115,000
Stevens	100,000
Okanogan	93,000
Lincoln	82,200
Klickitat	60,500
Whitman	38,000
Pend Oreille	26,200
Ferry	21,800
Douglas	18,800
Columbia	17,000
Asotin	14,400
Clallam	13,600
Garfield	6,600
Other counties	437,900
Total	3,603,000

Source: National Agricultural Statistic Services (2004)

Figure 1.3. Acres Allocated to Hay Production, by County, 2003

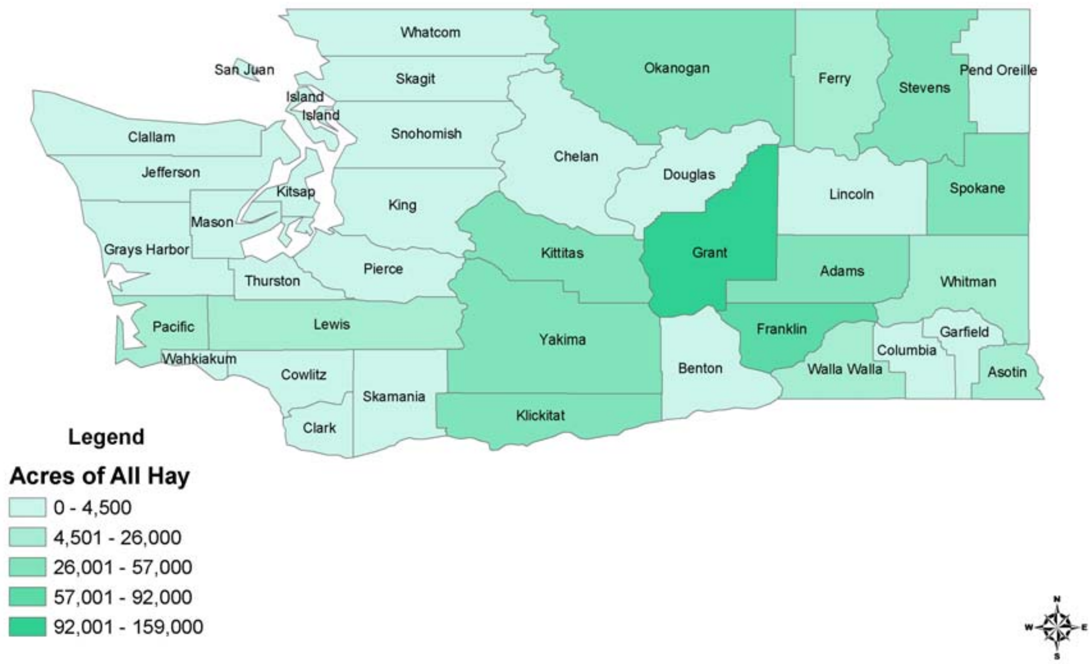
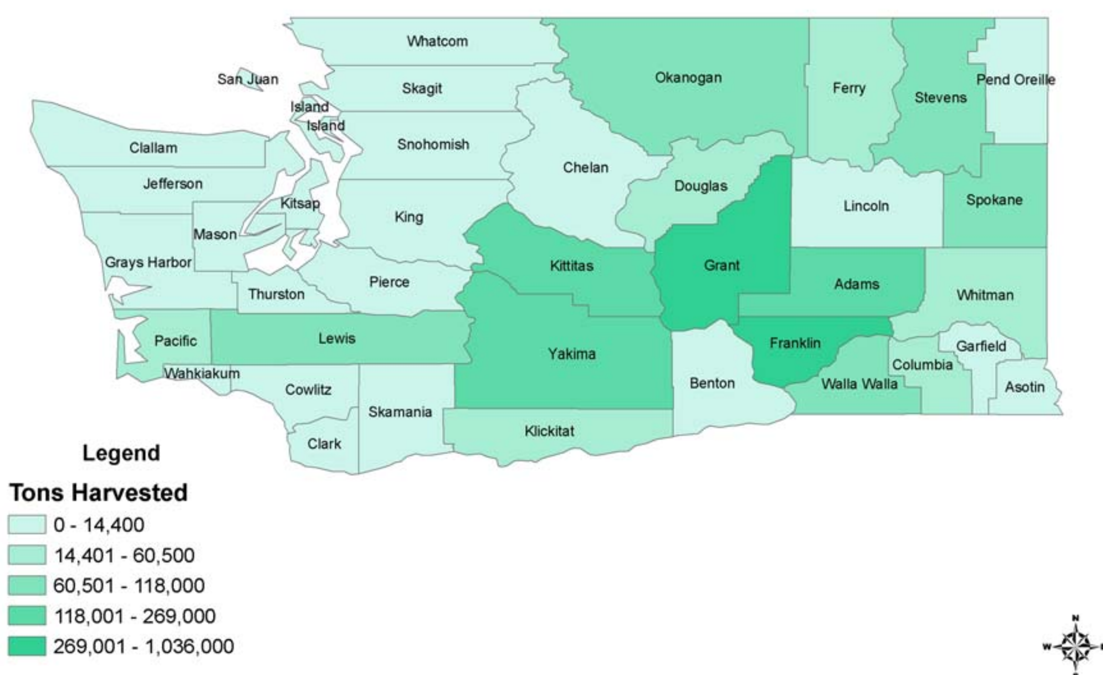


Figure 1.4. Total Tons in Hay Production, by County, 2003



Producer Destinations for Hay Shipments

Hay is transported from locations throughout the state of Washington to various destinations regionally and internationally, but predominantly shipped to feedlots and livestock farms within the state. The secondary location of hay shipments is to one of two destinations; to the coast (Port of Seattle and Port of Tacoma) or the Port of Pasco (bound to Port of Portland). When reaching these locations, hay is loaded into containers that are then placed on barges or ships for further destinations. These locations are destined for export markets in Asia, predominately Japan (Ford). Hay may also pass through an intermediate destination before reaching its final destination. Of the hay shipped from Washington producers a high of 67.2 percent stays in Washington and is transported to various livestock operations and 25.5 percent is shipped to Foreign Markets (Table 1.3).

Table 1.3. Annual Hay Shipments to Destinations from Producers

	Percentage of Each Destination
Destination	Percent
Washington	67.22%
Oregon	3.74%
California	-
Foreign Markets	25.51%
Other	3.53%
Total	100.00%

The average percentage of hay shipped to various destinations from the 12 Washington counties is reported in Table 1.4. Seven of the 12 counties ship at least 80 percent of their hay within Washington. The remaining counties still ship a significant amount (40 percent or higher) within Washington. Douglas, Klickitat, and Okanogan are the only reported counties that do not ship to foreign markets. Oregon had only 3 of the 12 counties shipping hay to them, whereas, California had no reported shipments of hay being transported for a final destination.

Table 1.4. Destination of Hay Shipments by County

	Percent of Hay Shipped				
County	Washington	Oregon	California	Foreign Markets	Other
Benton	73.33%	-	-	26.67%	-
Douglas	100.00%	-	-	-	-
Franklin	46.00%	7.08%	-	46.92%	-
Grant	60.00%		-	34.93%	5.07%
Klickitat	85.00%	15.00%	-	-	-
Okanogan	100.00%	-	-	-	-
Pend Oreille	40.00%	-	-	60.00%	-
Spokane	86.67%	-	-	6.67%	6.67%
Stevens	95.00%	-	-	2.50%	2.50%
Walla Walla	55.74%	24.59%	-	9.84%	9.84%
Whatcom	85.00%	-	-	7.50%	7.50%
Yakima	80.00%	-	-	20.00%	-
Total	67.22%	3.74%	-	25.51%	3.53%

Producer’s Modal Choice for Hay Shipments

Hay producers and processors were asked to identify the percentage of their hay shipped by each mode currently available from their farm/facility. Hay is shipped from producers to market destinations via truck and truck-barge. The percentage of each hay type that is shipped via transportation mode to various destinations is presented in Table 1.5.

Truck to Livestock Farms has a large percentage, representing over 60 percent for alfalfa and grass hay being shipped. The lower percentages of 4.73 percent and 5.27 percent for Truck to River Barge were for hay being shipped to the Port of Pasco (Table 1.5). The hay that is transported to the Port of Pasco is most commonly shipped to processing facilities and then loaded onto river barges to be further processed and shipped to markets abroad. It is important to note this survey was conducted prior to September 2004 when containers were shipped almost exclusively via barge on the Columbia River to the Port of Portland. Subsequent to this date there has been an enormous increase in usage of rail. A relatively large percentage of "other" hay is shipped via the "other" transportation mode, representing 40.36 percent (Table 1.5). This high percentage represents other variety hay being transported via truck to brokers and processing facilities. Major Hay processing facilities locations are in the central region of the state. The location of these facilities increase accessibility to producers all over the state creating short haul shipment opportunities within the state; therefore reduce transportation costs.

Table 1.5. Annual Hay Shipments via Transportation Mode from Producers

	Percentage Shipped Via Transportation Mode			
Transportation Modes	Alfalfa	Grass	Other	All
Truck to Livestock Farms	65.87%	61.04%	32.74%	53.22%
Truck to River Barge	4.73%	5.27%	-	3.33%
Truck to Ocean Port	12.23%	18.55%	26.91%	19.23%
Rail to River Barge	-	-	-	-
Rail to Ocean Port	-	-	-	-
Other	17.16%	15.14%	40.36%	24.22%
Total	100.00%	100.00%	100.00%	100.00%

There is some variation in modal choice among counties (Table 1.6). All counties primarily ship alfalfa using Truck to Livestock Farms except Benton County. This could be because Benton County borders the Columbia River, where access to river barge is more feasible. Trucks are more likely to be used for alfalfa shipments than for grass and other hay because alfalfa is more often shipped directly to a final market. In 11 counties, shipping by truck to the Livestock Farms is the predominant mode of shipment with a range of 0 percent to 100 percent of shipments by this mode. Okanogan and Walla Walla counties strictly ship their hay 100 percent via Truck to Livestock Farms, not utilizing river barge or ocean ports. The least used mode was Truck to River Barge for all counties and all hay types. Rail to river barge and rail to ocean port were not reported by any of the survey respondents.

Table 1.6. Hay Shipments via Transportation Mode by County

	Percent of Hay Shipped																	
	Alfalfa						Grass						Other					
County	Truck to livestock farms	Truck to river barge	Truck to ocean port	Rail to river barge	Rail to ocean port	Other	Truck to livestock farms	Truck to river barge	Truck to ocean port	Rail to river barge	Rail to ocean port	Other	Truck to livestock farms	Truck to river barge	Truck to ocean port	Rail to river barge	Rail to ocean port	Other
Adams	80.0%	-	-	-	-	20.0%	-	-	-	-	-	-	-	-	-	-	-	-
Benton	-	40.0%	10.0%	-	-	50.0%	-	-	-	-	-	-	-	-	-	-	-	-
Douglas	30.0%	-	-	-	-	70.0%	-	-	-	-	-	-	-	-	-	-	-	-
Franklin	47.9%	20.3%	18.2%	-	-	13.6%	1.0%	49.0%	50.0%	-	-	-	-	-	100.0%	-	-	-
Grant	54.0%	-	21.2%	-	-	24.8%	47.5%	6.5%	36.0%	-	-	10.1%	-	-	100.0%	-	-	-
Klickitat	100.0%	-	-	-	-	-	60.0%	-	-	-	-	40.0%	-	-	-	-	-	-
Okanogan	100.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spokane	92.9%	-	-	-	-	7.1%	80.0%	-	-	-	-	20.0%	-	-	-	-	-	100.0%
Stevens	68.3%	-	-	-	-	30.6%	59.3%	1.4%	-	-	-	39.3%	-	-	-	-	-	100.0%
Walla Walla	100.0%	-	-	-	-	-	100.0%	-	-	-	-	-	-	-	-	-	-	-
Whatcom	100.0%	-	-	-	-	-	100.0%	-	-	-	-	-	10.0%	-	-	-	-	90.0%
Yakima	84.6%	-	-	-	-	15.4%	100.0%	-	-	-	-	-	70.0%	-	-	-	-	30.0%

Seasonality of Hay Shipments

Hay is harvested throughout the summer months with the first cutting beginning in May. On average, 31 percent of hay is delivered from producers to various destinations during October-December time period (Table 1.7). This time period coincides with the period prior to the harsh winter months and immediately following the last harvest. Thus, livestock operations are securing anticipated feed requirements and hay producers are less constrained by harvest to ship during this time period. Percentages of hay delivered are lowest during April-June at 19.3 percent. The low percentage of hay distribution reflects the abundance of lush pasture grass that is used for grazing in the later spring months. The largest variation from the seasonal transportation pattern is the July-September time period. This time period has an average of 10.28 percent more hay delivered then the April-June time period. The increase of hay distribution from spring to summer months is due to the increase in consumption from cattle. July-September is an important time period for producers to fatten their cattle for slaughter. The cattle are gaining weight by consuming more roughage which increases the distribution during this time period.

The percentage of alfalfa, grass and other hay shipped varies slightly throughout the year. There is a pattern with alfalfa, grass, and other hay having a greater percentage of transportation in the July-September and October-December time period, reflecting the abundance of hay being supplied after the summer’s cuttings. The January-March and April-June time periods low percentages reflect the amount of hay availability prior to harvest. Alfalfa shipments show less overall variation during the year than grass and other hay for all shipment combinations (Table 1.7). Shipments vary between 18.87 percent in April-June to 29.87 percent in July-September.

Table 1.7. Annual Hay Distributed by Time Period

	Percent of Hay Distributed			
Time Period	Alfalfa	Grass	Other	All
January-March	22.47%	20.53%	17.29%	20.10%
April-June	18.87%	19.87%	19.16%	19.30%
July-September	29.78%	32.33%	26.64%	29.58%
October-December	28.88%	27.28%	36.92%	31.03%
Total	100.00%	100.00%	100.00%	100.00%

There is moderate variation among counties as to when hay is shipped. On average, 15 counties ship the majority of hay in the October-December time period. Franklin and Grant counties have a fairly steady flow of alfalfa hay shipments throughout the year. As for grass and other hay, there are extreme variations throughout the year in these two counties (Table 1.8). Adams, Benton, Douglas and Okanogan counties did not report any shipments of grass or other hay. These counties only reported alfalfa shipments, which show large variation throughout the four seasons. Grant, Kittitas, and Whatcom are the only counties to have reported shipment in all time periods with alfalfa, grass and other hay.

Table 1.8. Seasonality of Hay Shipments from Producers by County

	Percent of Hay Shipped											
	Alfalfa				Grass				Other			
County	Jan-March	April-June	July-Sept	Oct-Dec	Jan-March	April-June	July-Sept	Oct-Dec	Jan-March	April-June	July-Sept	Oct-Dec
Adams	22.00%	11.00%	16.00%	51.00%	-	-	-	-	-	-	-	-
Benton	14.86%	17.14%	49.14%	18.86%	-	-	-	-	-	-	-	-
Douglas	-	20.00%	30.00%	50.00%	-	-	-	-	-	-	-	-
Franklin	28.32%	18.65%	24.23%	28.80%	16.50%	0.50%	66.50%	16.50%	40.00%	-	-	60.00%
Grant	27.19%	22.45%	23.51%	26.86%	25.53%	21.33%	22.60%	30.53%	53.00%	13.00%	19.00%	15.00%
Grays Harbor	-	-	-	-	20.00%	20.00%	50.00%	10.00%	-	-	-	-
Kittitas	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	27.50%	37.50%	12.50%	22.50%
Klickitat	8.75%	11.25%	52.50%	27.50%	30.00%	10.00%	10.00%	50.00%	-	-	-	-
Okanogan	20.00%	-	20.00%	60.00%	-	-	-	-	-	-	-	-
Pend Oreille	-	-	-	-	10.00%	60.00%	20.00%	10.00%	-	-	-	-
Spokane	5.74%	11.57%	58.20%	20.49%	10.53%	27.63%	43.42%	18.42%	-	9.00%	36.00%	55.00%
Stevens	55.67%	10.64%	18.44%	15.25%	12.86%	20.71%	32.14%	34.29%	-	15.00%	50.00%	35.00%
Walla Walla	15.83%	15.00%	27.50%	41.67%	10.00%	12.50%	65.00%	12.50%	-	-	-	-
Whatcom	27.50%	27.50%	22.50%	22.50%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
Yakima	31.54%	16.57%	25.95%	25.95%	33.33%	5.00%	33.33%	28.33%	-	-	-	-

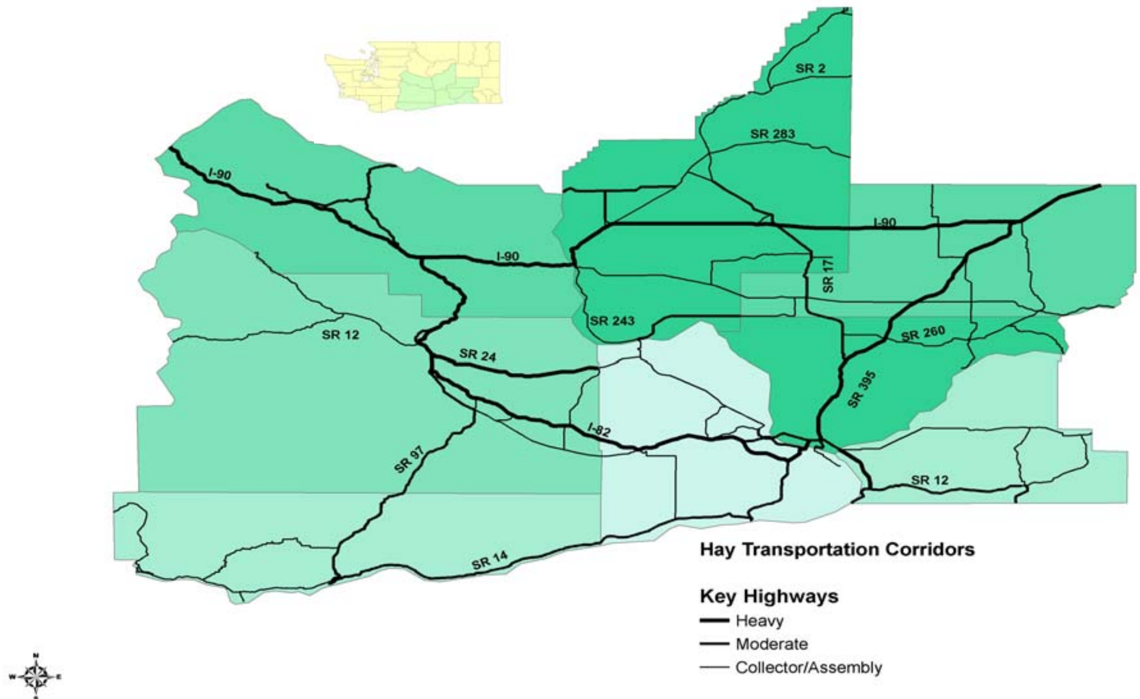
Primary State Highways from Producer to Processor

When examining the transportation of hay there are three separate, identifiable segments that should be examined. There is the raw product to processor, raw product to livestock farm and finished product from processors to final markets. It is beneficial for hay producers that want to sell their hay internationally to first process the hay for more efficient packaging (either compressed or cubed hay), typically performed at separate processing facilities owned by hay marketing firms or hay brokers. This is primarily due to the high costs of owning and operating a processing unit. Also, the processing facility will then find international buyers for the hay.

