Modeling Containerized Hay Shipments in the Pacific Northwest: Investigating Cost and Volume Impacts as Port of Portland Container Services is Reduced

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Total word count- 4,861
Text- 3,861
Tables and figures- 1,000

Submitted to the Transportation Research Forum

ABSTRACT

A recent issue impacting freight shipments in Washington State involves the reduction of container services at the Port of Portland, Oregon. Prior to this change, export containers filled with hay were shipped almost exclusively via barge down the Columbia River to the Port of Portland. After reaching Portland, the containers were then loaded onto one of three ocean container lines: Hyundai, K-Line, or Hanjin and destined to markets in Japan and China. As of September 2004, Hanjin is the only remaining carrier that calls at the Port of Portland.

This research effort has collected firm level data on the production, transportation and marketing of hay in Washington and incorporates this information in the design and development of a transportation optimization model of regional hay movements. This model is then utilized to evaluate industry shifts in transportation usage and modal choice in reaction due to these industry changes after September 2004.

The results indicate that after all barge and hay shipments are eliminated into Portland, region-wide transportation costs actually decrease initially overall, while some individual producers experience increased shipping costs. 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 truck rates are allowed to increase due to the shortage of trucks and the increased demand for truck services, the total transportation cost increases by $8.7 million.

As trucking rates increase due to the increased demand for trucking services, the industry transportation cost does increase to $47.5 million, a 15 percent increase from Scenario one and a 22 percent increase from Scenario two. While this increase is significant, it is not as severe or adverse as previously expected throughout the Pacific Northwest agricultural and hay industry. As expected, there is greater reliance on rail and truck transportation once barge shipments to Portland are eliminated.

INTRODUCTION

A recent change in the regional transportation landscape in the Pacific Northwest involves the reduction of container services at the Port of Portland, Oregon. As a result, the Ports of Seattle and Tacoma have experienced a considerable increase in container shipments since September 2004, including export hay shipments. Eastern Washington agricultural exporters save an estimated $500 per container in shipping costs due to the fact that a large numbers of "empties" are passing through on their way back to Asia (Pascall). 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 at the Port of Portland. 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. Containerized rail shipments eventually increased even further to 1,000 containers per month in early 2005 (Port of Pasco).

The expectation of regional hay producers, brokers and export market analyst is that this type of change in the transportation landscape in the Pacific Northwest could have a negative/detrimental impact on the hay industry as the overall transportation cost potentially increases. While shippers of hay and other agricultural commodities undoubtedly adjust to market conditions by shifting between modes as price/service per mode change, large shifts could result in lost markets as buyers in Japan and Asia shift to lower cost hay suppliers outside the Pacific Northwest or the U.S. This analysis seeks to identify the magnitude and degree of these transportation changes, in terms of both volume and cost impacts as shipments are re-allocated in a least-cost, optimal manner.

DATA AND INFORMATION

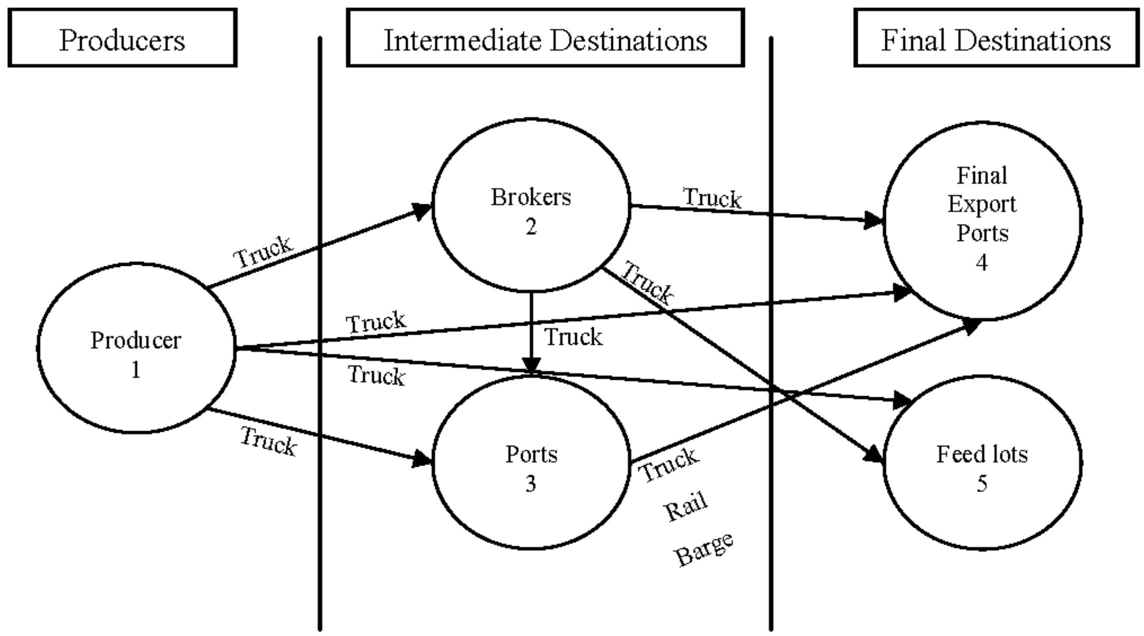
The primary data utilized in this study was collected via an in-depth transportation and market survey to both hay producers and brokers/processors throughout Washington State. This industry survey collected detailed information regarding transportation characteristics of inbound/outbound hay shipments, route utilized, timing/seasonality of shipments, product form, vehicle configuration and final demand markets to help shape and parameterize the transportation optimization model (For a more complete description of this data, see Meenach, et. al). In addition to this industry information collected by hay producer and processor surveys, the Port of Pasco, Portland, Seattle and Tacoma were all contacted by phone to obtain additional information on volume of hay shipments through port facilities. Information on feedlot operations in Washington State was also obtained from the Licensed Certified Feedlots, Washington State Department of Agriculture (WSDA, 2004). Trucking rates were obtained by phone interviews with processors and selected producers. Container rail rates were provided by Northwest Containers, Inc. and barge rates were the posted published rates from local barge service providers.

