POTENTIAL FOR FREIGHT MODE SHIFTING IN OREGON

Final Report

Oregon Department of Transportation

POTENTIAL FOR FREIGHT MODE SHIFTING IN OREGON

Final Report

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16. Abstract: The movement of freight is critical to the economic prosperity of Oregon. According to the Oregon Freight Plan, freight-dependent industries such as manufacturing, agriculture, construction and retail provided the state with 700,000 jobs and generated $29 billion of personal income in year 2008. Oregon ranks 9th in the nation for trade per capita – 2009 exports totaled $14.9 billion. Freight mode choice is a logistical decision made by private firms operating in competitive markets regionally, nationally and internationally. As such, each mode provides a range of competitive and complementary freight transportation options that are used by shippers to make modal choice decisions. The choice of a particular mode revolves around logistical factors related to cost, time, reliability, accessibility, security and safety. With this in mind, this study provides a high-level investigation of how private sector decisions are made for freight movement, identify key factors influencing these decisions, and identify market conditions likely to result in shifts in freight modes in Oregon given existing information and data. In addition, this report describes data challenges and limitations.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

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1.0 INTRODUCTION

1.1 BACKGROUND

The movement of freight is critical to the economic prosperity of Oregon. According to the Oregon Freight Plan, freight-dependent industries such as manufacturing, agriculture, construction and retail provided the state with 700,000 jobs and generated $29 billion of personal income in year 2008. Oregon ranks 9th in the nation for trade per capita—2009 exports totaled $14.9 billion. Oregon utilizes truck, rail, marine, pipeline and air modes to transport goods. Each mode provides a range of competitive and complementary freight transportation options that are used by shippers to make modal choice decisions. The choice of a particular mode revolves around logistical factors related to cost, time, reliability, accessibility, security and safety. As a result, each mode tends to serve commodities with similar logistic needs. For example, commodities shipped by air tend to be high-value/low weight and time-sensitive, while rail and marine freight usually move low-value/high weight and less time-sensitive shipments. Commodities moved by truck involve a range of logistical characteristics.

Freight mode choice is a logistical decision made by private firms operating in competitive markets regionally, nationally and internationally. Truck freight is the dominant mode of freight movement in Oregon. Over 70% of freight moves by truck. The Oregon Freight Plan (OFP) forecasts freight moved will increase over 60% by weight and nearly 120% by value between 2010 and 2035. An OFP survey of shippers indicated that congestion on highways and on rail facilities adds cost and uncertainty to freight movement. These are expected to increase as freight movement grows.

With this in mind, this study will provide a high-level investigation of how private sector decisions are made for freight movement, identify key factors influencing these decisions, and identify market conditions likely to result in shifts in freight modes in Oregon given existing information and data.

1.2 RESEARCH OBJECTIVES

The purpose of this study is to prepare information on freight mode choice in a form that supports the State of Oregon in making informed decisions in the area of freight-related investments and long range planning activity. The study goal is to facilitate understanding of conditions necessary for freight mode shift to occur. In order to meet this goal, the following objectives will be met:

1. Describe how firms make logistical decisions and how that translates into mode choice, including multimodal aspects.

2. Describe differences in freight logistics by commodity characteristics and provide detailed examples for representative Oregon commodities.

3. Identify market conditions necessary for mode shift to occur.

4. Identify Oregon commodities with potential for mode shift and describe the “tipping point” conditions necessary for shifts to occur.

5. Create illustrative examples of Oregon commodities with mode shift potential, assume market conditions change and the shift occurs, and describe the impacts to facility operations. For example, suppose commodity A moves by truck but could shift completely to rail. How many truckloads could be removed from the highway?

1.3 BENEFIT

Using available data and research conducted by ODOT and other sources, this study will provide information to be used to evaluate and assess impacts of ODOT projects on freight movement, such as projects submitted through the ConnectOregon program and projects designed to address freight bottlenecks. This will result in more effective investment decisions and provide ODOT with data and information to support those decisions.

The description of firm logistical decisions and conditions impacting freight mode choice will be used by ODOT Transportation Planning Analysis Unit for long range planning analysis tool development and freight analysis methods. Analysis benefiting from new information such as this include the recent “Rough Roads Ahead: The Cost of Poor Highway Conditions to Oregon’s Economy” and the “2014 Seismic Plus Report.”

1.4 IMPLEMENTATION

This information will provide the initial foundation for opportunities to make investments designed to provide cost effective modal choices to Oregon shippers in support of efficient freight movement. Several decision-making entities will be able to make more informed investment decisions by using the results from this research, such as Area Commissions on Transportation and the Oregon Freight Advisory Committee. Results of this research will support choosing freight projects based on fact-based, data-driven merit.

2.0 LITERATURE REVIEW

The following section introduces freight movement and mode choice characteristics by providing detailed results obtained from a thorough literature review. Literature was separated into three distinct categories:

1. Oregon Department of Transportation (ODOT)
2. Department of Transportation (DOTs other than Oregon)
3. Academic Literature (e.g. published, peer-reviewed papers)

This section provides syntheses of the reviewed literature for each of the three aforementioned categories. The ODOT and DOT syntheses detail applicable research regarding freight movement and logistics, while the academic syntheses detail relevant research regarding factors that influence freight mode choice

2.1 ODOT LITERATURE

ODOT has conducted three recent analyses related to freight movement:

- Oregon Commodity Flow Forecast
- Oregon Freight Plan Modeling Analysis
- Oregon State Highway Metrics Related to Freight

The commodity flow forecast (CFF) was prepared in 2009 to support analysis conducted for the Oregon Freight Plan *(Parsons Brinckerhoff 2009)*. The CFF is a county-level commodity flow forecast in tons and vehicle for truck, rail, marine, air, and pipeline modes from 2002 to 2035. CFF followed a methodology derived from the Federal Highway Administration (FHWA) Freight Analysis Framework (FAF^2) national commodity flow forecast. The methodology is transparent in its assumptions and data sources. An inability to alter the underlying FAF^2 economic forecasts is a potential shortcoming, as well as FAF^2 information being somewhat out of date. However, the growth assumptions are reasonable and suitable for long range planning analysis. This study is capable of forecasting commodity flows, but lacks a stable economic factor due to the data utilized. In addition, the study does not address any mode shifting ideology based on the forecast. Adequate economic data utilized in union with anticipated commodity forecasts can provide fundamental information that can be adopted to determine if a potential to shift mode occurs.

The purpose of the 2010 Oregon Freight Plan analysis was to gain an understanding of the spatial land use and transportation implications of different economic conditions on freight flows *(ODOT TPAU 2010)*. This analysis illustrated variation in statewide and regional activity and commodity flow in order to help evaluate the risk associated with economic volatility on alternative Freight Plan strategies. Decision makers use the information to better assess the robustness of freight strategies and to avoid creating barriers that prohibit the freight industry from reacting nimbly to economic change. The Statewide Integrated Model 2 (SWIM2) was used to model four scenarios: business-as-usual (Reference), Optimistic Economic Forecast, Pessimistic Economic Forecast, and High Transportation Cost. The analysis demonstrated future demands on the freight system will be large even if economic growth is muted. Rising transportation costs will affect where households and businesses locate, in turn affecting commodity flows. Oregon is trade-dependent, so transportation costs impact competitiveness. Oregon has diverse regional economies that have diverse logistical needs. This study succeeded in determining the impacts that various economic conditions will have on freight logistics; however, the scope of the study did not seek further impacts. Fluctuating economic conditions, such as transportation costs, may impact freight by creating situations in which mode shifting is a viable option.

ODOT prepared data and developed performance metrics in 2013 to implement action items identified in the Freight Plan *(ODOT TPAU 2013)*. A systematic data-oriented approach to reporting highway performance was used to pilot test a new approach. Nineteen highway corridors were included in the report. Metrics used included average annual daily traffic (AADT), daily vehicle miles traveled (VMT), truck share of AADT and VMT, highway user costs, delay, volume/capacity ratios, crashes, commodity flows and industry use. This approach revealed locations with performance issues for further in-depth analysis to determine whether problems significantly affect freight movement. Although a great quantity of metrics were provided within this study, the study failed to address the potential of mode shifting. The AADT, VMT and truck share metrics described in this study can be used in combination with economic and mode choice data to determine if a potential to shift modes exists.

2.2 OTHER STATE DEPARTMENTS OF TRANSPORTATION

2.2.1 Florida Department of Transportation

The Center of Urban Research (CUTR) at the University of South Florida conducted a study for the Florida Department of Transportation *(CUTR undated)*. The focus of the study was based on a question originally asked by the Washington State Department of Transportation, "How would highways be impacted if all the freight currently moving by rail had to, instead, be moved by truck?" To answer this question, the University of Florida Bureau of Economic and Business Research (BEBR) was consulted to allow the study to focus on the economics that would lead to such a situation. CUTR began by reviewing all relevant literature to determine industry sectors that would be more likely to shift mode, while BEBR provided economic explanations that would permit a modal shift. Upon determining the stages and factors leading to mode shifting, CUTR issued surveys to private firms; nevertheless, it received only 10 responses that were utilized for the study. Along with the survey responses, CUTR utilized two datasets to determine the 10 largest commodity groups being transported in Florida, the 1997 Commodity Flow Survey and 1998 TRANSEARCH data. Key mode choice factors determined by CUTR from the surveys are shown in Table 2.1.

Table 2.1: Primary Mode Choice Factors

Total Logistic Costs	Order and Handling Costs
	Transportation Charges
	Loss and Damage Costs
	Capital Carrying Cost in Transit
	Inventory Carrying Cost at Destination
	Unavailability of Equipment Costs
	Service Reliability Costs
	Intangible Service Costs (e.g. Billing Processes)
Physical Attributes of Goods	Shipment Size
	Package Characteristics
	Shipment Shelf Life
	Shipment Value
	Shipment Density
Flow and Spatial Distribution of Shipments	Shipment Frequency
	Distance of Shipment
Modal Characteristics	Capacity
	Trip Time and Reliability
	Equipment Availability
	Customer Service
	Handling Quality - Damage Loss Reputation

Source: *(CUTR undated)*

Upon further investigation, CUTR concluded that commodities fall within three potential mode shifting scenarios: (1) Very low/no shift potential, (2) Very small shift potential and (3) Possible/significant shift potential. The commodities for each scenario are described below:

- Very low/no shift potential

    1. Waste

    2. Coal

    3. Nonmetallic Minerals

- Very small shift potential

    1. Petroleum

- Possible/significant shift potential

1. Chemicals
2. Lumber
3. Transportation Equipment
4. Agriculture
5. Paper
6. Metal/Metal Products

Finally, CUTR established three mode choice stages with decision factors associated with each. These decisions where assigned a number from 1 to 9 to highlight at what point these factors come into play in the mode choice decision process. The following illustrates the three stages and associated mode choice decision factors:

- Immediate
  1. Total Logistic Cost
     - Transportation Costs
  2. Total Logistic Cost/Modal Characteristics
     - i. Capital Carrying Cost in Transit
     - ii. Service Reliability Costs
     - iii. Trip Time and Reliability
  3. Physical Attributed of Goods/Flow and Spatial Distribution of Shipments
     - i. Shipment Size
     - ii. Package Characteristics
     - iii. Shipment Shelf Life
     - iv. Shipment Value
     - v. Shipment Density
     - vi. Distance of Shipment
- Mid-term
  4. Firm Characteristics

        - Shippers and Receivers Situated on Rail Line
        - Shippers Near Highway
        - Firms Own Small Trucks

    5. Flow and Spatial Distribution of Shipments/Modal Characteristics
        i. Shipment Frequency
        ii. Capacity
        iii. Equipment Availability
        iv. Handling Quality - Damage Loss Reputation

- Final

    6. Total Logistics Cost
        - Order and Handling Costs
    7. Total Logistics Cost
        i. Loss and Damage Costs
        ii. Inventory Carrying Cost Destination
        iii. Unavailability of Equipment Costs
    8. Total Logistics Costs
        i. Intangible Service Costs
    9. Modal Characteristics
        i. Customer Service

- The study was effective in determining commodities that would have, or not have, the potential for mode shifting. Nevertheless, CUTR was unsuccessful in determining at what point mode shifting is likely to occur. In addition, the data utilized by CUTR represented only outbound freight, causing uncertainty in the mode shifting estimates.

For the Florida Department of Transportation, Dewey et al. conducted a study to examine the effect that a government subsidy would have on rail and truck shipments *(Dewey et al. 2002)*. The authors refer to Transportation Satellite Accounts for their data regarding purchases and sales of transportation services.

Initial analysis provided evidence that mode shifting has potential at the industry level (based on the account data), yet to further investigate this potential mode shifting due to a subsidy, Dewey et al. generated a model of the surface freight transportation market, a method adopted from previous work *(Friedlaender and Spady 1981)*.

The model developed by Dewey et al. consisted of two demand functions: (1) One characterizing Florida and (2) One characterizing the remainder of the United States where Florida railroads operate. Utilizing the commodity flow survey, it was determined that freight shipped by truck and freight shipped by rail were separated by approximately 10 billion ton-miles at 30.361 billion ton-miles and 19.822 billion ton-miles respectively. Furthermore, Dewey et al. adopted a price of 2.4 cents per rail ton-mile and 8.42 cents per truck ton-mile from previous literature *(Wilson 1999; Forkenbrock 1999)*. Lastly, to obtain a best fit model to estimate mode shifting, Dewey et al. produced the model assumption shown in Table 2.2.

Table 2.2: Model Assumptions and Parameters

Elasticity of Marginal Cost with Respect to Output	-0.5
Price of Freight Shipment, Railroads (Cents per Ton-Mile)	2.4
Price of Freight Shipment, Trucks (Cents per Ton-Mile)	8.42
Markup Rate, Railroads	1.34
Railroad Freight, Florida (Billion Ton-Miles)	19.822
Truck Freight, Florida (Billion Ton-Miles)	30.361
Elasticity of Demand for Shipment by Railroad	-1
Elasticity of Demand for Shipment by Truck with Respect to Rail Price	0.5
Elasticity of Demand for Shipment by Truck	-0.5
Elasticity of Demand for Shipment by Railroad with Respect to Truck Price	1
Elasticity of Demand for Shipment by Railroad with Respect to GSP	0.3
Elasticity of Demand for Shipment by Truck with Respect to GSP	0.6
Welfare Loss per Dollar of Tax Revenue	0.25
Florida Gross State Product (Billion $)	389.473
Other Region Gross State Product (Billion $)	3894.73

Source: *(Dewey et al. 2002)*

Dewey et al. define the optimal price as the intersection of the market demand curve and the industry supply curve, thus allowing the optimal subsidy to be the difference of the optimal price and the price charged by railroads. The authors continued to investigate the effect of the optimal subsidy, as the marginal cost elasticity related to freight varied from 0 to -0.9, by extrapolating the regression coefficients. The best fit model revealed that rail traffic would have a notable increase of 43%, while truck traffic would decrease by 16%. Ultimately, the gain in economic efficiency for the state of Florida would total $26 billion. A summary of their model results is shown in Table 2.3.

Table 2.3: Summary of Model Results

Optimal Subsidy (Percent of Price Paid)	0.34
Optimal Subsidy (Cents per Ton-Mile)	0.57
Change in Railroad Freight (Billion Ton-Miles)	8.5
Change in Truck Freight (Billion Ton-Miles)	-5
Total Subsidy Payments (Million Dollars)	161
Welfare Change, Subsidy Policy Alone (Million Dollars)	26
Welfare Change, Revenue Collection (Million Dollars)	-40
Welfare Change, Net (Million Dollars)	-14

Source: *(Dewey et al. 2002)*

Dewey et al. recognized that a subsidy policy that would be inclusive of multiple states would be more beneficial to the state of Florida, thus reducing the optimal subsidy to 0.45 cents per mile. Rail freight traffic would increase by 16 billion ton-miles; in contrast, truck traffic would decrease by 8 billion ton-miles. A complete summary of results with a coordinated subsidy policy are shown in Table 2.4.

Table 2.4: Subsidy for Railroads when Coordinating with Other States

Optimal Subsidy (Percent of Price Paid)	0.34
Optimal Subsidy (Cents per Ton-Mile)	0.45
Change in Railroad Freight (Billion Ton-Miles)	15.7
Change in Truck Freight (Billion Ton-Miles)	-7.7
Total Subsidy Payments (Million Dollars)	162
Welfare Change, Subsidy Policy Alone (Million Dollars)	48
Welfare Change, Revenue Collection (Million Dollars)	-40
Welfare Change, Net (Million Dollars)	8

Source: *(Dewey et al. 2002)*

Due to uncertainty with contemporary market conditions, Dewey et al. modeled two market demand scenarios: (1) 10 billion ton-miles and (2) 40 billion ton-miles. Results for both scenarios are displayed in Table 2.5.

Table 2.5: Uncertainty in Existing Market Demand

	Scenario 1	**Scenario 2**
Existing Market Demand (Billion Ton-Miles)	10	40
Optimal Subsidy (Percent of Price Paid)	0.34	0.34
Optimal Subsidy (Cents per Ton-Mile)	0.57	0.57
Change in Railroad Freight (Billion Ton-Miles)	4.3	17.3
Change in Truck Freight (Billion Ton-Miles)	-4.9	-4.9
Total Subsidy Payments (Million Dollars)	81	326
Welfare Change, Subsidy Policy Alone (Million Dollars)	13	53
Welfare Change, Revenue Collection (Million Dollars)	-20	-82
Welfare Change, Net (Million Dollars)	-7	-29

Source: *(Dewey et al. 2002)*

Also, Dewey et al. acknowledged a need to compare the demand price elasticities to the "would be" optimal subsidy price. This comparison provided the required subsidy to implement mode shifting based on various demand elasticities. A summary of the relationships are presented in Table 2.6.

Table 2.6: Comparison of Optimal Subsidy to Price Elasticity of Demand

Elasticity of Demand	**Optimal Subsidy**
-1.1	1000%
-1.8	125%
-2.0	100%
-3.0	50%
-3.9	34%
-4.0	33%

Source: *(Dewey et al. 2002)*

Considering all the scenarios modeled by Dewey et al., a subsidy for rail freight created, on average, a 16% decrease in freight moved by truck. The authors, however, state that the variation in variables that fluctuate net welfare outcomes generates results that are inconclusive. Upon a more exhaustive study that examines charged externality rates, subsidies in coordination with other states and subsidies constrained to specific commodities, an accurate prediction for mode shifting can be attainable. Utilizing the method provided in this study and accounting for the aforementioned factors, conditions that encourage mode shifting potential could be determined.

2.2.2 Maryland Department of Transportation

Maryland freight industries are expected to expand by 120% from 2000 to 2030; therefore, Mishra et al. conducted a study to address the needs of new methods to assess and enhance freight transportation efficiency *(Mishra et al. 2013)*. Mishra et al. utilized several datasets for this study: (1) Freight Analysis Framework (FAF) data, (2) National Transportation Atlas Database (NTAD), (3) Longitudinal Employer-Household Dynamics (LEHD) data and (4) Workplace Area Characteristics (WAC) data. The authors elected to use their data to fit a binary logit model to model the percentage of tonnage by truck versus the percentage of tonnage by others and create origin-destination matrices with the use of TransCAD. The data was disaggregated to represent commodity flows that could be converted into total truck trips by using payload factors. Mishra et al. obtained four distinct results by using the binary logit approach and are shown below:

- Commodity Group 1: Shipped from Maryland by Truck (Low Truck Share)

    1. Highway distance was found to be the most significant variable. The variable had a negative coefficient that implies trucks are less likely to be preferred for origin-destination pairs that are further apart.

    2. Truck distribution centers were found to be significant in origin and destination areas.

    3. Shipments leaving FAF zones are more likely to choose truck from zones that contain a higher amount of truck distribution centers.

    4. A positive correlation was discovered between truck centers and the probability of choosing truck.

- Commodity Group 2: Shipped from Maryland by Truck (Medium Truck Share)

    1. Highway distance was found to be significant and negative as it was for Commodity Group 1; Shipped from Maryland by Truck (Low Truck Share).

    2. Truck distributions were found not to be significant in origin and destination areas.

    3. Employment has a positive effect for this group; hence, a higher number of transportation employees in destination areas increase truck share.

- Commodity Group 1: Shipped to Maryland by Truck (Low Truck Share)

    1. Highway distance continued to have a negative coefficient, although was less significant than before.

    2. An indication that shipments to Maryland are less likely to be shipped by truck if more ports are located in the origin area.

3. Employment continues to have a positive impact and greatly impacts the probability of choosing truck.

- Commodity Group 2: Shipped to Maryland by Truck (Medium Truck Share)

1. Highway distance remains significant and negative, as it was with the previous three scenarios.

The authors lacked focus on shipments within the state of Maryland, as well as the potential to shift modes. Such a study, if taken a step further, could result in critical findings that can lead to a discovery of when and how mode shifting can occur.

2.2.3 Minnesota Department of Transportation

The Minnesota Department of Transportation (MDOT) investigated recent waterway closures within Minnesota to determine the financial cost of mode shifting *(MDOT 1997)*. MDOT utilized a thorough and relevant literature review to arrive at their inference. Inland waterways are capable of moving one ton of freight greater than double the distance of rail and nearly ten times greater than the distance of truck. The primary ferry moving shipments from Thunder Bay, Ontario, to Duluth, Minnesota, shut down due to increased taxes. Consequently, shipments were required to be transported via truck and rail. This closure caused the annual fuel use of 134,241 gallons by ship to increase to over 1,000,000 gallons for truck transport and resulted in an additional fuel cost of $1,018,019. Carbon monoxide and nitrous oxide increased by 414 tons due to the required increase in truck use, resulting in a cost $74,069 greater than the use of the waterway. The probability of crashes occurring on water was nearly 0.0%, but increased on highways to more than 5.0% due to the increased amount of trucks. The annual cost resulting from the shutdown drastically increased for the use of trucks, $41,174,318. Although this study does not focus on factors that may lead to mode shifting, it explicitly states various reasons indicating that shifting from truck to other modes would enhance the transportation system and economy immeasurably. Simple descriptive statistics (e.g. average changes in fuel use, air quality, rail traffic, accident occurrences, etc.) allowed MDOT to conclude that shifting freight modes from waterways to land-based transport had a great impact; still, this study lacked a method to determine a tipping point for mode shifting.

Levinson et al. conducted a study to assess operating cost elasticities of trucking companies by considering various factors *(Levinson et al. 2004)*. To accomplish this, the authors issued a “mail-out/mail-back” survey to the individuals responsible for making the freight operating cost decisions for trucking companies in Minnesota. Pertinent information obtained from the surveys included type of truck, number of axles, distance traveled, number of employees, commodity type, penalties for late or missed deliveries, individual responsible for route choice selections, total truckloads per year, operating cost per unit of distance, existence of fuel surcharge and the manner the drivers were compensated. Utilizing 186 responses, the authors developed their models. To analyze the mean response of their dependent variable “Total Annual Cost,” the authors used the following explanatory variables: Size of the firm (determined by kilometers per truckload and total number of truckloads), Firm Strategy (all customer and firm policies) and Type of Firm. To fit the most accurate model, the authors began with simple linear regression that was determined to not explain the data well. Secondly, the authors fit a Cobb-Douglas model (see *(Levinson et al. 2004)*). Although resulting in better estimates than the linear regression model, the authors elected to fit a Box-Cox model (see *(Levinson et al. 2004)*). The Box-Cox model presented no significant improvement over the Cobb-Douglas model; therefore, Levinson et al. elected to use the results from the Cobb-Douglas model to compute the elasticities of total annual operating costs relative to kilometers per truckload and the total number of truckloads. Results from the Cobb-Douglas model indicated that operating cost elasticities were close to 1; however, model coefficients were slightly greater than 1 indicating *possible* diseconomies of scale. The actual values from the survey and the predicted values from the model were extraordinarily close, as shown in Figure 2.1.

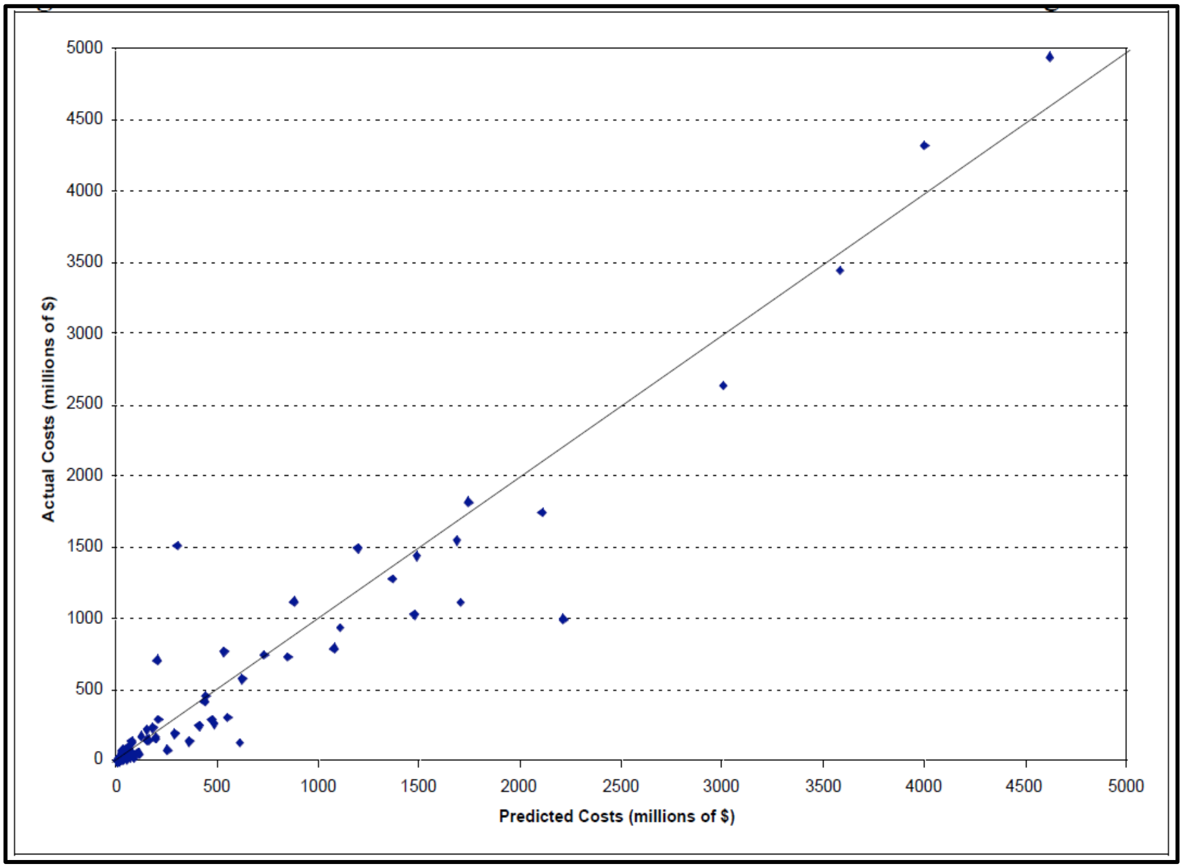

Figure 2.1: Actual Values versus Predicted Values of Best Fit Model (Source: (*Levinson et al. 2004*))

The best fit model provided an average cost function and marginal cost function that allowed Levinson et al. to calculate the estimated cost and estimated marginal cost. Using the mean of each explanatory variable in the best fit model, the average cost per truckload was $232, compared to the $249 per truckload obtained from the survey. Also utilizing the mean of each explanatory variable, the marginal cost per truckload was determined to be $6.51. Contrary to the possibility of diseconomies of scale alleged by the model, the calculations indicated that there are significant economies of scale due to the marginal cost being significantly less than the average cost per truckload.

Levinson et al. expressed that of all models considered, the Cobb-Douglas model provided the most accurate estimates of the observed data. This method can be applied when looking at elasticities for Potential for Freight Mode Shifting in Oregon study. Knowledge of the effect that one entity has on the trucking sector can greatly benefit the goal of determining when mode shifting is likely to occur. Levinson et al. also provided a cost function equation that may be adopted, if necessary.

2.2.4 European Union

To gauge changing transportation policies in Europe accurately, Jong et al. examined the role that price sensitivity has on the European freight transportation system *(Jong et al. 2010)*. To accomplish such, the authors focus on three types of price changes: (1) Fuel prices, (2) Vehicle kilometer prices and (3) Ton-kilometer prices. The three aforementioned price changes result in six types of price elasticities, as shown in Table 2.7.

Table 2.7: Price Elasticity Types

Price Change	**Impact On**		
	Fuel Use	**Vehicle Kilometers**	**Ton Kilometers**
Fuel Price	X	X	X
Vehicle Kilometer Price		X	X
Ton Kilometer Price			X

Source: *(Jong et al. 2010)*

Jong et al. discovered that five response mechanisms exist in road freight transportation: (1) Different market segments with different substitution possibilities, (2) Different components of total transport costs, (3) Price increases versus price decreases, (4) Price changes of different magnitude and (5) Different definitions of transportation mode. The authors continue by dividing the reactions as displayed in Table 2.8. Table 2.9 summarizes the response mechanisms by defining the decision makers and the type of effect the elasticities have on freight decisions.

Table 2.8: Response Mechanisms Definitions

Response Mechanism	Definition
1	Fuel Efficient Vehicles
2	Fuel Efficient Driving
3a	Optimize Allocation of Vehicles to Shipments
3b	Consolidate Shipments Originating from Same Company
3c	Consolidate Shipments Originating from Several Companies
3d	Change in Number and Location of Depots
3e	More Return Loads to Reduce Empty Driving
4	Change in Route and Time of Day
5	Increase Shipment Size
6	Change of Mode
7	Change in Production Technology
8a	Choice of Supplier and Receiver
8b	Production Volumes per Location
9	Reduction in Demand for the Product

Source: *(Jong et al. 2010)*

Table 2.9: Response Mechanisms – Decision Makers and Effects

			Type of Effect			Dimension of Output		
Reactions	Decision Maker	Time Scale	Fuel Efficiency	Transport Efficiency	Transport Volumes	Tons	Vkm	Tkm
1	C	S-M	X					
2	C	S-M	X					
3a	C	S-M		X			X	
3b	C/S	S-M		X			X	
3c	C	S-M		X			X	
3d	C/S	S-M		X			X	
3e	C	S-M		X			X	
4	C/S/R	S		X			X	X
5	S/R	S-M		X			X	
6	S/R	M-L			X	X	X	X
7	S/R	L			X	X	X	X
8a	S/R	L			X		X	X
8b	S/R	L			X		X	X
9	D	S-M			X	X	X	X

Source: *(Jong et al. 2010)*

Decision Maker: C = carrier, S = shipper, R = receiver, D = consumer (demand)
Time Scale: S = short term, M = medium term, L = long term

To illustrate how freight elasticities can be used to examine transportation impact, De Jong et al. conducted three exercises:

1. Increase diesel tax by €0.10 per liter of fuel used, CO_2 emitted and kilometers driven

2. Kilometer charge of €0.15 per kilometer of fuel used, CO_2 emitted and kilometers driven

3. 20% decrease in cost per ton-kilometer

Jong et al. determined that an increase in diesel tax reduces fuel demand and vehicle kilometers, as well as creates a 0.4% shift from truck to inland waterways and rail. The kilometer charge increased the transport cost, reducing the vehicle kilometers and creating a modal shift from truck to water and rail of 3.8%. The 20% decrease increased demand and created a modal shift from truck to water and rail of 8%. Table 2.10 displays the concluding fuel price elasticities.

Table 2.10: Fuel Price Elasticities

Price Change		**Impact On**		
		Fuel Use	**Vehicle Kilometers**	**Ton-Kilometers**
Fuel Price		-0.2 to -0.6	-0.1 to -0.3	-0.05 to -0.3
Vehicle Kilometer Price			-0.1 to -0.8	-0.10 to -0.5
Ton-Kilometer Price				-0.60 to -1.5

Source: *(Jong et al. 2010)*

Due to the lack of literature on fuel price elasticities, the authors were not capable of using the elasticities to determine a specific condition that would encourage mode shifting. Of the three exercises, all of them created a percentage of modal shifts, but the study lacked details about commodities and what would lead decision makers to make the decision to shift modes. If applied, the use of elasticities can prove to be valuable in determining accurate mode shifting conditions.