Hay harvest starts in late spring and runs through the end of the summer. During this time of year the hay industry related traffic peaks for processors, while producer's shipments remain fairly steady throughout the year. The harvest period involves several tons of hay being transported via truck across the state to processor or final markets.

There are three major routes that are used for movements of hay in the industry as identified by survey respondents; I-90, I-82 and SR 395 (Figure 1.5). These three major routes run through the two largest hay producing counties (Franklin and Grant) and provide both north-south and east-west access to markets within and beyond the state. A number of major hay processing facilities are located in these two counties making these routes critical to the hay industry.

Figure 1.5: Key Highways Supporting Hay Producer to Processor Shipments



SR-12, SR-14, SR-24 and SR-97 also generate significant truck traffic that intersects with I-90, I-82 and SR 395 for further shipment. These state roads are located in the central southern part of Washington which houses the largest hay production in the state as illustrated in Figure 1.5.

Processor's Modal Choice for Hay Shipments

After the hay has been transported to a processing facility a large percentage is shipped for outbound movement by truck. After it has been processed, hay is predominately destined for foreign markets via Truck or barge to Ocean Ports. Other hay is the only hay that is shipped 100 percent Truck to Ocean Ports. Alfalfa and grass both come in close with a high of 63 percent (Table 1.9). Table 1.8 clearly represents that few respondents shipped hay by rail.

Table 1.9. Annual Hay Shipments Via Transportation Mode from Processors

	Percent of Hay Shipped			
Destination	Alfalfa	Grass	Other	All
Truck to Livestock Farms	12.05%	15.87%	-	9.31%
Truck to River Barge	24.10%	3.17%	-	9.09%
Truck to Ocean Port	62.65%	80.95%	100.00%	81.20%
Rail to River Barge	-	-	-	-
Rail to Ocean Port	1.20%	-	-	0.40%
Other	-	-	-	-
Total	100.00%	100.00%	100.00%	100.00%

Seasonality of Hay Shipments by Processors

Hay processors have a comparatively consistent percentage of hay that is received and distributed throughout the year. One of the most evident patterns for other hay transportation is the even distribution of shipments at 25 percent received and distributed throughout the year (Table 1.10 and 1.11). Shipments of alfalfa and grass hay vary in the four seasons on the receiving end, but then remain even for distribution. The percentage of alfalfa and grass hay distributed during January-March is consistent at 20.53 percent, but then increases to 33.87 percent in the July-September time period (Table 1.11). Overall, there is more variation during the time when processors receive the hay rather then distribute it, which is indicative of the natural seasonal influences of hay production.

Table 1.10. Annual Hay Received by Time-Period

Time Period	Percent of Hay Received			
	Alfalfa	Grass	Other	All
January-March	15.00%	17.50%	25.00%	19.17%
April-June	21.67%	22.50%	25.00%	23.06%
July-September	41.67%	37.50%	25.00%	34.72%
October-December	21.67%	22.50%	25.00%	23.06%
Total	100.00%	100.00%	100.00%	100.00%

On average, hay which is received at processors is the lowest during the January-March time period at 19.17 percent, while the high was 34.72 percent in the July-September time period (Table 1.10). The distribution of all hay had a high of 30.91 percent in the July-September time period, with all other seasons remaining fairly consistent (Table 1.11). Processing facilities operate on a yearly base, not seasonal. The percentage of hay that is received at a processing facility experiences more of a variation than the processed hay that is distributed from these facilities. Hay shipment receipts coincide with harvest, whereas the hay that is distributed reflects the stable demand that is requested throughout the year.

Table 1.11. Annual Hay Shipments from Processors by Time-Period

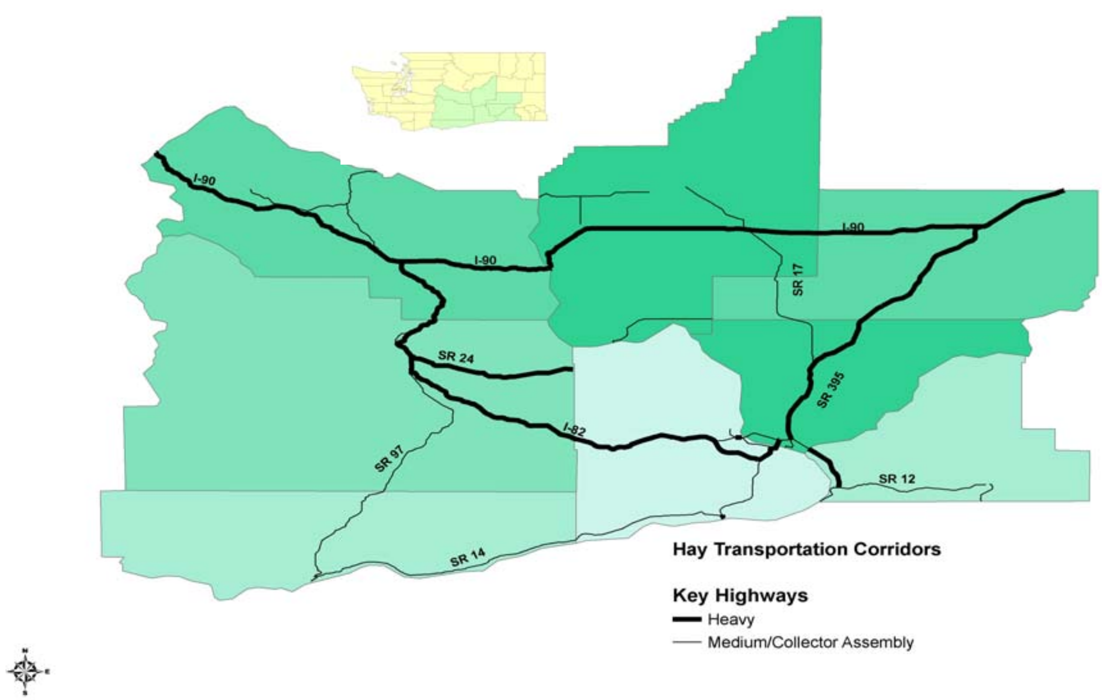
Time Period	Percent of Hay Distributed			
	Alfalfa	Grass	Other	All
January-March	20.53%	20.53%	25.00%	22.02%
April-June	21.67%	21.67%	25.00%	22.78%
July-September	33.87%	33.87%	25.00%	30.91%
October-December	23.87%	23.87%	25.00%	24.25%
Total	100.00%	100.00%	100.00%	100.00%

Primary State Highways from Processor to Final Destination

Key highways that support hay shipments from major hay processing facilities to final markets include; I-90, I-82, SR 24 and SR 395 (Figure 1.6). These highways support hay movements from hay processors to final destinations. I-90 and SR 395 are surrounded by the two leading hay producing counties in the state. Franklin and Grant County produced 43 percent of the total tons produced in Washington that travel on these highways.

After the hay has been processed, it is transported by truck to the Port of Seattle or the Port of Tacoma for further shipment. I-90 is a major corridor to large markets domestically and also internationally. Processed hay can also be barged from the Port of Pasco down the Columbia River for further shipments.

Figure 1.6: Key Highways Supporting Hay Shipments from Processor to Final Market



Research Objectives

The major objective of this research was to develop a transportation optimization model of hay shipments out of Washington that investigated impacts to shipping companies leaving the Port of Portland. Specific objectives were to:

1. Obtain a general perspective of the structure and performance of the hay industry in Washington, through hay producer and processor surveys.

2. Determine the existence and usage of transportation mode infrastructure by individual producers and processors.

3. Determine industry shifts in transportation usage and marketing actions in reaction to transportation changes.

4. Investigate the impacts on industry structure and operating practices as firms react to these changes in the market.

CHAPTER 2

MODE AND COST IMPLICATIONS DUE TO LOSS OF CONTAINER SERVICES AT THE PORT OF PORTLAND

Introduction

A recent change in the regional transportation landscape and one impacting hay shipments in Washington State involves the reduction of container services at the Port of Portland. As a result, the Port of Seattle and Tacoma have experienced a considerable increase in hay shipments since September of 2004. Prior to this date, containers filled with hay were shipped almost exclusively via barge on the Columbia River to the Port of Portland. After reaching Portland, the containers were then loaded onto one of three steamship lines: Hyundai, K-Line, or Hanjin. As of September 2004, Hanjin is the only carrier that calls on the Port of Portland. K-Line and Hyundai now require producers to haul their containers to the Port of Tacoma and Seattle by either truck or rail. As a result, barge shipments of containers out of the Port of Pasco decreased 75 percent, while rail shipments to the Port of Tacoma and Seattle grew from 40 containers per month to 600 containers per month. Rail shipments are expected to increase even further to 1000 containers per month in early 2005 (Port of Pasco). Transportation costs will undoubtedly increase for shippers from the Port of Pasco's barge terminal who are unable to secure space on remaining Portland cargo ships. Those shippers are now forced to spend more money to send containers by truck and rail to the ports of Seattle and Tacoma (St. John, Aug. 2004).

Shippers of hay and other agricultural commodities will adjust to this change by shifting from barge to rail and truck, even though shipping by rail or road costs an average of twice as much as shipping by river. Shippers are being paid three to four times as much to ship imports from China to the United States as they can get for the return trip (St. John, Nov. 2004). Chinese products headed to America are commanding a much higher rate of return for shippers than America's commodities headed back to Asia. Therefore, many shippers are choosing to return empty cargo containers to be filled at East Asian ports rather than wait for American goods for the return trip (St. John, Aug. 2004). Eastern Washington agricultural exporters save an estimated $500 per container in shipping costs due to the fact that large numbers of "empties" are passing through on their way back to Asia (Pascall). As China's exports boom, the need for such efficiencies will only grow. Bigger ports such as those in Seattle and Tacoma will benefit from this (Oregonian, 2004).

Literature Review

There have been numerous studies conducted that attempt to model freight transportation systems, utilizing different modeling and programming approaches. Many of these studies focus on different issues or have objectives much different then the focus of this modeling effort. The summary of precious studies offered here provides a collection of research that contributes to the understanding of transportation optimization modeling.

One recent study sought to investigate and create the most effective investment plan for an inland transportation infrastructure development and to evaluate the inland container transportation system in Korea (Koh Y-K, 2001). This modeling approach aims to identify the optimal inland container transport system by matching mathematically a framework for dynamic programming with a mechanism for linear programming with the concept of a systems approach and a heuristic algorithm. The modal splits for each region's container traffic depend on the annual growth rates of rail and coastal shipping. The share of each transport mode in each region's container traffic is based on the current capacities of each mode (Koh Y-K, 2001).

This model is used to identify the optimal investment and expansion plan over time leading to the development of eight berths in Kwangyang completed in 2002, 12 berths in Kwangyang from 2003-2008, and finally 14 berths in Gadukdo from 2009-2014. At the beginning Kwangyang port will attract the majority of the container cargo, with entry of Gadukdo after 2014; part of the traffic will switch to Gadukdo (Koh Y-K, 2001). This approach offers considerable flexibility for both optimizing model allocations and forecasting future continued growth at selected ports.

Another related study investigated inter-terminal transport systems for future growth of terminals. Containers have to be transported from the stack to other modes of transportation, like barges, rail and road (De Koster, 2003). With expected growth of terminals in the future, this inter-terminal transportation is more important. A multi-trailer system is studied in Krustjens el al. (1996) with a technique which tries to minimize the number of empty trips. An integer linear problem model is developed to obtain the minimum number of trucks needed (De Koster, 2003). It is concluded that the utilization of the multi-trailer systems can be reduced dramatically, but the number of transport vehicles can hardly be reduced.

Additional studies have been conducted for transporting containers to other destinations by rail. In Kozan (1997) an analytically based computer simulation model is developed to describe the container progress at a rail container terminal. The major factors influencing the throughput time of containers, which is a function of cranes, stackers and transfer systems, are discussed. The simulation model is combined with heuristic rules to describe the progress of containers in the system (De Koster, 2003). It can be concluded, by applying the Wilcoxon Rank Test between the simulation output and the observed for the total throughput times of containers, that the simulation program imitates the rail terminal effectively. The allocation of containers on trains was also observed using different models and solution methods tested on realistic data. It can also be concluded, the number of containers move and the use and quantity of equipment can be decreased (De Koster, 2003).

Another modeling approach is a simulation model that can be used in the design and evaluation of terminal facilities at the landslide (Ballis and Abacoumkin, 1996). Five heuristics are incorporated into this model to investigate the performance of the system. Experiences of operations managers are included in the model to obtain a realistic model. The comparison between different studies indicates that a shorter truck service time is feasible but that this leads to an increase of traffic conflicts in the internal transport network (De Koster, 2003).

Kozan (2000) addresses the problem of minimizing the handling and traveling times of import and export containers from the time the ship arrives at the port until the time they are leaving the terminal and vice versa. The complete trajectory that containers go through from the ship to road or rail terminals via storage areas is collaborated into a network model. The objective in this model is to minimize total throughput time, which is the sum of handling and traveling times of containers (Kozan, 2000). Long-term data collection is required before implementing the model. The results of the model can be used as a decision tool in the context of investment appraisals of multimodal container terminals (Kozan, 2000).

Park and Regan (2004) evaluate the evolution of capacity models in transportation. They use an optimization-based model that estimates the maximum freight volume that a rail network can accommodate while satisfying a set of constraints including fixed origin-destination traffic pattern and resources (Morlok and Riddle, 1999). A variant of the model is also developed by permitting the variations in the base traffic pattern to determine where capacity must be added to accommodate increased traffic. Freight movements depend not only on a modal network capacity, but also on the ability of system users to substitute transportation modes and transfer across networks through intermodal connections (Park and Regan, 2004).

Koh Y-K (2001) investigated the most effective investment plan for an inland transportation infrastructure development and evaluated the inland container transportation system in Korea. Koh Y-K (2001) investigated a given town’s evolution of construction towards having a comparative advantage in servicing rail-carried cargo. De

Koster (2003) studies were done to analyze an inter-terminal transport system for future growth of terminals for both rail and truck. Additional studies were done pertaining to this by Krustjens el al. (1996) which studied a multi-trailer with a method that is based on a technique which tries to minimize the number of empty trips. Kozan (2000) addresses the problem of minimizing the handling and traveling times of import and export containers from the time the ship arrives at the port until the time they are leaving the terminal. Park and Regan (2004) evaluate the evolution of capacity models in transportation specifically determining where capacity must be added to accommodate increased traffic.

The objective of this research is to develop a transportation model that accurately and realistically represents hay shipments throughout Washington's multi-modal transportation. This is accomplished by utilizing a constrained-optimization linear programming modal, equipped with firm-level transportation data required via industry surveys.