TRANSPORTATION OPTIMIZATION MODEL

The transportation optimization model developed to represent hay shipments throughout Washington's multi-modal transportation network operates under a cost minimization decision framework. This model is designed to accurately represent all shipping options for hay moving from production regions in Washington to final export ports. The collection of allowable origin and destination combinations of hay shipments in Washington State are displayed in Figure 3.1. There are three general 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 hay producers serve the origination point for all hay shipments and the export ports serve as and the final destinations. Each producer has the option of transporting hay by truck to brokers, intermediate ports, final export ports and/or feedlots. Producers also may ship hay directly to the final destinations or transship through intermediate 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) represents the average statewide production volume.

Since the intermediate destinations (nodes 2 and 3 in Figure 3.1) are the only transshipping possibilities, they each act both as a potential destination and as a potential source. The number of shipments 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. Ninety-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 Model



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. The objective function can be specifically stated as follows:

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

i = origin
j = intermediate destination
k = final destination
l = mode
si = supply of hay at origins (in tons)
dk = demand for hay at destinations (in tons)
cijkl = 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 X_{ijkl} elements and identify the (least-cost) optimal solution of the model. The transportation model is constrained to only allows positive shipments between each origin and destination point.

(2) **x_{ijkl} = amount of hay shipped 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 hay transportation 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 Si (3). Thus, the sum of all shipments from each producer cannot exceed the available production of each producer and the demand constraint 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 at each final destination (k), defined by D_k.

Observe supply limit at producer (i):

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

Satisfy demand at market (k):

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

The rail constraint (5) 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 total rail capacity for all final destinations (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 total barge capacity for all final destinations (k).

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

Constraints are included in this model so that the initial least-cost optimal solution also represents the way current hay shipments flow prior to any industry shifts. 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 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, if not approaching perfectly inelastic in the short-run, as illustrated in Figure 3.2.

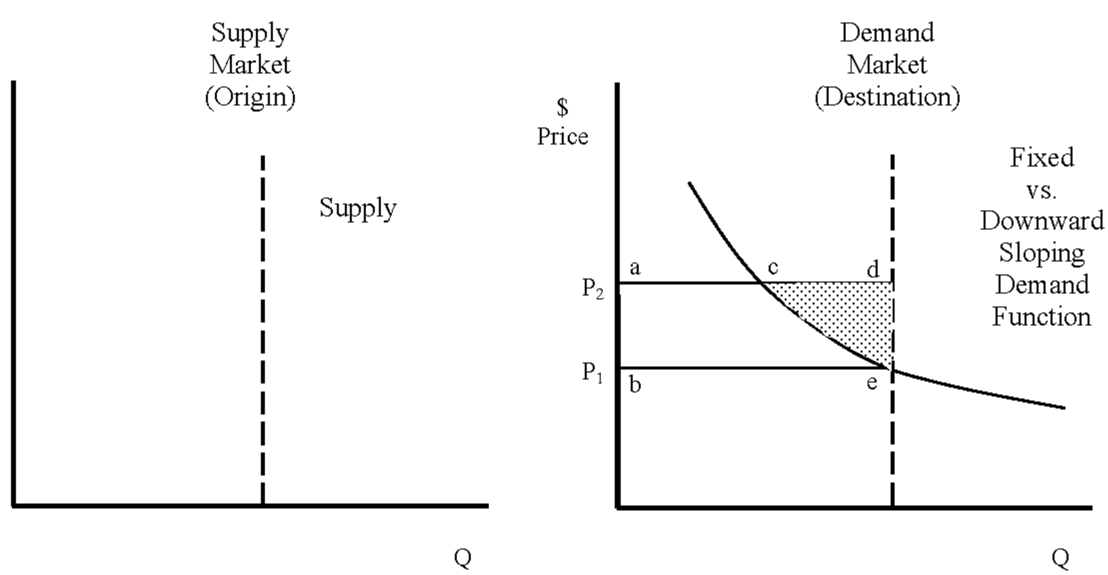
This transportation optimization model includes 4 processors, 2 ports and 9 destination markets (k) within Washington State. The quantity of hay demanded at each destination market is also treated as a constant. The true demand function for hay is downward sloping to the right instead of perfectly inelastic (Figure 3.2) due to the fact that most consumers are sensitive to price fluctuations. The implications from treating demand as a fixed constant instead of a downward sloping demand function is graphically represented in Figure 3.2. 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 due 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. Therefore, the loss in consumer surplus is generally 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 level and detail of information was not available and therefore this transportation optimization model approximates demand with the aforementioned limitations.