2.2.5 United States Department of Transportation

The United States Department of Transportation (U.S. DOT) carried out a study to assess modal shifting based on vehicle configurations within the Comprehensive Truck Size and Weight Limits Study (CTSW) *(U.S. DOT 2013)*. CTSW utilized an extremely disaggregated set of commodity flow data allowing them to investigate the practicality and cost of moving commodities between several origin-destination pairs by diverse vehicle configurations. Due to data from the U.S. Bureau of Economic Analysis (BEA) and the Freight Analysis Framework (FAF) creating an analysis procedure with a much greater level of difficulty, U.S. DOT elected to use county-to-county flow data. County-to-county flow data allowed U.S. DOT to perform a detailed analysis regarding the diverse vehicle configurations. The disaggregated data, purchased from an unknown private vendor, was used in a total logistics cost model to estimate mode choice decisions by determining the lowest total logistics cost for each mode. CTSW was based on a 10% decrease in all trucking costs, as was determined from the previous CTSW completed in 2000. Focusing on a multi-dimensional commodity flow matrix, a series of network routing and a 10% decrease in all trucking costs, U.S. DOT discovered the following *(U.S. DOT 2013)*:

- The primary logistics costs associated to alternative modes are:
    1. Transit time
    2. Warehousing and inventory costs
    3. Safety stock requirements
- Logistics costs vary greatly between truck and rail, while they vary just as greatly between diverse truck configurations.
- Mode shifting studies based on cross-elasticities are only as accurate as the cross-elasticities used in the study.

U.S. DOT continues the study by referring to studies conducted by other states. The primary consensus was that mode shifting configurations were based on expert opinion on the shipper side. However, U.S. DOT discovered a study in Virginia that used a distinct method, the ITIC model. The ITIC model, developed and maintained by FHWA, has been well documented. The ITIC model works by identifying and comparing total logistics costs for various modes of freight transport. This study consisted of primarily literature review and was unable to provide useful information regarding how and when mode shifting is likely to occur.

Transportation Economics and Management Systems (TEMS) investigated the impact of high oil prices and the resulting mode shift potential along five specific corridors *(TEMS 2008)*. A considerable amount of uncertainty in oil price changes lead TEMS to define 3 distinct scenarios: (1) A low (optimistic) case that assumes little change in oil prices, (2) A high (pessimistic) case that assumes extreme change in oil prices and (3) A central case that assumes no change in oil prices. TEMS utilized the Energy Information Administration (EIA) database to derive data from 2000 to 2007 and generated predictions/forecasts using growth rates established by EIA. FAF data was used to create an origin-destination matrix, and Bureau of Transportations Statistics data was used to define a traffic database on cross-border flows. These were inputted into the TEMS GOODS™ model. The model used a framework to assess the most substantial factors in shipper and carrier route choice decisions. The GOODS™ model determined that transit time, shipping cost, frequency and reliability would be the four critical factors considered in the study. TEMS discovered the impact that oil prices have on truck and rail services as a function of fuel price, and are shown in Table 2.11 and Table 2.12. The results in the following tables indicate that shippers would save a substantial amount of money if shifting from to truck to rail or truck to water.

Table 2.11: Trucking Costs as a Function of Fuel Price

Scenario	$/Barrel	Diesel/Gal	Truck Cost/Mile	Fuel % of 2005 Base	Truck % of 2005 Base
2002 Historic	$28.85	$1.37	$1.41	53%	80%
2005 Base	$54.79	$2.40	$1.75	100%	100%
2020 Optimistic	$59.61	$2.61	$1.82	109%	104%
2020 Central	$91.03	$3.99	$2.28	166%	130%
2020 Pessimistic	$157.18	$6.88	$3.24	287%	185%

Source: *(TEMS 2008)*

Table 2.12: Rail Costs as a Function of Fuel Price

Scenario	$/Barrel	Fuel % of 2005 Base	Rail Cost per FEU-Mile	Rail % of 2005 Base
2002 Historic	$28.85	53%	$0.30	84%
2005 Base	$54.79	100%	$0.36	100%
2020 Optimistic	$59.61	109%	$0.37	103%
2020 Central	$91.03	166%	$0.45	123%
2020 Pessimistic	$157.18	287%	$0.60	164%

Source: *(TEMS 2008)*

TEMS provided constructive information regarding fuel prices and the impact they can have on mode shifting. However, TEMS was unsuccessful in determining a point at which shippers would elect to shift modes. No commodity data was included in the results, consequently leaving questions regarding commodities, their potential to shift modes and when mode shifting would occur.

The studies that provided potential mode shifting situations had similar results as the Cambridge study. The factors that could lead to mode shifting were comparable. The following is taken verbatim from the Task F Technical Memorandum *(Cambridge Systems 2015)*:

Factors Influencing Modal Shift

General factors influencing BCOs and logistics service providers that control shipment routing on behalf of their customers to shift or not shift modes include:

- *Transportation costs;*
- *Access to service or mode;*
- *Modal capacity;*
- *Commodity characteristics;*

- *Equipment requirements and availability;*
- *Distance from source to processing or production facility or consumer market;*
- *Time-sensitivity and perishability of product;*
- *Inventory levels;*
- *Security needs, particularly for high value products;*
- *Public policy and regulations governing transportation; and*
- *Labor issues related to the various transportation modes.*

2.2.6 Academic Literature

Shen and Wang examined freight mode choice by using a binary logit model and geographical information systems (GIS) *(Shen and Wang 2012)*. The authors elected to use the Freight Analysis Framework (FAF) dataset. To make use of GIS, the authors used GIS format data acquired from FAF, the Bureau of Transportation Statistics (NTAD) and Oak Ridge National Laboratories. Shen and Wang processed 2006 NTAD within TransCAD to create results that were used to compare models. The results from TransCAD were obtained by considering origins and destinations that send and receive ***only*** cereal grain. Explanatory variables used in the binary logit model consisted of weight of shipment, value of shipment, shortest network for an origin-destination pair, travel time and fuel cost. The binary response variable consisted of truck and rail, where truck was represented by the number one so that inference could be made with respect to truck. Upon arriving at the best fit model, the authors compared the results to the previously obtained results from TransCAD. The numbers indicated that the binary logit model was an adequate alternative in determining freight mode choice, as the difference in values from TransCAD were at most 0.33%. Shen and Wang discovered that the binary logit method is adequate in estimating the factors that lead to freight mode choice; however, no data obtained from shippers was represented in the data used for the study. To better determine the factors that shippers consider when selecting modes, information from the decision makers is necessary. If data from shippers can be attained, an improved insight on shipper mode choice behavior can be estimated using a similar methodology and provide helpful information in determining the viability of mode shifting for shippers.

To assist the feasibility of modal shifts due to continued maximum capacity on highways, Arencibia et al. studied a population consisting of producers (e.g. shippers, distributors) of manufactured goods *(Arencibia et al. 2015)*. The area of study focused on a corridor that is responsible for 4.3% of all traffic between two locations where competition between freight modes is present. The authors issued a survey to the person responsible for making shipping decisions to several firms, then followed up with a second survey that was based on the responses of the first. A total of 93 usable surveys were collected for the study. Results from the first survey indicated that the most important factor in mode choice is the reliability of delivery times, with transport cost and transit time a close second. Albeit, certain commodities do not lend themselves to be shipped via the quickest mode. However, this was not within the scope of this study.   Surprisingly, the least important factor was environmental impact. Figure 2.2 displays the variation in the importance in mode choice decisions.

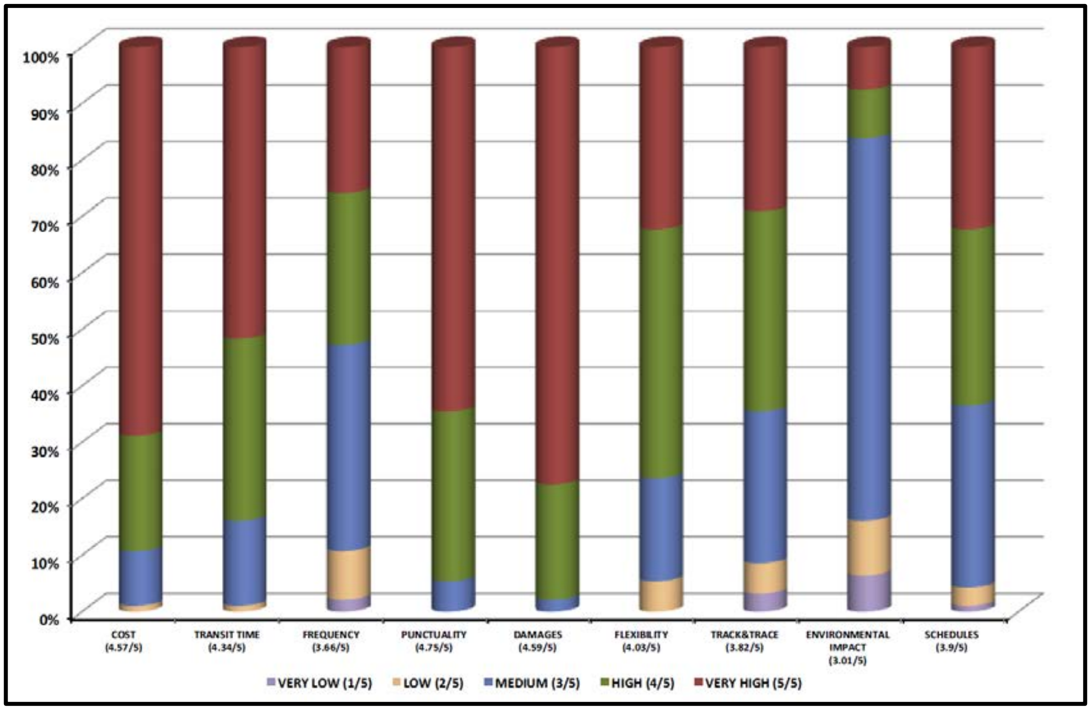

Figure 2.2: Importance of Freight Mode Choice Factors (Source: *(Arencibia et al. 2015)*)

The authors used the data obtained from the surveys to fit a multinomial logit model to estimate significant freight mode choice factors. Results from the multinomial logit model indicated that the driving decision for mode choice is the magnitude of delay. Elasticities from the best fit model are shown in Table 2.13.

Table 2.13: Elasticities for Best Fit Model

Attributes of the Own Mode	Elasticity of the Probability of Road		Elasticity of the Probability of Intermodal Alternative	
	Using the mean of est. parameters	Using simulated probabilities	Using the mean of est. parameters	Using simulated probabilities
Direct Elasticities				
Cost	-1.79	-1.53	-2.49	-1.79
Transit Time	-0.43	-0.37	-0.72	-0.55
Service Frequency	0.15	0.08	0.25	0.25
Delay Time	-0.27	-0.27	-0.35	-0.2
Attributed of the competing mode	**Elasticity of the Probability of Road**		**Elasticity of the Probability of Intermodal Alternative**	
	Using the mean of est. parameters	Using simulated probabilities	Using the mean of est. parameters	Using simulated probabilities
Cross-Elasticities				
Cost	1.7	1.31	2.61	2.09
Transit Time	0.50	0.4	0.63	0.51
Service Frequency	-0.17	-0.19	-0.22	-0.11
Delay Time	0.24	0.14	0.4	0.36

Source: *(Arencibia et al. 2015)*

This study presented a substantial amount of beneficial information in determining mode shifting, however did not address mode shifting. Understanding the factors that lead to decision maker behavior is a major part in determining if shippers would consider shifting modes if ideal conditions arise.

A study by Lloret-Batlle and Combes addressed incomplete freight mode choice models by examining a model that includes factors relating to shipment size, also known as inventory theory *(Lloret-Batlle and Combes 2013)*. The model is entirely demand oriented, with distance between origin-destination pairs, characteristics of the shipper-receiver pair and characteristics of transported commodities used as explanatory variables. Optimal shipment size and the total logistics costs of each mode were used to build the discrete choice models, and optimal shipment size was determined based on a cost function defined by Lloret-Batlle and Combes. The authors elected to use the ECHO database (see *(Lloret-Batlle and Combes 2013)* for data description) that is comprised of 10,462 shipments shipped by approximately 3,000 shippers. Results of the authors' models proved to be empirically relevant.

Results also indicated that commodity types shape mode choice: (1) Private transport is preferred for shipping refrigerated goods, (2) Rail is preferred for shipping hazardous bulk materials and (3) Combined transport is preferred for shipping fragile goods. The study provided evidence that shipment size based on weight and quantity impacts mode choice behavior of the shippers, thus indicating that the weight and quantity of shipments can impact the potential to shift modes. When considering the point at which mode shifting could take place, shipment size of the commodities must be accounted for when determining the role it has on shipper mode choice behavior.

Moschovou and Giannopoulos performed a study based on survey responses from shipping firms *(Moschovou and Giannopoulos 2010).* The authors issued a small sample (pilot) survey to assess the adequacy of the survey to help determine the features needed for the second part of the survey. Upon revising the survey, the authors issued it to a larger sample consisting of approximately 500 firms. The survey issued to the larger sample contained general questions, questions related to mode choice and questions regarding mode choice criteria and the order of importance. All respondents of the large sample were verified via phone interviews and resulted in the breakdown shown in Table 2.14.

Table 2.14: Survey Breakdown

Respondent	Percentage
Owners (Shippers & Receivers)	70%
Logistic Service Providers	12%
Operators	18%

Source: *(Moschovou and Giannopoulos 2010)*

The authors elected to use five commodity groups in their study: (1) Food & Drinks, (2) Building Materials, (3) Chemicals, (4) Machine Parts & Machines and (5) Cars & Other Vehicles. The transportation chain for each commodity group was analyzed, with special attention paid to the mode already being used and the factors that led to the decisions to use those modes. Findings were classified into four distances:

- *Distances of 0 to 200 kilometers* – 97.8% of respondents use trucks for shipments of this distance.

- *Distances of 200 to 600 kilometers* – 84.9% of respondents use trucks for shipments of this distance, while 10.6% and 4.5% use ships and rail/airplane for shipments respectively.

- *Distances of 600 to 1,000 kilometers* – 64% of firms contacted did not make a large amount of shipments of this distance, or did not respond. Of the 36% that did respond, 47% of respondents use airplanes for shipments of this distance.

- *Distances of greater than 1,000 kilometers* – 76% of respondents reported no shipments of this distance; notwithstanding, truck and airplane were the primary modes at 45.5% and 40.9% respectively.

Finally, based on all analyses performed within the study, the authors determined the top 10 factors in freight mode choice are as follows[1]:

1. Reliability and quality of transportation services

2. Transportation cost

[1] See Section 4.1 for detailed descriptions of the freight mode choice factors

3. Probability for load damage or load loss
4. Customer service quality
5. Load size and packaging characteristics
6. Cargo lifetime
7. Cargo value
8. Frequency of service
9. Capability of shipment tracking and tracing
10. Availability of loading and unloading equipment

Although this study did not focus on mode shifting, it provided useful information regarding shipper mode choice behavior. Such shipping behavior must be considered when determining a potential for mode shifting. Results from this study can be applied in studies relating to mode shifting.

The factors influencing mode choice found throughout the academic literature were similar to that of the Cambridge study *(Cambridge Systematics 2015)*. The Task F Technical Memorandum concludes *(Cambridge Systematics 2015)*:

It is recognized that there are many factors that influence mode choice made by logistics professionals. These include freight costs, minimum shipment volume, transit times, time-sensitivity and perishability of the product, market location and service availability, carrier schedules, carrier availability, special handling required, product packaging, product characteristics such as density and weight, buying terms of sale that determine product ownership and liability, empty equipment availability, rail access, truck capacity, air carrier capacity, road and highway congestion, physical barrier[2]s and beneficial cargo owner (BCO) preferences.

2.3 SUMMARY OF LITERATURE REVIEW

The review of relevant literature provides insights into the conditions impacting freight mode choice, and to some extent, how firms make logistical decisions. Various literature based on several locations have determined that primary mode choice factors are consistent despite geographical locations. Geographical areas will lend themselves to one mode over another, yet the premise in which the mode choice is chosen is analogous. Several methods were presented that provide frameworks to estimate mode choice behavior of shippers; however, some may not be applicable to the current study but provide valuable insights into factors that motivate the mode choice process. On the other hand, studies regarding the use of direct and cross elasticities for various economic factors (conditions), given the time frame of the current study and availability of data, show the greatest promise.

[2] Physical barriers are barriers that prevent a commodity from using a specific mode (e.g. a river or mountain).

Furthermore, several data sources used in previous studies proved to be helpful in determining freight mode shifting potential. That is, several studies described methods used to integrate data sources resulting in more complete and accurate information for analysis purposes. The studies displayed that integrating several forms of data with several factors affecting freight mode choice is the best route to determine freight logistics and economic conditions that can contribute to mode shifting. In the absence of shipper survey data, knowledge of the essential mode choice factors as presented in the literature review proved beneficial for the present study.

3.0 COLLECT AND ANALYZE DATA

Section 3 visually illustrates commodity flow characteristics, modal split and highly used routes based on industry dependency, utilizing existing information and data sources within the state of Oregon. Task 3 used four specific data sources:

1. Freight Analysis Framework ($FAF^{3.5}$)
2. Geographical Information Systems (GIS) shapefiles
3. Data prepared for the Oregon Freight Plan *(ODOT TPAU 2013)*
4. Bureau of Transportation Statistics

This section provides a descriptive overview for each data source. Several graphs were generated to further illustrate the commodity flow characteristics that are present in Oregon. The $FAF^{3.5}$ provides Oregon commodity groups being imported and exported by mode and by FAF region. The GIS data presents a statewide view of freight systems and intermodal facilities. The data obtained from the Oregon Freight Plan analysis provides freight movement within the state of Oregon. Lastly, data obtained from the Bureau of Transportation Statistics highlight the fluctuation in fuel prices and highway vehicle-miles travelled over several years.

3.1 $FAF^{3.5}$ DATA

The Freight Analysis framework data is divided into commodity groups, with specific commodities belonging to each group. The FAF data provides flow information based on commodity groups and not specific commodities. Table 3.1 shows the commodity groups referenced in this report and an example of a specific commodity that falls within that commodity group.

Table 3.1: Commodity Groups and Example Commodities

Commodity Group	Example Commodity
Live Animals and Live Fish	Livestock and Live Fish
Cereal Grains	Wheat, Corn
Other Agricultural Products	Fresh/Chilled Potatoes, Edible Vegetables; Soya Beans; Oil Seeds
Animal Feed & Products of Animal Origin, N.E.C.	Cereal Straw, Animal Feed Preparations
Meat, Fish, Seafood and Their Preparations	Meat, Fish, Extracts, Juices
Milled Grain Products and Preparations and Bakery Products	Wheat Flour, Malt, Starches, Bakery Products
Other Prepared Foodstuffs, and Fats, Oils	Dairy Products, Coffee, Tea
Alcoholic Beverages	Malt Beer, Wine
Tobacco Products	Tobacco
Monumental or Building Stone	Monumental or Building Stone (Not Dolomite)
Natural Sands	Natural Sands (Not Metal-Bearing)
Gravel and Crushed Stone	Gravel and Crushed Stone (Not Dolomite & Slate)
Nonmetallic Minerals, N.E.C.	Salt, Dolomite
Metallic Ores and Concentrates	Iron Ores and Concentrates
Coal	Non-Agglomerated Bituminous Coal
Gasoline and Aviation Turbine Fuel	Gasoline & Aviation Turbine Fuel (Type A & B)
Fuel Oils	Fuel Oils
Coal and Petroleum Products, N.E.C.	Lubricating Oils, Refined Petroleum Oils, Gaseous Hydrocarbons
Basic Chemicals	Sodium Hydroxide and Potassium Hydroxide, Inorganic Chemicals, Phenols
Pharmaceutical Products	Pharmaceutical Products
Fertilizers	Fertilizers and Their Materials
Chemical Products and Preparations, N.E.C.	Paints, Essential Oils, Perfumery, Soap, Photographic Film, Insecticides
Plastics and Rubber	Plastic in Primary Forms, Rubber in Primary Forms, Manmade Fibers, Rubber Articles
Logs and Other Wood in the Rough	Logs and Other Wood in the Rough
Wood Products	Wood Chips, Lumber, Veneer Sheets, Builders Joinery
Pulp, Newsprint, Paper and Paperboard	Pulp of Fibrous Cellulosic Materials, Newsprint, Uncoated and Coated Paper
Paper or Paperboard Articles	Paper or Paperboard Articles
Printed Products	Printed Books, Newspapers, Advertising Material
Textiles, Leather and Articles of Textiles or Leather	Fibers, Yarn, Footwear, Leather, Textile Clothing and Accessories

Table 3.1 (Cont.)	
Non-Metallic Mineral Products	Hydraulic Cements, Ceramic Products, Glass
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	Iron and Steel in Primary Forms, Flat-Rolled Products
Articles of Base Metal	Pipes, Structures and Parts, Hand Tools
Machinery	Internal-Combustion Piston Engines, Turbines, Boilers, Pumps, Air-Conditioning, Refrigerating
Electronic and Other Electrical Equipment, Components and Office Equipment	Electric Motors, Cooking Appliances, Line Telephone, Computer and Office, Media
Motorized and Other Vehicles (Including Parts)	Motor Vehicles, Motor Vehicles for the Transport of Goods, Road Tractors
Transportation Equipment, N.E.C.	Locomotives, Aircraft, Spacecraft, Ships, Boats
Precision Instruments and Apparatus	Optical Elements, Photographic Machines, Surveying, Instruments
Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings	Furniture, Mattresses, Lamps, Lighting Fittings
Miscellaneous Manufactured Products	Arms and Ammunition, Toys, Games, Sporting Equipment
Waste and Scrap	Metallic and Not-Metallic Waste and Scrap
Mixed Freight	Mixed Freight

(Data: *(Bureau of Transportation Statistics 2012)*)

To understand commodity group flows originating in Oregon and destined to Oregon, FAF$^{3.5}$ data was used. The dataset describes commodity group flow by mode, value, ton and ton-miles for Oregon's two FAF regions—Portland being one region, with the remainder of the state being the other. The two regions were analyzed separately, as were the origin and destination data (e.g. The Portland region origin data and destination data were evaluated independently). The FAF$^{3.5}$ data incorporates 2012 provisional data; therefore, 2015 values were used for evaluation (2015 represents the present year and the first year of forecasts provided by the FAF$^{3.5}$ data).

Before establishing the modes that should be considered for this study, determining a modal split of freight flow in Oregon was essential. Utilizing the FAF$^{3.5}$ data, four modes were investigated:

1. Truck
2. Rail
3. Air
4. Marine (Water)

3.1.1 Modal Split in Oregon

3.1.1.1 Origin – Portland FAF Region

Figure 3.1 shows the modal split for commodity groups originating in Portland in terms of value. Truck represents 95.41% of the modal split, while air is second at 2.74%. Rail accounts for 1.37%, while only 0.48% of commodity groups being shipped from Portland are leaving by water. This is surprising, as the Port of Portland is located in this FAF region.

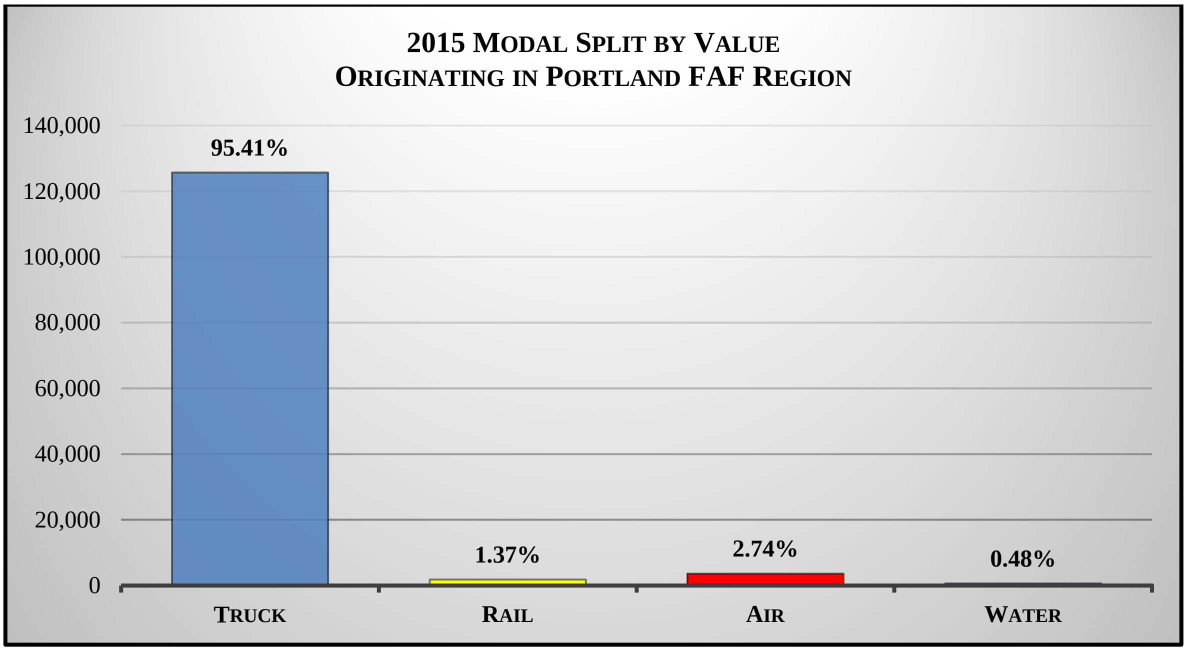

Figure 3.1: 2015 Modal Split of Commodity Groups Originating in Portland by Value

Figure 3.2 displays the modal split for commodity groups originating in Portland in terms of tons. Truck, again, accounts for greater than 95%, while rail is second at 2.71%. In terms of value, commodity groups being shipped by water were less than 1.0%, but nearly 2.0% in terms of tons. Due to commodity groups being shipped by modes other than air—in terms of tons—the 0.01% is not a surprise, although it is quite low.

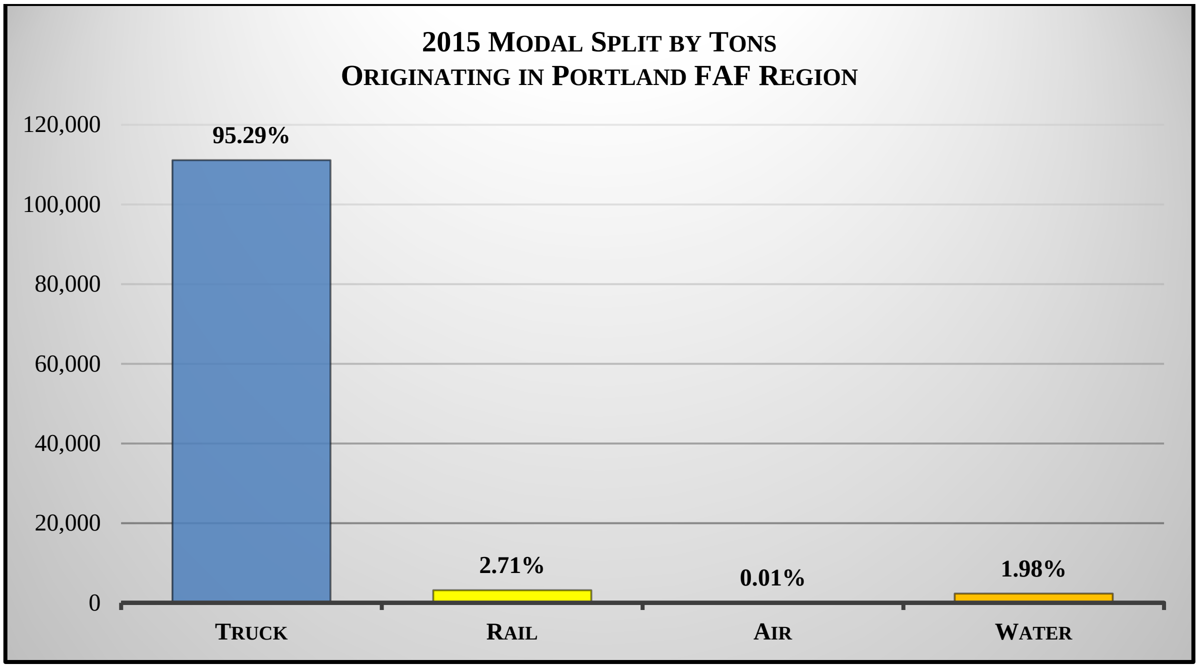

Figure 3.2: 2015 Modal Split of Commodity Groups Originating in Portland by Ton

Figure 3.3 illustrates the modal split for commodity groups originating in Portland in terms on ton-miles. Although the percentage is not as high as for value and tons, truck is still the dominant mode, representing 84.18% of the modal split. Rail is next at 10.00%, and water accounts for 5.77%.

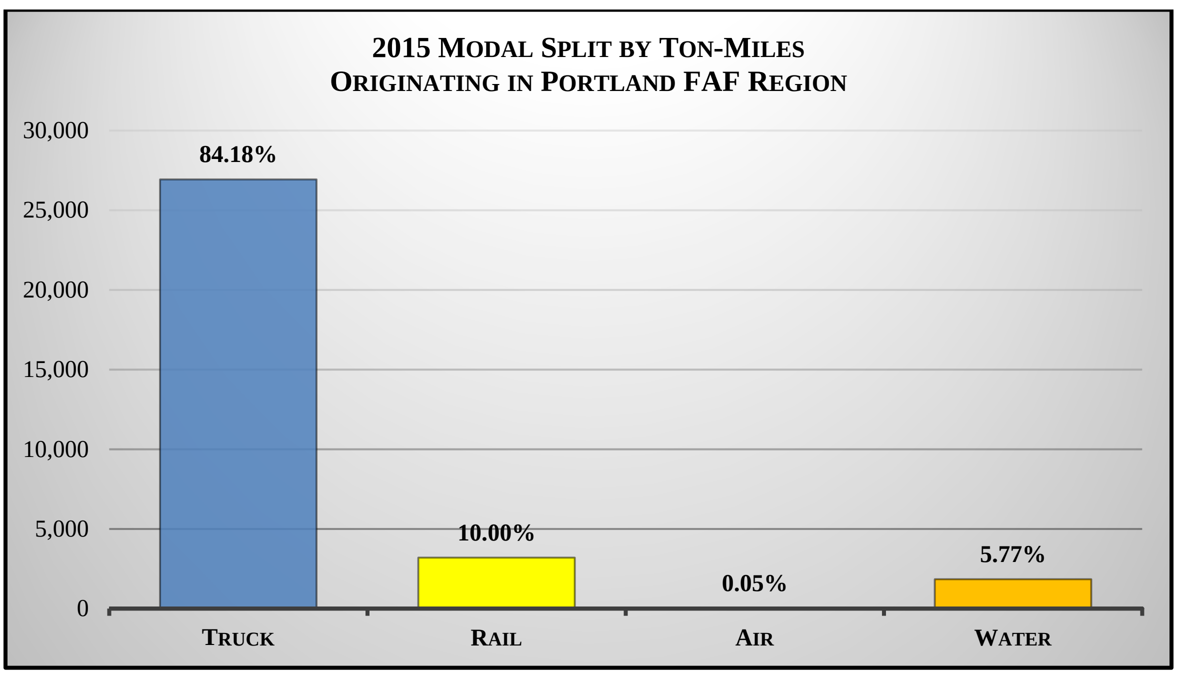

Figure 3.3: 2015 Modal Split of Commodity Groups Originating in Portland by Ton-Miles

3.1.1.2 Destination – Portland FAF Region

Figure 3.4 presents the modal split for commodity groups destined to Portland in terms of value. Truck accounts for the largest mode share at roughly 90%, with rail and air representing 6.95% and 3.88% respectively.