CHAPTER 3

TRANSPORTATION OPTIMIZATION MODEL

Data and Methods

In addition to the industry information collected by producer and processor surveys and presented earlier, the Port of Pasco, Portland, Seattle and Tacoma were all contacted by phone to obtain additional information on volume of hay shipments into final destinations. The amount of hay (in tons) that was received and distributed from each port was obtained, in addition to information from each port regarding product form, number of containers leaving each port annually, tonnage per container, destination of container and mode of transportation.

Information on feedlot operations in Washington State was also from the Licensed Certified Feedlots, Washington State Department of Agriculture (WSDA, 2004). The feedlots were also contacted by phone and volume information for each location was either obtained or approximated.

Trucking rates were obtained by phone interviews with processors and selected producers. The rate was given in a total transportation costs per one-way trip. The total transportation costs included fuel surcharge, mileage and tonnage. Processors and the ports' trucking rates were slightly lower then the producer's rates. This was due to the lower per ton rate that the processors offered.

Northwest Containers is the Pacific Northwest's foremost provider of containerized logistics transportation services. Rail rates were supplied by Northwest

Container. Prices on rail rates for shipping hay are based on volume. Rates decrease if the container is being shipped both ways. There is an additional fuel surcharge that is added to the quoted price.

The Port of Pasco was contacted for barge rates. Northwest Container Services, under contract with the Port of Pasco, also operates an Intermodal Transportation Facility located at the Big Pasco Industrial Center in Pasco, Washington. The facility ships agricultural products produced in southeast Washington bound for Asian markets. Hay is a primary commodity that is transported by barge down the Columbia River to be shipped to international markets. The port quoted a round trip dry storage rate, in which hay would be categorized as, plus a handling fee.

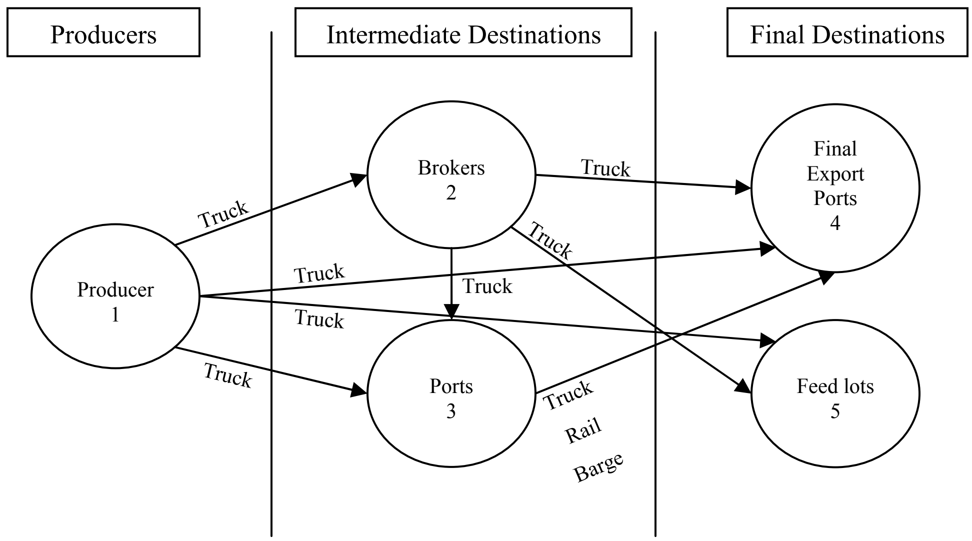
Transportation Optimization Model

A transportation model is developed for this research to accurately and realistically represent hay shipments throughout Washington's multi-modal transportation network. A cost minimization transportation optimization model is developed for hay shipments out of Washington that is then used to investigate impacts to hay producers, brokers and ports.

The collection of allowable origin and destination combinations of hay shipments in Washington State are displayed in Figure 3.1. There are three categories: Producers, Intermediate Destinations which include brokers and ports (Pasco and Portland) and Final Destinations which include final export ports (Portland, Seattle and Tacoma) and feedlots. The producers act as the source of hay shipments originating throughout the state and the final destinations serve as the end demand points. Each producer in the state has the option of transporting their hay by truck to brokers, intermediate ports, final export ports and/or feedlots. Producers also can ship hay directly to the final destinations or to intermediate destinations and from there it will be shipped to the final destinations. The intermediate destinations act as temporary collection/processing points from which hay is then allocated to final destinations. The total amount of hay produced in the state (3.6 million tons) will eventually move from producers to final destinations.

Since the intermediate destinations (nodes 2 and 3 in Figure 3.1) are the only transshipping locations, they each act both as a potential destination and as a potential source. The number of movements transshipped through each location is included as an option for both the demand for the locations as a destination and the supply for that location as a source (Hillier and Lieberman, 1974). Brokers transport all processed hay by truck to final export ports, river ports and feedlots. After hay has been processed by a broker its primary destination is to foreign markets. Ninty-one percent of processed hay is exported to foreign markets while 9 percent is distributed domestically. Intermediate ports have the option of transporting by barge, rail or truck. The Columbia River is an inexpensive alternative to shipping hay by barge from the Port of Pasco to the Port of Portland. These two intermediate ports transport hay exclusively to final export ports.

Figure 3.1. Transshipment Possibilities for Original Destination Combinations



The objective of individual producers and/or processors is to determine the optimal allocation and routing of shipments that minimize total transportation costs. Most all producers and processors have access to multiple modes of transportation via orts, but are generally limited to truck for shipments leaving the farm. There is a decision process for choosing the mode that best fits the objectives of the producer and/or processor.

The transportation optimization model allocates shipments in order to minimize total transportation costs, as defined by the objective function (1). The cost per unit (c_{ijkl}) for shipments between origin i, intermediate destination j and final destination k via mode l ($/ton) is multiplied by the amount of hay (x_{ijkl}) that is shipped from origin i to intermediate destination j to final destination k via mode l (tons). Thus, the objective is to minimize total cost subject to five separate supply and demand constraints which add realism to the model. The objective function can be specifically stated as follows:

(1) Minimize $\sum_i \sum_j \sum_k \sum_l c_{ijkl}\, x_{ijkl}$

i = origin
j = intermediate destination
k = final destination
l = mode

s_i = supply of hay at origins (in tons)
d_k = demand for hay at destinations (in tons)
c_{ijkl} = cost per unit shipment between origin i, intermediate destination j and final destination k on mode l ($/ton)

The decision variables for this model are the elements x_{ijkl} under control for the model and their values determine the optimal solution of the model. The decision variables x_{ijkl} in function (2) is equal to the amount of hay that is shipped from origin (i) to intermediate destination (j) to final destination (k) on mode (l) (tons). The transportation model only allows positive shipments between each origin and destination point.

(2) x_{ijkl} = amount of hay to ship from origin i to intermediate destination j to final destination k on mode l (tons)

with $x_{ijkl} \geq 0$, for all i, j, k and l

The optimization model includes basic supply and demand constraints for realism. The supply constraint limits total shipments from each origin (i) that is available from each supply point, defined by S_i (3). Thus, the sum of all shipments from each producer cannot exceed the available production of each producer. The demand constraint in function (4) observes that the sum of all shipments from origin (i) and/or intermediate destination (j) has to be greater than or equal to the demand of each final destination (k), defined by D_k.

Observe supply limit at producer (i):

(3) $\sum_{jk} x_{ijk} \leq S_i$, for all i

Satisfy demand at market (k):

(4) $\sum_{ij} x_{ijk} \geq D_k$, for all k

Function (5) displays the rail constraints for hay shipments within Washington State. The rail constraints observes that the sum of mode (l) (rail) for the amount of hay from origin (i) to final destination (j) has to be less than or equal to the rail capacity for all final destination (k).

(5) $\sum_{l} x_{ik} \leq R_k$

The barge constraint assures that the sum of mode (l) (barge) for the amount of hay from origin (i) to final destination (j) has to be less than or equal to the barge capacity for all final destination (k).

(6) $\sum_{l} x_{ik} \leq B_k$

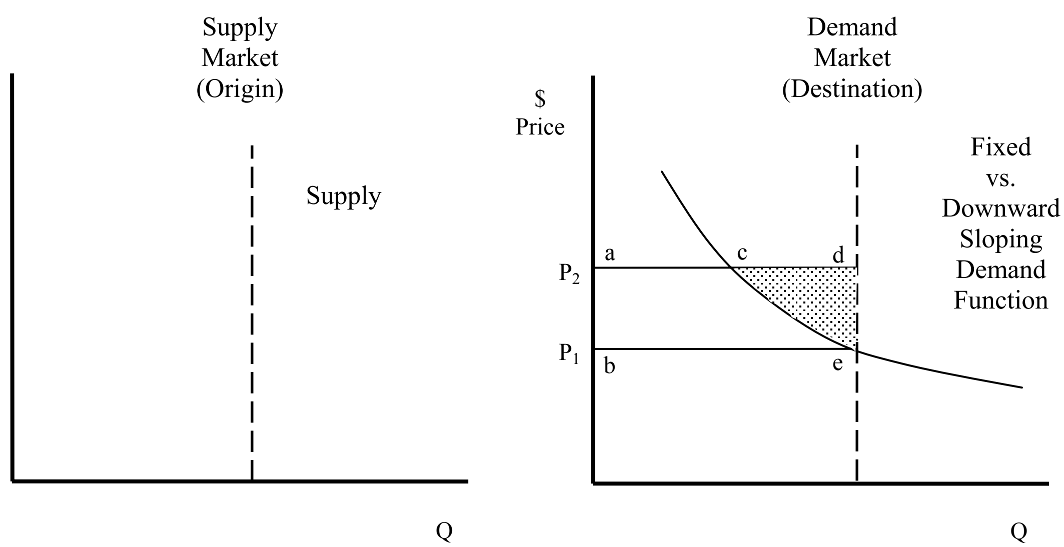
Constraints are needed in this hay transportation optimization model to find the least-cost optimal solution that would identify flows and modes that best satisfy the objective function. Without some reality constraints on the amount of shipments leaving each origin point by truck, rail or barge, all hay shipments from origin points would be entirely shipped directly to final destinations; never passing through an intermediate destination. Though, this would be the least-cost optimum it is not realistic of hay shipments out of Washington State. The rail and barge constraints are added to accurately reflect reality and better estimate the impacts of increased rail usage since September 2004.

There are 40 hay production locations serving as origin points which represent the majority (by volume) of hay tonnage by area in the state of Washington. The quantity of supply from each origin point enters the linear program model as a constant (perfectly inelastic). Given the nature of hay production, this particular assumption related to price and quantity responses in the hay supply market are not unjustifiably limiting. Production decisions within the hay industry require long-term financial commitments in capital, land and equipment. The price elasticity of supply is certainly inelastic, approaching perfectly inelastic, as illustrated in Figure 3.2.

This transportation optimization model includes 4 processors, 2 ports and 9 destination markets (k) within Washington State. The quantity of hay demanded at each destination market is also treated as a constant. The true demand function for hay is downward sloping to the right instead of perfectly inelastic (Figure 3.2) due to the fact that most consumers are sensitive to price fluctuations.

Figure 3.2 graphically presents the implications from treating demand as a fixed constant instead of a downward sloping demand function. The financial impact from an increase in price from P_1 to P_2 is equal to the area a, d, e, b without an associated quantity response to changing prices. This corresponds to the reduction in consumer surplus due to a price increase. Realistically, as prices increase from P_1 to P_2, consumers will adjust their quantity consumed by substituting away from Washington hay to markets elsewhere. As a result, the true loss in consumer surplus will be the smaller area defined as a, c, e, b. The difference between the two estimation measures is represented in Figure 3.2 shaded area. The loss is consumer surplus is overstated by treating demand as fixed; this amount is also represented in the shaded area. However, in order to estimate unique supply and demand schedules for each market an overwhelming amount of firm level data would be required through time. This information isn't available and therefore this transportation optimization model approximates demand with the aforementioned limitations.

Figure 3.2. Supply and Demand Market Relationships



CHAPTER 4

FINDINGS AND RESULTS

Scenarios

Three separate scenarios are analyzed in this study in order to estimate the cost and volume implications resulting from loss of container services at the Port of Portland. A constrained optimization base-case scenario is first developed and presented to accurately reflect least-cost flows of hay shipments prior to September 2004 to identify and compare the implications of modal and routing changes. The data and information collected from producer and industry surveys is assumed to accurately represent Washington hay shipments within the state. The optimization model reflects near real-world hay flows assuming that hay movements are determined by shippers seeking to minimize transportation cost by choosing the mode and destination market in their least-cost feasibility set.

The volume of hay that moves for the year in total does not vary and total supply must equal total quantity demanded. Thus, no hay is stored and subsequently sold at a later date. This model compares changes in transportation cost when final destination (k) shipments and modal choice changes occur during a given period of time but the volume shipped per supply origin (i) remains consistent. The amount that is received into each destination market on each mode does vary depending upon a variety of factors such as relative geographical proximity between individual supply and destination markets and the relative rates between truck, rail and barge for each origin/destination combination.

The optimal base scenario transportation flows reveal the comparative advantages of each mode. Recent studies conducted the summer of 2004 found that destination markets, such as Portland, were most viable by barge due to relatively lower transportation rates. The majority of hay movements were shipped via truck due to factors listed above; geographical location, relative rates, etc. The base scenario did not show much activity on rail. There was very minimal tonnage shipped via rail by processors and zero shipped directly by producers. Rail is not a viable option for producers due to a lack of accessibility and the difficulty with loading/unloading hay from truck to rail container. The noticeable fact that minimal movements were shipped via rail is evidence that service related modal advantages of truck as compared to rail include; timeliness, less handling, point-to-point pickup and delivery, and schedule flexibility are all significant to hay transportation.

The second scenario utilizes a similar model but eliminates all barge activity and relaxes the volume constraint on rail. With no constraint on rail, much of the reallocated hay shipments will move by rail due to its least-cost advantage over truck. Portland's hay demand is set to zero; meaning all hay that was shipped to Portland is now redistributed to Seattle (25 percent) and Tacoma (75 percent). The Port of Pasco will continue to handle the same volume but now distributed between truck and rail. No other changes were made to the model. This model represents the hay flows after September 2004 when two of the three main steamship lines pulled out of the Port of Portland and now call on the Port of Seattle and Port of Tacoma. Due to this event, the barge activity on the Snake/Columbia River that used to flow from the Port of Pasco to the Port of

Portland has diminished considerably for all container movements and ceased all together for hay container shipments. While there are no changes in the total volume of shipments, the modal share of each destination and the transportation costs will change under the new least-cost optimal solution. These model results reflect the different transportation costs that are realized by the modal shifts from barge to truck and rail.

The final scenario maintains all assumptions as Scenario 2 but introduced a 25 percent increase in trucking rates due to truck shortages brought about by increased demand and limited supply. Scenario 3 is designed to provide a realistic representation of hay movements once market conditions have responded to the reduction in container services at the Port of Portland. This scenario reflects the new transportation costs, volumes by mode and also the shadow prices that will occur due to the shift in the model.

This 25 percent increase in truck rates is the result of several contributing factors. The major issue being the loss of container services at Port of Portland due to two of the three oceanic steam ship lines pulling out. The containers that were once barged down the Snake/Columbia River now have to be redistributed to truck and rail leading to increased demand for truck services. The second issue that affects the increase in truck rates is the recent changes to the federal guidelines controlling truck drivers' hours of service. The new rule states that truck drivers and operators may drive 11 hours after 10 hours of being off-duty but cannot exceed 14 hours of driving after the same 10 hour break. Trucking firms will need additional drivers and equipment to compensate for lower hours of operation and productivity per driver (Jessup, 2005). This change is expected to increase costs of operation. The third issue that affects the increase in trucking rates is the national and regional truck driver shortage. Truck drivers are increasingly seeking alternative employment as they choose not to deal with the difficult working conditions and relative low pay (Jessup, 2005).