Scenarios

Three separate scenarios are analyzed in this study to estimate the cost and volume implications as a result of reduced container services at the Port of Portland.

The initial base case scenario illustrates the existing comparative advantage of each mode and depicts flows prior to loss of container services at the Port of Portland. The second scenario utilizes a similar model but eliminates all barge activity and relaxes the volume constraint on rail. Portland's hay demand is then set to zero; meaning all hay that was shipped to Portland on barge is now redistributed to Seattle (25 percent) and Tacoma (75 percent). This change represents the hay flows after September 2004 when two of the three main container ship lines pulled out of the Port of Portland and now call at the Port of Seattle and Port of Tacoma. The final scenario maintains all assumptions as Scenario 2 but introduces a 25 percent increase in trucking rates due to truck shortages brought about by increased demand and limited truck availability and 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 as a result of the transportation shift.

Figure 3.2. Supply and Demand Market Relationships



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 effectively will need additional drivers and equipment to compensate for lower hours of operation and productivity per driver. This change is expected to increase costs of operation.

RESULTS

Scenario I

The optimal base scenario outlines current transportation flows of each mode. All hay movements are shipped via truck from producers and the large majority of shipments go directly from producers to feedlots within the state, accounting for 57 percent of all producer shipments (Table 4.1). The next largest destination for producers is hay brokers, where additional processing occurs before being reallocated to final destinations. 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. 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.

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 4.2).

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		

Table 4.2 Transportation Costs, by 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		

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 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 considerable change in Scenario 2 when barge is eliminated and shipments are then redistributed to Seattle and Tacoma in a least-cost fashion. In Scenario 2 Portland's demand is reduced to zero and shipments from producers to intermediate destinations continue as in Scenario 1. Producers do shift away from trucking hay to Tacoma, experiencing a 95 percent decrease. However, the reduction of truck 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.

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 available export port, Seattle (41 percent or 644,336 tons).

There is also 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 and closer geographical proximity to Seattle and Tacoma from the 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 4.2).

Scenario III

In Scenario 3 there is a 25 percent increase in truck rates, 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 increases 23 percent from the second scenario. A large proportion of this cost is a result of the shipments from producers to intermediate and final destinations ($27.7 million or 58 percent). Also, 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 4.2). Scenario 3 increased as well (8 percent) which was expected with the trucking rate increase.

Hay shipments from broker to final destination represents 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.

SUMMARY AND CONCLUSIONS

Three different transportation scenarios are presented and evaluated including one which characterizes hay shipments prior to September 2004. 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 follows a similar set of constraints but also includes a 25 percent increase in trucking rates. The results from the third scenario represent the most likely market impacts after the freight market has responded to the increased demand for trucks.

The results indicate that after all barge and hay shipments are eliminated into Portland, total transportation costs decrease initially overall as hay volume is moved by truck and rail to ocean ports in Seattle and Tacoma. The primary reason for the lower overall transportation cost is due to the increase rail utilization and the closer geographical proximity of the Ports of Seattle and Tacoma relative to Portland. However, not all producers experience shipping cost savings which depends largely upon their geographical location. Those producers experiencing shipping cost increases are those located in the eastern and southeastern areas of Washington State and are forced to truck hay shipments for longer distances. However, the industry overall is not adversely impacted due to the initial elimination of container services at the Port of Portland.

As trucking rates increase due to the increased demand for trucking services, the industry transportation cost does increase to $47.5 million, a 15 percent increase from Scenario one and a 22 percent increase from Scenario two. While this increase is significant, it is not as severe or adverse as previously expected throughout the Pacific Northwest agricultural and hay industry. As expected, there is greater reliance on rail and truck transportation once barge shipments to Portland are eliminated.

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