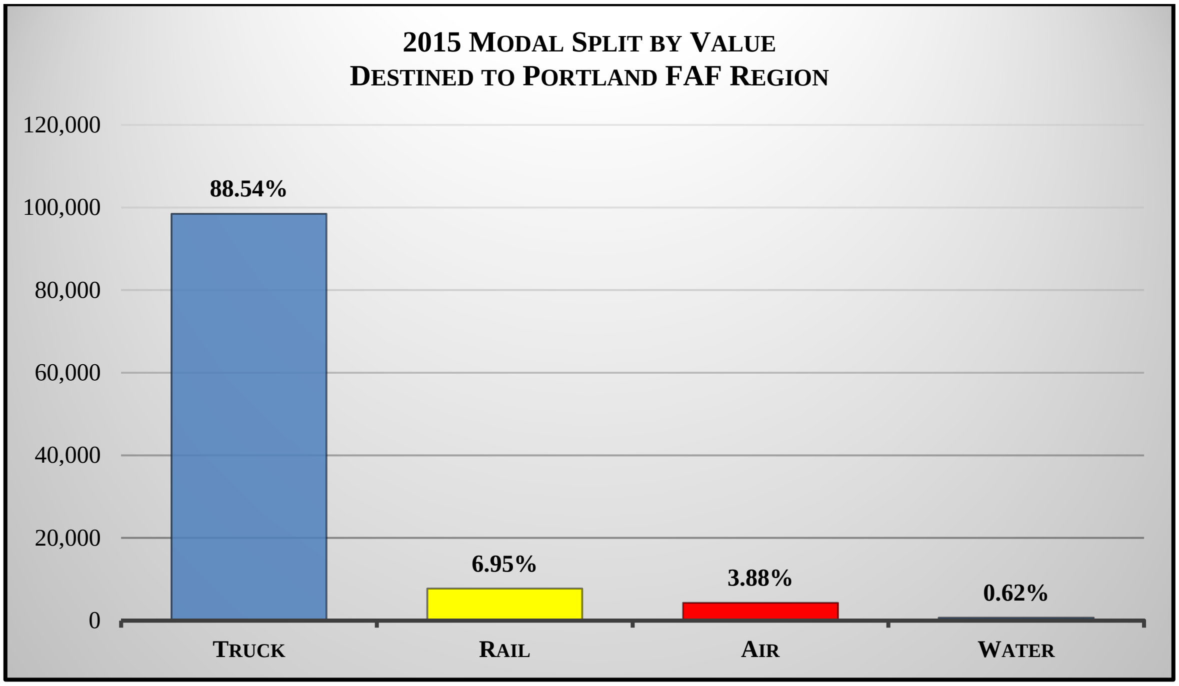

Figure 3.4: 2015 Modal Split of Commodity Groups Destined to Portland by Value

Figure 3.5 shows the modal split of commodity groups destined to Portland in terms of tons. Truck is still the dominant share at 77.02%, but rail represents a significant amount at 20.21%. Air accounts for nearly nothing, and the share for water is 2.74%.

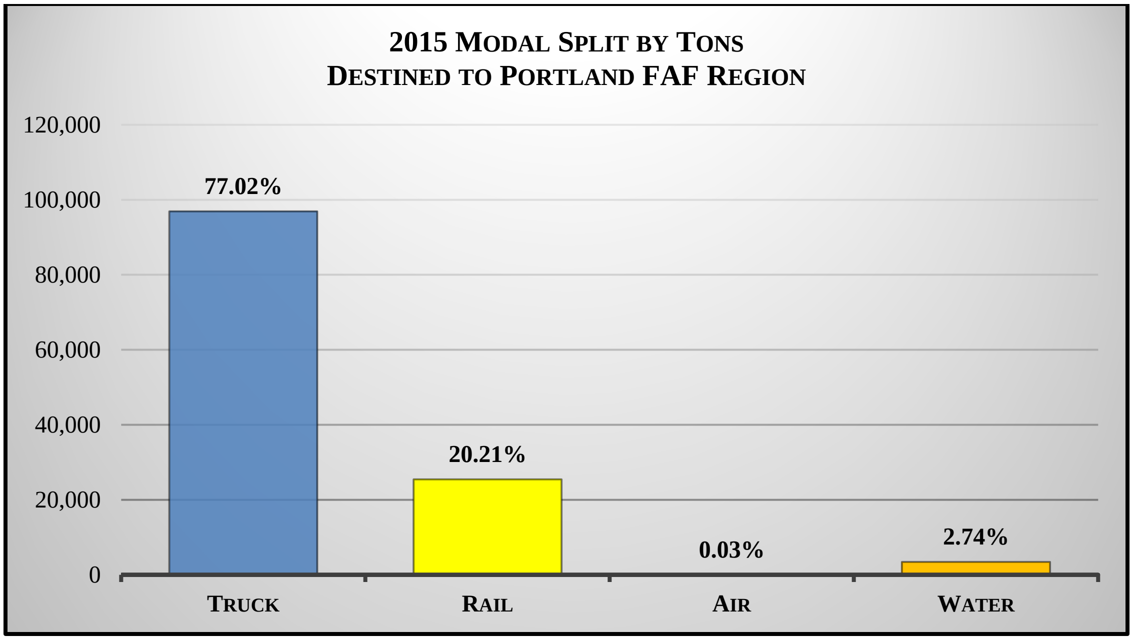

Figure 3.5: 2015 Modal Split of Commodity Groups Destined to Portland by Tons

Figure 3.6 displays the modal split of commodity groups destined to Portland in terms on ton-miles. This modal split was the only in which rail accounted for a larger share than truck at 47.93% to 45.68% respectively. Again, air accounts for nearly nothing and the share for water is slightly greater than 6.00%.

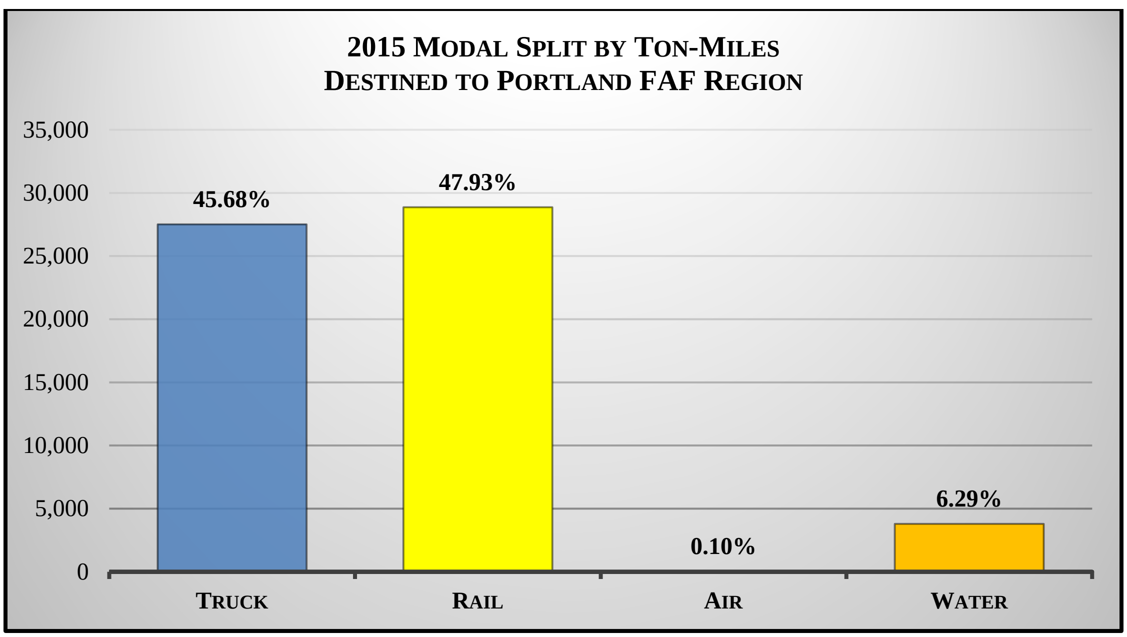

Figure 3.6: 2015 Modal Split of Commodity Groups Destined to Portland by Ton-Miles

3.1.1.3 Origin – Oregon (Remainder of State) FAF Region

Figure 3.7 shows the modal split of commodity groups originating in Oregon in terms of value. Truck is the dominant mode by accounting for 95.38% of the mode share. Water and air are each less than 0.05%, while rail accounts for 4.41%.

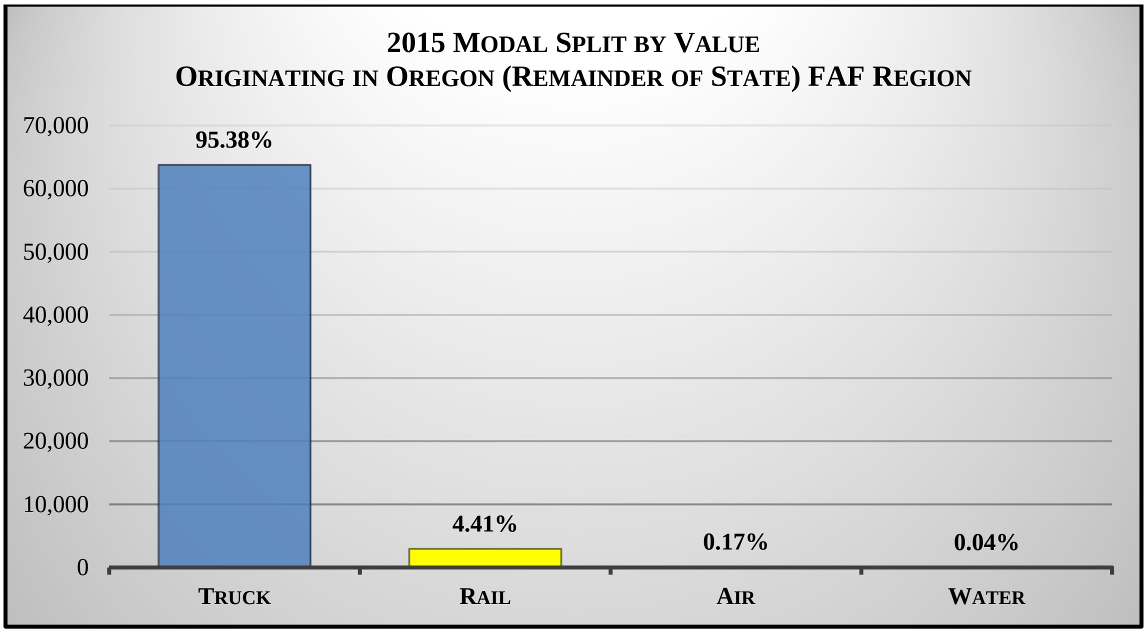

Figure 3.7: 2015 Modal Split of Commodity Groups Originating in Oregon by Value

Figure 3.8 illustrates the modal split of commodity groups originating in Oregon in terms of tons. Water and air account for roughly 0.00% of the mode share, while truck is still the dominate mode share at 94.86%. Rail, however, does account for slightly greater than 5.00% of commodity groups originating in Oregon.

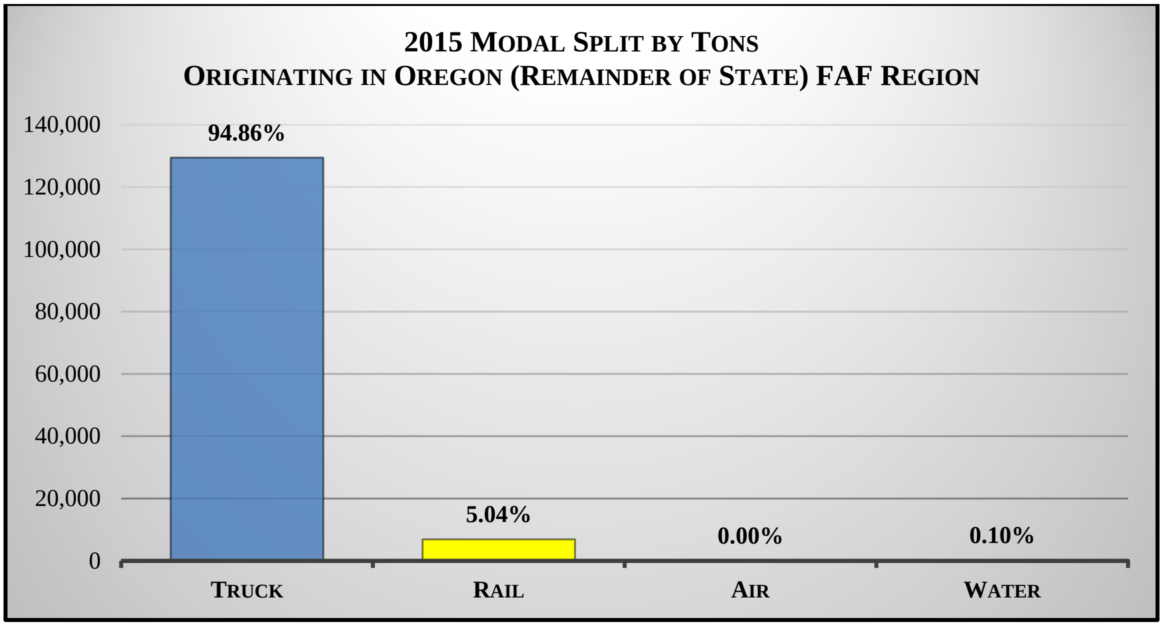

Figure 3.8: 2015 Modal Split of Commodity Groups Originating in Oregon by Tons

Figure 3.9 presents the modal split of commodity groups originating in Oregon in terms of ton-miles. Although truck is the dominant share at 74.94%, rail does account for 24.61% of the mode share. Still, water and air represent roughly 0.00% of the mode share.

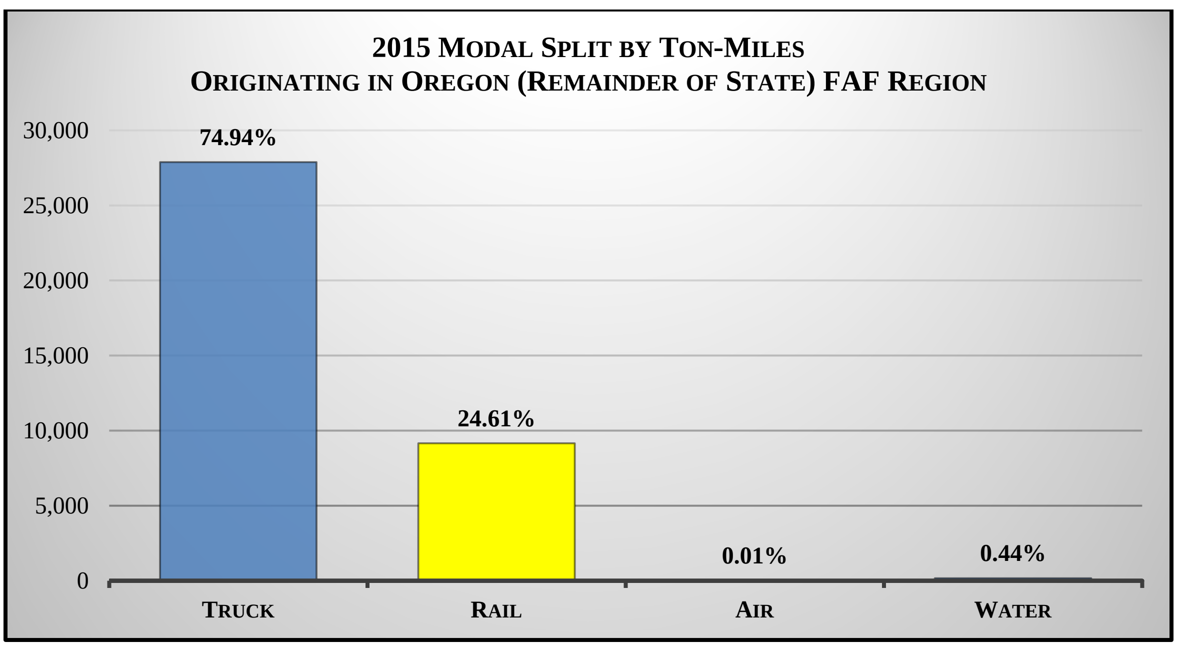

Figure 3.9: Modal Split of Commodity Groups Originating in Oregon by Ton-Miles

3.1.1.4 Destination – Oregon (Remainder of State) FAF Region

Figure 3.10 shows the modal split of commodity groups destined to Oregon in terms of value. Truck and rail are the two primary modes used to ship goods to

Oregon. Truck, again, is the dominate mode at 94.38%, with rail accounting for 5.59%.

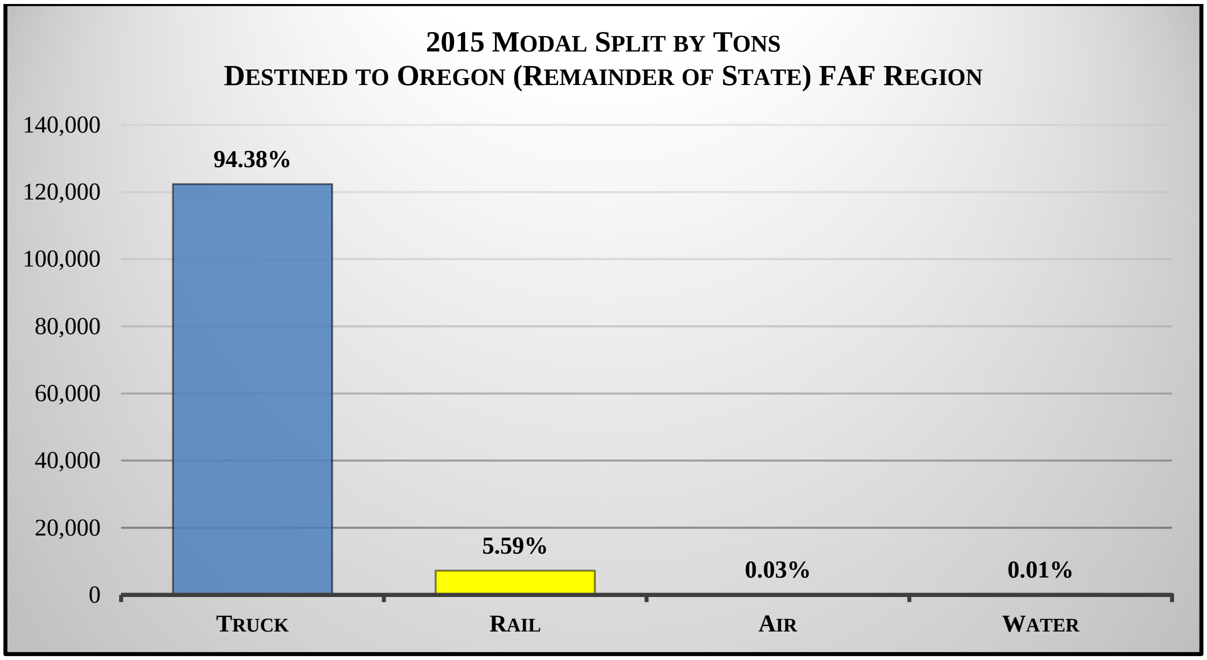

Figure 3.10: 2015 Modal Split of Commodity Groups Destined to Oregon by Value

Figure 3.11 displays the modal split of commodity groups destined to Oregon in terms of tons. In terms of tons, air surprisingly accounts for 1.78% of the mode share, yet the dominate mode is truck at 93.81%. Rail is next at 4.39% and water is accounts for approximately 0.00% of the mode share.

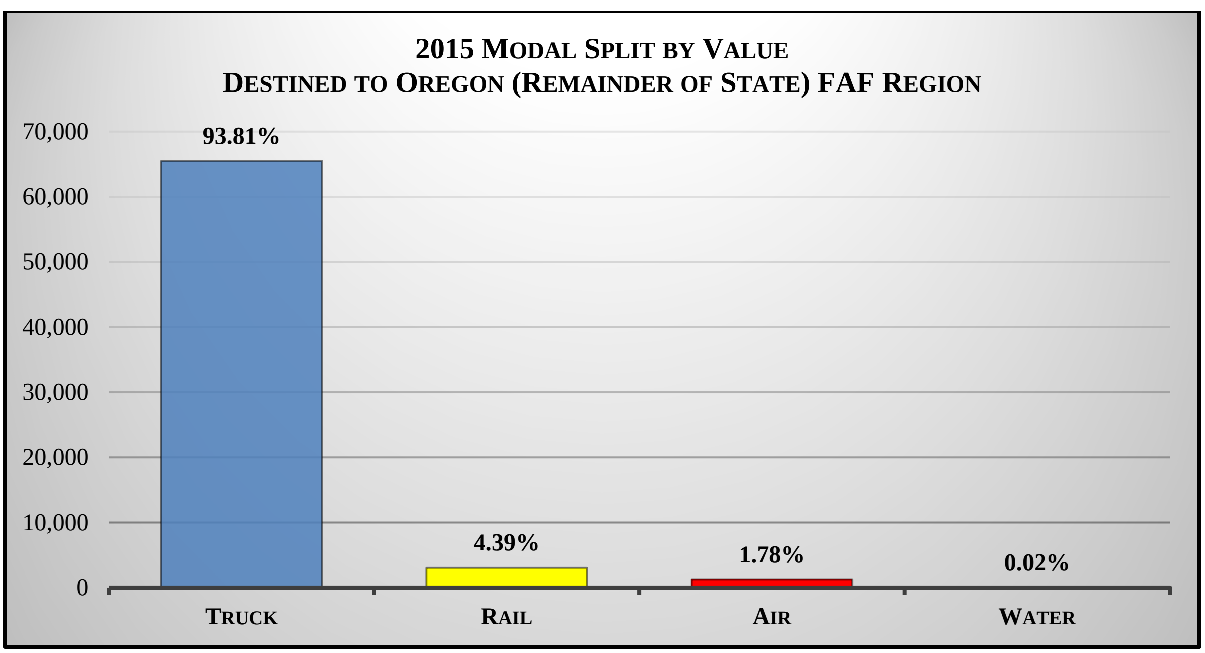

Figure 3.11: 2015 Modal Split of Commodity Groups Destined to Oregon by Tons

Figure 3.12 illustrates the modal split of commodity groups destined to Oregon in terms of ton-miles. Rail accounts for greater than 25.00% of the modal share and truck is still the dominate mode at 72.50%. Again, water and air represent approximately 0.00% of the mode share for commodity groups destined to Oregon.

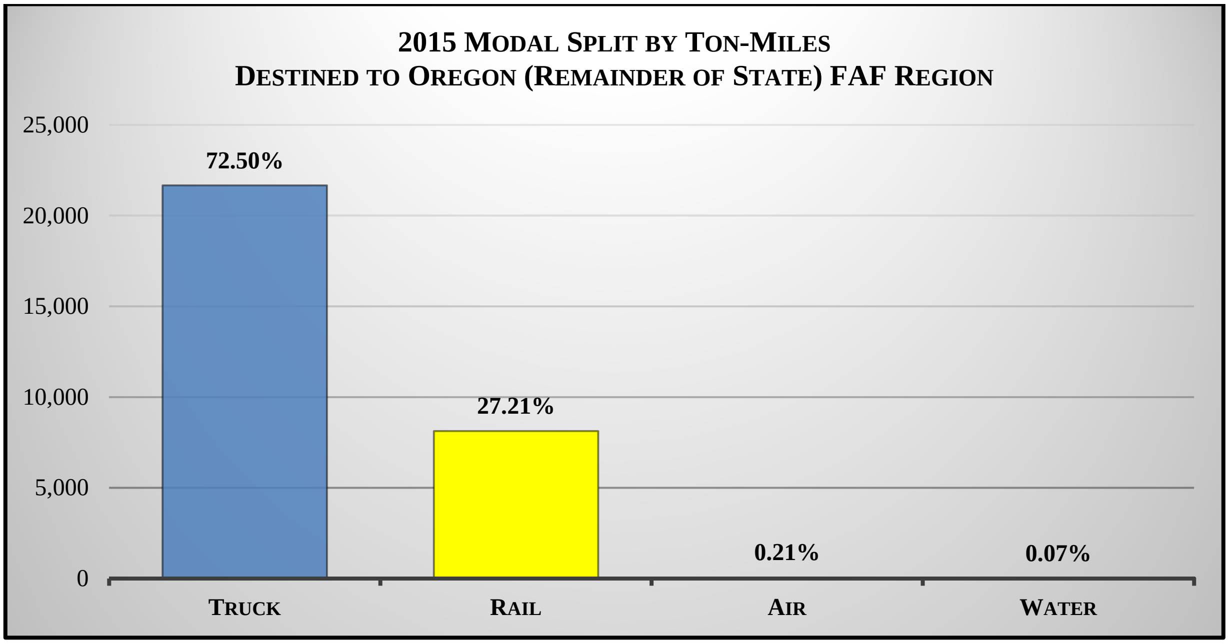

Figure 3.12: 2015 Modal Split of Commodity Groups Destined to Oregon by Ton-Miles

Based on the modal split investigation, it can be seen that the two dominate modes are truck and rail, with truck being the primary mode of choice in most cases. This indicates that truck ships almost all freight, therefore the potential mode shift is likely to be truck shifting to rail. With that in mind, the scope of this study will focus on commodity group flow for truck and rail only. This study will investigate the potential for commodity groups shipped by truck to be shifted to rail. A deeper investigation into commodity group flow in Oregon by truck and rail is discussed in the next section of this report.

3.1.2 Portland FAF Region

The Portland FAF region consists of the Portland metropolitan and a small halo region that surrounds the metropolitan area. To evaluate commodity group flow originating and destined to Portland, this section examines commodity group flow by truck and rail based on three metrics:

1. Value
2. Weight (Tons)
3. Ton-Miles

3.1.2.1 Truck Origin – Portland FAF Region

Figure 3.13 displays the top commodity groups by value originating in the Portland FAF region. The top five commodity groups account for approximately $28,429 million worth of commodities being shipped from Portland via truck, roughly 23% of the total value shipped from Portland by truck. Motorized and Other Vehicles is responsible for roughly 31% of the total value of the top five commodity groups, with Machinery accounting for roughly 27%. These values are important to describe the value of the key commodity groups originating in Portland.

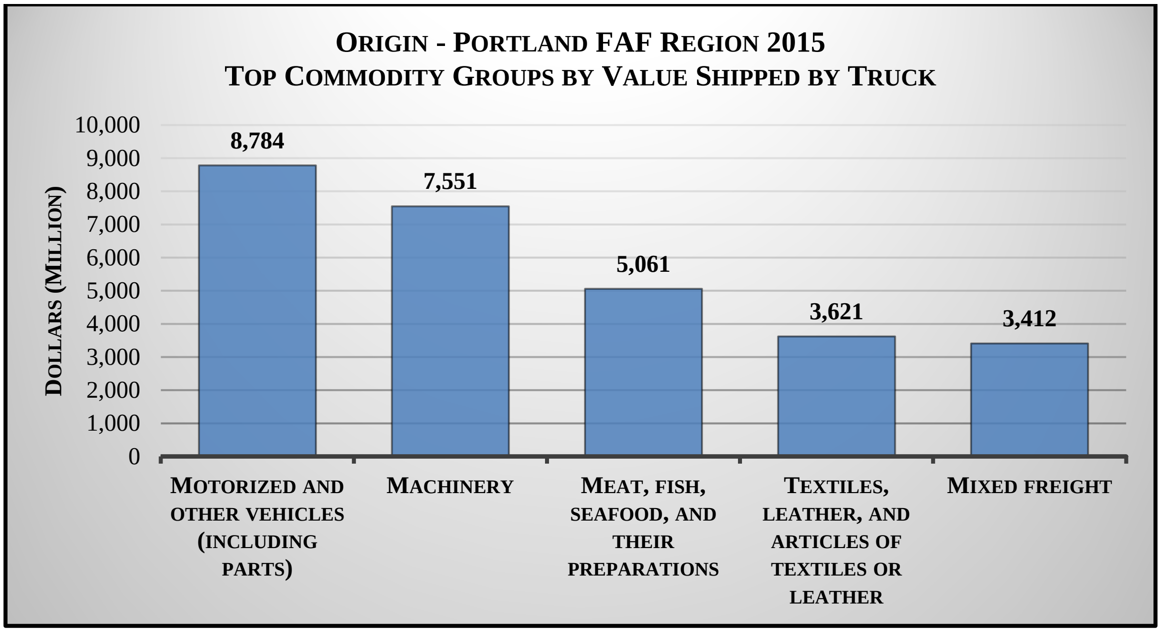

Figure 3.13: Top Commodity Groups by Value Shipped From Portland by Truck in 2015

Figure 3.14 displays the top five commodity groups originating in Portland by tons. The top five commodity groups account for approximately 37,571 thousand tons, roughly 34% of the total tons originating in Portland by truck. Of the five commodity groups, Non-Metallic Mineral Products represent roughly 37%, with no other commodity group accounting for more than 25% of the top five commodity groups.

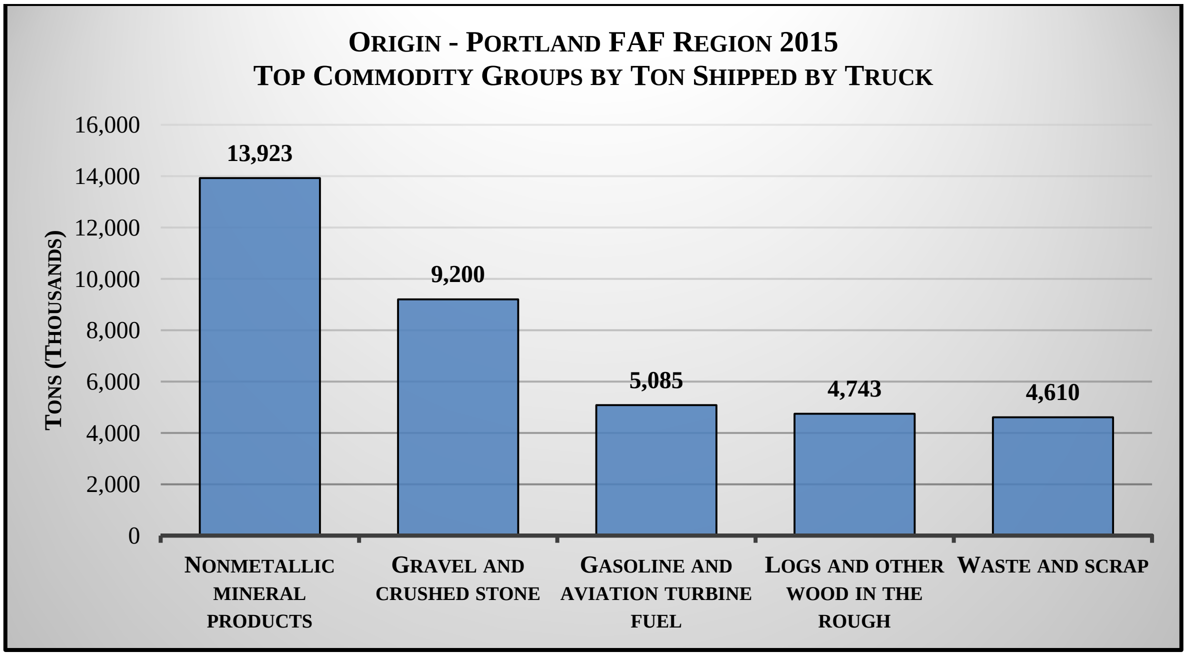

Figure 3.14: Top Commodity Groups by Ton Shipped from Portland by Truck in 2015

Figure 3.15 displays the top five commodity groups being shipped from Portland in terms of ton-miles. Unlike the previous two metrics, one commodity group accounts for nearly two-thirds of the total ton-miles represented by the top five commodity groups. At roughly 64%, Non-Metallic Mineral Products is responsible for the largest quantity of ton-miles at 3,537 million ton-miles. Although Motorized and Other Vehicles is the topmost commodity group in terms of value, it can be seen that Non-Metallic Mineral Products dominates the other two metrics.