Results

Base Scenario I

The optimal base scenario outlines transportation flows of each mode. All hay movements were shipped via truck from producers, their only available transportation mode. The base scenario did not show any activity on rail from producers given that the model did not allow this option due to the lack of loading/unloading facilities and timeliness of shipments. The large majority of shipments from producers go directly to feedlots within the state, accounting for 57 percent of all producer shipments. The next largest destination for hay shipments from producers is hay brokers, to be processed and then reallocated for further final destinations. Producers shipped very little hay (1 percent) directly to Portland due to the distance in comparison to Seattle and Tacoma (Table 4.1). A producer’s proximity is a leading factor determining where they ship their hay. Their geographical location, trucking rates, transportation cost all influences the choices of destination for shipments. For example, Producer 16 and 20 located in the northwest corner of the state, transport all their hay directly to the Port of Seattle and Tacoma because of their relatively close distance to the ports. Where as, Producer 17

Table 4.1 Volume of Hay Shipments, by Scenario

	Volume (Tons)								
Type of Movement	% of total hay distribution	Base Scenario 1	% of total hay distribution	Scenario 2	% Δ change from Base Scenario	% of total hay distribution	Scenario 3	% Δ change from Base Scenario	% Δ change from Scenario 2
Producer to Intermediate Destination (Truck):									
Broker	24%	880,573	24%	880,573	0%	24%	880,573	0%	0%
Port	3%	119,980	3%	119,980	0%	3%	119,980	0%	0%
Producer to Final Destination (Truck):									
Seattle	9%	334,578	15%	550,770	65%	15%	550,770	65%	0%
Tacoma	6%	200,777	0.3%	10,001	-95%	0.3%	10,001	-95%	0%
Portland	1%	25,416			-100%			-100%	
Feedlots	57%	2,041,676	57%	2,041,676	0%	57%	2,041,676	0%	0%
Total	100%	3,603,000	100%	3,603,000		100%	3,603,000		
Broker to Final Destination (Truck):									
Port of Pasco	22%	193,726			-100%	4%	35,223	-82%	100%
Feedlot									
Port of Seattle			11%	93,566	100%	11%	93,566	100%	0%
Port of Tacoma	28%	249,422	89%	787,007	216%	85%	751,784	201%	-4%
Port of Portland	50%	437,425			-100%				
Total	100%	880,573	100%	880,573		100%	880,573		
Port to Final Destination:									
Port of Seattle									
Truck									
Rail									
Port of Tacoma									
Truck									
Rail			100%	119,980	100%	100%	155,203	100%	29%
Port of Portland									
Truck									
Rail	48%	149,697			-100%				
Barge	52%	164,009			-100%				
Total	100%	313,706	100%	119,980		100%	155,203		

(located in near Mattawa) ships directly to surrounding Feedlots 2, 3, 4 and 6 (Figure 4.10). Producer 17 is within a few miles of these four feedlots making it more cost effective to ship directly.

A total of 880,573 tons of hay is shipped from producers to brokers, primarily from producers within close geographical proximity to their facility. Producers ship 24 percent of their total production to brokers. Two of the four brokers represented in the model are located in Central Washington where access to the Port of Seattle and Tacoma is more feasible via truck. The second two brokers are located in Pasco. The Port of Pasco is a major corridor for shipments via barge down the Columbia River to the Port of Portland.

Of the 880,573 tons of hay shipped from producers to brokers, 22 percent is then transported via truck to the Port of Pasco for a total of 193,726 tons. These hay shipments are from the two brokers located near the Port of Pasco which rely upon efficient barge access. Twenty-eight percent of hay shipments leaving brokers go directly to Tacoma via truck and 50 percent is shipped to Portland also using truck. These are primarily shipments from hay brokers in Ellensburg, WA who are relatively closer to the Ports at Tacoma and Portland, and ship directly using truck rather then going to Pasco and utilizing barge transport.

The total volume of shipments arriving at the Port of Pasco (119,980 tons from producers and 193,726 tons from brokers) is shipped entirely to the Port of Portland, divided between barge (52 percent) and rail (48 percent). This modal split is determined by the rail and barge constraints in the transportation model and closely approximates what actually moves out of the Port of Pasco prior to container services being reduced at Portland.

The distribution of all hay shipments into ocean ports is heavily weighted toward Portland, accounting for 50 percent of the export market with 776,547 tons. This is followed by the ocean ports at Tacoma (29 percent) and Seattle (21 percent). Overall, exports account for 43 percent of all hay shipments and 57 percent remaining in the state and destined to feedlots throughout the state (Table 4.2).

Total transportation costs for Scenario I is $41.2 million, with the largest proportion of this cost resulting from shipments from producers to intermediate and final destinations ($22.9 million or 56 percent). It is interesting to note that while 57 percent of total shipments leaving producers go to feedlots, this type of movement only accounts for 38 percent of total cost (Table 4.3). Again, location is the primary explanation given that most of the feedlots demand is provided by producers within close proximity of hay production and truck access.

Approximately 26 percent of the producer to intermediate and final destination shipping costs is attributed to the producer to broker portion at $6.1 million. Producer to Seattle and Tacoma truck shipments represent 18 percent and 15 percent of outbound producer costs, respectively, relative to only 9 percent and 6 percent of outbound tonnage to each of these markets.

Shipments which arrive at brokers represents nearly 24 percent of total hay tonnage, but outbound shipments from the brokers represents 32 percent of the total transportation costs. The largest component of this cost is attributed to truck shipments to

Table 4.2. Total Arrivals (Tons) and distribution Percentage to Each Final Destination

	Arrivals (Tons)					
Final Destinations	% Final Distribution	Base Scenario 1	% Final Distribution	Scenario 2	% Final Distribution	Scenario 3
Port of Seattle	9%	334,578	18%	644,336	18%	644,336
Port of Tacoma	12%	450,199	25%	916,988	25%	916,988
Port of Portland	22%	776,547				
Total		1,561,324		1,561,324		1,561,324
Feedlot 1	19%	694,169	19%	694,169	19%	694,169
Feedlot 2	6%	204,167	6%	204,167	6%	204,167
Feedlot 3	1%	40,834	1%	40,834	1%	40,834
Feedlot 4	6%	204,167	6%	204,167	6%	204,167
Feedlot 5	13%	469,585	13%	469,585	13%	469,585
Feedlot 6	12%	428,754	12%	428,754	12%	428,754
Total		2,041,676		2,041,676		2,041,676
Final Total	100%	3,603,000	100%	3,603,000	100%	3,603,000

Portland (76 percent), accounting for $10.2 of the $13.4 million transportation cost for outbound broker shipments. Broker shipments to Tacoma on truck account for the remaining 24 percent.

Scenario II

Transportation flows experience much change in Scenario 2 when barge is eliminated and shipments are then redistributed to Seattle and Tacoma. In Scenario 2 Portland's demand is reduced to zero and shipments from producers to intermediate destinations continue as in Scenario 1. Producers did shift away from trucking hay to Tacoma experiencing a decrease of 95 percent. However, the loss of shipments to Tacoma and Portland from producers was gained in Seattle. The Port of Seattle increased its total volume arrivals by 65 percent (Table 4.1). Volume and transportation costs both increased over 60 percent for shipments from producers to the Port of Seattle via truck.

Scenario 2 eliminates barge activity, consequently there are no shipments moving from Broker to the Port of Pasco resulting in a 100 percent decrease. The least-cost solution in the Base Scenario identifies shipments going from Broker to Port that is to be shipped by rail or barge to the Port of Portland. After the elimination of barge, brokers now ship by truck to Seattle (11 percent) and Tacoma (89 percent). As for Ports, there is a shift away from rail and barge going to Portland towards shipments on rail to the Port of Tacoma (119,980 tons). Brokers now utilize Tacoma as their least-cost alternative, increasing the transportation cost 255 percent (Table 4.3).

Table 4.3. Transportation Costs Involved with Each Given Scenario

	Transportation Costs								
Type of Movement	% total transportation cost distribution	Base Scenerio 1	% total transportation cost distribution	Scenario 2	% Δ change from Base Scenario	% total transportation cost distribution	Scenario 3	% Δ change from Base Scenario 1	% Δ change from Scenario 2
Producer to Intermediate Destination (Truck):									
Broker	26%	$6,061,830	25%	$5,522,549	-9%	26%	$7,167,078	18%	30%
Port	1%	$236,218	3%	$719,880	205%	3%	$776,558	229%	8%
Producer to Final Destination (Truck):									
Seattle	18%	$4,241,413	32%	$7,160,684	69%	32%	$8,950,948	111%	25%
Tacoma	15%	$3,439,315	1%	$124,720	-96%	1%	$155,882	-95%	25%
Portland	2%	$379,735			-100%			-100%	
Feedlots	38%	$8,628,285	39%	$8,595,495	-0.4%	38%	$10,604,292	23%	23%
Total	56%	$22,986,797	57%	$22,123,328		58%	$27,654,760		
Broker to Final Destination (Truck):									
Port of Pasco	0.1%	$7,555			-100%	0.1%	$9,158	21%	
Feedlot									
Port of Seattle			16%	$2,230,617	100%	8%	$1,320,218		-41%
Port of Tacoma	24%	$3,185,115	84%	$11,307,084	255%	92%	$14,485,382	355%	28%
Port of Portland	76%	$10,200,758			-100%			-100%	
Total	32%	$13,393,428	35%	$13,537,701		33%	$15,814,759		
Port to Final Destination:									
Port of Seattle									
Truck									
Rail									
Port of Tacoma									
Truck			100%	$3,084,686	100%	100%	$3,990,269		29%
Rail									
Port of Portland									
Truck									
Rail	68%	$3,327,764			-100%				
Barge	32%	$1,540,045			-100%				
Total	12%	$4,867,809	8%	$3,084,686		8%	$3,990,269		
Total Costs		$41,248,034		$38,745,715			$47,459,788		

The distribution of all hay shipments in Scenario 2 into ocean ports has shifted away from Portland and is now weighted toward Tacoma, accounting for 59 percent of the export markets with 916,988 tons. This is followed by the only other export port, Seattle (41 percent or 644,336 tons).

There is a shift in flow resulting from the changing demand. Transportation costs decreased $2.5 million from the base scenario to a total of $38.7 million due to the convenient location of Seattle and Tacoma from its supply points. There is less distance for producers to transport hay to Seattle and Tacoma versus the lengthy haul to Portland. The largest portion of this cost is still resulting from shipments from producers to intermediate and final destinations ($22 million or 57 percent).

Producer to Seattle truck shipments represent 32 percent of outbound producer costs, a significant increase from the base scenario. However, Seattle only accounts for 15 percent of outbound tonnage to this market (Table 4.1). Approximately 39 percent of the producer to final destinations costs is credited to the hay shipments from producer to feedlots portion at $8.6 million, a minor decrease of 0.4 percent from the base scenario (Table 4.3).

Shipments which arrive at brokers represent 24 percent of total hay tonnage, but outbound shipments from the brokers represent 35 percent of the total transportation costs. The largest component of this cost is attributed to truck shipments to Tacoma (84 percent), accounting for $11.3 of the $13.5 million transportation cost for outbound broker shipments. Broker shipments to Tacoma on truck account for the remaining 16 percent. The Port of Pasco shifted away from shipping to Portland and now ship 119,980 tons to the Port of Tacoma accounting for 8 percent of the total transportation costs.

Scenario III

There is a 25 percent increase in truck rates due in Scenario 3, bringing total transportation costs to a total of $47 million. The allocation of hay remained the same as Scenario 2 for the shipments from producer to intermediate and final destinations. However, Brokers did increase their volume to the Port of Pasco (35,223 tons) which resulted in a 4 percent decrease in shipments from brokers to the Port of Tacoma. The 29 percent increase in shipments from the Port of Pasco to the Port of Tacoma reflected the 35,223 tonnage increase that Pasco experienced in this scenario. The increase in volume that occurred at the Port of Pasco also increased transportation costs by 21 percent from the Base Scenario.

Total transportation costs for Scenario 3 increase a total of 23 percent from the second scenario. A large proportion of the total cost is a result of the shipments from producers to intermediate and final destinations ($27.7 million or 58 percent). Though total volume from producers to brokers and ports has remained the same in the three scenarios, the transportation costs have fluctuated. In the second scenario the transportation costs for producer to broker decreased 9 percent from the base scenario but then increase 18 percent in the third scenario. A large factor contributing to the 9 percent decrease is the change in distribution from Producer 8 (located near Coulee City). The 147,076 tons that was shipped from Producer 8 previously was shipped to Broker 3 and

Broker 4 in Scenario 1. In Scenario 2, Producer 8 shipped all 147,076 tons to only Broker 3 reducing transportation costs.

The increase of transportation costs in Scenario 3 was the result of the 25 percent increase in trucking rates that was imposed. On the other hand, Ports experienced a drastic increase of 205 percent in transportation costs in the second scenario bringing the total from $236,218 to $719,880 (Table 4.3). Scenario 3 increased as well (8 percent) which was expected with the trucking rate increase.

Hay shipments from broker to final destination represent 24 percent of total hay tonnage, but outbound shipments from brokers represent 33 percent of the total transportation costs. The largest component of this cost is attributed to truck shipments to Tacoma (92 percent), accounting for $14.5 million of the $15.8 million transportation cost for outbound broker shipments. Port of Tacoma's total transportation costs in the second scenario increased 255 percent from the Base Scenario and an additional 28 percent from the second to the third scenario.

The 41 percent decrease that the Port of Seattle experienced in transportation costs from brokers was due to the change in allocation of hay distribution from the brokers. In Scenario 2, Broker 1 and Broker 2 (located in Pasco) were shipping a total of 93,566 tons to Seattle. In Scenario 3, Broker 4 (located in Ellensburg) was shipping all 93,566 tons to Seattle. The transportation costs decreased due to the shorter distance from Ellensburg to Seattle versus Pasco to Seattle, plus the trips were reduced from two trips (one from each broker) to one trip from one broker.

Shadow Prices

In the context of a cost minimization problem with constraints, the shadow price on a constraint is the amount that the objective function would change if the constraint were relaxed by one unit. The relative magnitude of shadow prices is important to supply chain marketing because it provides an overall perspective on the importance of each producer in satisfying hay demand, the value of intermediate destinations such as ports and brokers and comparison of demand markets between ocean ports and feedlots.

The demand constraint requires that the sum of all shipments from origin (i) and/or intermediate destination (j) be greater than or equal to the demand at each final destination (k). Therefore, relaxing the demand requirement at any demand location results in a decrease in volume shipped and a corresponding decrease in transportation cost. For example, if Feedlot 1 (Moses Lake) decreased its demand requirements by one unit, the transportation costs would decrease by $21.88 (Table 4.4). If Feedlot 1 increased its demand requirement, transportation cost would increase by $21.88.

By comparing the relative magnitude of each shadow price amongst feedlots and ocean ports, improved understandings of how important each demand market is for the marketing of hay products is achieved. For ocean ports, Portland has the largest shadow price at $49.25, followed by Tacoma ($38.70) and Seattle ($34.57). The importance of each export port is determined by both the demand at each point and relative proximity of each to the production/processing of hay. For demand at feedlots, Feedlot 5 has the largest shadow price in the Base Scenario at $30.00 per unit change in

Table 4.4. Shadow Prices for all hay movements in Washington State

	Shadow Prices				
Type of Movement	Base Scenerio 1	Scenario 2	% Δ change from Base Scenario	Scenario 3	% Δ change from Base Scenario
Demand Requirements:					
Feedlot 1	21.88	21.88	0%	27.34	25.0%
Feedlot 2	28.88	28.88	0%	36.09	25.0%
Feedlot 3	29.50	29.50	0%	36.87	25.0%
Feedlot 4	30.00	30.00	0%	37.49	25.0%
Feedlot 5	25.63	25.63	0%	32.03	25.0%
Feedlot 6	28.13	28.13	0%	35.15	25.0%
Seattle	34.57	39.63	14.6%	49.53	43.3%
Tacoma	38.70	41.11	6.2%	51.38	32.8%
Portland	49.25		-100.0%		-100.0%
Supply Requirements:					
Producer 1	-12.88	-12.88	0%	-16.09	25.0%
Producer 2	-34.87	-21.25	-39.1%	-26.56	-23.8%
Producer 3	-6.63	-6.63	0%	-8.28	25.0%
Producer 4	-2.75	-2.75	0%	-3.43	24.7%
Producer 5	-5.50	-5.50	0%	-6.87	24.9%
Producer 6					
Producer 7	-21.25	-21.25	0%	-26.56	25.0%
Producer 8	-16.63	-16.63	0%	-20.77	24.9%
Producer 9	-2.25	-2.25	0%	-2.81	24.9%
Producer 10	-6.00	-6.00	0%	-7.5	25.0%
Producer 11	-27.70	-27.70	0%	-34.61	25.0%
Producer 12	-23.50	-23.50	0%	-29.37	25.0%
Producer 13	-20.26	-20.26	0%	-25.31	25.0%
Producer 14	-34.62	-22.38	-35.4%	-27.96	-19.2%
Producer 15	-25.00	-25.00	0%	-31.25	25.0%
Producer 16	-21.57	-26.63	23.4%	-33.28	54.3%
Producer 17	-22.38	-22.38	0%	-27.96	25.0%
Producer 18	-22.38	-22.38	0%	-27.97	25.0%
Producer 19	-21.50	-21.50	0%	-26.87	25.0%
Producer 20	-26.82	-31.88	18.8%	-39.84	48.5%
Producer 21	-35.87	-33.86	-5.6%	-42.32	18.0%
Producer 22	-8.88	-10.63	19.7%	-13.28	49.6%
Producer 23	-19.63	-19.63	0%	-24.53	25.0%
Producer 24	-18.38	-18.38	0%	-22.96	25.0%
Producer 25	-25.38	-25.38	0%	-31.72	25.0%
Producer 26	-21.63	-21.63	0%	-27.02	24.9%
Producer 27	-22.26	-22.26	0%	-27.81	25.0%
Producer 28	-29.38	-29.38	0%	-36.71	25.0%
Producer 29	-8.88	-8.88	0%	-11.09	25.0%
Producer 30	-27.13	-27.13	0%	-33.9	25.0%
Producer 31	-28.50	-28.50	0%	-35.62	25.0%
Producer 32	-21.75	-21.75	0%	-27.19	25.0%
Producer 33	-3.50	-3.50	0%	-4.37	24.9%
Producer 34	-6.88	-6.88	0%	-8.59	24.9%
Producer 35	-19.63	-19.63	0%	-24.53	25.0%
Producer 36	-28.13	-28.13	0%	-35.15	25.0%
Producer 37	-19.63	-19.63	0%	-24.53	25.0%
Producer 38	-23.75	-23.75	0%	-29.68	25.0%
Producer 39	-41.12	-16.11	-60.8%	-20.13	-51.0%
Producer 40	-26.75	-26.75	0%	-33.43	25.0%
Broker Capacity:					
Broker 1	-1.39	9.84	-805.9%	12.3	-982.4%
Broker 2	-1.19	9.84	-930.4%	6.62	-658.6%
Broker 3	2.33	-0.08	-103.4%	-0.11	-104.7%
Broker 4	2.33	-0.08	-103.4%	-0.11	-104.7%
Port Capacity:					
Port of Pasco	-1.40	10.23	-833.3%	6.36	-555.9%

the constraint. This is followed closely by Feedlot 3 ($29.50), Feedlot 2 ($28.88) and Feedlot 6 ($28.13). Thus, fluctuations in the demand at Portland has the largest impact on shipping cost of hay to ocean ports for Scenario 1 and Feedlot 4 has the largest impact on shipping cost for hay moving to feedlots. This relative importance does not change for Scenarios 2 and 3, except for the elimination of Portland and the subsequent increase in the shadow price for Tacoma and Seattle.

The supply constraint limits total shipments from each origin (i) that is available from each supply point stating that the sum of all shipments from each producer cannot exceed the available production of each producer. A negative shadow price (increase relationship) for the supply constraint implies that if a producer relaxed the constraint by one unit (increased supply by one unit) the transportation costs would decrease by a given amount. The shadow price for producers allows comparison of different producers in supplying had to destination demand markets. The larger (in absolute terms) the magnitude of the shadow price for each producer, the more critical each is in supplying hay.

All but seven producers mentioned the same shadow prices from the Base Scenario to Scenario 2, excluding Producer 6 which did not have a shadow price. Producer 6 does not ship all of its hay, meaning there is no shadow price (Table 4.4). Producer 2, Producer 14, and Producer 39 experienced smaller shadow prices from the Base Scenario 1 to Scenario 2 (Figure 4.1, 4.2 and 4.3). These three producers are close to the Columbia River making barge their least-cost option and also explaining why their shadow prices are relatively larger compared to other producers in Scenario 1. However, once the river is not available and Portland's demand moves to Seattle and Tacoma those three producers no longer have a geographic advantage. Now, it costs more to ship by truck or rail, where as before, barge was the most feasible option for them. Producer 21 also increased in transportation costs because their location was closer to Portland.

Producers 16, 20, and 22 became more valuable in Scenario 2 due to their advantageous location to Seattle and Tacoma (Figure 4.1 and 4.2).

Figure 4.1. Base Scenario 1 Producer Shadow Prices

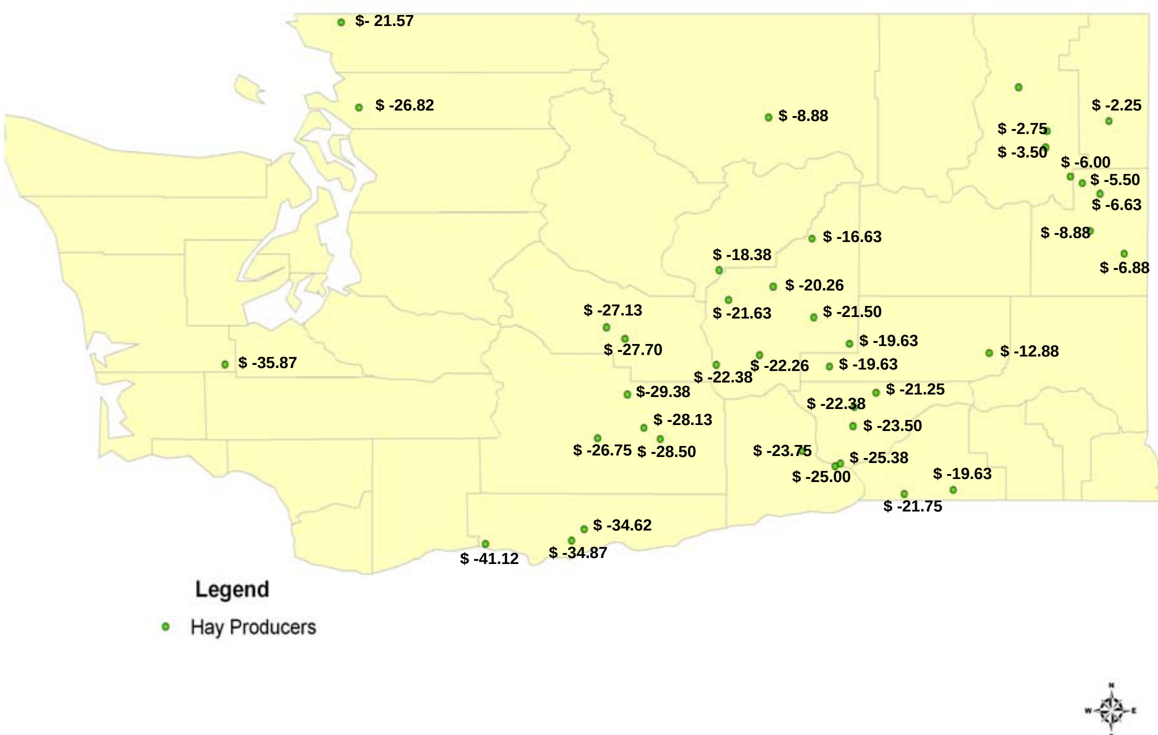


Figure 4.2. Scenario 2 Producer Shadow Prices

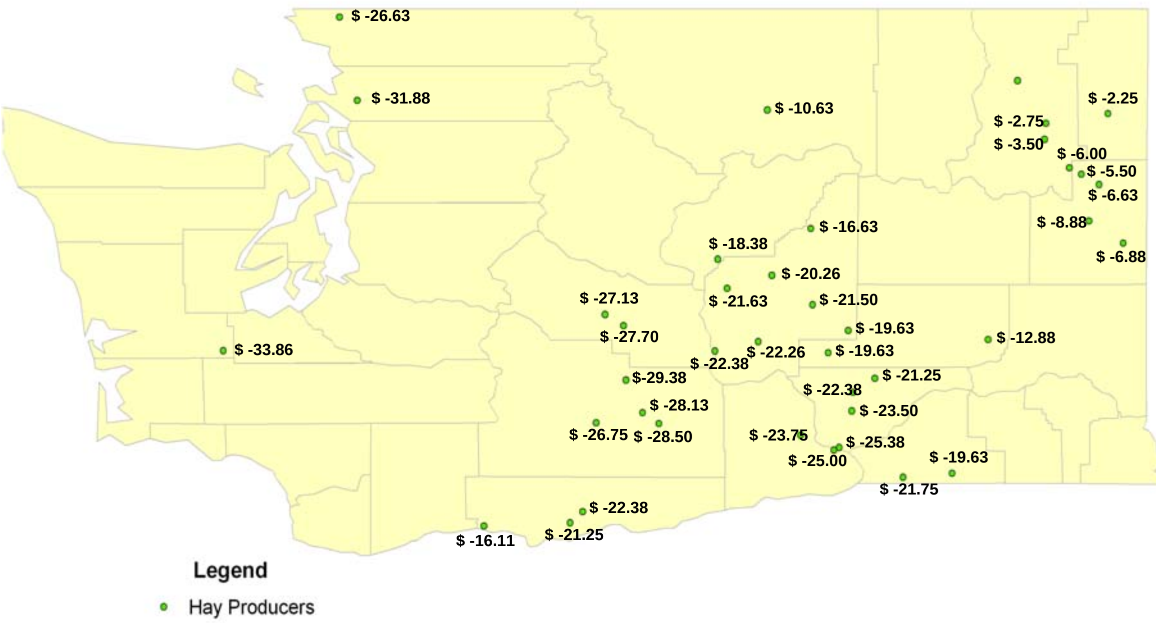
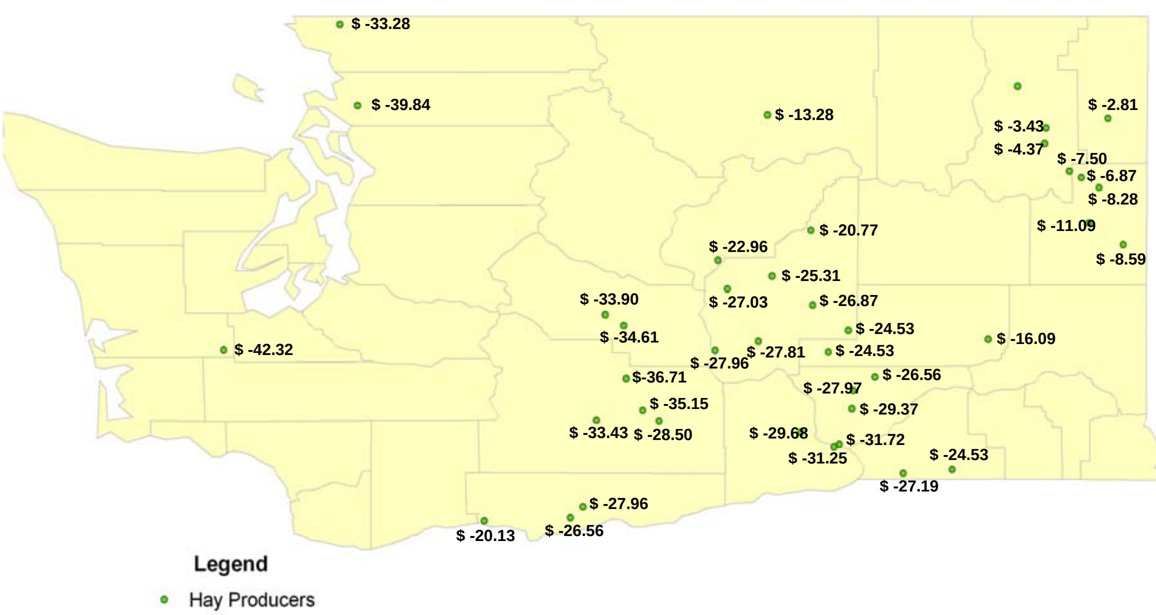


Figure 4.3. Scenario 3 Producer Shadow Prices



When barge is available in Scenario 1, the two brokers that are located near the Port of Pasco have a shadow price of $-1.39 and $-1.19, indicating that for every additional ton of hay shipped through these brokers, total transportation costs system wide will decrease. This is due to barge being the least-cost mode of transportation which supplied the Port of Portland with their large demand of hay that was exported. However, the two brokers that are located in Central Washington have a shadow price of $2.33 illustrating the disadvantage of being located in Central Washington when Portland is the primary hay market and barge transport is available (Figure 4.4, 4.5 and 4.6). Once barge is eliminated and Seattle/Tacoma becomes the primary hay market the opposite occurs with shadow prices. The two brokers that are located in Central Washington are closer to the Port of Seattle and Tacoma where all the shipments are being rerouted to, now have a geographic advantage. The shadow prices for these two brokers is $0.08 decrease in transportation costs, as oppose to the brokers in the Tri-Cities area that now have a shadow price of $9.84 (Table 4.4).

Figure 4.4. Base Scenario 1 Broker Shadow Prices

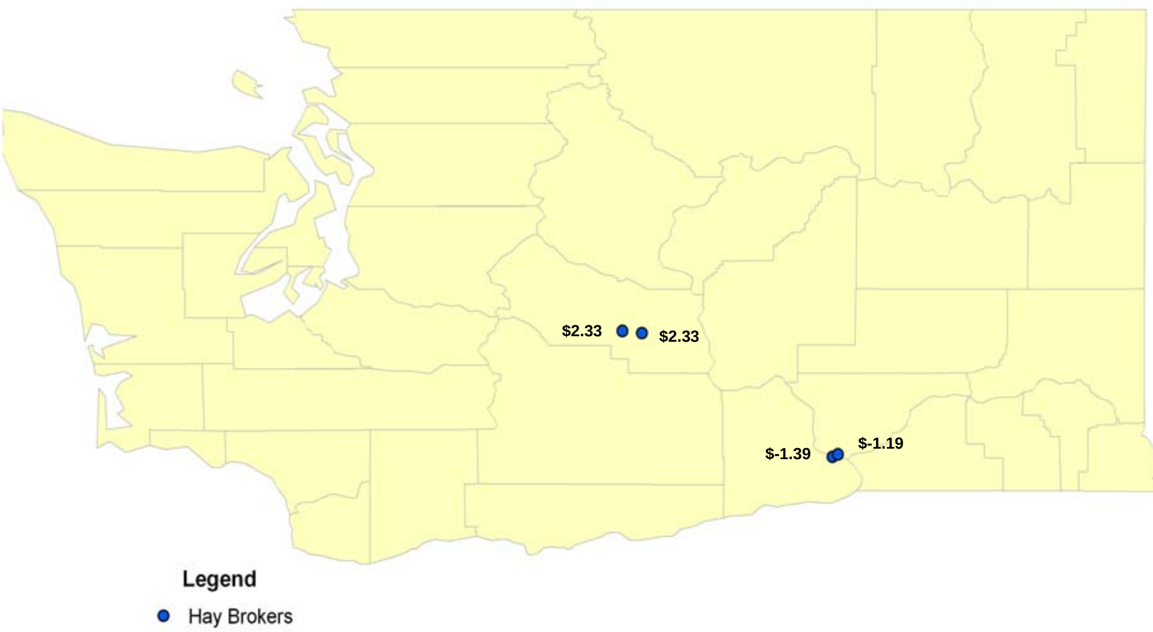
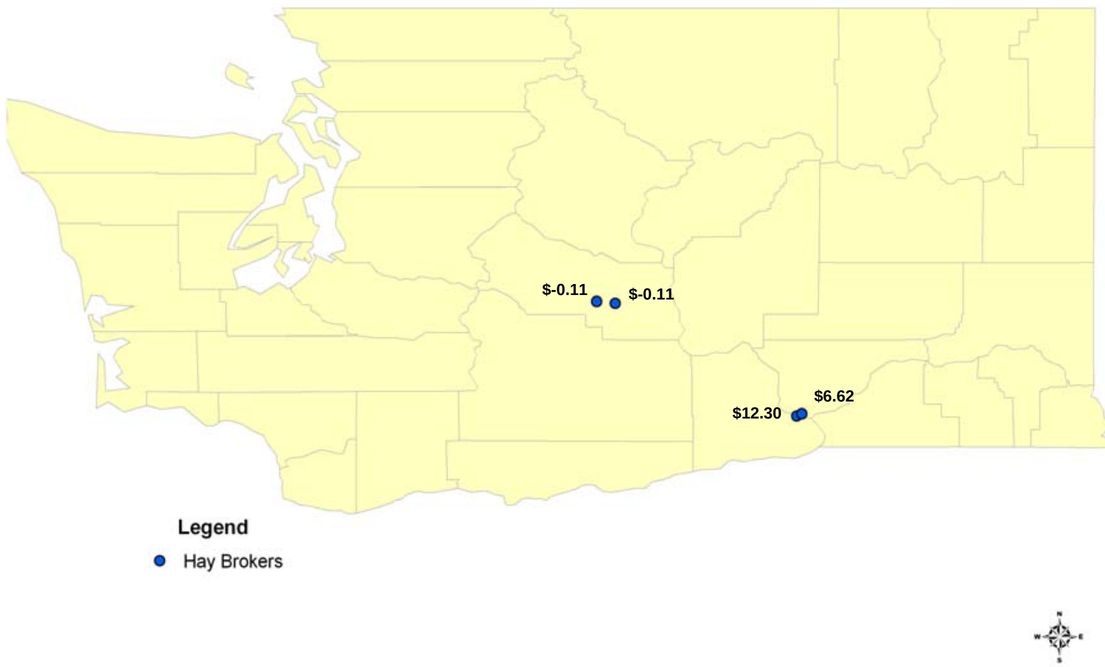


Figure 4.5. Scenario 2 Broker Shadow Prices

Figure 4.6. Scenario 3 Broker Shadow Prices



A very similar situation occurs to the Port of Pasco. When Portland is still a viable demand market and the river is available for barge shipments, shipping hay through the port reduces overall transport cost by $1.40. In Scenario 2, shipping through the Port of Pasco becomes a liability instead of a benefit, as each additional unit raises total transportation cost by $10.23. The Port of Pasco becomes less of a liability in Scenario 3, where truck rates increase and help make transshipments from barge to rail in Portland more feasible (Figure 4.8 and 4.9).