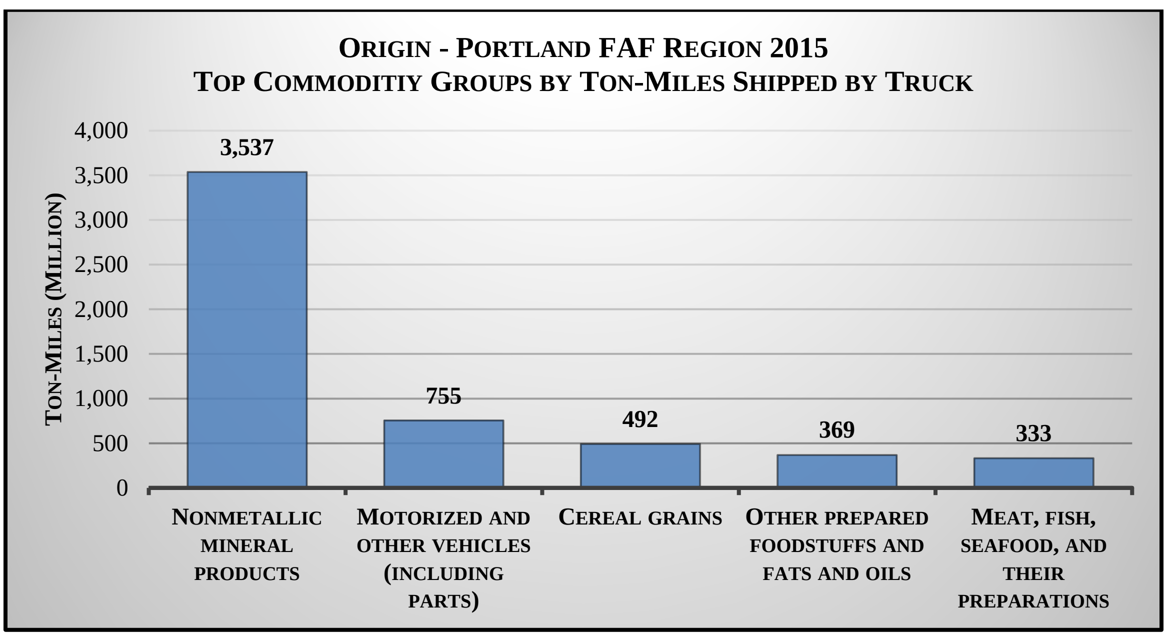

Figure 3.15: Top Commodity Groups by Ton-Miles Shipped from Portland by Truck in 2015

3.1.2.2 Rail Origin – Portland FAF Region

Figure 3.16 displays the top 5 commodity groups originating in the Portland FAF region by value. Immediately it can be seen that the difference in value being shipped by truck and rail is considerable. Compared to the $28,429 million worth of commodity groups being shipped by truck, rail's top five commodity groups' account for about $465 million. Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes represents roughly 37% of the five commodity groups, while Machinery is responsible for 23%. Machinery is also the second largest commodity group in terms of value being shipped from Portland via truck, however, the only other commodity group to be in the top five for both modes is Meat, Fish, Seafood and Their Preparations. Approximately $7,551 million worth of Machinery is being shipped by truck, while $107 million is being shipped by rail. Furthermore, $5,061 million worth of Meat, Fish, Seafood and Their Preparations is being shipped by truck in contrast to $50 million being shipped by rail.

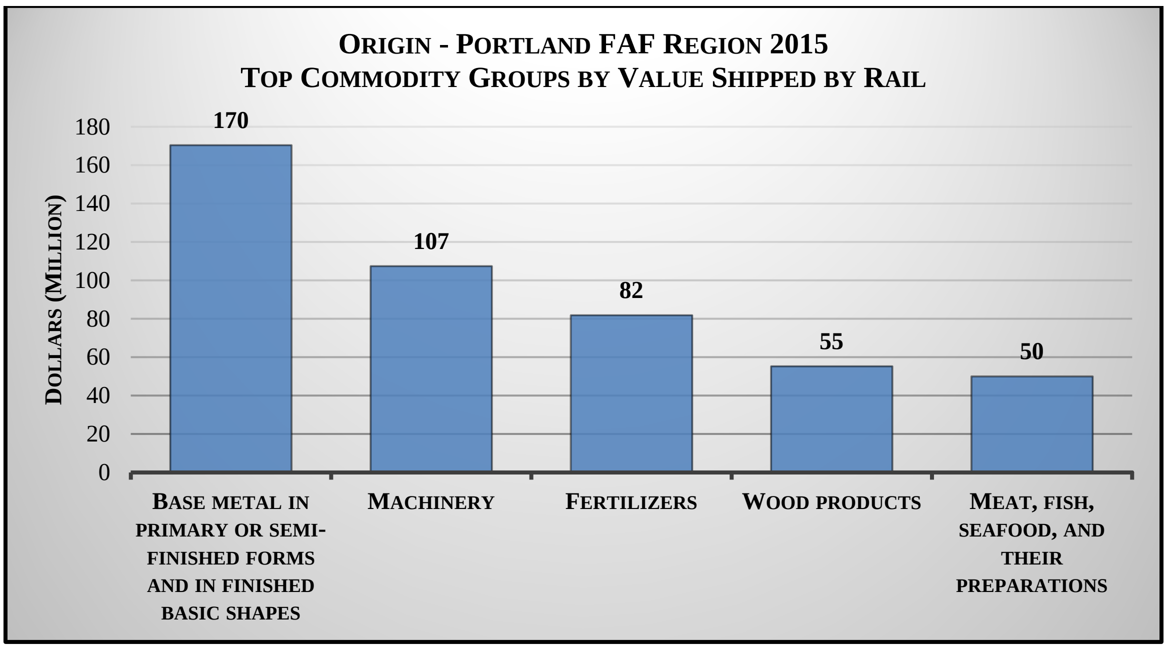

Figure 3.16: Top Commodity Groups by Value Shipped from Portland by Rail in 2015

Figure 3.17 illustrates the top five commodity groups in terms of tons being shipped from Portland via rail. The top five commodity groups shipped by rail account for an approximate weight of 765 thousand tons compared to trucks that ship nearly 46 times that weight (37,571 thousand tons). Turning to the top commodity groups, the commodity group accounting for the most tons being shipped by truck is nearly 45 times greater than the greatest quantity of tons being shipped by rail – 13,923 thousand tons to 312 thousand tons respectively. Comparing the top five commodity groups by tons for both truck and rail, Waste & Scrap is the only commodity group that is common to both.

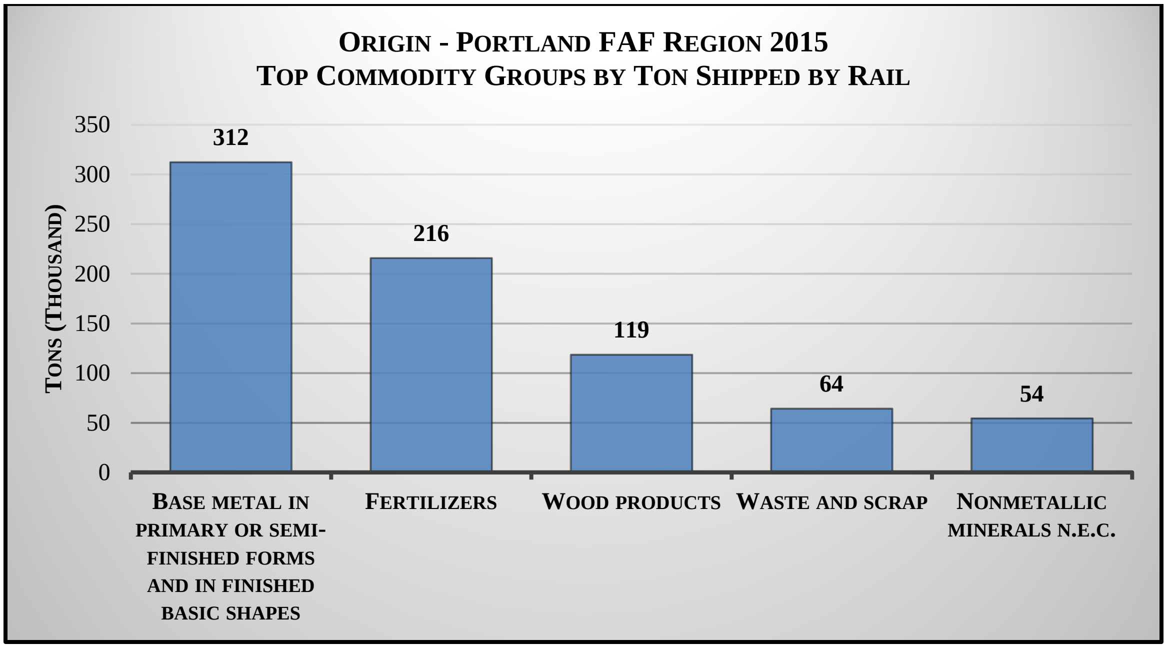

Figure 3.17: Top Commodity Groups by Ton Shipped from Portland by Rail in 2015

Figure 3.18 presents the top five commodity groups in terms of ton-miles being shipped from Portland by rail. The top five rail commodity groups account for 686 million ton-miles, while the top five commodity groups being shipped by truck account for 5,487 million ton-miles. When comparing truck and rail modes by million ton-miles, Cereal Grains is present in both modes and where rail exhibits roughly one-tenth of the ton-miles shipped by truck. Unlike the commodity groups shipped by truck, rail contains one commodity group that is significantly present in all three metrics, Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes.

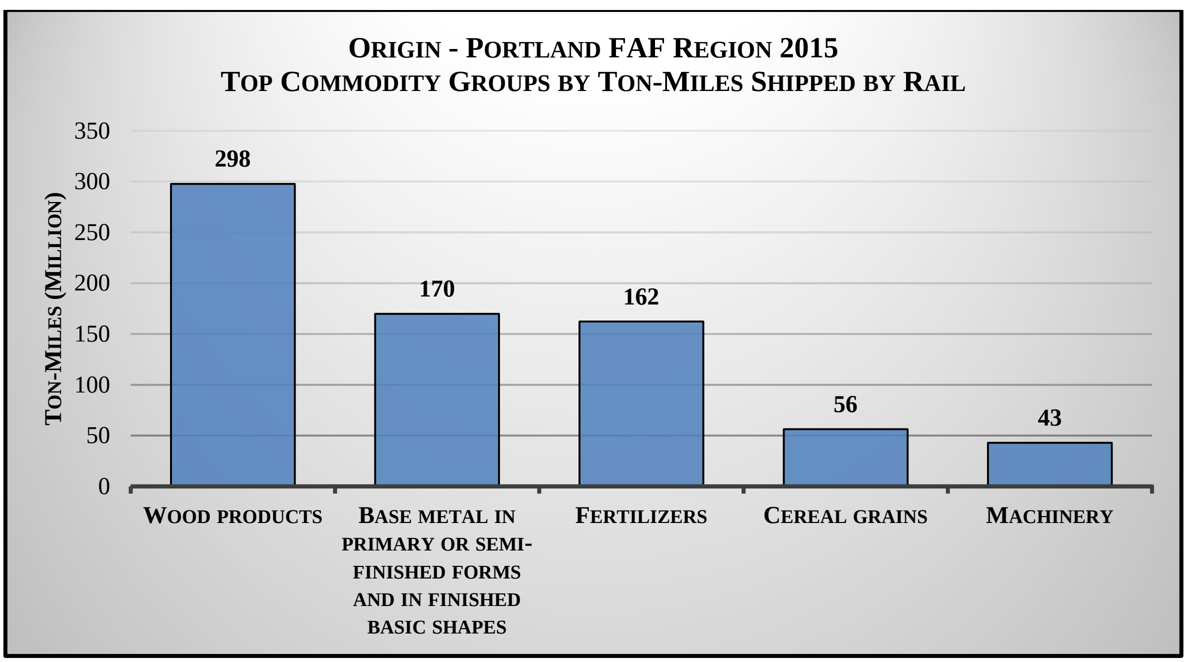

Figure 3.18: Top Commodity Groups by Ton-Miles Shipped from Portland by Rail in 2015

3.1.2.3 Truck Destination – Portland FAF Region

Figure 3.19 illustrates the top five commodity groups in terms of value being shipped to Portland by truck. The top five commodity groups shipped to Portland by truck total $19,770 million, approximately two-thirds of the commodity group value being shipped *from* Portland. Machinery is the second largest commodity group value being shipped *from* Portland, but accounts for the largest commodity group value being shipped *to* Portland, representing roughly 38% of the top five commodity groups.

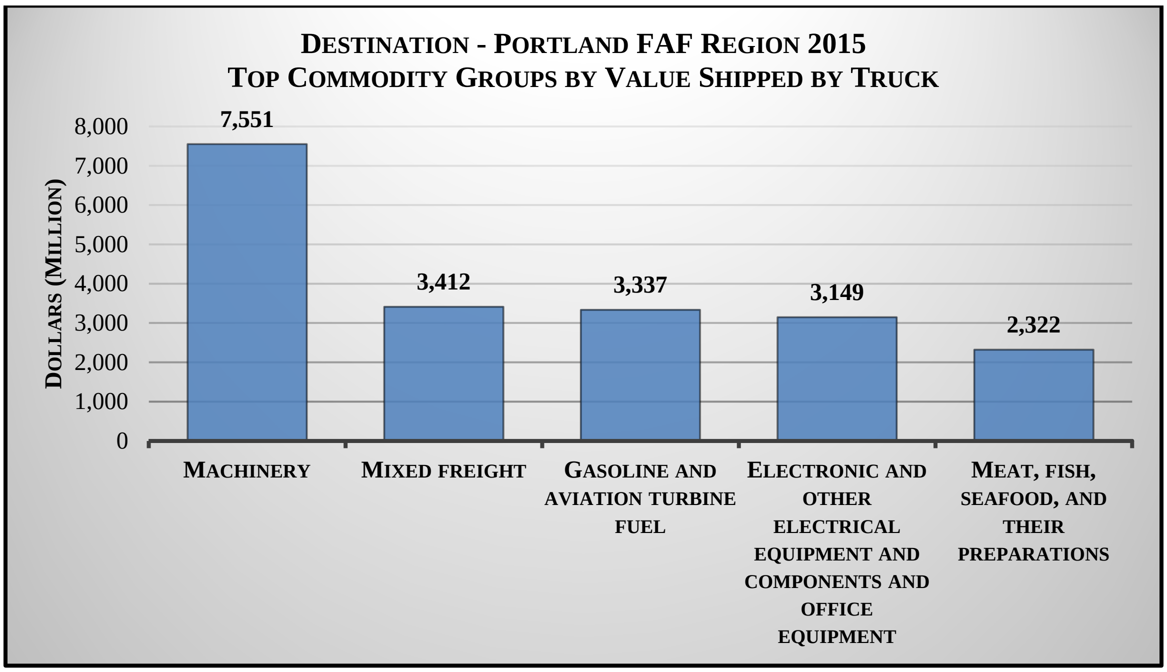

Figure 3.19: Top Commodity Groups by Value Shipped to Portland by Truck in 2015

Figure 3.20 presents the top five commodity groups in terms of tons being shipped to Portland by truck. Surprisingly, the same commodity groups and quantities are being shipped by truck both *to* and *from* Portland. This indicates that these commodity groups are not just the top five commodity groups by tons, but they are leaving and arriving within the Portland FAF region.

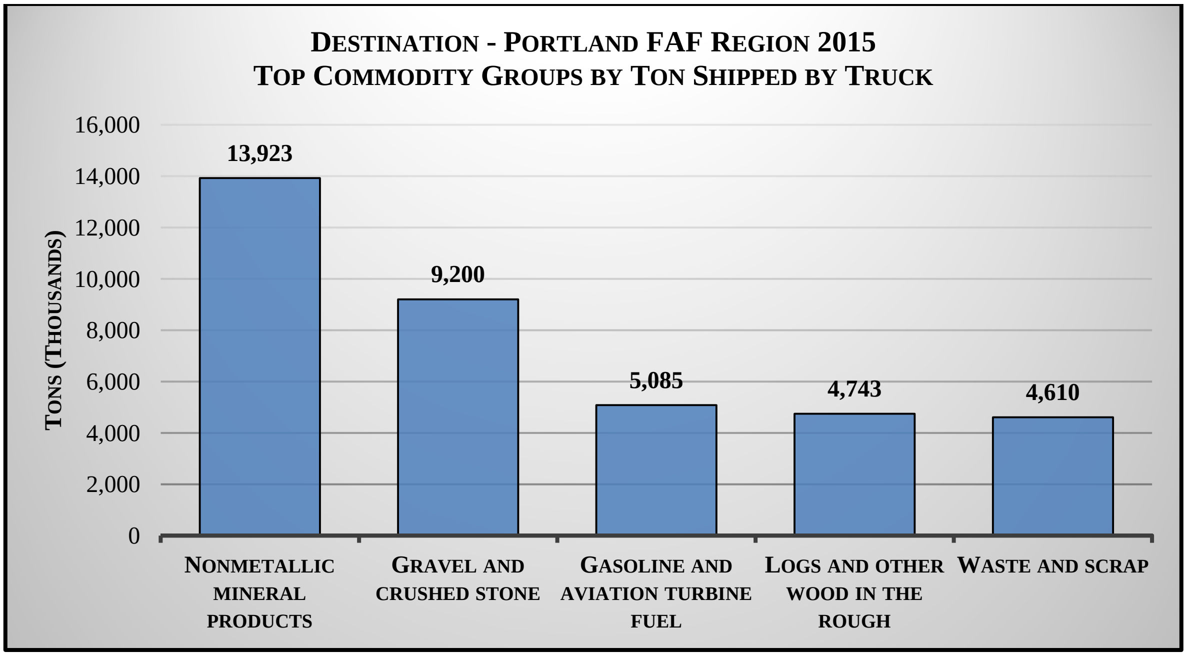

Figure 3.20: Top Commodity Groups by Ton Shipped to Portland by Truck in 2015

Figure 3.21 shows the top five commodity groups in terms of ton-miles being shipped to Portland by truck. The top five commodity groups represent 4,425 million ton-miles of freight being shipped to Portland, compared to the 5,487 million ton-miles being shipped from Portland. Non-Metallic Mineral Products is the largest commodity group, in terms of ton-miles, being shipped *from* Portland; however, it is the smallest being shipped *to* Portland.

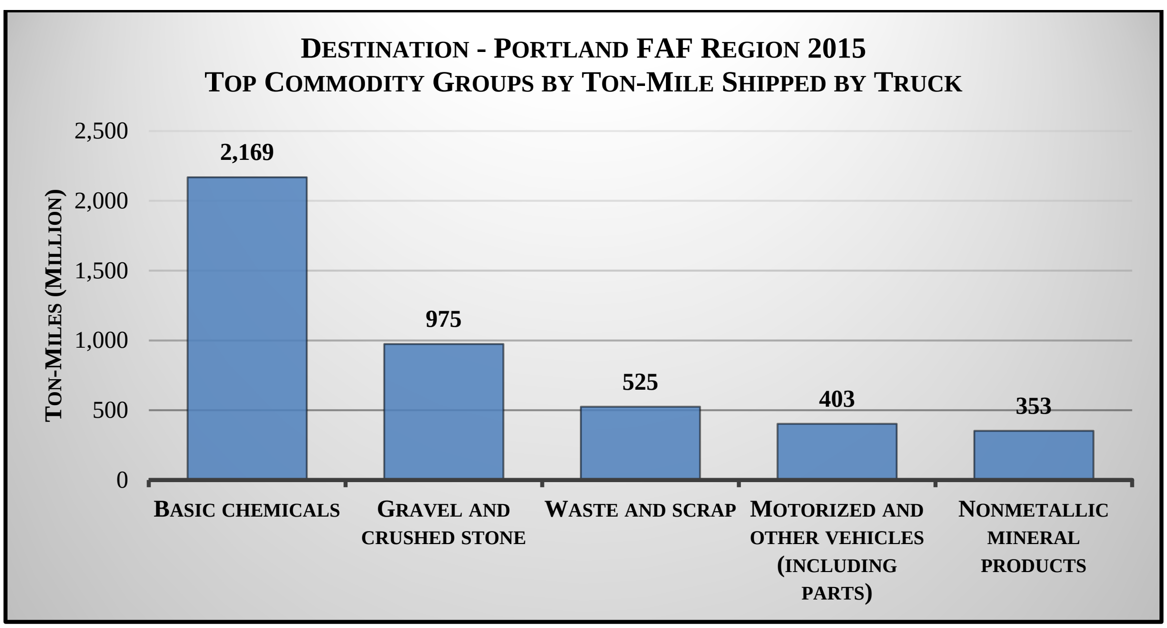

Figure 3.21: Top Commodity Groups by Ton-Miles Shipped to Portland by Truck in 2015

3.1.2.4 Rail Destination – Portland FAF Region

Figure 3.22 presents the top five commodity groups in terms of value being shipped to Portland by rail. The top five commodity groups destined to Oregon are much greater in value than the top five commodity groups originating in Oregon, $4,019 million to $465 million respectively. Additionally, the top five destination commodity groups for truck are entirely different than the top five destination commodity groups for rail in terms of value.

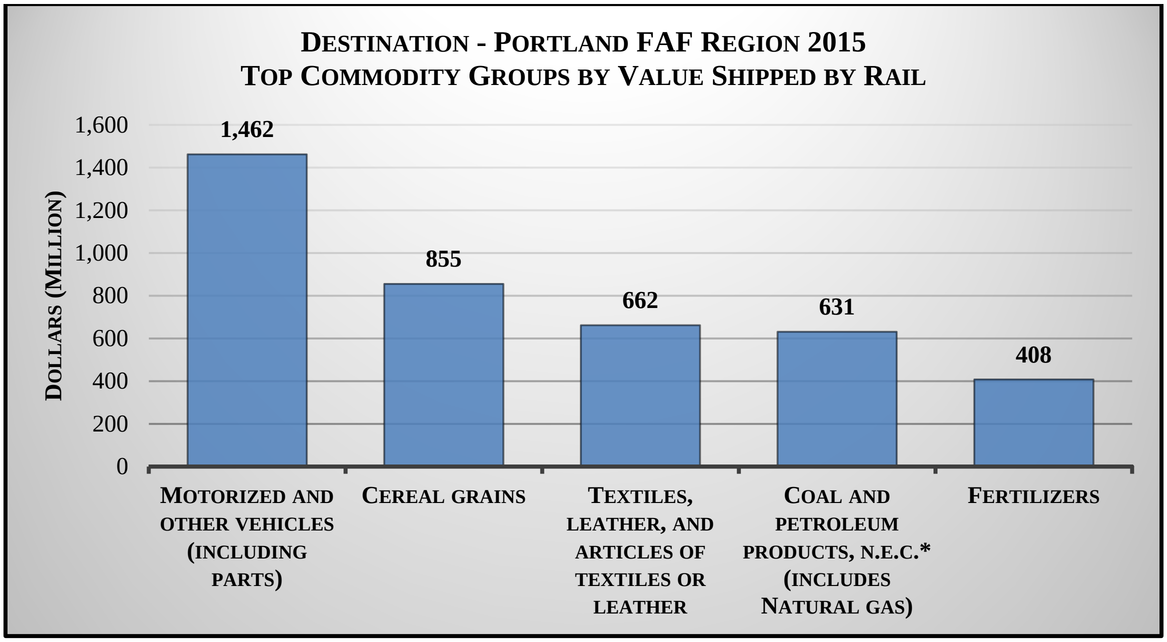

Figure 3.22: Top Commodity Groups by Value Shipped to Portland by Rail in 2015

Figure 3.23 illustrates the top five commodity groups in terms of tons being shipped to Portland by rail. The top five commodity groups are responsible for 15,540 thousand tons of goods destined to Oregon. The only commodity group shared by both rail and truck is Waste and Scrap at 4,610 thousand tons and 980 thousand tons respectively. Additionally, the quantity of Waste and Scrap is larger entering Portland (980 thousand tons) than leaving (64 thousand tons).

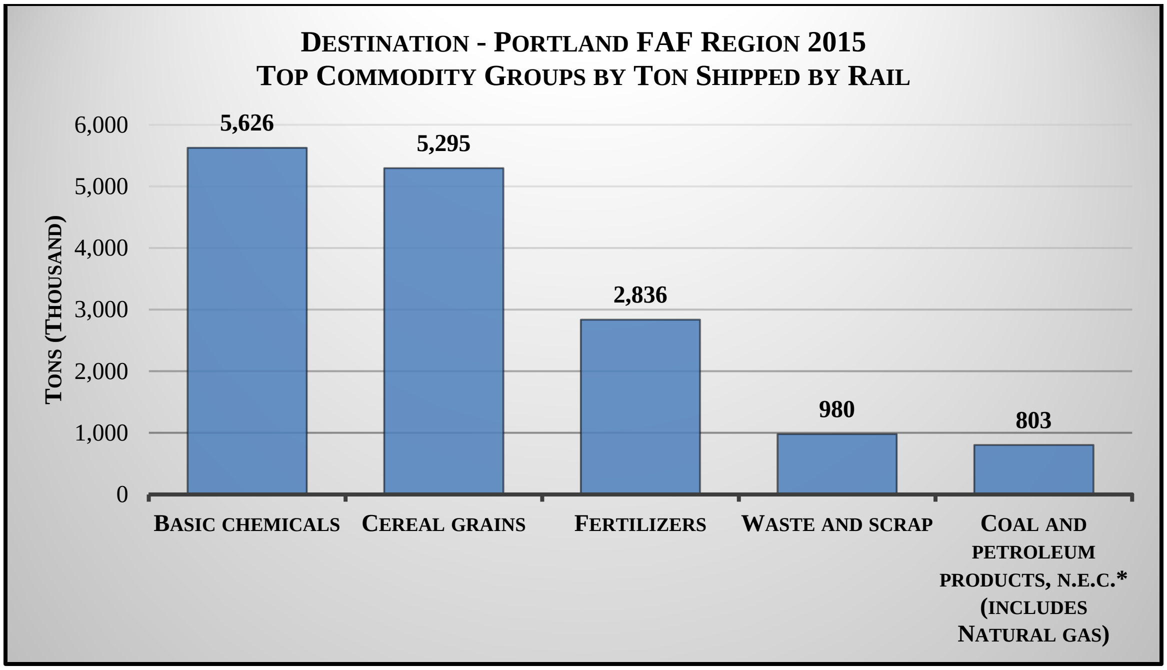

Figure 3.23: Top Commodity Groups by Ton Shipped to Portland by Rail in 2015

Figure 3.24 displays the top five commodity groups in terms of ton-miles shipped to Portland by rail. The top five commodity groups total 17,418 million ton-miles. The amount leaving Portland by rail is roughly 5% of the amount that is arriving in Portland by rail at 820 million ton-miles. Cereal Grains is in the top two commodity groups being shipped to Portland by rail in each of the three metrics.

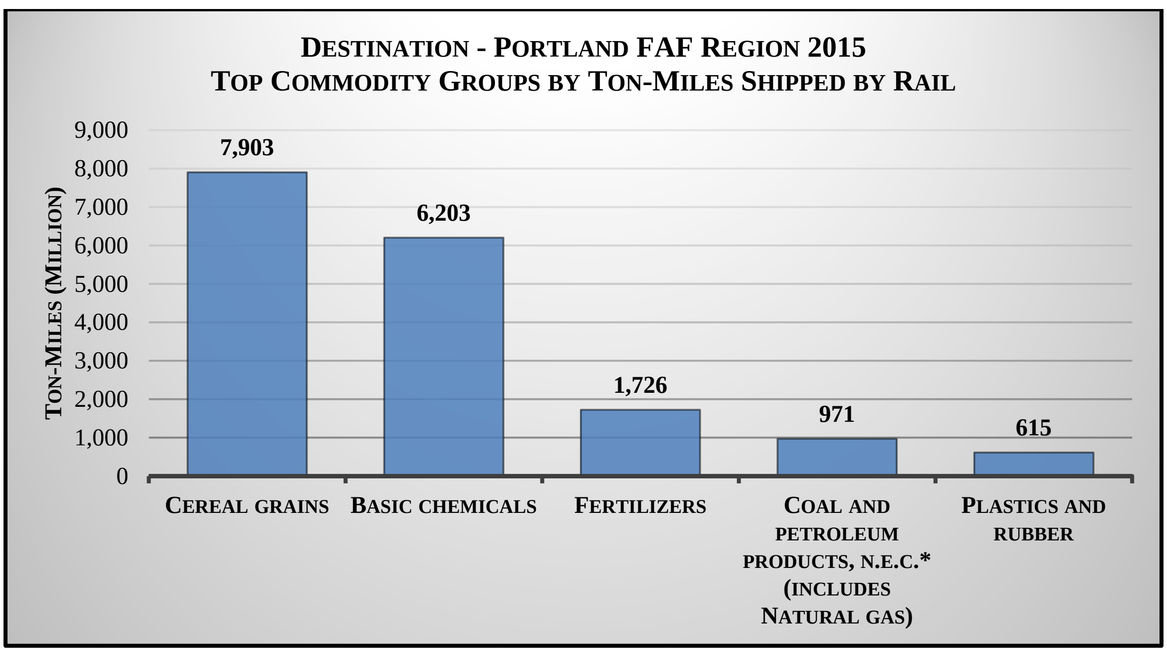

Figure 3.24: Top Commodity Groups by Ton-Miles Shipped to Portland by Rail in 2015

3.1.3 Oregon (Remainder of State) FAF Region

To better understand Oregon's commodity flow characteristics, Oregon's other FAF region needed to be investigated. Similar to the previous section, this section looks at the top five commodity groups originating and destined to the remainder of the state utilizing the same criteria as Section 2.2.2.

3.1.3.1 Truck Origin _ Oregon (Remainder of State) FAF Region

Figure 3.25 illustrates the top five commodity groups in terms of value being shipped from Oregon by truck. The total commodity value represented by the top five commodity groups totals $14,730 million, approximately $13,700 million less than the commodity value originating in Portland. Machinery and Mixed Freight are top five commodity groups for both FAF regions; however, larger values originate from Portland. Roughly $7,551 million worth of Machinery is shipped from Portland, while $6,174 million is shipped from the remainder of the state. Furthermore, $3.412 million worth of Mixed Freight is shipped from Portland, with about $1,893 million being shipped from the remainder of the state.

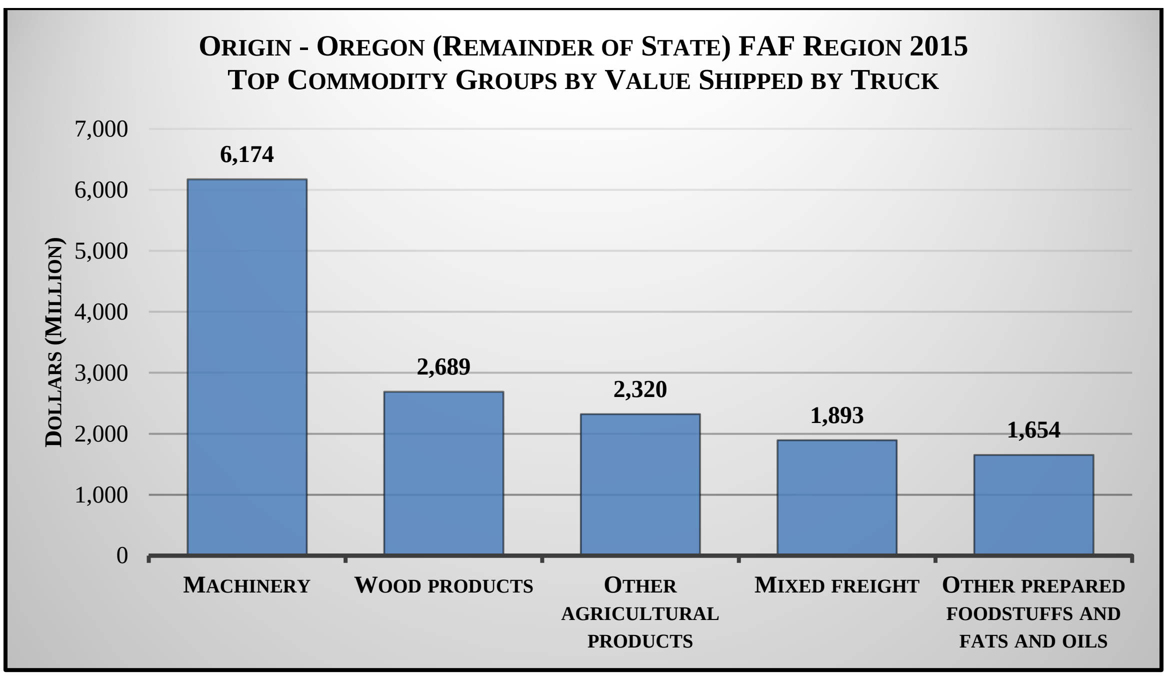

Figure 3.25: Top Commodity Groups by Value Shipped From Oregon by Truck in 2015

Figure 3.26 presents the top five commodity groups in terms of tons being shipped from Oregon by truck. The top five commodity groups consist of 62,273 thousand tons, roughly 24,712 thousand tons more than commodity groups originating in Portland. Three groups are present in the top five commodity groups for both FAF regions:

- Non-Metallic Mineral Products

- Gravel and Crushed Stone
- Logs and Other Wood in the Rough

Non-Metallic Mineral Products is the largest commodity group originating in Portland at 13,923 thousand tons, yet it's the smallest commodity group originating in Oregon at 6,592 thousand tons. Gravel and Crushed Stone both are top two commodity groups, but more than double originates in Oregon (remainder of state) compared to Portland, 25,083 thousand tons to 9,200 thousand tons respectively.