Figure 4.7. Base Scenario 1 Ports Shadow Prices

Figure 4.8. Scenario 2 Ports Shadow Prices

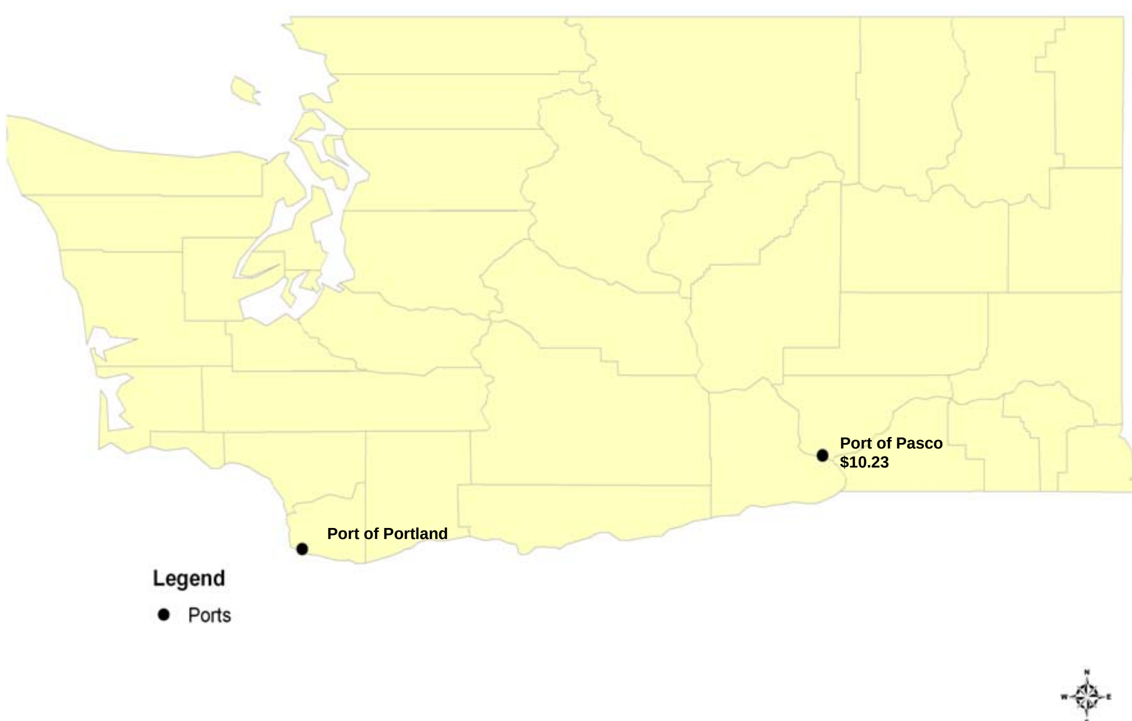
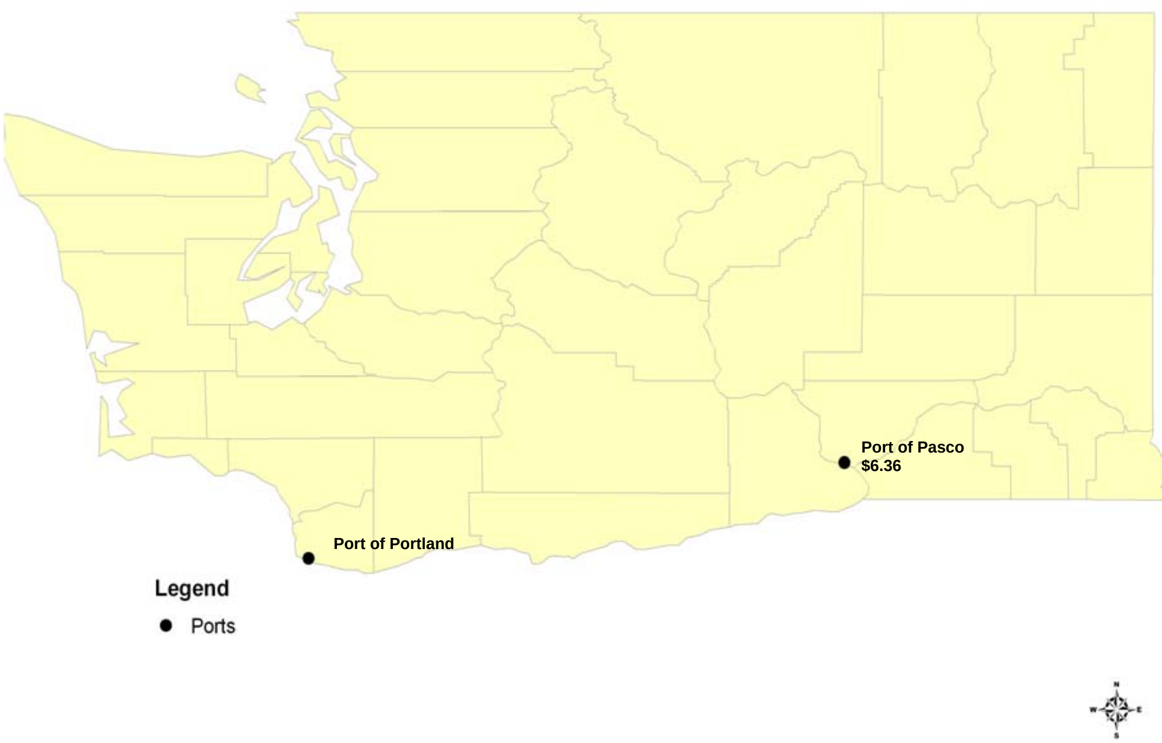


Figure 4.9. Scenario 3 Ports Shadow Prices



The final destination ports, brokers and intermediate ports were influenced differently by the 25 percent increase. The change in shadow prices for final destination ports between Scenario1 and Scenario 3 resulted in an increase between 33 and 43 percent due to the reallocation of hay shipments from Portland to Seattle and Tacoma (Table 4.4). Brokers also experience a decrease in the percentage change of shadow prices from Scenario 1 to Scenario 3 (Figure 4.10, 4.11 and 4.12).

Figure 4.10. Base Scenario 1 Final Destination Shadow Prices

Figure 4.11. Scenario 2 Final Destination Shadow Prices

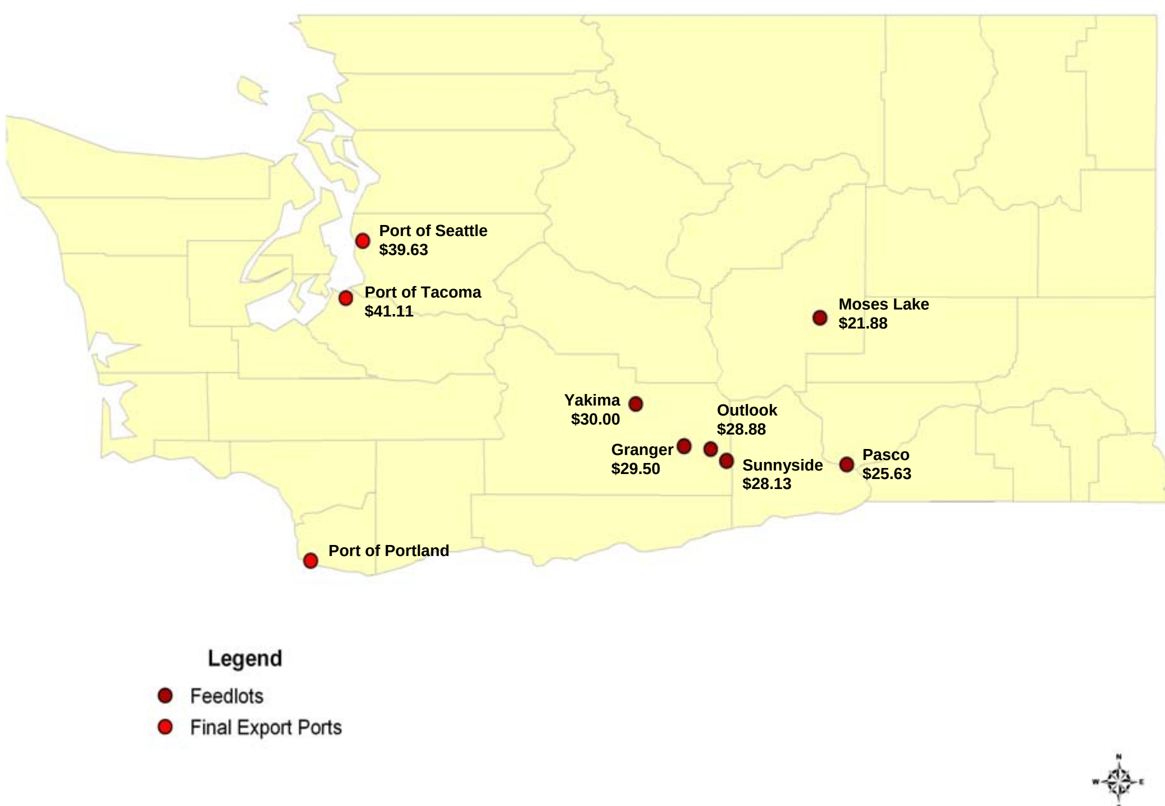
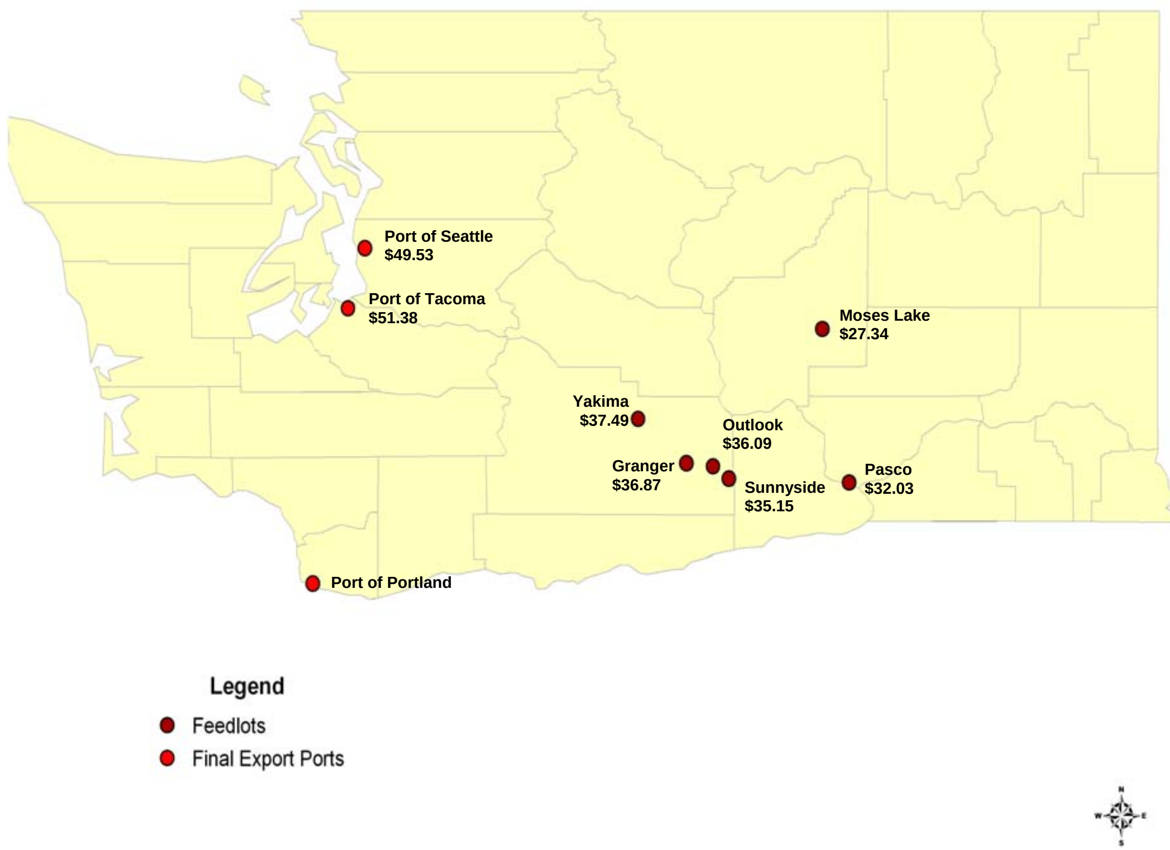


Figure 4.12. Scenario 3 Final Destination Shadow Prices



Summary and Conclusion

The hay industry in Washington relies heavily on truck movements, significantly in the central southern part of the state. Truck transportation is the dominant mode of transportation utilized by processors to receive raw product from fields as well as to ship products to final markets. Maintaining an efficient highway freight transportation system is essential to the economic success of Washington's hay industry.

Hay movements in Washington consist of two final destination points; feedlots and ocean ports. The largest amount of transported hay within the state is shipped via truck to feedlots. The remaining percent of hay is exported to foreign markets, specifically the Pacific Rim. Efficient truck connections to Western Washington ocean ports, as well as, Port of Pasco and Port of Portland are key to international market success for the hay industry.

There is year-round demand for hay, which requires an efficient and multimodal transportation infrastructure supporting hay movements. The seasonlity of hay shipments into processing facilities is more varied and less differentiated than shipments from processing faclities, illustrating the natural climatic factors inflcuing hay production and the product transformation occuring at processing facilities to satisfy export demand markets.

Those highways supporting hay movements from the producer tend to be more local and county highways whereas shipments from hay processors are primarily state and interstate highways. The key highways supporting producer and processor shipments run through the two leading producing counties in Washington; Grant and Franklin. These two counties alone, produce 43 percent of Washington's total hay production.

A cost minimization transportation optimization model is developed for hay shipments out of Washington that is used to investigate impacts to producers, brokers and ports. This study focused specifically on the impacts towards shipping companies leaving the Port of Portland following September 2004. Transportation mode and usage were evaluated in the state before and after this date. This research effort developed a transportation optimization model richly equipped with recent primary data from surveys and industry expert interviews to identify the impacts of modal change and usage to final destinations. Overall transportation costs were minimized providing a path to evaluate changes in total transportation costs overall due to modal and market changes.

Three different transportation scenarios were presented and evaluated including one which characterized hay shipments prior to September 2004 with Port of Portland assessed in the model as both a port and final destination. The second scenario considers hay movements and flows after September 2004 eliminating barge activity to the Port of Portland as a shipping option. The third scenario was structured the same as the second scenario but also increased trucking rates by 25 percent.

The results indicate that after all barge and hay shipments were eliminated into Portland, total transportation costs decrease initially overall, while some producers experience shipping cost increase. Both rail and truck volumes increase substantially in the absence of container shipments on barge. The total industry impact is a $6.3 million increase in transportation costs from the Base Scenario to Scenario 3. Also, once trucks rates are allowed to increase due to the shortage of trucks and the increased demand for truck services, the total transportation cost increased by $8.7 million.

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APPENDIX A

GAMS MODEL

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SETS     N   NODES FOR WHOLE
             NETWORK
   /  PR01
      PR02
      PR03
      PR04
      PR05
      PR06
      PR07
      PR08
      PR09
      PR10
      PR11
      PR12
      PR13
      PR14
      PR15
      PR16
      PR17
      PR18
      PR19
      PR20
      PR21
      PR22
      PR23
      PR24
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      PR27
      PR28
      PR29
      PR30
      PR31
      PR32
      PR33
      PR34
      PR35
      PR36
      PR37
      PR38
      PR39
      PR40
      BR01
      BR02
      BR03
      BR04
      FD01
      FD02
      FD03
      FD04
      FD05
      FD06
      Pasco
      Portland
      PortlandP
      Tacoma
      Seattle/
M       MODES /TRUCK,RAIL,BARGE/
R(M)    RAIL MODE /RAIL/
B(M)    BARGE MODE /BARGE/
```

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*  HAY SUPPLY NODES
           ********************************
HS1(N)  HAY FIRST NODES
  /   PR01
      PR02
      PR03
      PR04
      PR05
      PR06
      PR07
      PR08
      PR09
      PR10
      PR11
      PR12
      PR13
      PR14
      PR15
      PR16
      PR17
      PR18
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      PR26
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      PR28
      PR29
      PR30
      PR31
      PR32
      PR33
      PR34
      PR35
      PR36
      PR37
      PR38
      PR39
      PR40/
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HS2(N)   HAY 2NDARY SOURCES
  /   PR01
      PR02
      PR03
      PR04
      PR05
      PR06
      PR07
      PR08
      PR09
      PR10
      PR11
      PR12
      PR13
      PR14
      PR15
      PR16
      PR17
      PR18
      PR19
      PR20
      PR21
      PR22
      PR23
      PR24
      PR25
      PR26
      PR27
      PR28
      PR29
      PR30
      PR31
      PR32
      PR33
      PR34
      PR35
      PR36
      PR37
      PR38
      PR39
      PR40
      BR01
      BR02
      BR03
      BR04
      Pasco
      PortlandP /
```

```
BROK(N) HAY BROKERS
  /   BR01
      BR02
      BR03
      BR04 /

HINT(N)   HAY INTERMEDIATE NODES
  /   BR01
      BR02
      BR03
      BR04
      Pasco
      PortlandP /

HD(N) HAY DEST NODE
  /   Portland
      Tacoma
      Seattle
      FD01
      FD02
      FD03
      FD04
      FD05
      FD06 /

HD2(N)  HAY 2NDARY DESTINATIONS
  /   FD01
      FD02
      FD03
      FD04
      FD05
      FD06
      BR01
      BR02
      BR03
      BR04
      Pasco
      PortlandP
      Portland
      Tacoma
      Seattle/

IPORT(N) INTERMEDIATE PORTS
  /   Pasco
      PortlandP/

CAPSET (N) HAY BROKER WITH MAX
            CAPACITIES
  /   BR01
      BR02
      BR03
      BR04/
```

```
ALIAS (N,NP) ;
TABLE HARCS (N,NP,M) TRANSPORT AND
        HANDLING COSTS BY MODE
              TRUCK        RAIL
        BARGE

Pasco.Portland        22.89        22.23        9.39
Pasco.PortlandP        22.89        22.23
        9.39
PortlandP.Tacoma        15.09        8.75
PortlandP.Seattle       18.36        8.75
Pasco.Tacoma        25.32        35.71
Pasco.Seattle       23.95        35.71
PR01.BR01        12.75
PR02.BR01        15.75
PR03.BR01        19.13
PR04.BR01        23.00
PR05.BR01        20.25
PR06.BR01        25.75
PR07.BR01        4.38
PR08.BR01        14.50
PR09.BR01        23.38
PR10.BR01        19.75
PR11.BR01        15.00
PR12.BR01        2.13
PR13.BR01        11.25
PR14.BR01        16.00
PR15.BR01        0.63
PR16.BR01        40.38
PR17.BR01        8.00
PR18.BR01        3.25
PR19.BR01        8.88
PR20.BR01        35.25
PR21.BR01        36.88
PR22.BR01        25.88
PR23.BR01        6.00
PR24.BR01        16.50
PR25.BR01        0.25
PR26.BR01        13.13
PR27.BR01        8.88
PR28.BR01        11.00
PR29.BR01        16.88
PR30.BR01        15.88
PR31.BR01        12.88
PR32.BR01        3.88
PR33.BR01        22.25
PR34.BR01        18.88
PR35.BR01        6.00
PR36.BR01        9.25
PR37.BR01        7.63
PR38.BR01        2.00
PR39.BR01        19.50
PR40.BR01        11.25
PR01.BR02        12.75
PR02.BR02        15.75
PR03.BR02        19.13
PR04.BR02        23.00
PR05.BR02        20.25
PR06.BR02        25.75
PR07.BR02        4.38
PR08.BR02        14.50
PR09.BR02        23.38
PR10.BR02        19.75
PR11.BR02        15.00
PR12.BR02        2.13
PR13.BR02        11.25
PR14.BR02        16.00
PR15.BR02        0.63
PR16.BR02        40.38
PR17.BR02        8.00
PR18.BR02        3.25
PR19.BR02        8.88
PR20.BR02        35.25
PR21.BR02        36.88
PR22.BR02        25.88
PR23.BR02        6.00
PR24.BR02        16.50
PR25.BR02        0.25
PR26.BR02        13.13
PR27.BR02        8.88
PR28.BR02        11.00
PR29.BR02        16.88
PR30.BR02        15.88
PR31.BR02        12.88
PR32.BR02        3.88
PR33.BR02        22.25
PR34.BR02        18.88
PR35.BR02        6.00
PR36.BR02        9.25
PR37.BR02        7.63
PR38.BR02        2.00
PR39.BR02        19.50
PR40.BR02        11.25
PR01.BR03        17.50
PR02.BR03        14.25
PR03.BR03        23.75
PR04.BR03        27.75
PR05.BR03        25.00
PR06.BR03        30.50
PR07.BR03        11.75
PR08.BR03        11.63
PR09.BR03        28.13
PR10.BR03        24.38
PR11.BR03        0.65
PR12.BR03        12.88
PR13.BR03        8.00
```

PR14.BR03	13.25
PR15.BR03	15.13
PR16.BR03	25.63
PR17.BR03	5.88
PR18.BR03	11.63
PR19.BR03	8.88
PR20.BR03	20.38
PR21.BR03	22.00
PR22.BR03	19.38
PR23.BR03	9.00
PR24.BR03	9.88
PR25.BR03	15.00
PR26.BR03	6.63
PR27.BR03	6.00
PR28.BR03	4.13
PR29.BR03	21.63
PR30.BR03	1.13
PR31.BR03	7.13
PR32.BR03	18.63
PR33.BR03	27.00
PR34.BR03	23.63
PR35.BR03	20.75
PR36.BR03	6.13
PR37.BR03	10.88
PR38.BR03	13.38
PR39.BR03	20.13
PR40.BR03	7.75
PR01.BR04	17.50
PR02.BR04	14.25
PR03.BR04	23.75
PR04.BR04	27.75
PR05.BR04	25.00
PR06.BR04	30.50
PR07.BR04	11.75
PR08.BR04	11.63
PR09.BR04	28.13
PR10.BR04	24.38
PR11.BR04	0.56
PR12.BR04	12.88
PR13.BR04	8.00
PR14.BR04	13.25
PR15.BR04	15.13
PR16.BR04	25.63
PR17.BR04	5.88
PR18.BR04	11.63
PR19.BR04	8.88
PR20.BR04	20.38
PR21.BR04	22.00
PR22.BR04	19.38
PR23.BR04	9.00
PR24.BR04	9.88
PR25.BR04	15.00
PR26.BR04	6.63
PR27.BR04	6.00
PR28.BR04	4.13
PR29.BR04	21.63
PR30.BR04	1.13
PR31.BR04	7.13
PR32.BR04	18.63
PR33.BR04	27.00
PR34.BR04	23.63
PR35.BR04	20.75
PR36.BR04	6.13
PR37.BR04	10.88
PR38.BR04	13.38
PR39.BR04	20.13
PR40.BR04	7.75
PR01.FD01	17.50
PR02.FD01	14.25
PR03.FD01	23.75
PR04.FD01	27.75
PR05.FD01	25.00
PR06.FD01	30.50
PR07.FD01	11.75
PR08.FD01	11.63
PR09.FD01	28.13
PR10.FD01	24.38
PR11.FD01	0.49
PR12.FD01	12.88
PR13.FD01	8.00
PR14.FD01	13.25
PR15.FD01	15.13
PR16.FD01	25.63
PR17.FD01	5.88
PR18.FD01	11.63
PR19.FD01	8.88
PR20.FD01	20.38
PR21.FD01	22.00
PR22.FD01	19.38
PR23.FD01	9.00
PR24.FD01	9.88
PR25.FD01	15.00
PR26.FD01	6.63
PR27.FD01	6.00
PR28.FD01	4.13
PR29.FD01	21.63
PR30.FD01	1.13
PR31.FD01	7.13
PR32.FD01	18.63
PR33.FD01	27.00
PR34.FD01	23.63
PR35.FD01	20.75
PR36.FD01	6.13
PR37.FD01	10.88
PR38.FD01	13.38
PR39.FD01	20.13

PR40.FD01	7.75
PR01.FD02	17.50
PR02.FD02	14.25
PR03.FD02	23.75
PR04.FD02	27.75
PR05.FD02	25.00
PR06.FD02	30.50
PR07.FD02	11.75
PR08.FD02	11.63
PR09.FD02	28.13
PR10.FD02	24.38
PR11.FD02	0.49
PR12.FD02	12.88
PR13.FD02	8.00
PR14.FD02	13.25
PR15.FD02	15.13
PR16.FD02	25.63
PR17.FD02	5.88
PR18.FD02	11.63
PR19.FD02	8.88
PR20.FD02	20.38
PR21.FD02	22.00
PR22.FD02	19.38
PR23.FD02	9.00
PR24.FD02	9.88
PR25.FD02	15.00
PR26.FD02	6.63
PR27.FD02	6.00
PR28.FD02	4.13
PR29.FD02	21.63
PR30.FD02	1.13
PR31.FD02	7.13
PR32.FD02	18.63
PR33.FD02	27.00
PR34.FD02	23.63
PR35.FD02	20.75
PR36.FD02	6.13
PR37.FD02	10.88
PR38.FD02	13.38
PR39.FD02	20.13
PR40.FD02	7.75
PR01.FD03	17.50
PR02.FD03	14.25
PR03.FD03	23.75
PR04.FD03	27.75
PR05.FD03	25.00
PR06.FD03	30.50
PR07.FD03	11.75
PR08.FD03	11.63
PR09.FD03	28.13
PR10.FD03	24.38
PR11.FD03	0.49
PR12.FD03	12.88
PR13.FD03	8.00
PR14.FD03	13.25
PR15.FD03	15.13
PR16.FD03	25.63
PR17.FD03	5.88
PR18.FD03	11.63
PR19.FD03	8.88
PR20.FD03	20.38
PR21.FD03	22.00
PR22.FD03	19.38
PR23.FD03	9.00
PR24.FD03	9.88
PR25.FD03	15.00
PR26.FD03	6.63
PR27.FD03	6.00
PR28.FD03	4.13
PR29.FD03	21.63
PR30.FD03	1.13
PR31.FD03	7.13
PR32.FD03	18.63
PR33.FD03	27.00
PR34.FD03	23.63
PR35.FD03	20.75
PR36.FD03	6.13
PR37.FD03	10.88
PR38.FD03	13.38
PR39.FD03	20.13
PR40.FD03	7.75
PR01.FD04	17.50
PR02.FD04	14.25
PR03.FD04	23.75
PR04.FD04	27.75
PR05.FD04	25.00
PR06.FD04	30.50
PR07.FD04	11.75
PR08.FD04	11.63
PR09.FD04	28.13
PR10.FD04	24.38
PR11.FD04	0.49
PR12.FD04	12.88
PR13.FD04	8.00
PR14.FD04	13.25
PR15.FD04	15.13
PR16.FD04	25.63
PR17.FD04	5.88
PR18.FD04	11.63
PR19.FD04	8.88
PR20.FD04	20.38
PR21.FD04	22.00
PR22.FD04	19.38
PR23.FD04	9.00
PR24.FD04	9.88
PR25.FD04	15.00

PR26.FD04	6.63
PR27.FD04	6.00
PR28.FD04	4.13
PR29.FD04	21.63
PR30.FD04	1.13
PR31.FD04	7.13
PR32.FD04	18.63
PR33.FD04	27.00
PR34.FD04	23.63
PR35.FD04	20.75
PR36.FD04	6.13
PR37.FD04	10.88
PR38.FD04	13.38
PR39.FD04	20.13
PR40.FD04	7.75
PR01.FD05	17.50
PR02.FD05	14.25
PR03.FD05	23.75
PR04.FD05	27.75
PR05.FD05	25.00
PR06.FD05	30.50
PR07.FD05	11.75
PR08.FD05	11.63
PR09.FD05	28.13
PR10.FD05	24.38
PR11.FD05	0.49
PR12.FD05	12.88
PR13.FD05	8.00
PR14.FD05	13.25
PR15.FD05	15.13
PR16.FD05	25.63
PR17.FD05	5.88
PR18.FD05	11.63
PR19.FD05	8.88
PR20.FD05	20.38
PR21.FD05	22.00
PR22.FD05	19.38
PR23.FD05	9.00
PR24.FD05	9.88
PR25.FD05	15.00
PR26.FD05	6.63
PR27.FD05	6.00
PR28.FD05	4.13
PR29.FD05	21.63
PR30.FD05	1.13
PR31.FD05	7.13
PR32.FD05	18.63
PR33.FD05	27.00
PR34.FD05	23.63
PR35.FD05	20.75
PR36.FD05	6.13
PR37.FD05	10.88
PR38.FD05	13.38
PR39.FD05	20.13
PR40.FD05	7.75
PR01.FD06	17.50
PR02.FD06	14.25
PR03.FD06	23.75
PR04.FD06	27.75
PR05.FD06	25.00
PR06.FD06	30.50
PR07.FD06	11.75
PR08.FD06	11.63
PR09.FD06	28.13
PR10.FD06	24.38
PR11.FD06	0.49
PR12.FD06	12.88
PR13.FD06	8.00
PR14.FD06	13.25
PR15.FD06	15.13
PR16.FD06	25.63
PR17.FD06	5.88
PR18.FD06	11.63
PR19.FD06	8.88
PR20.FD06	20.38
PR21.FD06	22.00
PR22.FD06	19.38
PR23.FD06	9.00
PR24.FD06	9.88
PR25.FD06	15.00
PR26.FD06	6.63
PR27.FD06	6.00
PR28.FD06	4.13
PR29.FD06	21.63
PR30.FD06	1.13
PR31.FD06	7.13
PR32.FD06	18.63
PR33.FD06	27.00
PR34.FD06	23.63
PR35.FD06	20.75
PR36.FD06	6.13
PR37.FD06	10.88
PR38.FD06	13.38
PR39.FD06	20.13
PR40.FD06	7.75
BR01.FD01	23.63
BR02.FD01	20.75
BR03.FD01	6.13
BR04.FD01	10.88
BR01.FD02	23.63
BR02.FD02	20.75
BR03.FD02	6.13
BR04.FD02	10.88
BR01.FD03	23.63
BR02.FD03	20.75
BR03.FD03	6.13

BR04.FD03	10.88
BR01.FD04	23.63
BR02.FD04	20.75
BR03.FD04	6.13
BR04.FD04	10.88
BR01.FD05	23.63
BR02.FD05	20.75
BR03.FD05	6.13
BR04.FD05	10.88
BR01.FD06	23.63
BR02.FD06	20.75
BR03.FD06	6.13
BR04.FD06	10.88
PR01.Pasco	12.75
PR02.Pasco	15.75
PR03.Pasco	19.13
PR04.Pasco	23.00
PR05.Pasco	20.25
PR06.Pasco	25.75
PR07.Pasco	4.38
PR08.Pasco	14.50
PR09.Pasco	23.38
PR10.Pasco	19.75
PR11.Pasco	15.00
PR12.Pasco	2.13
PR13.Pasco	11.25
PR14.Pasco	16.00
PR15.Pasco	0.63
PR16.Pasco	40.38
PR17.Pasco	8.00
PR18.Pasco	3.25
PR19.Pasco	8.88
PR20.Pasco	35.25
PR21.Pasco	36.88
PR22.Pasco	25.88
PR23.Pasco	6.00
PR24.Pasco	16.50
PR25.Pasco	0.25
PR26.Pasco	13.13
PR27.Pasco	8.88
PR28.Pasco	11.00
PR29.Pasco	16.88
PR30.Pasco	15.88
PR31.Pasco	12.88
PR32.Pasco	3.88
PR33.Pasco	22.25
PR34.Pasco	18.88
PR35.Pasco	6.00
PR36.Pasco	9.25
PR37.Pasco	7.63
PR38.Pasco	2.00
PR39.Pasco	19.50
PR40.Pasco	11.25
PR01.Portland	38.13
PR02.Portland	14.38
PR03.Portland	46.25
PR04.Portland	51.25
PR05.Portland	47.38
PR06.Portland	52.88
PR07.Portland	31.50
PR08.Portland	38.63
PR09.Portland	50.50
PR10.Portland	46.88
PR11.Portland	27.63
PR12.Portland	29.25
PR13.Portland	35.00
PR14.Portland	14.63
PR15.Portland	26.75
PR16.Portland	34.50
PR17.Portland	29.00
PR18.Portland	30.38
PR19.Portland	35.88
PR20.Portland	29.25
PR21.Portland	13.38
PR22.Portland	47.13
PR23.Portland	33.25
PR24.Portland	36.88
PR25.Portland	27.13
PR26.Portland	33.50
PR27.Portland	33.00
PR28.Portland	23.63
PR29.Portland	44.00
PR30.Portland	28.63
PR31.Portland	20.75
PR32.Portland	28.13
PR33.Portland	49.38
PR34.Portland	46.00
PR35.Portland	31.13
PR36.Portland	21.63
PR37.Portland	34.75
PR38.Portland	28.63
PR39.Portland	8.13
PR40.Portland	25.00
PR01.PortlandP	38.13
PR02.PortlandP	14.38
PR03.PortlandP	46.25
PR04.PortlandP	51.25
PR05.PortlandP	47.38
PR06.PortlandP	52.88
PR07.PortlandP	31.50
PR08.PortlandP	38.63
PR09.PortlandP	50.50
PR10.PortlandP	46.88
PR11.PortlandP	27.63
PR12.PortlandP	29.25
PR13.PortlandP	35.00