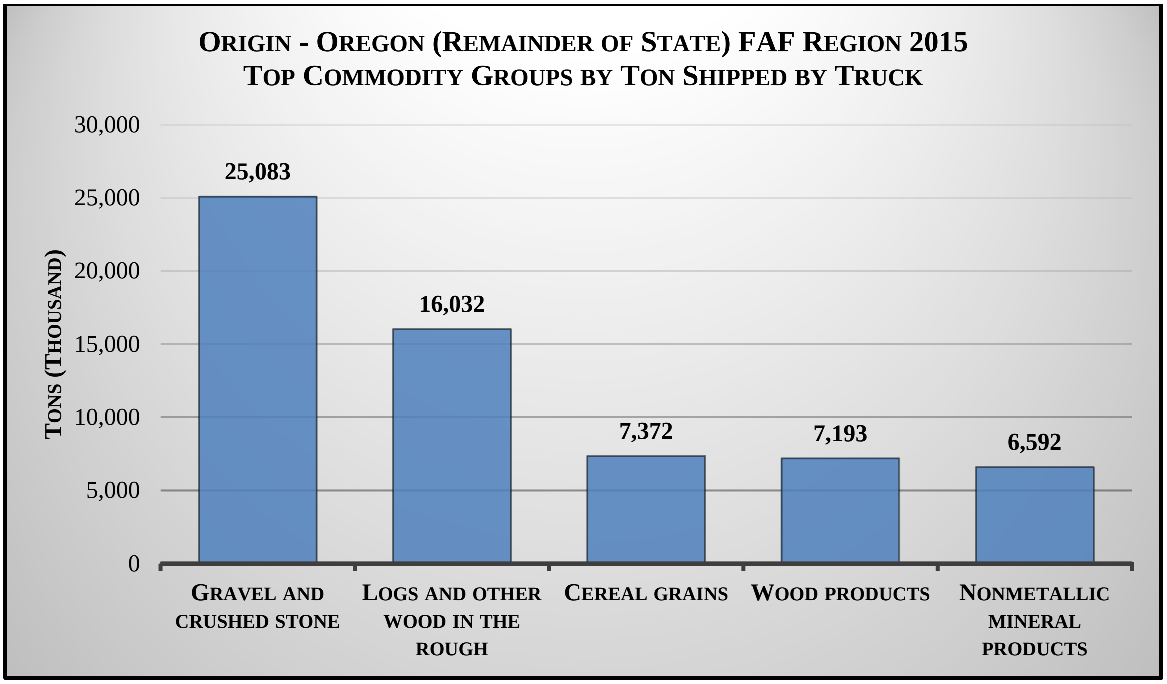

Figure 3.26: Top Commodity Groups by Ton Shipped from Oregon by Truck in 2015

Figure 3.26 shows the top five commodity groups in terms of ton-miles being shipped from Oregon by truck. The amount of ton-miles being shipped from Oregon is slightly greater than that being shipped from Portland, 6,397 million ton-miles to 5,487 million ton-miles respectively. Non-Metallic Mineral Products is the only commodity group present for both FAF regions, but it accounts for the least ton-miles originating in Oregon (677 million ton-miles) and the most ton-miles originating in Portland (3,537 million ton-miles).

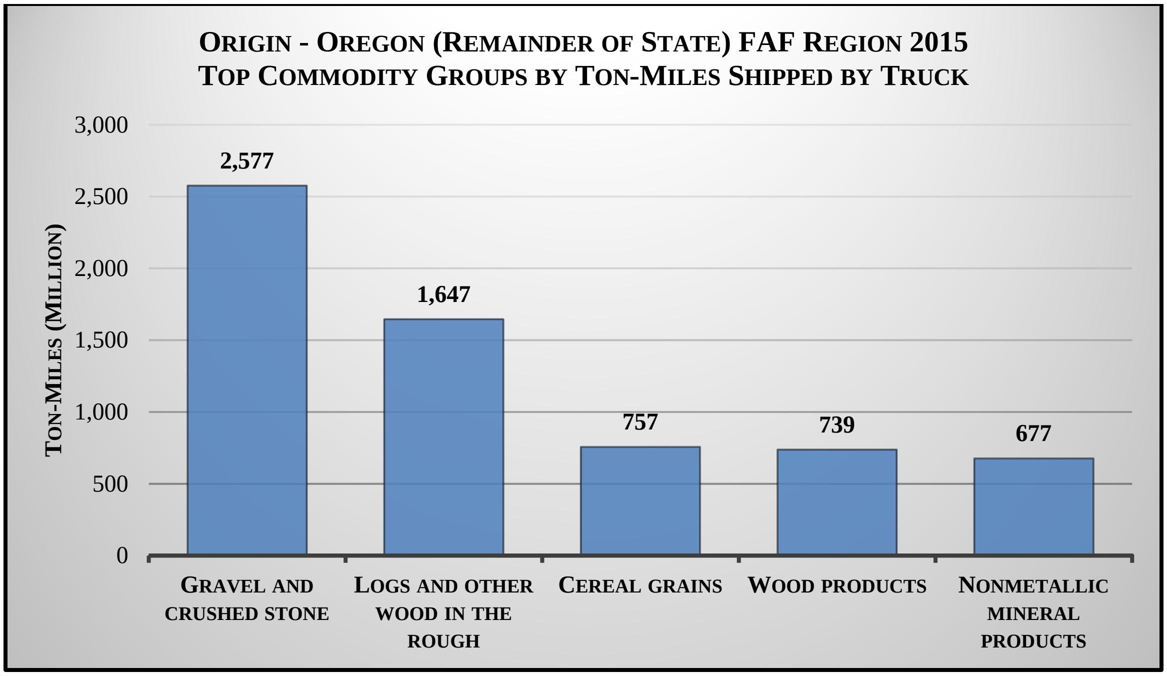

Figure 3.27: Top Commodity Groups by Ton-Miles Shipped from Oregon by Truck in 2015

3.1.3.2 Rail Origin – Oregon (Remainder of State) FAF Region

Figure 3.28 displays the top five commodity groups in terms of value being shipped from Oregon by rail. Total value shipped from Oregon is roughly $302 million more than value shipped from Portland. The two FAF regions share three commodity groups in terms of value shipped by rail:

- Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes
- Wood Products
- Machinery

Machinery and Wood Products are present in both modes for this FAF region; still, the value shipped by truck is significantly larger than rail.

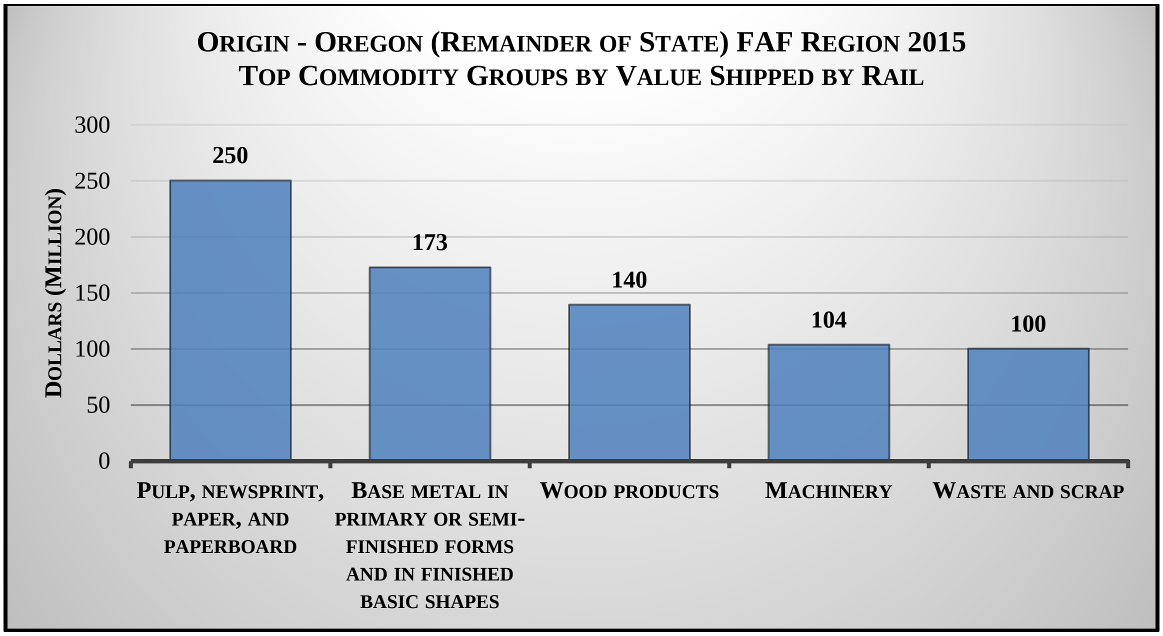

Figure 3.28: Top Commodity Groups by Value Shipped from Oregon by Rail in 2015

Figure 3.29 illustrates the top five commodity groups in terms of tons being shipped from Oregon by rail. As can been seen from Figures 3.12 and Figure 3.15, the total for the top five commodity groups shipped by rail (1918 thousand tons) is considerably less than the tons shipped by truck (62,273 thousand tons). The top three commodity groups in Figure 3.15 are closer in weight than that of any other top five commodity groups. Wood Product is the only commodity group present in the top five for truck and rail, but rail ships only 6.5% of the 7,193 thousand tons shipped by truck.

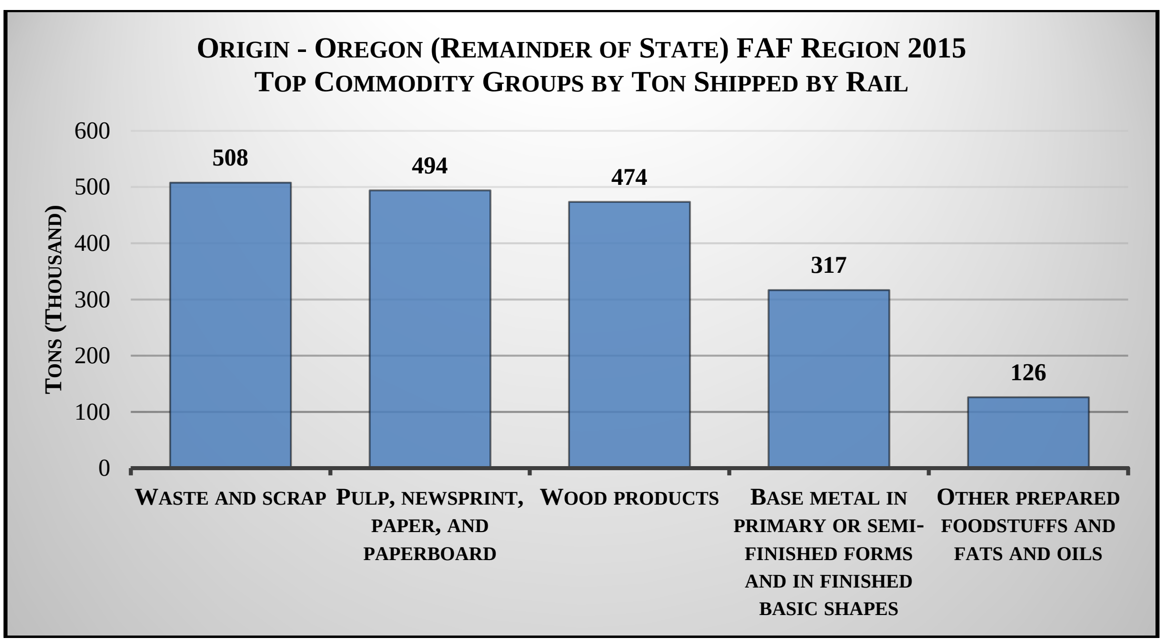

Figure 3.29: Top Commodity Groups by Ton Shipped from Oregon by Rail in 2015

Figure 3.30 presents the top five commodity groups in terms of ton-miles being shipped from Oregon by rail. The top five commodity groups account for 1,430 million ton-miles, roughly 4,967 million ton-miles less than commodity groups shipped by truck. Wood Products is the only commodity group present for both truck and rail, although does not have a large difference in ton-miles. Wood Products shipped by truck total approximately 739 million ton-miles and Wood Products shipped by total 567 million ton-miles.

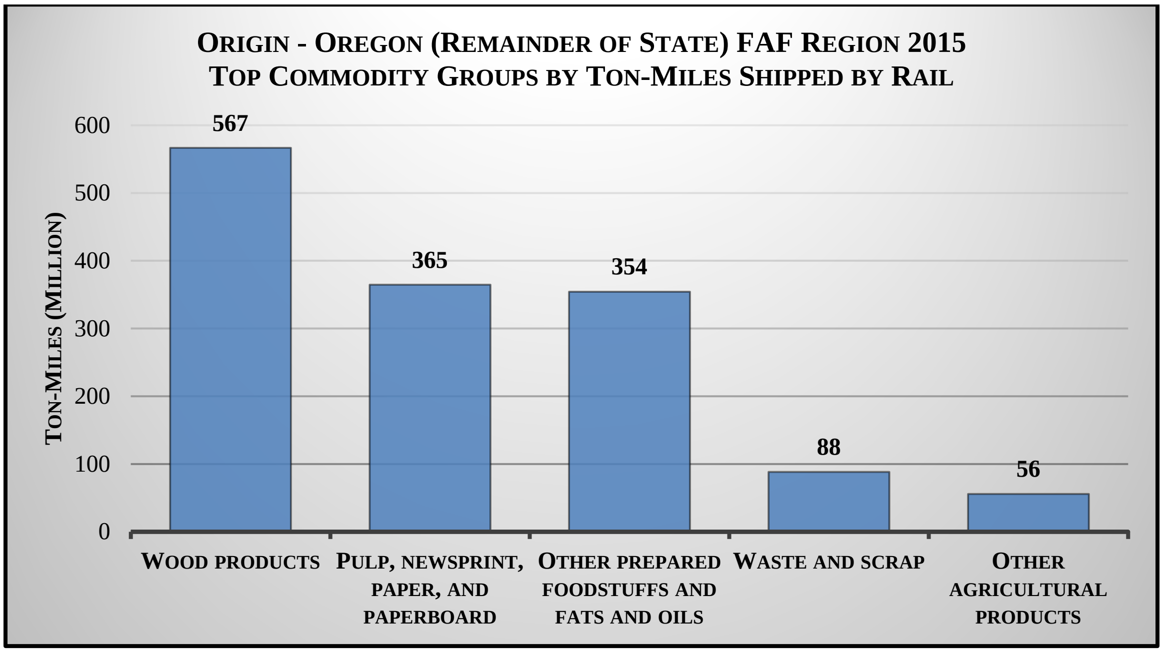

Figure 3.30: Top Commodity Groups by Ton-Miles Shipped from Oregon by Rail in 2015

3.1.3.3 Truck Destination – Oregon (Remainder of State) FAF Region

Figure 3.31 shows the top five commodity groups in terms of value being shipped to Oregon by truck. The top five commodity groups represent approximately $15,826 million worth of freight being shipped to Oregon, slightly less than the $19,770 million being shipped to Portland. Machinery accounts for the highest percentage of the top five commodity groups, which is also true for commodity flow into Portland by truck. Some of the commodity groups in this top five are also present in the top five commodity groups originating in this FAF region with the same values. This occurs due to the respective commodity groups bearing the same origin and destination.

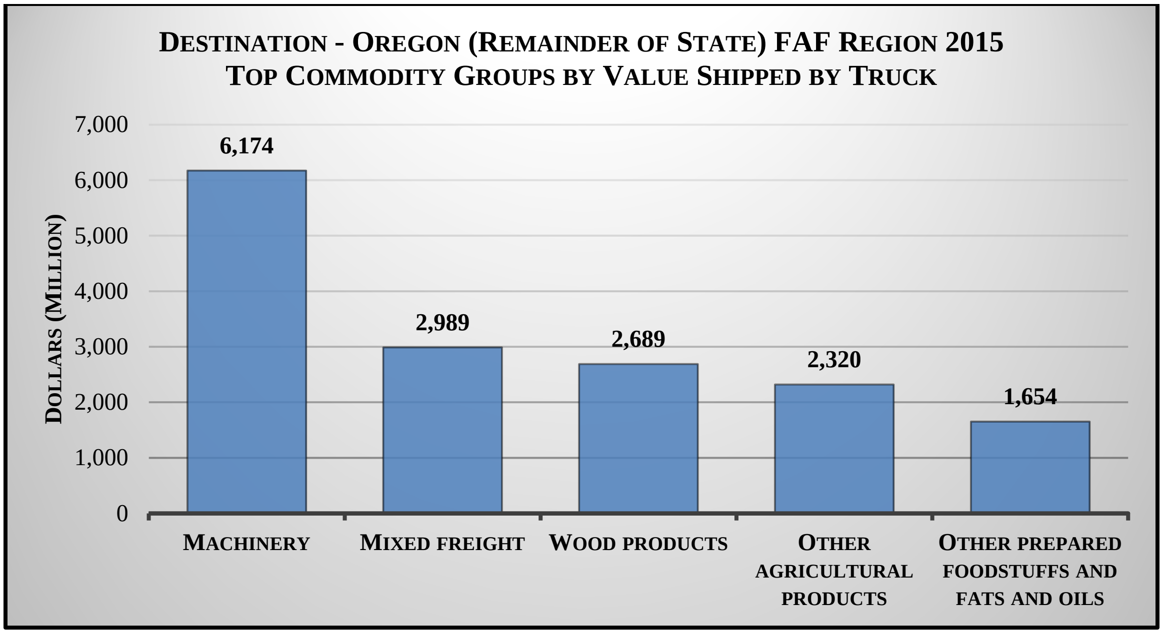

Figure 3.31: Top Commodity Groups by Value Shipped to Oregon by Truck in 2015

Figure 3.32 displays the top five commodity groups in terms of tons being shipped to Oregon by truck. These top five commodity groups mirror the top five commodity groups shipped by truck originating in this FAF region. This occurs due to the commodity groups' origin and destination being the same FAF region.

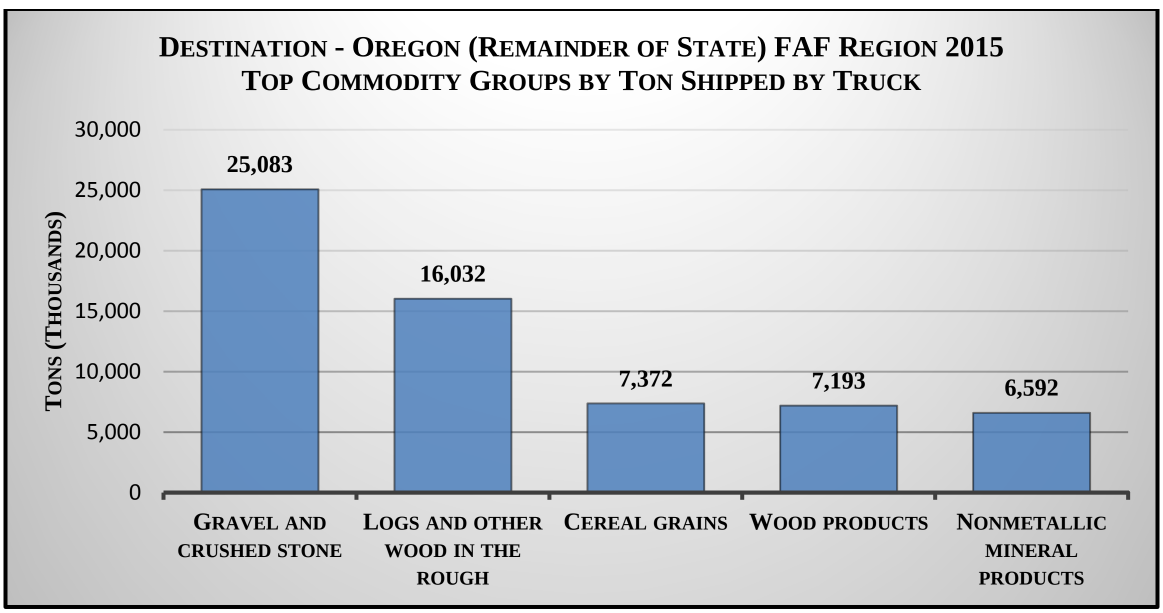

Figure 3.32: Top Commodity Groups by Ton Shipped to Oregon by Truck in 2015

Figure 3.33 illustrates the top five commodity groups in terms of ton-miles being shipped to Oregon by truck. Similar to other top five commodity groups, this top five shares all five commodity groups with shipments originating in this FAF region. The quantities originating in this FAF region are the same quantities arriving in this FAF region. Non-Metallic Minerals, however, differs in ton-miles. Non-Metallic Minerals originating in this FAF region account for approximately 677 million ton-miles, but account for 805 million ton-miles destined to this FAF region.

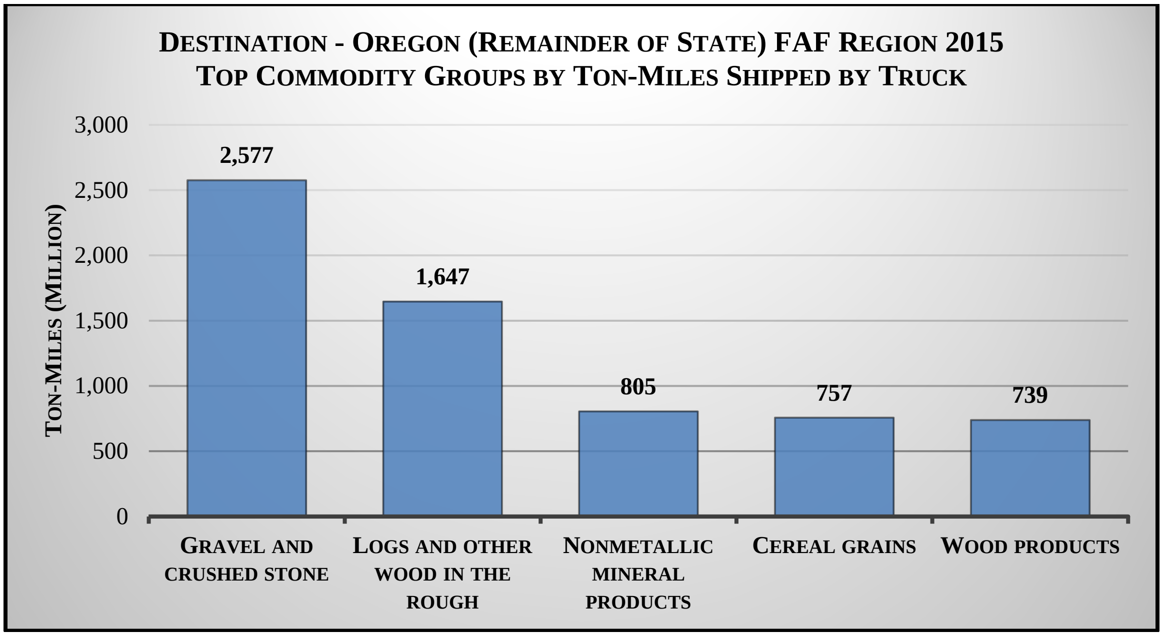

Figure 3.33: Top Commodity Groups by Ton-Miles Shipped to Oregon by Truck in 2015

3.1.3.4 Rail Destination – Oregon (Remainder of State) FAF Region

Figure 3.34 presents the top five commodity groups in terms of value being shipped to Oregon by rail. The top five commodity groups represent approximately $1,642 million worth of commodity groups being shipped to this FAF region by rail. Wood Products is the only commodity group that is present in the top five for both truck and rail, however $101 million is shipped by rail compared to $2,689 million shipped by truck.

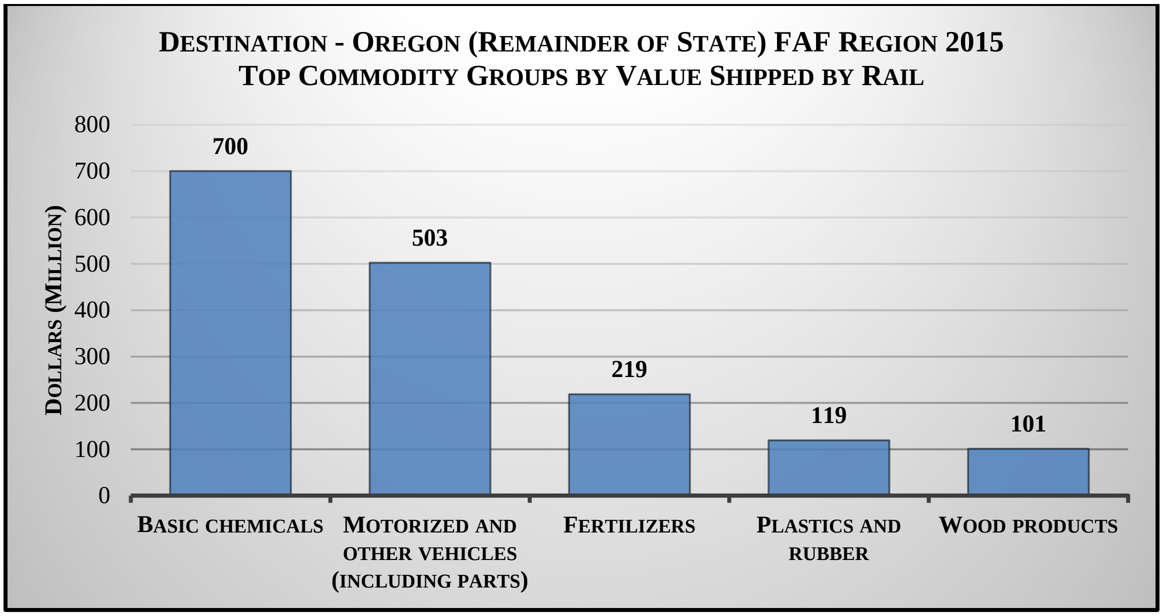

Figure 3.34: Top Commodity Groups by Value Shipped to Oregon by Rail in 2015

Figure 3.35 shows the top five commodity groups in terms of tons being shipped to Oregon by rail. The top five commodity groups account for 3,927 thousand tons that are shipped to Oregon by rail. Wood Products is the only top five commodity group to be shipped to this FAF region by both truck and rail at 7,193 thousand tons and 564 thousand tons respectively. Surprisingly, Waste and Scrap represents 635 thousand tons arriving, but just 508 thousand tons leaving.

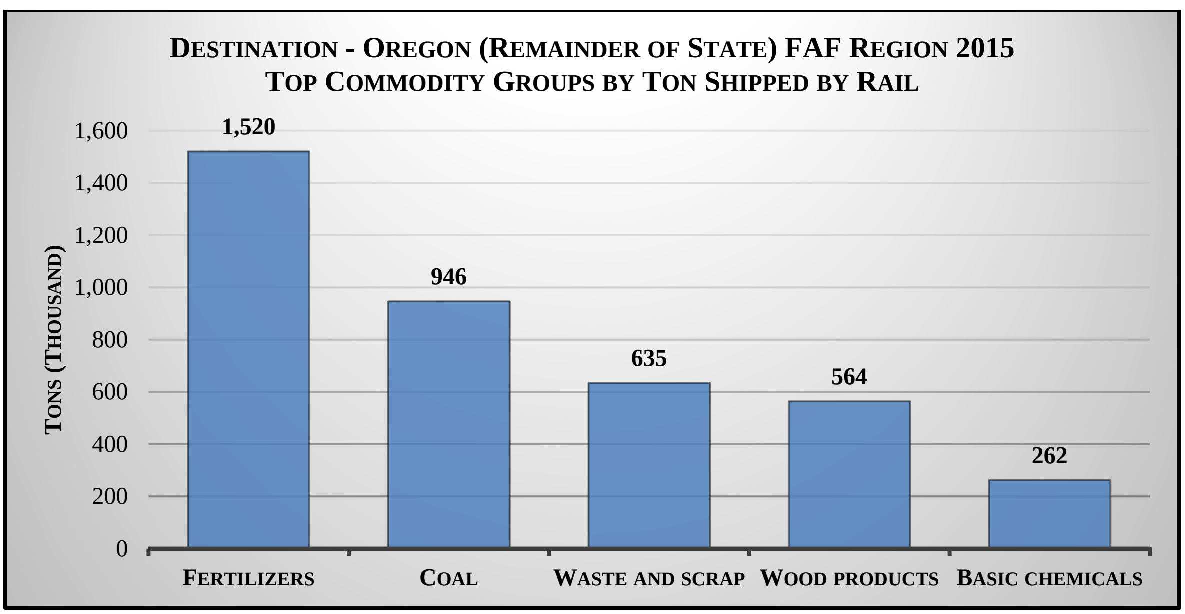

Figure 3.35: Top Commodity Groups by Ton Shipped to Oregon by Rail in 2015

Figure 3.36 displays the top five commodity groups by ton-miles being shipped to Oregon by rail. The top five commodity groups represent 3,690 million ton-miles of freight destined to this FAF region. Of the five commodity groups, Wood

Products is the only commodity group to be present for both truck and rail at approximately 739 million ton-miles and 341 million ton-miles respectively. Coal represents slightly more ton-miles than Fertilizers at 1,260 million ton-miles to 1,085 million ton-miles. No other commodity group accounts for more than 675 million ton-miles.

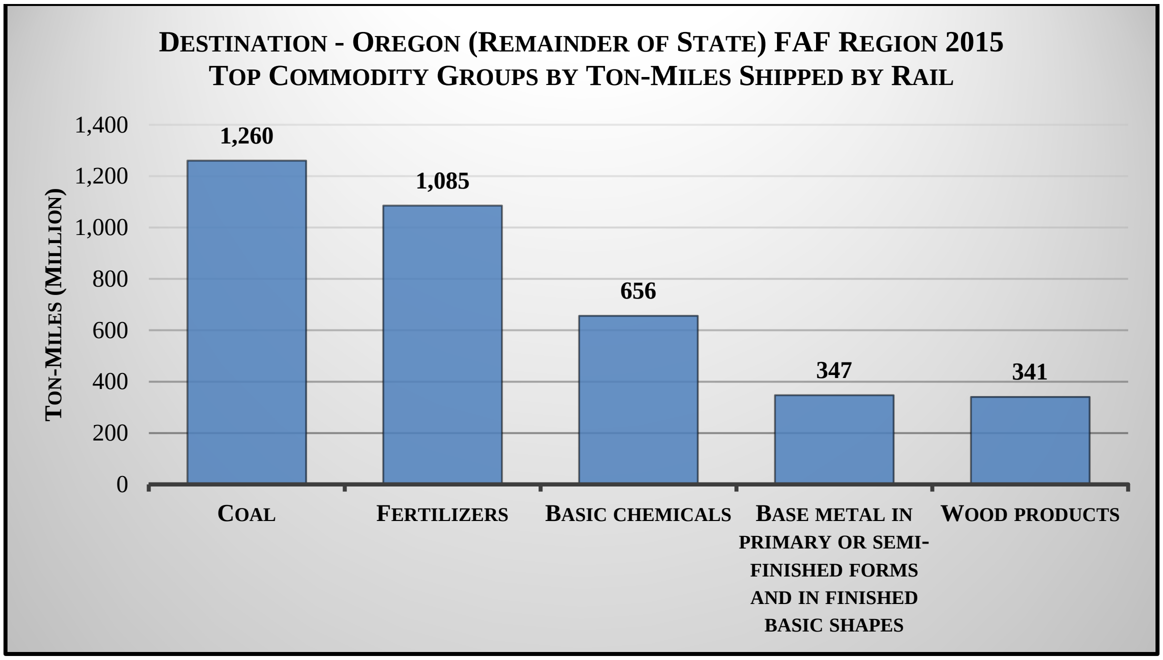

Figure 3.36: Top Commodity Groups by Ton-Miles Shipped to Oregon by Rail in 2015

In summary, the statistical analysis performed in this section provides essential information for investigating mode shift potential in the following portions of this study. For example, separating each FAF region by origin and destination provided a clearer picture of the top commodity groups flowing in and out of the state. With this in mind, the following sections provide additional insight into the corridors that are most widely used to transport goods in the state in addition to visualizing the current transport networks of truck and rail. Although there may be some transport network overlap between truck and rail, this does not necessarily translate into mode shifts.

The results of the analysis identified similar commodity groups found in the Cambridge study conducted for the Port of Portland *(Cambridge Systematics 2015)*. The following is taken verbatim (quoted materials are formatted in italics and extends from "Projected Domestic, Import, and Exports Tonnage for the Major Commodities" through "Potential Modal Shifts of the Top Commodities as Defined by Weight") from the Task F Technical Memorandum *(Cambridge Systematics 2015)*:

Projected Domestic, Import, and Exports Tonnage for the Major Commodities

This section examines the major domestic, import and export commodities currently, and how they will likely grow in the future. Note that for imports and exports, both the foreign and domestic modes are included to give a more complete picture of how the modes interact together. For instance, a trip that arrives at the Port of Portland by Ocean and then by Rail will be counted under both modes.

Major Domestic Commodities of the Region

In 2007, 188 million tons of freight was characterized as domestic commodities in the study region. Table 3.2 displays freight flows by weight and rank in 2007 and 2040. By 2040, these commodities are expected to grow a total of 135 million tons or 172 percent above their 2007 tonnage. By 2040, it is projected that 68 percent of the Domestic share will be generated from ten commodities listed below, with over 48 percent of the Domestic share coming from the top five commodities (with their corresponding FAF3 commodity codes):

- *31 – Nonmetallic mineral products (drops from 15 percent share in 2007 to 12.5 percent by 2040);*
- *12 – Gravel and Crushed stone (retains share with 15 percent of the total domestic commodity moved);*
- *17, 18, 19 – Petroleum, fuels n.e.c. (drops from 13 percent share in 2007 to 10 percent share in 2040).*
- *26 – Wood products (share drops from 7.8 percent in 2007 to 6.2 percent volume share in 2040);*
- *02 – Cereal Grains (stays at fifth with about 7 percent share;*

Table 3.2: ***Top 10 Domestic Commodities by Weight***
Tons in Thousands; 2007 to 2040

Commodity	***2007***	***Rank 2007***	***2040***	***Rank 2040***	***Total Growth***	***CAGR 2007-2040***	***Percent of Total 2007***	***Percent of Total 2040***
Nonmetal min. prods.	*32,417*	*1*	*44,222*	*2*	*36%*	*0.9%*	*15.2%*	*12.5%*
Gravel	*30,978*	*2*	*53,834*	*1*	*74%*	*1.7%*	*14.5%*	*15.2%*
Petroleum, fuels n.e.c	*27,852*	*3*	*35,641*	*3*	*28%*	*0.7%*	*13.1%*	*10.1%*
Wood prods.	*16,579*	*4*	*21,853*	*6*	*32%*	*0.8%*	*7.8%*	*6.2%*
Cereal grains	*13,890*	*5*	*24,847*	*5*	*79%*	*1.8%*	*6.5%*	*7.0%*
Other foodstuffs	*13,386*	*6*	*24,916*	*4*	*86%*	*1.9%*	*6.3%*	*7.0%*

Commodity	2007	Rank 2007	2040	Rank 2040	Total Growth	CAGR 2007-2040	Percent of Total 2007	Percent of Total 2040
and alcoholic beverages								
Waste/scrap	*7,566*	*7*	*15,272*	*7*	*102%*	*2.2%*	*3.5%*	*4.3%*
Newsprint/paper	*6,865*	*8*	*9,196*	*10*	*34%*	*0.9%*	*3.2%*	*2.6%*
Mixed freight	*6,689*	*9*	*14,526*	*8*	*117%*	*2.4%*	*3.1%*	*4.1%*
Basic chemicals	*6,279*	*10*	*9,616*	*9*	*53%*	*1.3%*	*2.9%*	*2.7%*
All Other.	*50,676*		*99,736*		*97%*	*2.1%*	*23.8%*	*28.2%*
Total	*213,176*		*353,659*		*66%*	*1.5%*	*100.0%*	*100.0%*
	Change		***140,483***					

Source: Cambridge Systematics with 2007-2040 IHS Global data and FAF3 Forecast.

Figure 3.37 below shows the total domestic tons by mode. Air mode is anticipated to have the largest annual growth rate of all modes, although, very limited tonnage will be moved by this mode compared to the other modes. Truck is projected to grow at an annual rate of 1.6 percent from 163 million tons in 2007 to 273 million tons in 2040. Trucking will continue to hold three-quarters of the modal share. Rail is estimated to grow 1.3 percent annually from 27 million tons in 2007 to 41 million tons by 2040, continuing to hold a 12-13 percent modal share Pipeline movements are projected to grow 1.5 percent annually, from 10 million tons in 2007 to 16 million tons in 2040.

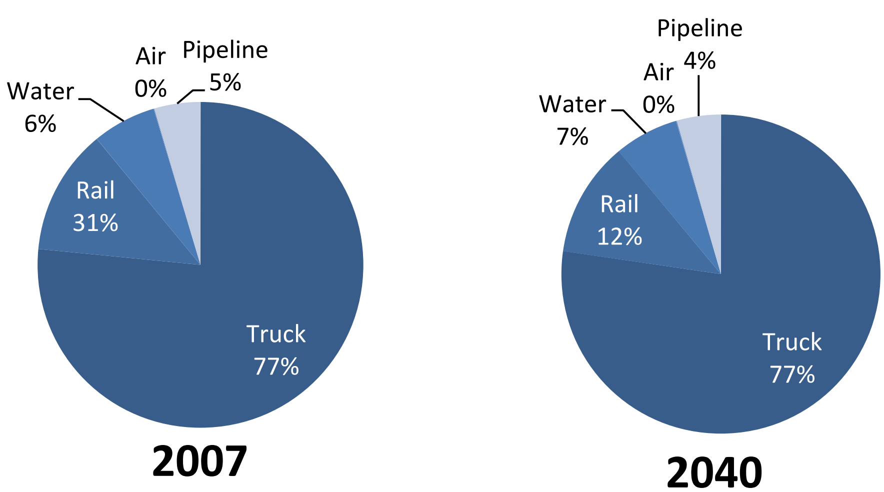

Figure 3.37: Total Domestic Tons by Mode
Source: Cambridge Systematics with 2007-2040 IHS Global data and FAF3 Forecast.

Major Import Commodities of the Region

By 2040, it is projected that 74 percent of the Import share will be generated from ten commodities listed below, with over 43 percent of the Import share coming from the top five commodities (with their corresponding FAF3 commodity codes):

- *31– Nonmetallic mineral products (growing from 12 percent share in 2007 to 15 percent by 2040);*
- *13 – Nonmetallic minerals n.e.c (starting in 2007 with a 11 percent share, dropping to little under an 9 percent share by 2040);*
- *32 – Base metals (dropping 2 percentage points in its share from a high of 11 percent share in 2007 to an 9 percent share of total imports by 2040);*
- *26 – Wood products (dropping in share significantly from 11 percent in 2007 to 4 percent in 2040); and*
- *22 – Fertilizers (drop in share from 10 percent in 2007 to 8 percent in 2040).*

Table 3.3 below shows the anticipated import volume growth for the Portland/ Vancouver region of each of the major import commodities.

Table 3.3: ***Top 10 Import Commodities by Weight***
Tons in Thousands; 2007 to 2040

Commodity	***2007 Tonnage***	***Rank 2007***	***2040 Tonnage***	***Rank 2040***	***Total Growth***	***CAGR 2007-2040***	***Percent of Total 2007***	***Percent of Total 2040***
Nonmetal min. prods.	*3,330*	*1*	*11,639*	*1*		*3.9%*	*11.9%*	*14.9%*
Nonmetallic minerals	*3,059*	*2*	*6,865*	*2*	*124%*	*2.5%*	*10.9%*	*8.8%*
Base metals	*3,034*	*3*	*6,736*	*3*	*122%*	*2.4%*	*10.8%*	*8.6%*
Wood prods.	*3,005*	*4*	*2,702*	*11*	*-10%*	*-0.3%*	*10.7%*	*3.5%*
Fertilizers	*2,782*	*5*	*5,850*	*7*	*110%*	*2.3%*	*9.9%*	*7.5%*
Petroleum, fuels n.e.c.	*2,621*	*6*	*6,154*	*4*	*135%*	*2.6%*	*9.3%*	*7.9%*
Motorized vehicles	*1,965*	*7*	*3,415*	*8*	*74%*	*1.7%*	*7.0%*	*4.4%*
Basic chemicals	*1,872*	*8*	*5,908*	*6*	*216%*	*3.5%*	*6.7%*	*7.5%*
Articles-base metal	*1,049*	*9*	*3,217*	*9*	*207%*	*3.5%*	*3.7%*	*4.1%*
Machinery	*616*	*10*	*6,046*	*5*	*881%*	*7.2%*	*2.2%*	*7.7%*
All Other	*4,724*		*19,771*		*319%*	*4.4%*	*16.8%*	*25.2%*

Commodity	2007 Tonnage	Rank 2007	2040 Tonnage	Rank 2040	Total Growth	CAGR 2007-2040	Percent of Total 2007	Percent of Total 2040
Total	*28,057*		*78,304*		*179%*	*1.7%*		
Change 2007-2040			***50,246***					

Source: Cambridge Systematics with 2007-2040 IHS Global data and FAF3 Forecast.

Total import tonnage is anticipated to grow from 28.5 million tons in 2007 to 78.3 million tons by 2040, or a 279 percent increase. The largest increase in import tons (881 percent) is anticipated to occur for machinery. This commodity group is projected to grow at a compound average growth rate (CAGR) of 7.2 percent from 0.6 million tons in 2007 to 6.0 million tons by 2040. Petroleum, fuels n.e.c. is forecasted to grow 135% from 2.6 million tons to 6.2 million tons.

Figure 3.38 below shows the total import tons by domestic mode. The largest total increase is predicted to be experienced by the trucking mode as it is projected to grow by 3.5 percent annually from 11.6 million tons in 2007 to 35.7 million tons by 2040. Rail is estimated to grow 2.6 percent annually from 5.3 million tons in 2007 to 12.4 million tons by 2040. Pipeline is projected to grow 3.1 percent annually, a 175 percent increase, from 1.1 million tons in 2007 to 3.1 million tons in 2040. In addition, Air tonnage is projected to have the highest growth rate, growing with a CAGR of 5.9 percent, though the share is very small. Finally, Ocean mode, which is a foreign mode, will growth at a rate of 2.9 percent, on par with the trucking and rail modes – modes in which the same trips would take once they reach land.

Figure 5.2 Total Import Tons by Mode

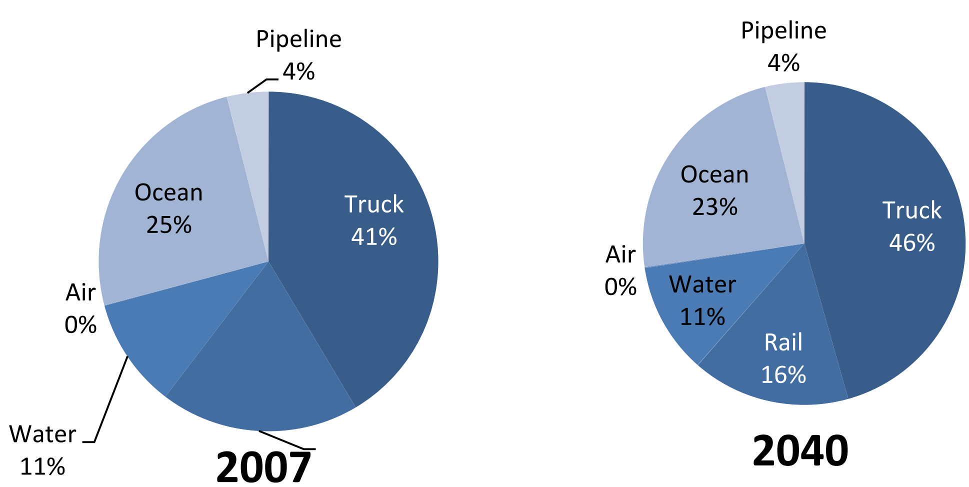

Figure 3.38: Total Import Tons by Mode

Source: Cambridge Systematics with 2007-2040 IHS Global data and FAF3 Forecast.

Major Export Commodities of the Region

In 2007, 75 percent of the total export tons was represented in the top five commodity groups. Total Export Tons were led by Cereal Grains at 46 percent share of all export tonnage. Based upon the individual growth projections for each of these commodities, by 2040 the top five commodity groups are projected to hold less than 60 percent share of the export volume. Cereal grains are projected to drop from 46 percent share of total exports in 2007 to a 28 percent share by 2040. By 2040, it is projected that 85 percent of the export share will be generated from ten commodities listed below, with over 65 percent of the Domestic share coming from the top five commodities (with their corresponding FAF3 commodity codes):

- *02 – Cereal Grains (remains the top export commodity by weight although its share drops form 46 percent in 2007 to 28 percent by 2040;*
- *22 – Fertilizers (drops in share from 9 percent in 2007 to 6 percent in 2040);*
- *20 – Basic Chemicals (share roughly remains at 7 percent);*
- *03 – Other Ag. Products (share increases from 7 percent in 2007 to 12 percent in 2040); and*
- *14 – Metallic Ores (share increases from 5 percent in 2007 to 6 percent in 2040).*

This information is further displayed in Table 3.4 below. The table shows the anticipated volume growth and ranking for the Portland/ Vancouver region of each of the major export commodities. Cereal grains are anticipated to remain as the largest export commodity of the region. Although, it is anticipated to see the smallest annual growth rate among the export commodities at only a CAGR of 1.6 percent during the forecast period.

Table 3.4: ***Total Export Commodities by Weight***

Commodity	*2007*	*Rank 2007*	*2040*	*Rank 2040*	*Total Growth*	*CAGR 2007-2040*	*Percent of Total 2007*	*Percent of Total 2040*
Cereal grains	*27,941*	*1*	*46,510*	*1*	*66%*	*1.6%*	*45.7%*	*28.8%*
Fertilizers	*5,592*	*2*	*9,806*	*5*	*75%*	*1.7%*	*9.1%*	*6.1%*
Basic chemicals	*4,440*	*3*	*11,392*	*4*	*157%*	*2.9%*	*7.3%*	*7.1%*
Other ag prods.	*4,420*	*4*	*18,983*	*3*	*329%*	*4.5%*	*7.2%*	*11.8%*
Metallic ores	*3,299*	*5*	*9,792*	*6*	*197%*	*3.4%*	*5.4%*	*6.1%*
Animal feed	*2,864*	*6*	*6,216*	*7*	*117%*	*2.4%*	*4.7%*	*3.8%*
Waste/scrap	*2,829*	*7*	*21,034*	*2*	*643%*	*6.3%*	*4.6%*	*13.0%*
Wood prods.	*1,515*	*8*	*4,185*	*10*	*176%*	*3.1%*	*2.5%*	*2.6%*
Other foodstuffs and alcoholic beverages	*1,462*	*9*	*4,760*	*9*	*226%*	*3.6%*	*2.4%*	*2.9%*
Newsprint/paper	*1,035*	*10*	*5,229*	*8*	*405%*	*5.0%*	*1.7%*	*3.2%*
All Other	*5,739*		*23,586*		*311%*	*4.4%*	*9.4%*	*14.6%*
Total	*61,137*		*161,492*		*164%*	*3.0%*		
Change 2007-2040			***100,356***					

Source: Cambridge Systematics with 2007-2040 IHS Global data and FAF3 Forecast.

Figure 3.39 below shows the total export tons by mode. The largest tonnage increase is predicted to be experienced by the trucking mode, as it is projected to grow by 3.4 percent annually from 26 million tons in 2007 to 79 million tons by 2040. Truck transportation is anticipated to grow from a modal share of 42 percent in 2007 to 49 percent by 2040. Rail is estimated to grow 2.6 percent annually from 10 million tons in 2007 to 23 million tons by 2040. Rail is projected to lose approximately three percentage points of modal share, dropping from 18 percent in 2007 to 15 percent in 2040. Inland water transportation is projected to decrease two percent annually for export tonnage from 35 million tons in 2007 to 3 million tons by 2040. Air (3.6 percent CAGR) and Pipeline (4.6 percent CAGR) movements are anticipated to grow the largest annual rates of all modes, although very limited tonnage is exported by either of these modes. In addition, the Ocean mode is also expected to grow at a rate on par with the key inland modes, at a rate of 2.7 percent.

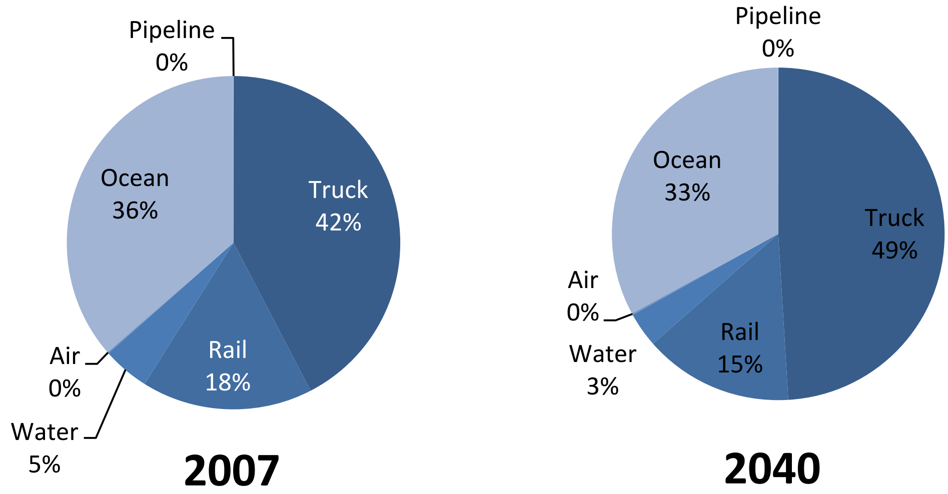

Figure 3.39: Export Tone by Domestic Mode

Source: Cambridge Systematics with 2007-2040 IHS Global data and FAF3 Forecast.

Future Mode Utilization

In summary, Figure 3.40 displays the forecasted modal shares of the total freight movements by weight. It is anticipated that in the future ocean will gain an increasing share of transportation, from 10 percent to 12 percent. Inland water transportation will maintain its market share at around 6 percent, while the rest of the modes will more or less keep its market share or lose by 1 percentage point.

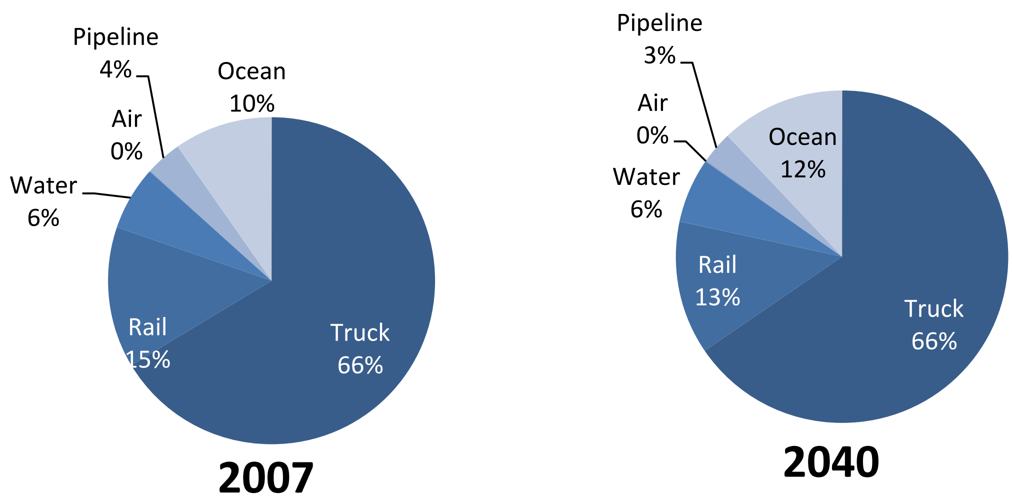

Figure 3.40: Total Freight Tonnage by Mode

Factors That Could Affect Modal Shifts for the Region's Top Commodities

The approach to estimating mode shares used by FAF and generally adopted in this study to any adjustments to FAF is to maintain a constant mode share by commodity/origin-destination. That means, for example, that if rail captured 60 percent of the share of grain shipped from Kansas to Portland in the base year, rail would capture the same 60 percent of future grain shipments for Kansas to Portland. Using this approach, the only drivers of changes in future overall mode share for the region are changes in the commodity mix or the origin-destination mix of the commodity flows. This does not take into account any of the following factors that have been identified previously as affecting BCO mode choice:

- *Changes in the relative cost of the modes;*
- *Changes in modal capacity in the region;*
- *Changes in the relative performance of the modes with respect to transit times, reliability, loss and damage, and other service characteristics;*
- *Changes in supply chain approaches that affect distribution patterns, size and frequency of shipments, and other supply chain management objectives; and*
- *Changes in access to modes.*

The following sections describe how changes in some of these factors could affect potential modal shifts of the major commodities by weight and value that are shipped in the Portland/Vancouver region.

Potential Modal Shifts of the Top Commodities as Defined by Weight

Nonmetallic mineral products*: Examples of non-metallic minerals include potassium, phosphorus, calcium, magnesium, sulfur. This type of commodity is being imported and primarily railed out. Thus, the importation of these minerals will be primarily dependent on fairly priced rail transportation which moves over an efficient rail system. There may be diversion of these bulk products to road if the final destination is within a 500 mile radius of the region. If the final destination is more than 500 miles, rail will continue to be the mode of choice, but diversion could occur to another port if the PNW rail system is not efficient and or provides a cost effective delivery cost to the final destination.*

Gravel and Crushed Stone*: This bulk product is primarily a domestic commodity. Like nonmetallic minerals delivery distance will indicate the modal choice between rail and truck. Congestion on either rail or highways will affect the movement of this commodity in the future as it is a low value/ton product.*

Cereal grains: *This product is moved primarily by rail into the region and then exported by water. This commodity's modal choice may change from bulk grain cars to some of the product moving in containers as export customers seek to identify other ways of preserving the product. In either case, the majority of the product will continue to move by rail into the region.*

Waste and Scrap*: This product includes metallic waste and scraps as well as non-metallic waste and scraps. Metallic waste and scraps include metal slag, ash, and residues; Other waste and scrap of ferrous metals; and Other waste and scrap of non-ferrous metals (includes precious metals). Non-metallic waste and scrap (excludes from food processing) includes: sawdust and wood waste and scrap; waste and scrap of paper or paperboard; and waste and scrap of glass. The paper related scraps usually arrive primarily by truck to be transloaded into containers for export. This modal choice may change in the future if the international markets for this recycled paper decline or domestic facilities are build where this product is used as an input or source. Metal scraps arrive by multiple modes, usually by rail or truck to be loaded into a vessel for export markets. Again, these modes may shift in the future if more waste processing occurs in the U.S. instead of abroad.*

Wood Products: *This is primarily a domestic commodity moving by truck and rail for manufacturing facility to end destination. As long as road and rail congestion and transportation costs of these modes do not make the region uncompetitive for this product, it is anticipated that there will not be any major modal shift for this commodity.*

Potential Modal Shifts of the Top Commodities as Defined by Value

Precision Instruments: *This is the top valued domestic commodity and currently moved primarily by truck followed by rail. This modal choice/ share could change in the future if delivery to the end destination cannot be guaranteed due to delays* *on either the road or rail. Air transportation may be utilized more in the future if the costs of transportation and delay penalties become too high.*

Machinery: *This commodity is the top valued commodity for all trade types: domestic, import as well as export. Depending on destination, this commodity has traditionally been treated as break-bulk and moved by truck or rail flat beds. The methodology for moving the commodity changes based on Origin and Destination pairings and the availability and pricing of containers in those respective markets. In this study, commodities that have previously been classified as intermodal cargos under "multiple modes and mail" have been allocated to the respective individual modal segments as much as possible. Thus, a commodity such as machinery that would move by rail whether on a flatbed/flatcar or in an intermodal container would still be classified as rail or road respectively.*

Electronics: *This commodity is a top export as well as a top domestic commodity on the basis of value. Traditionally, the cargo has moved in a containerized format either by rail or truck depending origin-destination pairings. As it is a high value/low weight commodity containerization or domestic truck is the most secure method of transport. The choice of modes could change in the future based upon the relocation of either current factories or the development of new factories outside the larger urbanized areas as land becomes more expensive for such factories. If this is the case, then trucking along with rail transportation will remain the prime modes. Air may be an option for some of the products if reliable/ timely delivery schedules cannot be kept due to excessive congestion on either the road or rail networks.*

Motorized and Other vehicles: *As long as there is a demand for foreign made vehicles and the region is able to reserve land at or near the ports in the region to support this import in a cost effective manner, this commodity will remain in the region. The vehicles primarily arrive by water and leave either by truck or rail depending on the location of the destination. If congestion on the roads or rail increases the transportation costs significantly, the vehicle processor currently located in the region will change the supply chain for at least the vehicles moving east to the mid-west and beyond to another port of entry that is more cost effective for the specific destinations. As long as there continue to be processors in the region, local deliveries (those that can be trucked or approximately a 500 mile radius) will continue to be imported into the region and trucked to their destinations.*

Misc. manufactured products: *This commodity includes a wide range of products. For example: clocks, watches, pre-fabricated buildings, musical instruments, jewelry, works of art, etc. Other than pre-fabricated buildings the most efficient and secure way to transport this commodity would be by container. Thus, if there continues to be a container operation in the region these products will continue to be imported and moved out by road or rail. Some of the products may convert to air if their value is such or the delivery schedule requires the use of a faster transportation method. Pre-fabricated building depending on size may arrive by* *container or break-bulk. The mode chosen for final delivery is anticipated to remain road or rail depending on the distance to the destination. If costly congestion on the road/ rail network occurs without relief, then this type of product will be imported into another port and delivery by truck or rail from that new port of entry to its destination. Barge (water) could be used depending on it final destination and the feasibility to deliver to site by water or least minimal road transportation at the destination.*

3.2 GEOGRAPHICAL INFORMATION SYSTEMS (GIS) DATA

Figure 3.41 illustrates Oregon's truck highway system, railroads, halo zone and intermodal facilities. GIS data obtained from Oregon's Department of Transportation .ftp website was used to spatially depict the existing truck and rail network in Oregon. In addition to the data provided by ODOT, a separate GIS data file was used to illustrate intermodal facilities located in Oregon and the surrounding halo region as defined in the Oregon Statewide Integrated Model *(ODOT TPAU 2010; BTS 2012)*. Location of railroads in relation to highways and intermodal facilities impact mode shift potential (e.g. shifting is unable to occur if other modes or facilities are not present). The most used corridors (shown in the next section of this report) have some railroads coinciding with them. Additionally, intermodal facilities are present at all Oregon borders, indicating the potential for freight that is moved across the state to shift modes if applicable.

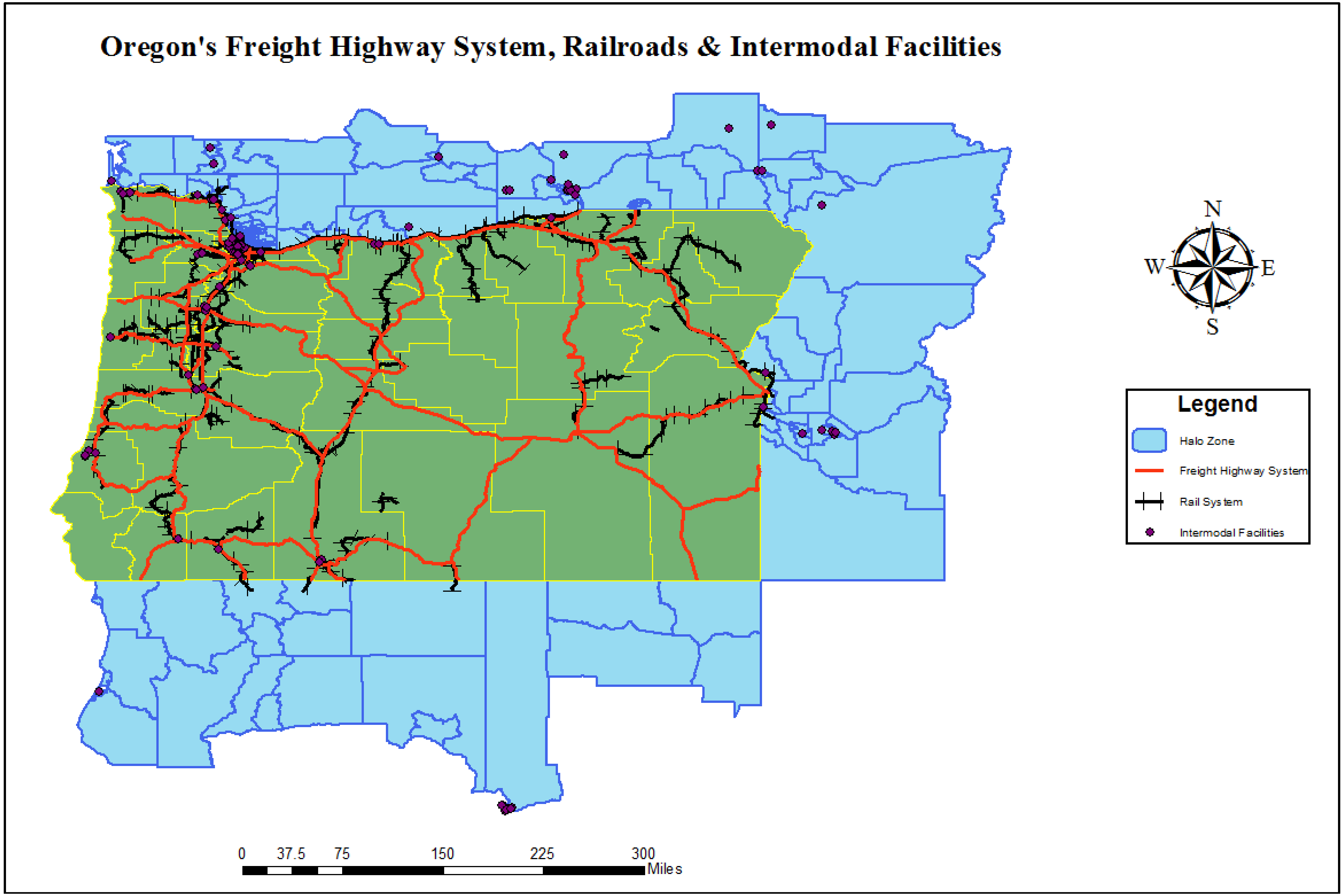

Figure 3.41: Oregon's Freight Highway System, Railroads, Halo Zone & Intermodal Facilities

3.3 ODOT'S PERFORMANCE AND METRICS DATA

Figure 3.42 displays the truck share of total VMT of the 19 corridors within ODOT's study *(ODOT TPAU 2013)*. This figure identifies corridors with a high percentage of trucks, therefore providing routes that could be candidates for mode shift potential. I-84 contains a 28% truck share of VMT, more than one-quarter of the total VMT.