PR14.PortlandP	14.63
PR15.PortlandP	26.75
PR16.PortlandP	34.50
PR17.PortlandP	29.00
PR18.PortlandP	30.38
PR19.PortlandP	35.88
PR20.PortlandP	29.25
PR21.PortlandP	13.38
PR22.PortlandP	47.13
PR23.PortlandP	33.25
PR24.PortlandP	36.88
PR25.PortlandP	27.13
PR26.PortlandP	33.50
PR27.PortlandP	33.00
PR28.PortlandP	23.63
PR29.PortlandP	44.00
PR30.PortlandP	28.63
PR31.PortlandP	20.75
PR32.PortlandP	28.13
PR33.PortlandP	49.38
PR34.PortlandP	46.00
PR35.PortlandP	31.13
PR36.PortlandP	21.63
PR37.PortlandP	34.75
PR38.PortlandP	28.63
PR39.PortlandP	8.13
PR40.PortlandP	25.00
PR01.Tacoma	32.50
PR02.Tacoma	29.25
PR03.Tacoma	38.75
PR04.Tacoma	42.63
PR05.Tacoma	39.88
PR06.Tacoma	45.50
PR07.Tacoma	27.75
PR08.Tacoma	26.63
PR09.Tacoma	43.13
PR10.Tacoma	39.38
PR11.Tacoma	15.13
PR12.Tacoma	27.88
PR13.Tacoma	23.00
PR14.Tacoma	28.25
PR15.Tacoma	30.00
PR16.Tacoma	17.13
PR17.Tacoma	20.75
PR18.Tacoma	26.63
PR19.Tacoma	23.88
PR20.Tacoma	11.88
PR21.Tacoma	7.25
PR22.Tacoma	30.75
PR23.Tacoma	24.13
PR24.Tacoma	24.88
PR25.Tacoma	30.00
PR26.Tacoma	21.63
PR27.Tacoma	21.00
PR28.Tacoma	19.13
PR29.Tacoma	36.63
PR30.Tacoma	14.25
PR31.Tacoma	22.00
PR32.Tacoma	33.63
PR33.Tacoma	42.00
PR34.Tacoma	38.63
PR35.Tacoma	35.75
PR36.Tacoma	21.13
PR37.Tacoma	25.75
PR38.Tacoma	28.38
PR39.Tacoma	25.00
PR40.Tacoma	22.63
PR01.Seattle	30.88
PR02.Seattle	27.50
PR03.Seattle	37.13
PR04.Seattle	41.00
PR05.Seattle	38.25
PR06.Seattle	43.75
PR07.Seattle	26.00
PR08.Seattle	25.00
PR09.Seattle	41.38
PR10.Seattle	37.63
PR11.Seattle	13.38
PR12.Seattle	26.13
PR13.Seattle	21.25
PR14.Seattle	26.50
PR15.Seattle	28.38
PR16.Seattle	13.00
PR17.Seattle	19.13
PR18.Seattle	24.88
PR19.Seattle	22.13
PR20.Seattle	7.75
PR21.Seattle	11.13
PR22.Seattle	29.00
PR23.Seattle	22.38
PR24.Seattle	23.13
PR25.Seattle	28.25
PR26.Seattle	19.88
PR27.Seattle	19.25
PR28.Seattle	17.50
PR29.Seattle	34.88
PR30.Seattle	12.50
PR31.Seattle	19.75
PR32.Seattle	31.88
PR33.Seattle	40.25
PR34.Seattle	36.88
PR35.Seattle	34.13
PR36.Seattle	19.38
PR37.Seattle	24.13
PR38.Seattle	26.63
PR39.Seattle	28.75

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PR40.Seattle        20.88
BR01.Pasco          0.21
BR02.Pasco          0.21
BR03.Pasco          12.66
BR04.Pasco          12.66
BR01.Portland       22.89
BR02.Portland       22.89
BR03.Portland       23.32
BR04.Portland       23.32
BR01.PortlandP      22.89
BR02.PortlandP      22.89
BR03.PortlandP      23.32
BR04.PortlandP      23.32
BR01.Tacoma         25.32
BR02.Tacoma         25.32
BR03.Tacoma         12.77
BR04.Tacoma         12.77
BR01.Seattle        23.84
BR02.Seattle        23.84
BR03.Seattle        11.29
BR04.Seattle        11.29
          ;
```

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PARAMETER HSUP(N) AVAILABLE HAY
        TONS
/   PR01            47946.66
    PR02            3529.82
    PR03            2647.36
    PR04            1764.91
    PR05            16472.47
    PR06            3529.82
    PR07            735.38
    PR08            147075.63
    PR09            7059.63
    PR10            10295.29
    PR11            117660.51
    PR12            97069.92
    PR13            111777.48
    PR14            5883.03
    PR15            84215.51
    PR16            514764.71
    PR17            728024.38
    PR18            5883.03
    PR19            448874.83
    PR20            20590.59
    PR21            7059.63
    PR22            7059.63
    PR23            378866.83
    PR24            8824.54
    PR25            315330.15
    PR26            101776.34
    PR27            55006.29
    PR28            13236.81
    PR29            4706.42
    PR30            8824.54
    PR31            10001.14
    PR32            53535.53
    PR33            8824.54
    PR34            58830.25
    PR35            8824.54
    PR36            47064.20
    PR37            117660.51
    PR38            2941.51
    PR39            2941.51
    PR40            15884.17   /;
```

```
PARAMETER HDEM(N) HAY DEMAND
        REQUIREMENTS
  /     FD01        783218
        FD02        234539
        FD03        54825
        FD04        236371
        FD05        567833
        FD06        509092
        Portland    432345
        Tacoma      450199
        Seattle     334578   /;

PARAMETER RAILCAPH(N) RAIL
        CAPACITY FOR HAY W RAIL
  /     Pasco           364000
        PortlandP        83720  /;

PARAMETER BARGCAPH(N) BARGE
        CAPACITY FOR HAY W BARGE
  /     Pasco           445500 /;
PARAMETER CAPRHS(N) Broker
        CAPACITIES
  /     BR01      90000
        BR02      20000
        BR03      85000
        BR04      300000  /;
PARAMETER CAPRHS2(N) UPDATED
        Broker CAPACITIES;
CAPRHS2(N) = 1*CAPRHS(N);
PARAMETER RAILCAPH2(N) UPDATED
        WHT RAIL MAX VALUES;
RAILCAPH2(N) = 1*RAILCAPH(N);


VARIABLES H(N,NP,M) HAY FLOW ON
        ARCS N TO NP VIA MODE M

TC   TOTAL COST
HTC  TOTAL COST HAY
HC83  TOTAL COST 83 HAY
HC84  TOTAL COST 84 HAY
HC85  TOTAL COST 85 HAY
HC34  TOTAL COST 34 HAY
HC35  TOTAL COST 35 HAY
HC45  TOTAL COST 45 HAY
TRH TOTAL HAY RAIL
POSITIVE VARIABLES H;

EQUATIONS
HNB(N) NODE BALANCE HAY
HDB(N) DESTINATION BALANCE HAY
HSB(N) SUPPLY BALANCE HAY
CAP(N) CAPACITIES ON BROKERS
RAILH(N) RAIL CAPACITY FOR HAY
BARGH(N) BARGE CAPACITY FOR HAY
HCOST   ACCTING: TOTAL COST HAY

HCOST83  ACCTING: TOTAL COST 83 HAY
HCOST84  ACCTING: TOTAL COST 84 HAY
HCOST85  ACCTING: TOTAL COST 85 HAY
HCOST34  ACCTING: TOTAL COST 34 HAY
HCOST35  ACCTING: TOTAL COST 35 HAY
HCOST45  ACCTING: TOTAL COST 45 HAY

TCOST   ACCTING: TOTAL COST;

HDB(HD)..
        SUM((HS2,M)$HARCS(HS2,HD,M),H
        (HS2,HD,M))=G= HDEM(HD) ;

HSB(HS1)..
        SUM((HD2,M)$HARCS(HS1,HD2,M),
        H(HS1,HD2,M)) =L= HSUP(HS1);

HNB(HINT)$SUM((N,M),HARCS(HINT,N,M))
        ..
SUM((HS1,M)$HARCS(HS1,HINT,M),
        H(HS1,HINT,M))
=E= SUM((HD,M)$HARCS(HINT,HD,M),
        H(HINT,HD,M)) ;

CAP(CAPSET)..
SUM((HS1,M)$HARCS(HS1,CAPSET,M),
        H(HS1,CAPSET,M)) =L=
        CAPRHS2(CAPSET);

RAILH(HINT)..
SUM((HD,R)$HARCS(HINT,HD,R),
        H(HINT,HD,R))
=L= RAILCAPH(HINT);

BARGH(HINT)..
SUM((HD,B)$HARCS(HINT,HD,B),
        H(HINT,HD,B))
=L= BARGCAPH(HINT);

TCOST..
        TC=E=SUM((N,NP,M)$HARCS(N,NP
        ,M),HARCS(N,NP,M)*H(N,NP,M)) ;

HCOST83..
        HC83=E=SUM((HS1,BROK,M)$HAR
        CS(HS1,BROK,M),HARCS(HS1,BRO
        K,M)*H(HS1,BROK,M));
```

```
HCOST84..
        HC84=E=SUM((HS1,HINT,M)$HARC
        S(HS1,HINT,M),HARCS(HS1,HINT,
        M)*H(HS1,HINT,M));

HCOST85..
        HC85=E=SUM((HS1,HD,M)$HARCS(
        HS1,HD,M),HARCS(HS1,HD,M)*H(H
        S1,HD,M));

HCOST34..
        HC34=E=SUM((BROK,HINT,M)$HA
        RCS(BROK,HINT,M),HARCS(BROK,
        HINT,M)*H(BROK,HINT,M));

HCOST35..
        HC35=E=SUM((BROK,HD,M)$HARC
        S(BROK,HD,M),HARCS(BROK,HD,
        M)*H(BROK,HD,M));

HCOST45..
        HC45=E=SUM((HINT,HD,M)$HARC
        S(HINT,HD,M),HARCS(HINT,HD,M)
        *H(HINT,HD,M));

HCOST..
        HTC=E=SUM((N,NP,M)$HARCS(N,N
        P,M),HARCS(N,NP,M)*H(N,NP,M));

MODEL TEST /ALL/;
OPTION LIMROW = 5;
OPTION LIMCOL = 5;
OPTION RESLIM = 5000;
OPTION ITERLIM = 100000;
SOLVE TEST MINIMIZING TC USING LP;
DISPLAY H.L;

 FILE RES /'EJ2.DAT'/;
 PUT RES;
 PUT "TOTAL COST =" /;
 PUT TC.L /;
 PUT /;
 PUT "TOTAL COST HAY =" /;
 PUT HTC.L /;
 PUT /;
 PUT "TOTAL COST 83 HAY ="/;
 PUT HC83.L /;
 PUT /;
 PUT "TOTAL COST 84 HAY ="/;
 PUT HC84.L /;
 PUT /;
 PUT "TOTAL COST 85 HAY ="/;
 PUT HC85.L /;
 PUT /;
 PUT "TOTAL COST 34 HAY ="/;
 PUT HC34.L /;
 PUT /;
 PUT "TOTAL COST 35 HAY ="/;
 PUT HC35.L /;
 PUT /;
 PUT "TOTAL COST 45 HAY ="/;
 PUT HC45.L /;
 PUT /;

***PUT "HAY ARCS" /;
***LOOP ((N,NP,M),
***IF (H(N,NP,M) GT 0,
***PUT N.TL, NP.TL, M.TL, H.L(N,NP,M) /));

***PUT "HAY ARCS FOR PRODUCTION TO
        BROKERS" /;
*LOOP ((HS1,CAPSET,M),
*IF (H(HS1,CAPSET,M) GT 0,
*PUT HS1.TL, CAPSET.TL, M.TL,
        H.L(HS1,CAPSET,M) /));

*PUT "HAY ARCS FOR PRODUCTION TO
        PORTS" /;
*LOOP ((HS1,IPORT,M),
*IF (H(HS1,IPORT,M) GT 0,
*PUT HS1.TL, IPORT.TL, M.TL,
        H.L(HS1,IPORT,M) /));

*PUT "HAY ARCS FOR BROKERS TO
        PORTS" /;
*LOOP ((CAPSET,IPORT,M),
*IF (H(CAPSET,IPORT,M) GT 0,
*PUT CAPSET.TL, IPORT.TL, M.TL,
        H.L(CAPSET,IPORT,M) /));

*PUT "HAY ARCS FOR PORTS TO FINAL
        DEMAND" /;
*LOOP ((IPORT,HD,M),
*IF (H(IPORT,HD,M) GT 0,
*PUT IPORT.TL, HD.TL, M.TL,
        H.L(IPORT,HD,M) /));
```

APPENDIX B

MARKETING AND TRANSPORTATION OF WASHINGTON HAY SURVEY

School of Economic Sciences
Washington State University

Marketing and Transportation of Washington Hay

Thank you for your participation in this study. If at any time should you require assistance completing this form, or have any other questions or concerns about this project feel free to contact Stephanie Meenach Graduate Research Assistant at (509) 335-8189. Thank you once again for your assistance.

Please list your name, the name of your business and the address of your farm(s).

Name ______________________________

Company ______________________________

Address ______________________________

Transportation of Hay ***FROM*** this Facility (farm):

1) For a typical year, please estimate the annual volume of hay shipped **from** this facility (farm). ____________Tons per year.

2) Do you have rail service at this location: ____Yes ____No

If you **do not** have local rail, please give the **NAME** of the nearest rail facility that you use (or would use if you used local rail) and the general route to travel between your facility and that rail facility:
NAME: ____

GENERAL ROUTE USED (indicate state and county roads used in %):

	Road Name	Percent
a)		_________%
b)		_________%
c)		_________%
d)		_________%
e)		_________%
	Total	**100 %**

3) Please indicate the **NAME** of the RIVER PORT FACILITY that you use (or would use if you go to the river):
NAME: ____

4) Please identify the destination and percent of shipments leaving this facility.

Check the following that apply: Percent

_______% Washington
_______% Oregon
_______% California
_______% Foreign markets
_______% Other (please specify)
100 %Total

Transportation of Hay ***FROM*** this Facility (farm):

5) What are the different forms and an estimate of the weight in each form that is shipped **from** your facility?

	Form	Weight
a) Cubed	______%	______lbs
b) Compressed	______%	______lbs
c) Small bales	______%	______lbs
d) Large (3 string bales)	______%	______lbs
e) 1 ton bales	______%	______lbs
f) Round bales	______%	______lbs
g) Other (please specify)	______%	______ lbs

6) Please estimate the typical percentage of hay shipped **from** this facility for each month in a typical year.

	Alfalfa	**Grass**	**Other**
a) January – March	______%	______%	______%
b) April - June	______%	______%	______%
c) July - September	______%	______%	______%
d) October - December	______%	______%	______%
Total	**100 %**	**100 %**	**100 %**

7) Please provide the truck type for inbound and outbound hay movements.

	Inbound	Outbound
a) Single Axle Flatbed	_______%	________%
b) Semi-Flatbed	_______%	________%
c) Semi-Container	_______%	________%
d) Goose-neck Flat bed Trailer	_______%	________%
e) Other (please specify)	_______%	________%
Total	**100 %**	**100 %**

Transportation of Hay ***FROM*** this Facility (farm):

8) Please estimate the approximate percentage (average over 3 years) of Washington HAY shipped **from** this location via each one of the following transportation modes.

	Alfalfa Average Percent Shipped	**Grass** Average Percent Shipped	**Other** Average Percent Shipped
Truck to livestock farms	______%	______%	______%
Truck to River Barge	______%	______%	______%
Truck to Ocean Port	______%	______%	______%
Rail to River Barge	______%	______%	______%
Rail to Ocean Port	______%	______%	______%
Other (please specify)	______%	______%	______%
TOTAL	**100 %**	**100 %**	**100 %**

9) Please estimate the percentages of Washington local and state roads that are utilized most frequently to transport hay products **from** this facility (e.g. I-82, US395, and Wheeler Road).

Road Name	Percent
a)	_________%
b)	_________%
c)	_________%
d)	_________%
e)	_________%
Total	**100 %**

Transportation of Hay ***FROM*** this Facility (farm):

10) Most shippers of Washington hay seem to prefer shipping by truck rather than rail. In your opinion, what improvements to rail transportation must be made in order to make it a viable alternative?

____

____

____

11) Please list the location of any Processing (cubing, compressing, etc.) operations that you utilize that have not been included in this survey.

Plant 1 ____

____

Plant 2 ____

____

Plant 3 ____

____

12) A new technology is Round-up Ready hay (GMO); Do you currently produce or handle this type of hay? Yes____ No____

Comments: ____

____

____

____

Transportation of Hay ***FROM*** this Facility (farm):

13) How well do you believe Round-up Ready hay will be received in the international markets?

____

____

____

____

14) Would you like a copy of the results of this survey? Yes___ No___

THANK YOU for taking the time to complete this survey!

All information will be kept completely confidential.