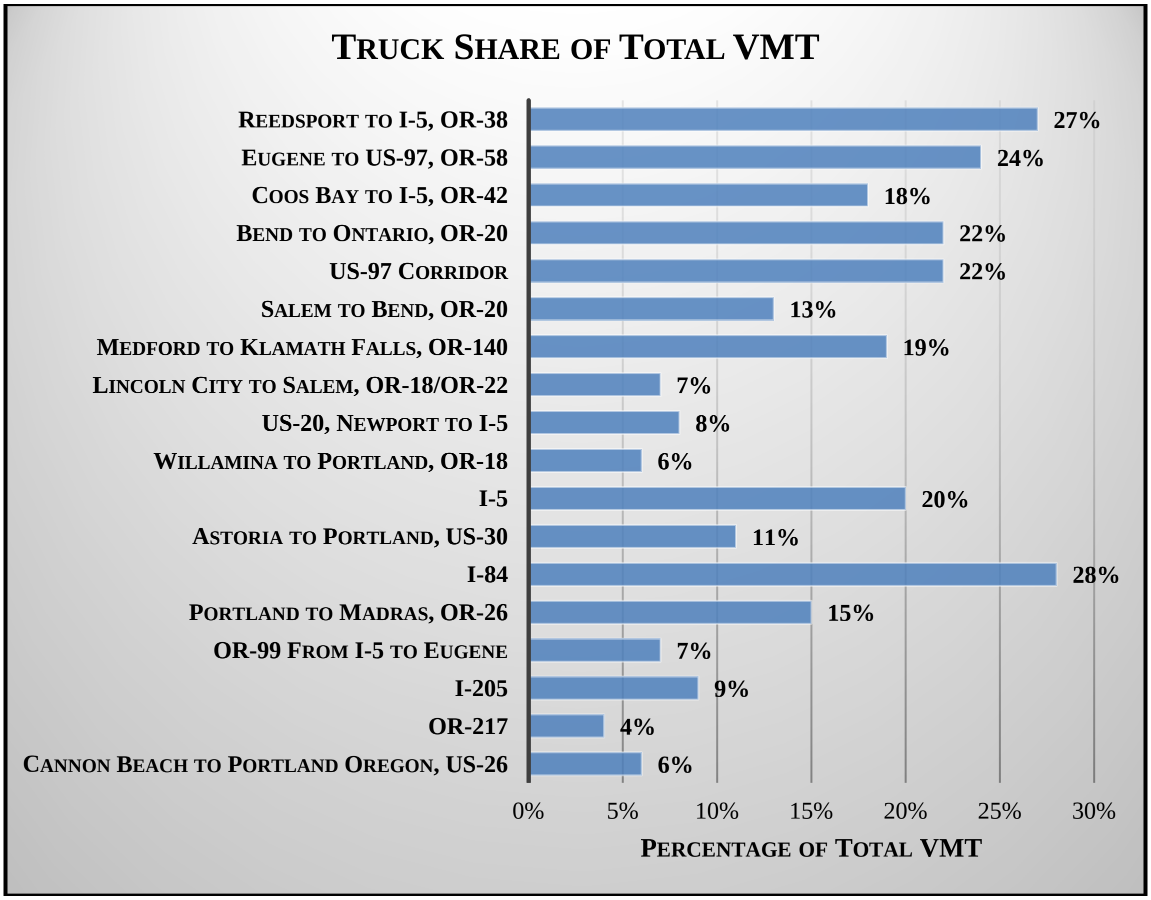

Figure 3.42: Truck Share of Total Vehicle Miles Traveled (Data Source: *(ODOT TPAU 2013)*)

Figure 3.43 presents the range in average annual daily traffic (AADT) along the 19 corridors provided by ODOT's study *(ODOT 2013)*; each corridor was separated into segments. Additionally, Figure 3.44 displays the range in truck share of AADT along those same 19 corridors based on the corridor segments defined in the same study *(ODOT 2013)*. This data depicts routes that have a potential for mode shifting due to the high amount of freight that is currently being transported along these corridors.

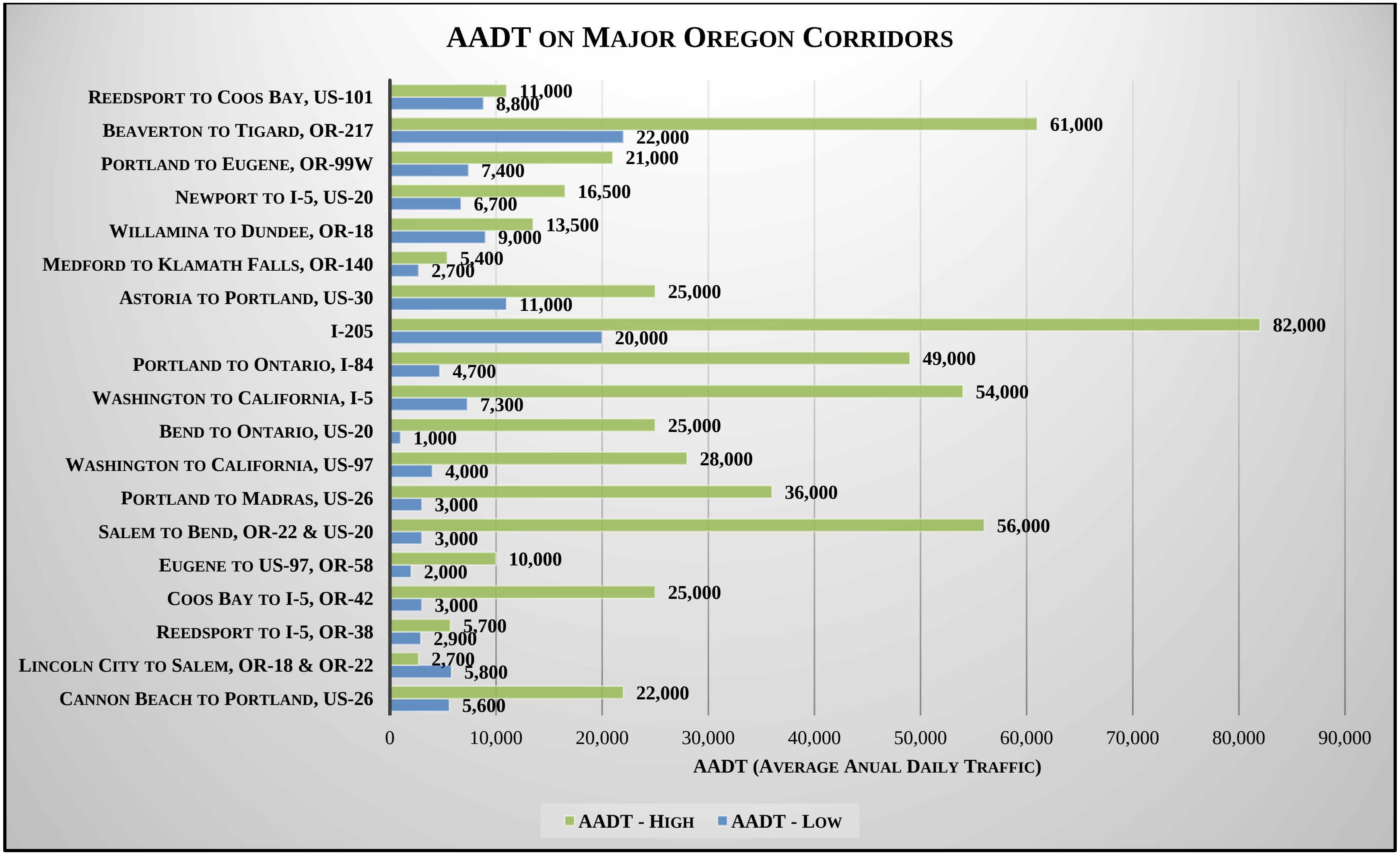

Figure 3.43: Average Annual Daily Traffic on Major Oregon Corridors (Data Source: *(ODOT TPAU 2013)*)

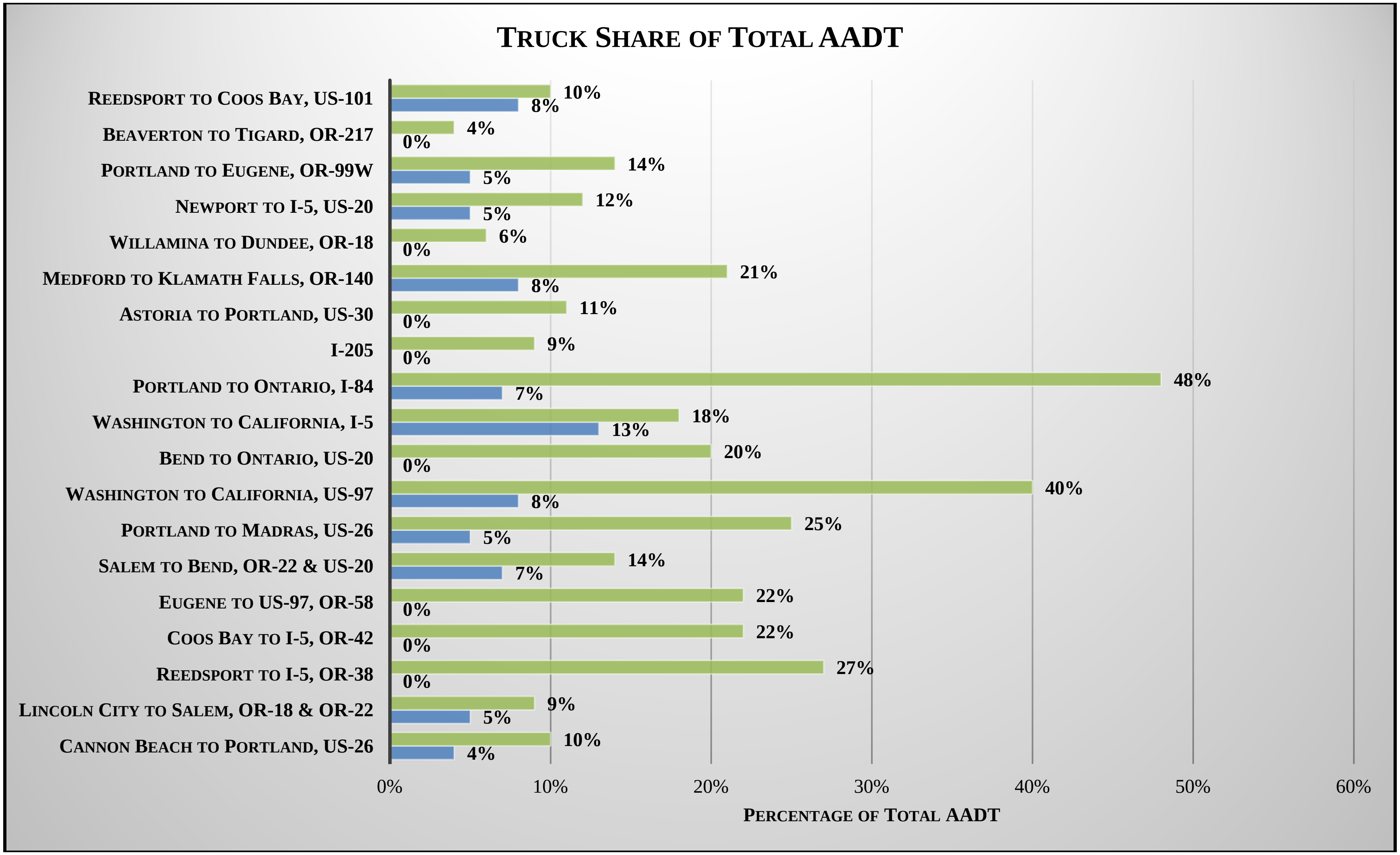

Figure 3.44: Truck Share of Average Annual Daily Traffic on Major Oregon Corridors (Data Source: *(ODOT TPAU 2013)*)

3.4 BUREAU OF TRANSPORTATION STATISTICS DATA

Figure 3.45 presents the change in retail diesel prices from January 2005 to August 2015. This data provides crucial economic information on market forces that can influence modal shift. As fuel price decreases, freight being distributed by truck may become more appealing. However, if diesel price increases (seen Jan-08 in Figure 3.30), shippers distributing freight by truck may begin to look for another mode of transport.

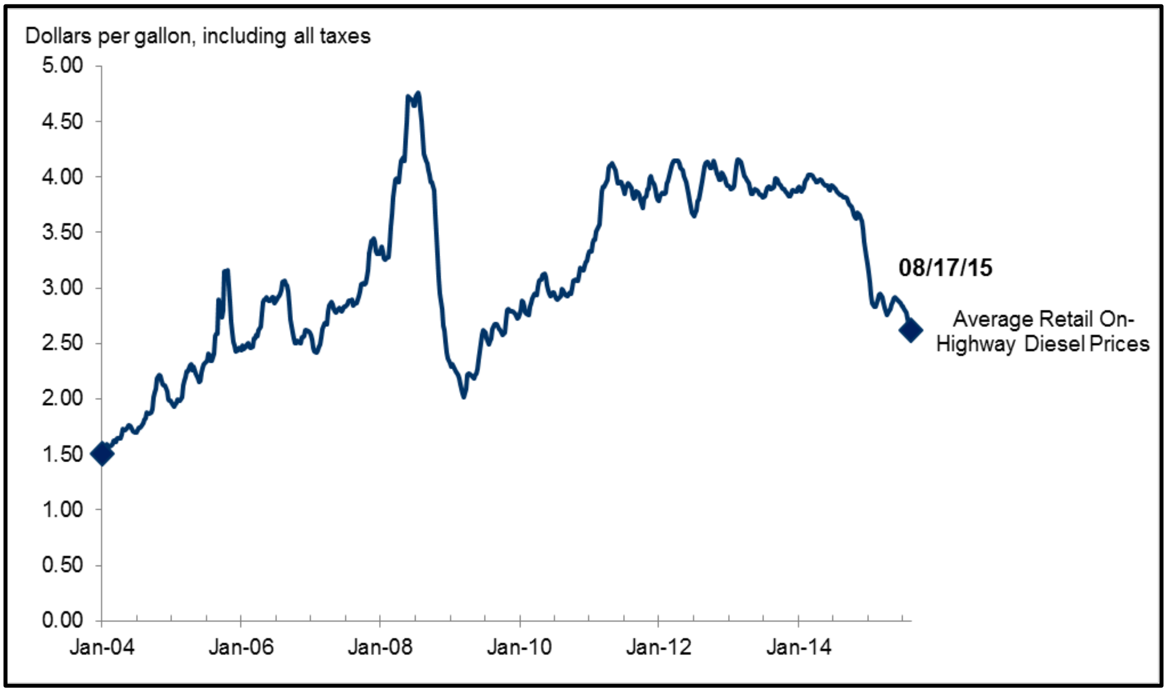

Figure 3.45: Retail Diesel Prices (Jan. 2005 to Aug. 2015) (Source: U.S. Department of Energy, 2015)

Figure 3.46 displays the total highway vehicle miles traveled (VMT) from January 2004 to February 2015. The figure illustrates a continuous “up and down” trend for highway VMT, exhibiting traffic behavior that may help explain a mode shifting situation. As VMT increases, so does delay and congestion that impacts the transport of goods. Understanding that a higher VMT can lead to such things, other modes can be considered to lessen the delay of goods. On the other hand, if VMT is decreasing (assuming diesel prices are not changing), there is more room on the highway allowing more trucks to ship goods. If shipping by truck is quicker than shipping by rail and diesel prices are not changing, there could be a legitimate potential to shift modes.

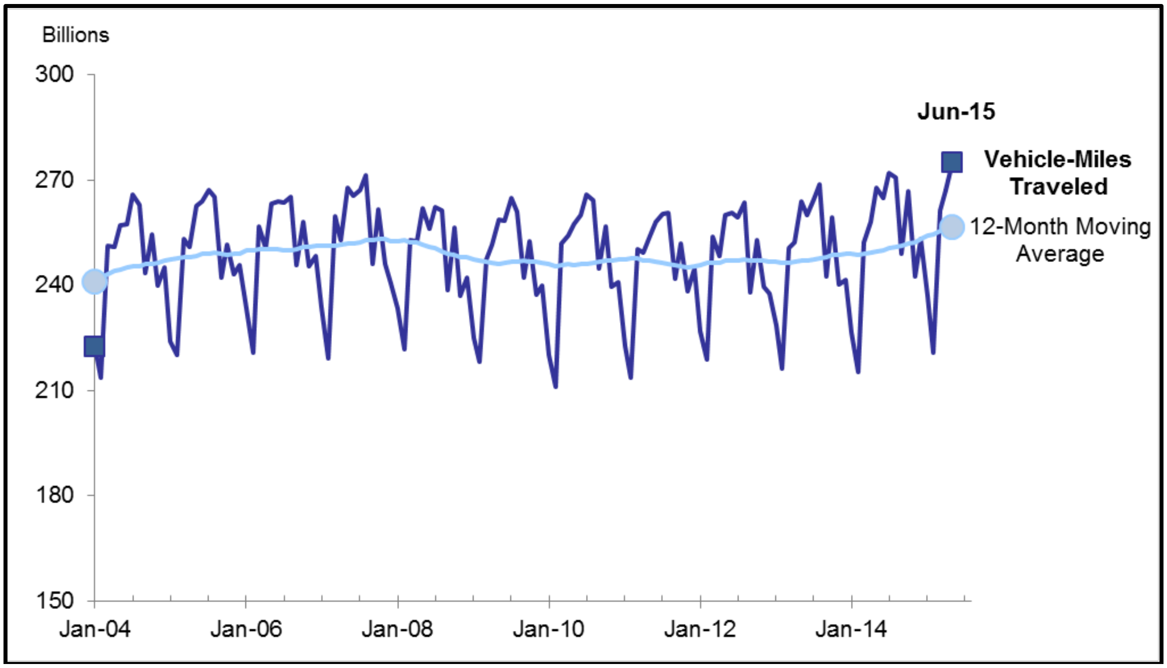

Figure 3.46: United States Highway VMT (Jan. 2004 to June 2015) (Source: U.S. DOT 2013)

4.0 MODE SHIFT POTENTIAL AND ANALYSIS

Using the data described in Section 3, a mode shift analysis can be conducted on the following four commodity groups:

- Gravel and Crushed Stone
- Logs and Other Wood in the Rough
- Non-Metallic Mineral Products
- Waste and Scrap

These four commodity groups are top five commodity groups by tons and ton-miles in Oregon's two Freight Analysis Framework (FAF) regions. Upon further examination, it was determined that the above commodity groups are being shipped to and from the same FAF region or from one Oregon FAF region to another. Based on the scope of this project, these conditions provide the most likely scenario for a mode shift.

Ahead of conducting any analysis, the factors impacting mode choice must be entirely understood, hence are detailed in the subsequent section.

4.1 FIRMS AND THEIR LOGISTICAL DECISIONS

As was previously discussed in the literature review, the key factors impacting mode choice are as follows *(Moschovou and Giannopoulos 2010)*:

- Reliability and quality of transportation services
- Transportation costs
- Likelihood of damage and loss of goods
- Customer service
- Size of load and packaging characteristics
- Cargo lifetime
- Cargo value
- Frequency of service

- Capability of tracking and tracing
- Availability of equipment for loading and unloading

The ensuing subsections thoroughly characterize each of the aforementioned factors impacting freight mode choice.

4.1.1 Reliability and Quality of Transportation Services

When a shipper makes a mode choice decision, reliability and quality are quite important. Quality and reliability go hand-in-hand; that is, if the reliability of a service is in question, it is likely that the quality of that service is substandard. For example, if a shipper is to deliver on a regularly scheduled day and time twice a week but fails to arrive on schedule, the shipping method is not reliable. Although shipping by truck allows the twice-per-week delivery, the shipper may choose to ship via rail with once-per-week deliveries to avoid the unreliability and poor quality of the previous service.

4.1.2 Transportation Costs

Transportation costs are simply costs sustained by shipping commodities and consist of factors such as, but not limited to:

- Fuel
- Wages
- Insurance (Driver and packages)
- Equipment

4.1.3 Likelihood of Damage and Loss of Goods

Protection of commodities being shipped impacts mode choice. A shipper is unlikely to ship goods by rail or ship if there is a high probability goods being damaged during transit. In addition, if the shipper feels that using a certain service increases the likelihood of losing shipments, it is likely that the shipper will choose to distribute commodities using a safer shipping method.

4.1.4 Customer Service

Customer service can be similar to the quality of transportation services. That is, transportation services that supply great customer service are likely to be chosen to transport the shippers' goods. An example of anticipated customer service would be the manner in which a shipping service handles mistakes, damaged goods and/or lost goods. These customer service qualities are considered when making a mode choice decision.

4.1.5 Size of Load and Packaging Characteristics

Load sizes and packaging play a role in mode choice. Smaller items that must be packaged in tighter areas, as they may be susceptible to damage otherwise, are not likely to be shipped in large trucks or rail with large open spaces.

4.1.6 Cargo Lifetime

This is simply referring to perishable and non-perishable items. Commodities with a shorter lifespan (e.g. fruit, vegetables, flowers) are better shipped by a mode that can deliver commodities quickly. Such items are often shipped by truck to reach their destination before the commodities perish.

4.1.7 Cargo Value

The value of the commodities being shipped impacts mode choice. For example, a highly valuable shipment that must reach its destination in the quickest manner is likely to be shipped via air. Conversely, a less valuable (possibly more heavy) shipment that is allotted more time to reach its destination is likely to be shipped via truck or rail, and possibly water if a water corridor is available. Conclusively, the cargo value influences shippers and their mode choice.

4.1.8 Frequency of Service

Shippers rely on the frequency of their deliverables; for that reason, frequency of shipping services impacts mode choice. For instance, in the case of shippers that prefers to ship by rail and require at least two deliveries per week, if rail is only available once per week, the shippers are going to choose a mode that provides a higher frequency of shipments.

4.1.9 Capability of Tracking and Tracing

With today's technology, tracking and tracing packages has become a very popular and useful tool for commodities in transit. Specifically, shippers likely want to know when their shipment is to arrive and where the shipment is currently. Shipments of high value that are unable to be traced or tracked are more likely to be distributed by a mode that has tracking and tracing capabilities.

4.1.10 Availability of Equipment for Loading and Unloading

Although the last on the list, this factor is highly significant. If a shipping service with good rates, customer service, frequency, reliability, tracking/tracing does not have the proper equipment to load and unload given commodities, shippers are going to choose a mode that has such capabilities. Simply put, a shipper cannot ship commodities by a shipping service that is unable to load and unload the goods.

4.2 MARKET CONDITIONS WITH MODE SHIFT POTENTIAL

The two primary market conditions considered for analysis in this study were fuel price and the price distributors pay to ship commodities by truck. Although fuel price is a component of mode choice, there are other contributing costs that lead to mode choice decisions: inventory costs, risk mitigation/compliance costs, in-transit costs, etc. However, for this analysis only fuel price was considered, yet it should be noted that the aforesaid costs are also primary transportation costs associated with mode choice.

4.2.1 Fuel Price Conditions

To assess the potential to shift modes from truck to rail, a cross-elasticity analysis was conducted based on the fluctuating price of fuel. To do this, the following cross-elasticity equation was used *(Sinha and Labi 2007)*:

$$\mathrm{E_C} = \frac{\mathrm{P_1^A} + \mathrm{P_2^A}}{\mathrm{Q_1^B} + \mathrm{Q_2^B}} \times \frac{\Delta \mathrm{Q^B}}{\Delta \mathrm{P^A}} \qquad (\mathbf{4.1})$$

where E_C is the cross-elasticity for a given commodity group; P_1^A and Q_1^B is the price of fuel and the quantity for truck respectively; P_2^A and Q_2^B is the price of fuel and the quantity for rail respectively; ΔQ^B is the change in quantity between truck and rail; and ΔP^A is the change in fuel price between truck and rail. Solving for Q_2^B in Equation 1 and using the cross-elasticities listed in Table 4.1, the change in rail quantity based on the change in fuel price for truck was calculated with Equation 2.

Table 4.1: Cross-Elasticities by Commodity Group

Commodity Group	Rail-Truck Elasticity
Bulk Farm Products	0.02 to 0.03
Bulk Food Products	0.60 to 0.80
Lumber and Wood	0.60 to 0.70
Pulp and Paper	0.70 to 0.90
Bulk Chemicals	0.50 to 0.70
Primary Metals	1.20 to 1.50
Waste and Scrap	0.17 to 0.22
All Other Bulk	0.14 to 0.19

Source: *(Austin 2014)*

$$\mathrm{Q_2^B} = \frac{\mathrm{Q_1^B}\left[\mathrm{E_C}\left(\mathrm{P_1^A} - \mathrm{P_2^A}\right) + \mathrm{P_1^A} + \mathrm{P_2^A}\right]}{\mathrm{E_C}\left(\mathrm{P_1^A} - \mathrm{P_2^A}\right) - \mathrm{P_1^A} - \mathrm{P_2^A}} \qquad (\mathbf{4.2})$$

Using the most current retail diesel prices and the quantity given in the FAF$^{3.5}$ data, it was determined how rail quantity potentially changes as the fuel price for truck increases or decreases for the following commodity groups:

- Gravel and Crushed Stone
- Logs and Other Wood in the Rough
- Non-Metallic Mineral Products
- Waste and Scrap

Utilizing the quantities obtained from the elasticity analysis, the number of equivalent truckloads—dependent on carrying capacity—were calculated to provide a tangible metric in assessing mode shift potential. Two truck configurations were used to measure the number of truckloads *(Jack Faucett Associates 1991)*: (1) 7-axle 40'+ 28' truck with a payload of 69,200 pounds and (2) 5-axle twin 28' truck with a payload of 48,800 pounds.

Figure 4.1 illustrates the potential change in rail quantity of Gravel and Crushed Stone based on fuel prices for truck with cross-elasticities of 0.14 to 0.19. Based on a cross-elasticity of 0.19 and a current quantity of 9,200 thousand tons, when fuel price increases to $6.00, the quantity of rail increased is equivalent to approximately 43 thousand truckloads and 61 thousand truckloads for the 7-axle truck and 5-axle truck over a one-year period. If the elasticity is on the low end, the potential number of equivalent truckloads is still significant at roughly 31 thousand for the 7-axle truck and 44 thousand for the 5-axle truck over a one-year period. For best fit equations of each elasticity curve and the equivalent number of truckloads by elasticity, see Table 4.2 and Table 4.3.

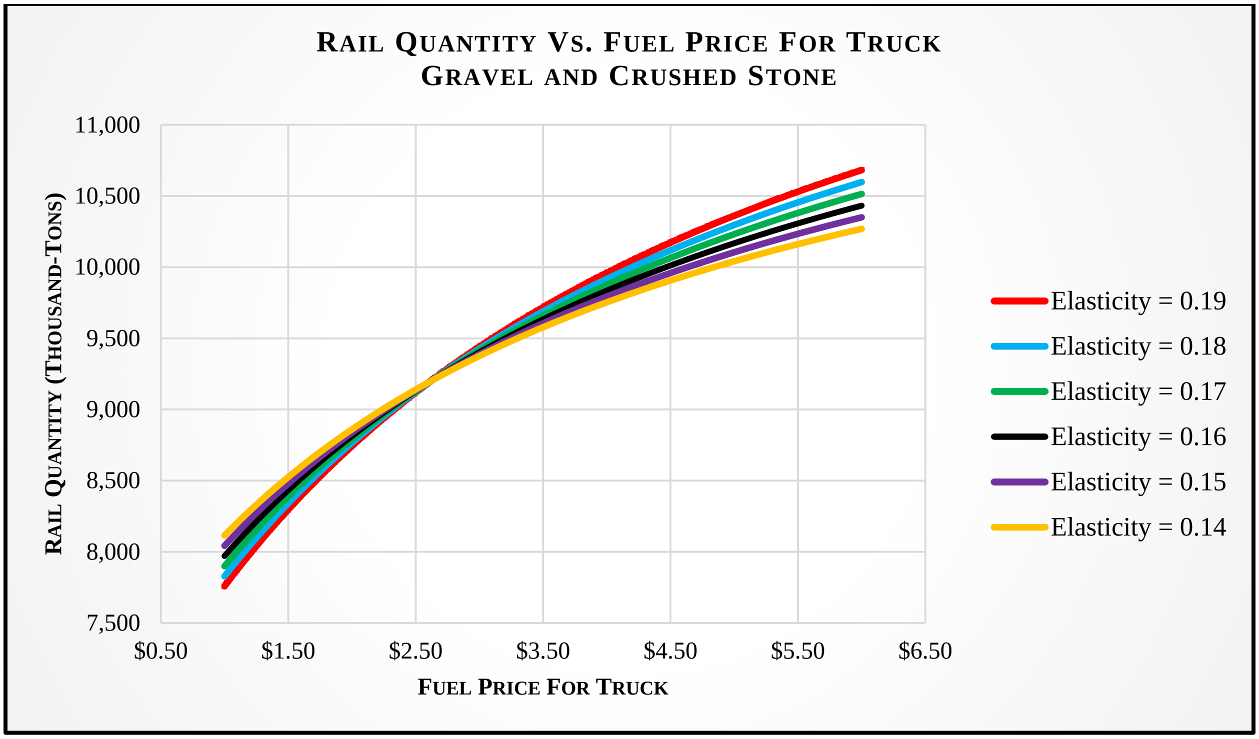

Figure 4.1: Change in Rail Quantity Due to Fuel Price for Truck – Gravel & Crushed Stone

Table 4.2: Best Fit Equations of Elasticity Curves for Gravel and Crushed Stone

Elasticity	Best Fit Equation	R^2
0.14	$y = 1249.0[\ln(x)] + 8020.0$	0.9988
0.15	$y = 1339.2[\ln(x)] + 7936.4$	0.9987
0.16	$y = 1429.5[\ln(x)] + 7852.8$	0.9986
0.17	$y = 1519.9[\ln(x)] + 7769.3$	0.9984
0.18	$y = 1610.6[\ln(x)] + 7685.9$	0.9983
0.19	$y = 1701.4[\ln(x)] + 7602.5$	0.9981

Table 4.3: Equivalent Truckloads by Elasticity – Gravel and Crushed Stone

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.14	30,889	43,801
0.15	33,233	47,125
0.16	35,597	50,477
0.17	37,980	53,857
0.18	40,384	57,266
0.19	42,808	60,704

Figure 4.2 shows the potential change in rail quantity of Logs and Other Wood in the Rough as the fuel price for truck varies from $1.00 to $6.00 and has a current quantity of 16,032 thousand tons. When fuel price reaches $6.00, the largest potential rail increase is nearly 75 thousand

truckloads and 106 thousand truckloads for the 7-axle truck and 5-axle truck over a one-year period. Best fit equations for the elasticity curves are shown in

Table 4.4 and the number of equivalent truckloads by elasticity are seen in Table 4.5.

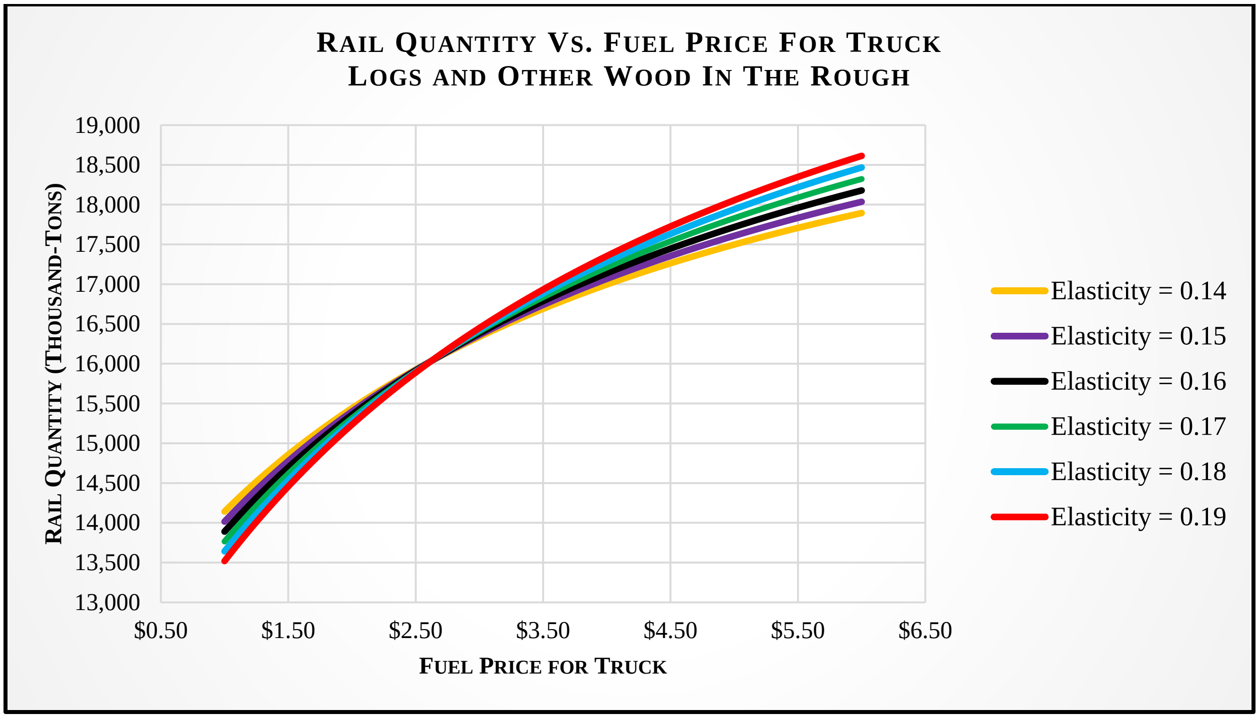

Figure 4.2: Change in Rail Quantity Due to Fuel Price for Truck – Logs and Other Wood in The Rough

Table 4.4: Best Fit Equations for Elasticity Curves – Logs and Other Wood in The Rough

Elasticity	Best Fit Equation	R^2
0.14	$y = 2176.5[\ln(x)] + 13{,}976$	0.9988
0.15	$y = 2333.6[\ln(x)] + 13{,}830$	0.9987
0.16	$y = 2491.0[\ln(x)] + 13{,}684$	0.9986
0.17	$y = 2648.7[\ln(x)] + 13{,}539$	0.9984
0.18	$y = 2806.6[\ln(x)] + 13{,}394$	0.9983
0.19	$y = 2964.9[\ln(x)] + 13{,}248$	0.9981

Table 4.5: Equivalent Truckloads by Elasticity – Logs and Other Wood in The Rough

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.14	53,827	76,328
0.15	57,912	82,121
0.16	62,031	87,962
0.17	66,185	93,853
0.18	70,374	99,792
0.19	74,598	105,783

The potential change in rail quantity of Non-Metallic Mineral Products with respect to fuel price for truck is shown in Figure 4.3. As fuel price rises to $6.00 with a current quantity of 6,592 thousand tons, the maximum potential quantity for rail increases by approximately 31 thousand truckloads and 44 thousand truckloads for the 7-axle truck and 5-axle truck over a one-year period. Table 4.6 presents the best fit equations for the elasticity curves seen below and Table 4.7 displays the number of equivalent truckloads by elasticity.

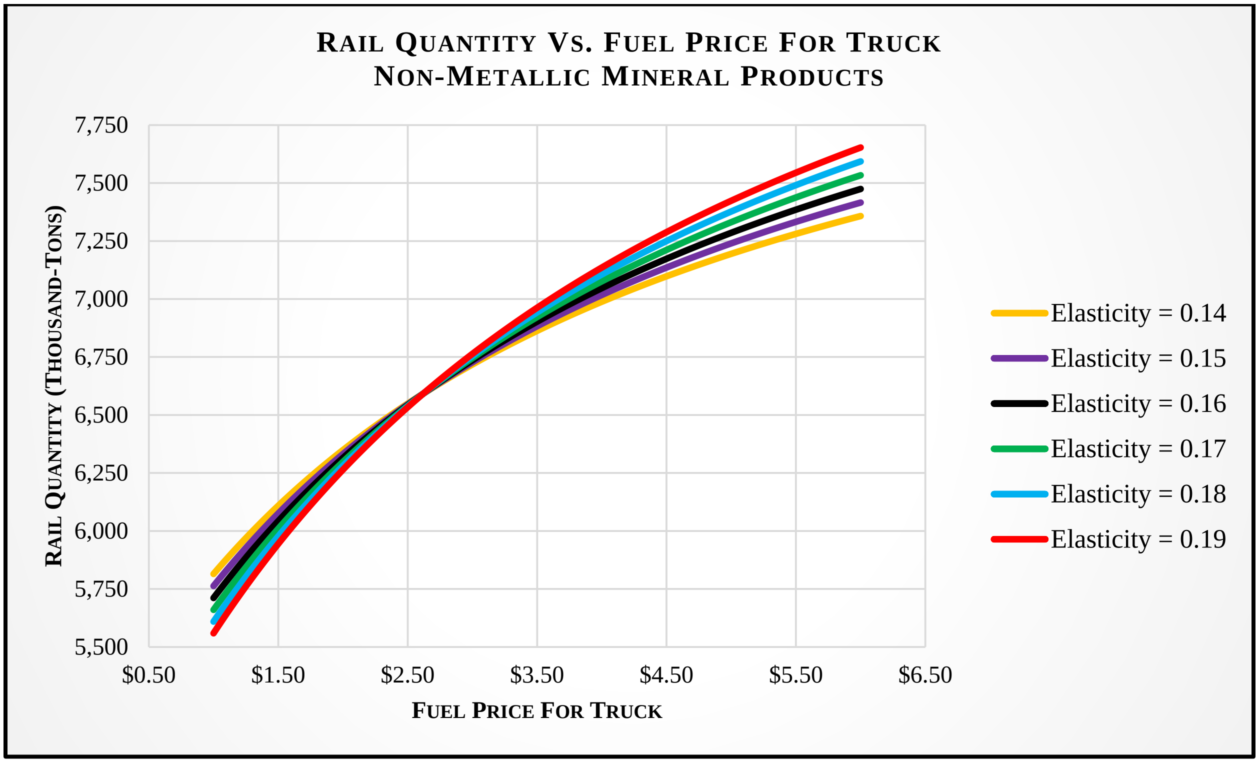

Figure 4.3: Change in Rail Quantity Due to Fuel Price for Truck – Non-Metallic Mineral Products

Table 4.6: Best Fit Equations for Elasticity Curves – Non-Metallic Mineral Products

Elasticity	Best Fit Equation	R^2
0.14	y = 3405.3[ln(x)] + 21,866	0.9988
0.15	y = 3651.1[ln(x)] + 21,638	0.9987
0.16	y = 3897.3[ln(x)] + 21,410	0.9986
0.17	y = 4144.0[ln(x)] + 21,182	0.9984
0.18	y = 4391.1[ln(x)] + 20,955	0.9983
0.19	y = 4638.7[ln(x)] + 20,728	0.9981

Table 4.7: Equivalent Truckloads by Elasticity – Non-Metallic Mineral Products

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.14	22,132	31,384
0.15	23,812	33,766
0.16	25,506	36,168
0.17	27,214	38,590
0.18	28,936	41,032
0.19	30,673	43,496

Figure 4.4 illustrates the potential change in rail quantity of Waste and Scrap due to change in fuel price for truck. For this commodity group, cross-elasticities of 0.17 to 0.22 and a current quantity of 4,610 thousand tons were used for analysis. As fuel price increases to $6.00, the potential quantity of rail has a maximum increase equivalent to approximately 26 thousand truckloads and 36 thousand truckloads for the 7-axle truck and 5-axle truck over a one-year period. A list of the best fit equations for the elasticity curves in Figure 4.4 are shown in Table 4.8 and the equivalent number of truckloads are presented in Table 4.9.

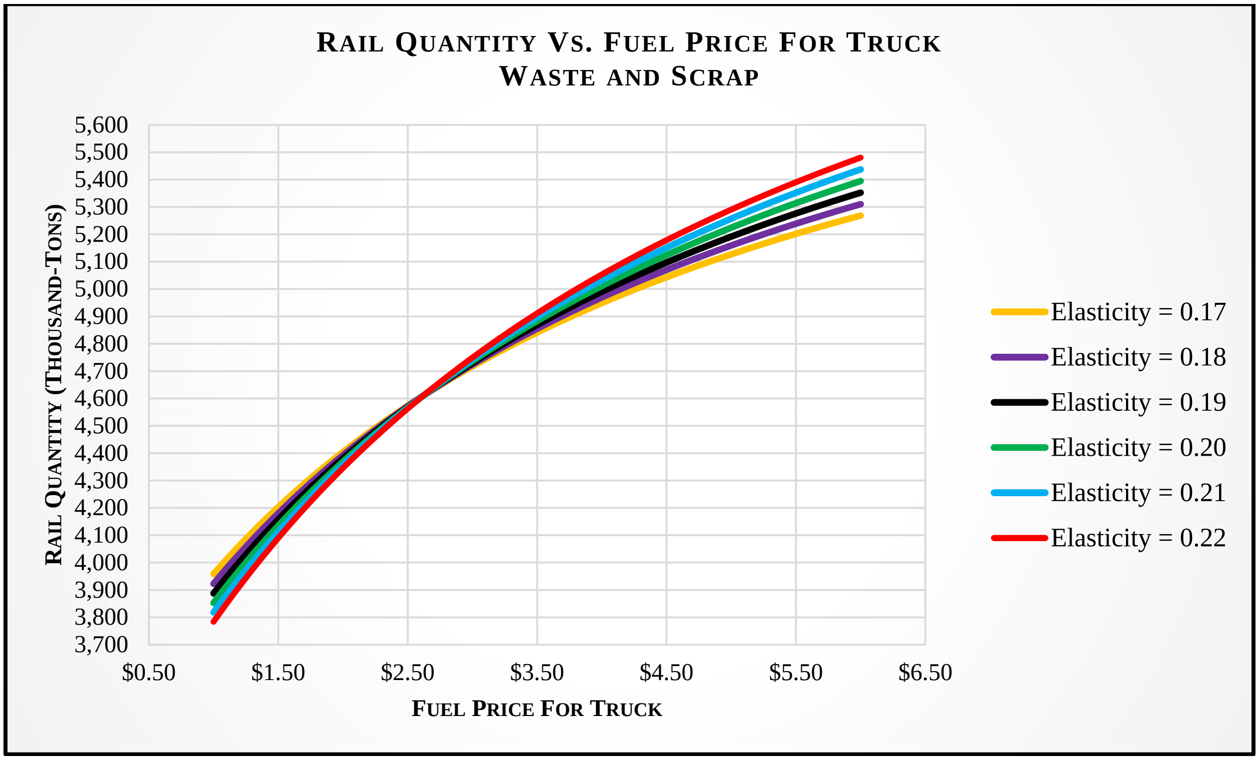

Figure 4.4: Change in Rail Quantity Due to Fuel Price for Truck – Waste and Scrap

Table 4.8: Best Fit Equations for Elasticity Curves – Waste and Scrap

Elasticity	Best Fit Equation	R^2
0.17	$y = 761.62[\ln(x)] + 3893.1$	0.9984
0.18	$y = 807.04[\ln(x)] + 3851.3$	0.9983
0.19	$y = 852.55[\ln(x)] + 3809.5$	0.9981
0.20	$y = 898.15[\ln(x)] + 3767.8$	0.9979
0.21	$y = 943.84[\ln(x)] + 3276.0$	0.9977
0.22	$y = 989.63[\ln(x)] + 3684.3$	0.9975

Table 4.9: Equivalent Truckloads by Elasticity – Waste and Scrap

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.17	19,031	26,987
0.18	20,236	28,695
0.19	21,451	30,418
0.20	22,676	32,155
0.21	23,911	33,907
0.22	25,157	35,674

4.2.2 Shipper Cost

Using the elasticity method described in Section 3.3.1, the potential shift to rail based on shipper cost per mile was examined. Three specific types of shipments were evaluated: (1) Less-Than-Truckload (LTL), (2) Truckload (TL) and (3) Specialized (SP). The cost per mile of each shipment type is shown in Table 4.10. Using cross-elasticities of 0.25, 0.30 and 0.35 the impact shipper cost has on potential rail quantities was investigated *(Levin 1978)*. The largest quantity with a probable shift occurred with a cross-elasticity of 0.35 for each commodity group considered.

Table 4.10: Shipper Costs Per Mile by Type of Shipment

Shipment Type	Cost Per Mile
Less-Than-Truckload (LTL)	$1.79
Truckload (TL)	$1.51
Specialized (SP)	$1.73

Source: *(Robinson 2015)*

4.2.2.1 Less-Than-Truckload (LTL) shipping Cost

Figure 4.5 illustrates the change in rail quantity of Gravel and Crushed Stone based on shipper cost for less-than-truckload shipments. As shipper costs increases from $1.79 to $6.00, there is a maximum potential shift to rail equal to approximately 103 thousand truckloads for the 7-axle truck and roughly 146 thousand truckloads for the 5-axle truck over a one-year period. Best fit equations for the elasticity curves are shown in Table 4.11 and the equivalent number of truckloads by elasticity can be seen in Table 4.12.

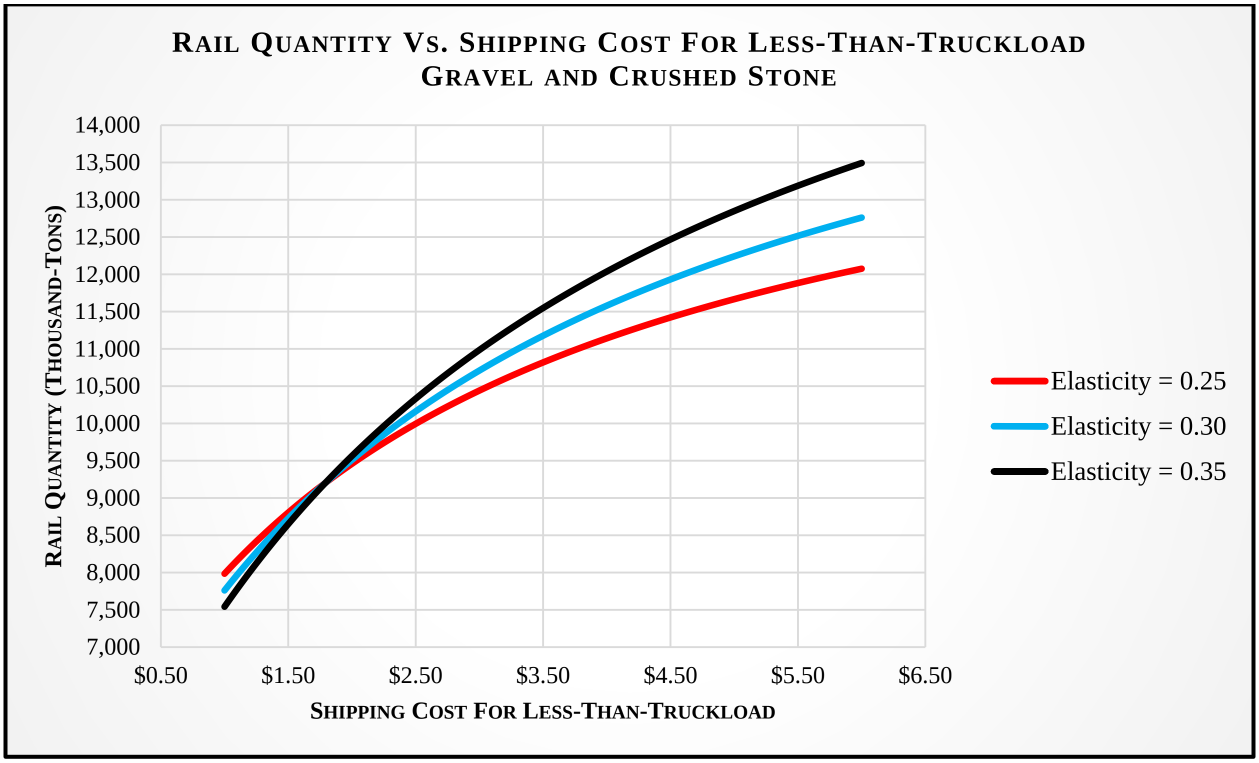

Figure 4.5: Change in Rail Quantity Due to Shipper Cost for Less-Than-Truckload – Gravel and Crushed Stone

Table 4.11: Best Fit Equations for LTL Elasticity Curves – Gravel and Crushed Stone

Elasticity	Best Fit Equation	R^2
0.25	$y = 2358.2[\ln(x)] + 7859.4$	0.9995
0.30	$y = 2895.7[\ln(x)] + 7557.9$	0.9991
0.35	$y = 3460.0[\ln(x)] + 7242.1$	0.9984

Table 4.12: Equivalent LTL Truckloads by Elasticity – Gravel and Crushed Stone

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	68,113	96,587
0.30	84,849	120,319
0.35	102,872	145,875

The potential change in rail quantity due to less-than-truckload shipper cost for Logs and Other Wood in the Rough is shown in Figure 4.6. If shipper cost for less-than-truckload increases to $6.00 and has a current quantity of 16,032 thousand tons, the potential quantity moved to rail is equivalent to approximately 179 thousand truckloads for the 7-

axle truck and 254 thousand truckloads for the 5-axle truck for a one-year period. The potential number of truckloads is enormous as a result of the considerable current quantity being shipped. Best fit equations for the elasticity curves are shown in Table 4.13 and the number equivalent truckloads by elasticity are shown in Table 4.14.

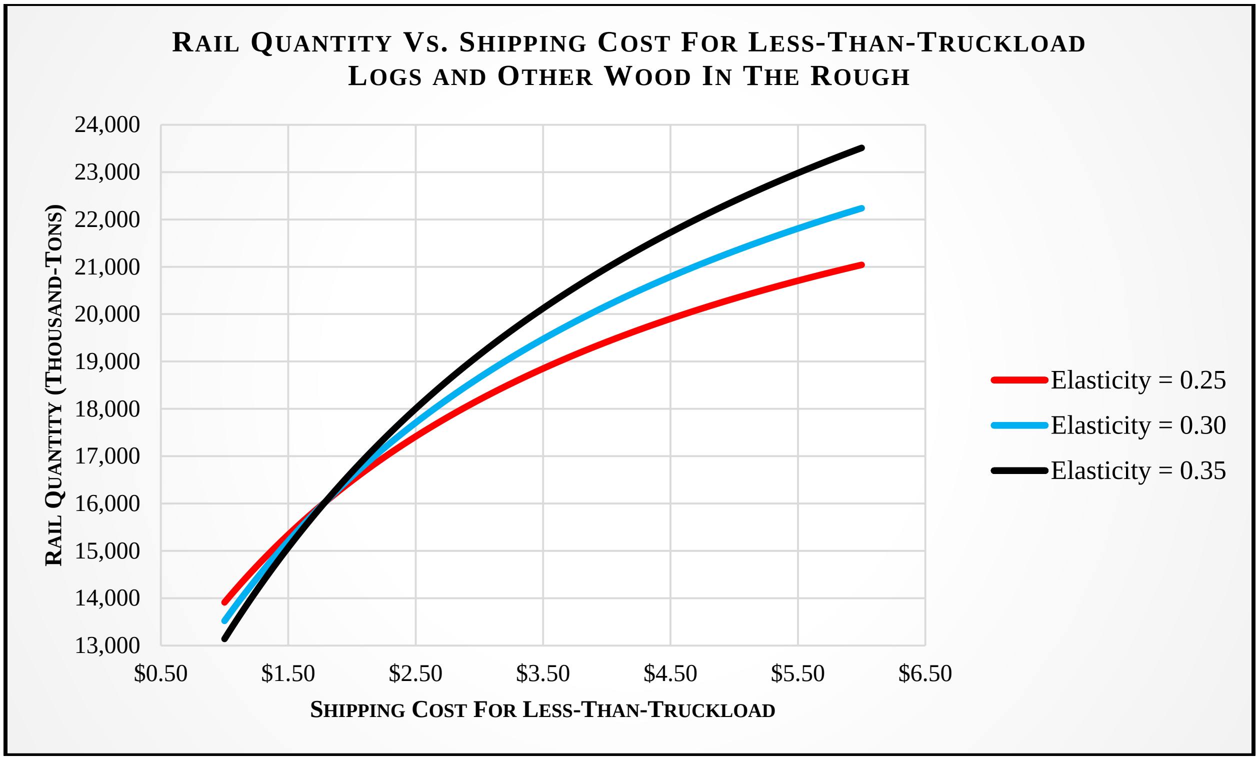

Figure 4.6: Change in Rail Quantity Due to Shipper Cost for Less-Than-Truckload - Logs & Other Wood in the Rough

Table 4.13: Best Fit Equations for LTL Elasticity Curves – Logs and Other Wood in the Rough

Elasticity	Best Fit Equation	R^2
0.25	$y = 4109.4[\ln(x)] + 13,695$	0.9995
0.30	$y = 5046.1[\ln(x)] + 13,170$	0.9991
0.35	$y = 6029.4[\ln(x)] + 12,260$	0.9984

Table 4.14: Equivalent LTL Truckloads by Elasticity – Logs and Other Wood in The Rough

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	118,694	168,313
0.30	147,859	209,669
0.35	179,265	254,204

Figure 4.7 presents the change in rail quantity for Non-Metallic Mineral Products due to the shipping cost of less-than-truckload. As shipper cost increases to $6.00 with a current quantity of 6,592 thousand tons, the equivalent number of potential truckloads shifted to rail are roughly 71 thousand for the 7-axle truck and 101 thousand for the 5-axle truck during a one-year period. Best fit equations for the elasticity curves and the number of equivalent truckloads by elasticity are shown in Table 4.15 and Table 4.16.

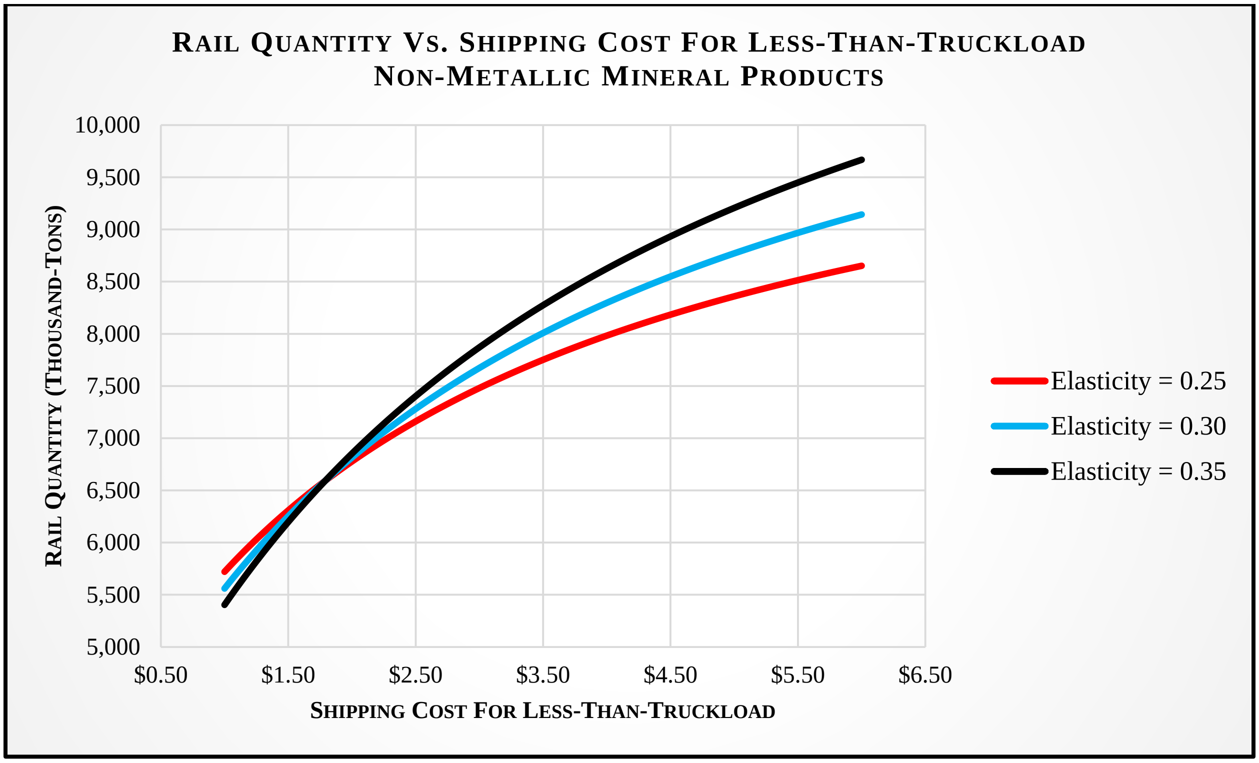

Figure 4.7: Change in Rail Quantity Due to Shipper Cost for Less-Than-Truckload – Non-Metallic Mineral Products

Table 4.15: Best Fit Equations for LTL Elasticity Curves – Non-Metallic Mineral Products

Elasticity	Best Fit Equation	R^2
0.25	y = 1689.7[ln(x)] + 5631.4	0.9995
0.30	y = 2074.8[ln(x)] + 5415.4	0.9991
0.35	y = 2479.2[ln(x)] + 5189.1	0.9984

Table 4.16: Equivalent LTL Truckloads by Elasticity – Non-Metallic Mineral Products

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	46,831	66,408
0.30	58,399	82,811
0.35	70,878	100,507

If shipper cost for less-than-truckload inflates to $6.00, the potential shift to rail for Waste and Scrap is shown in Figure 4.8. When considering a 7-axle 40´ + 28´ truck and current quantity of 4,610 thousand tons, the equivalent number of truckloads shifted to rail over a one-year period is roughly 50 thousand and increases to approximately 70 thousand truckloads for a 5-axle twin 28´ truck. For the best fit elasticity equations and the number of equivalent truckloads by elasticity, refer to Table 4.17 and Table 4.18.

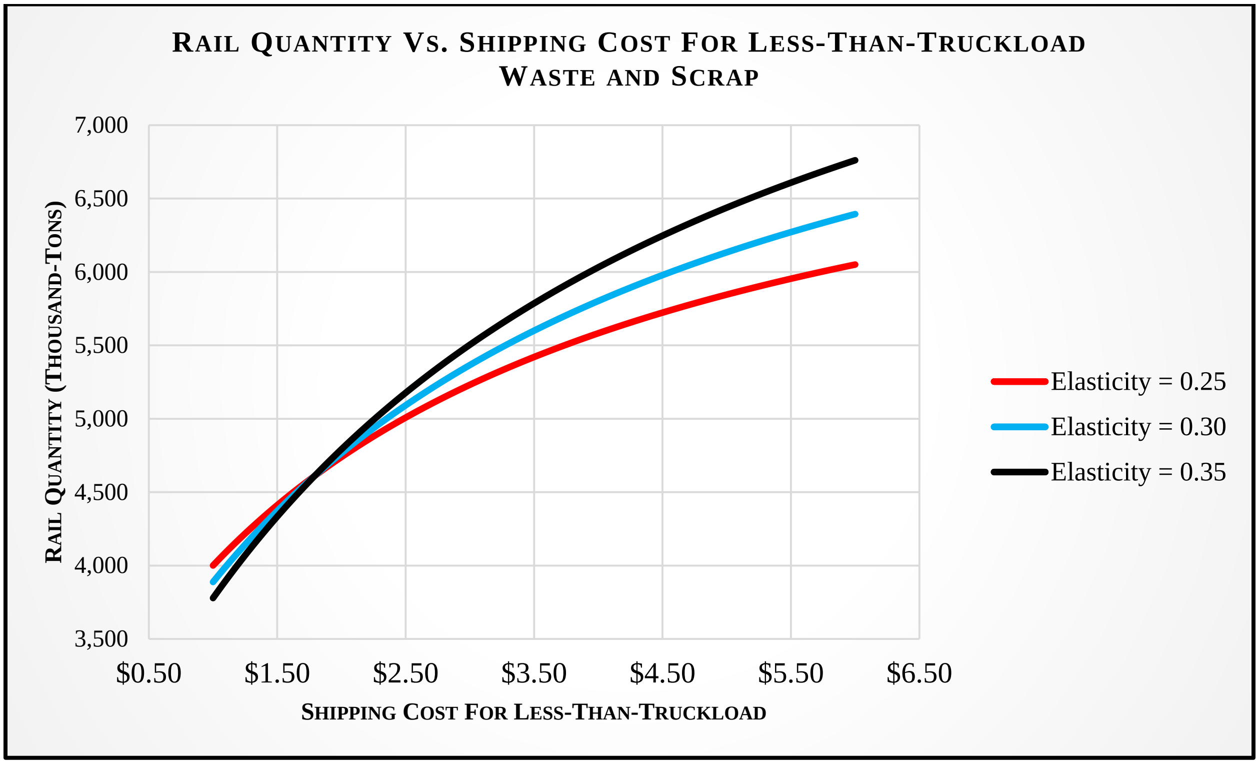

Figure 4.8: Change in Rail Quantity Due to Shipper Cost for Less-Than-Truckload – Waste and Scrap

Table 4.17: Best Fit Equations for LTL Elasticity Curves – Waste and Scrap

Elasticity	Best Fit Equation	R^2
0.25	y = 1181.7[ln(x)] + 3938.3	0.9995
0.30	y = 1451.0[ln(x)] + 3787.2	0.9991
0.35	y = 1733.8[ln(x)] + 3628.9	0.9984

Table 4.18: Equivalent LTL Truckloads by Elasticity – Waste and Scrap

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	32,750	46,441
0.30	40,840	57,913
0.35	49,567	70,288

4.2.2.2 Truckload (TL) Shipping Cost

The current shipping cost per mile of truckload shipments is now used to evaluate a potential shift to rail. If shipping cost were to increase to $6.00 with a current quantity of 9,200 thousand tons, the number of corresponding truckloads of Gravel and Crushed Stone with a potential to shift to rail are roughly 102 thousand and 145 thousand for the 7-axle and 5-axle truck respectively, over the span of one year. The change in rail quantity is shown in Figure 4.9. Best fit equations for the elasticity curves can be seen in Table 4.19, and the number of equivalent truckloads by elasticity are presented in Table 4.20.

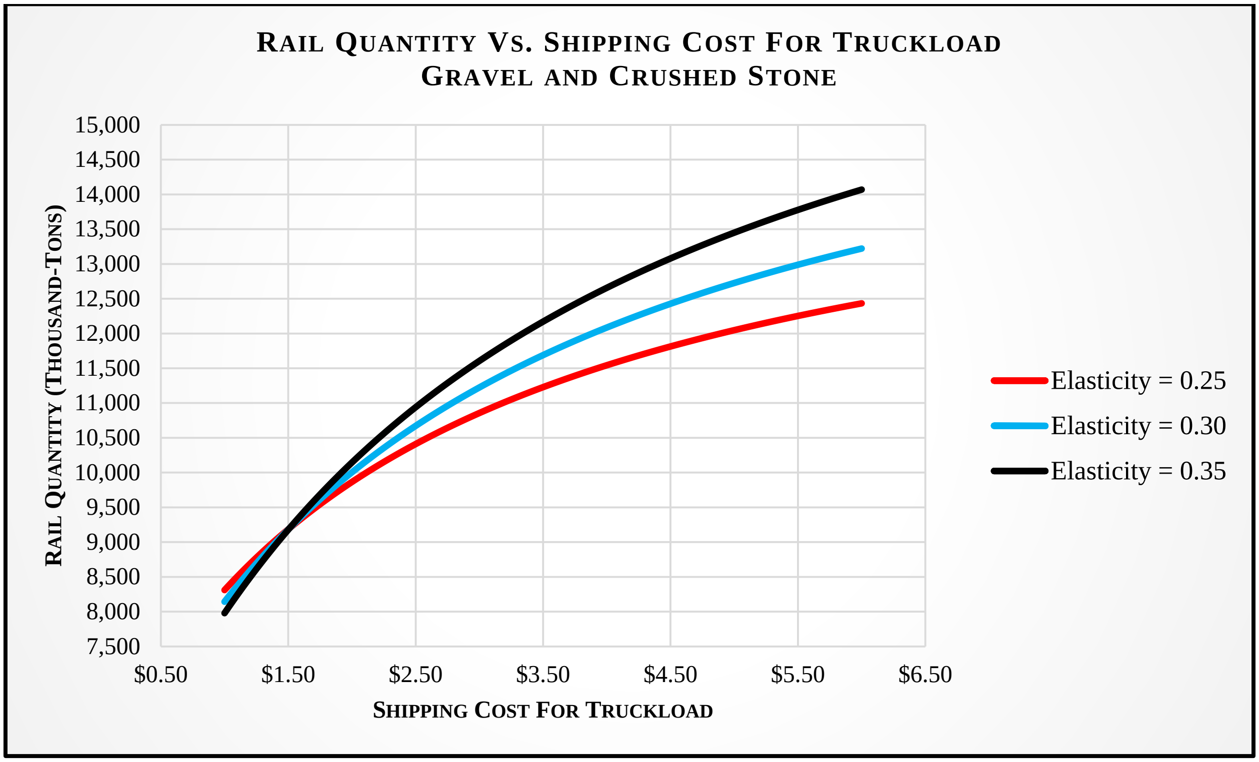

Figure 4.9: Change in Rail Quantity Due to Shipper Cost for Truckload – Gravel and Crushed Stone

Table 4.19: Best Fit Equations for TL Elasticity Curves – Gravel and Crushed Stone

Elasticity	Best Fit Equation	R^2
0.25	$y = 2358.4[\ln(x)] + 8252.0$	0.9997
0.30	$y = 2919.8[\ln(x)] + 8018.2$	0.9997
0.35	$y = 3518.5[\ln(x)] + 7765.3$	0.9994

Table 4.20: Equivalent TL Truckloads by Elasticity – Gravel and Crushed Stone

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	66,565	94,392
0.30	83,634	118,596
0.35	102,307	145,075

Figure 4.10 displays the change in rail quantity of Logs and Other Wood in The Rough due to an increase in truckload shipper cost. At $6.00—the highest shipper cost considered in this analysis—and current quantity of 16,032 thousand tons, there is a highly significant number of equivalent truckloads with potential to shift to rail. The largest number of truckloads for the 7-axle truck is approximately 178 thousand and 253 thousand for the 5-axle truck during the course of one year. Best fit equations for the elasticity curves are shown in Table 4.21 and the number of equivalent truckloads by elasticity can be seen in Table 4.22.

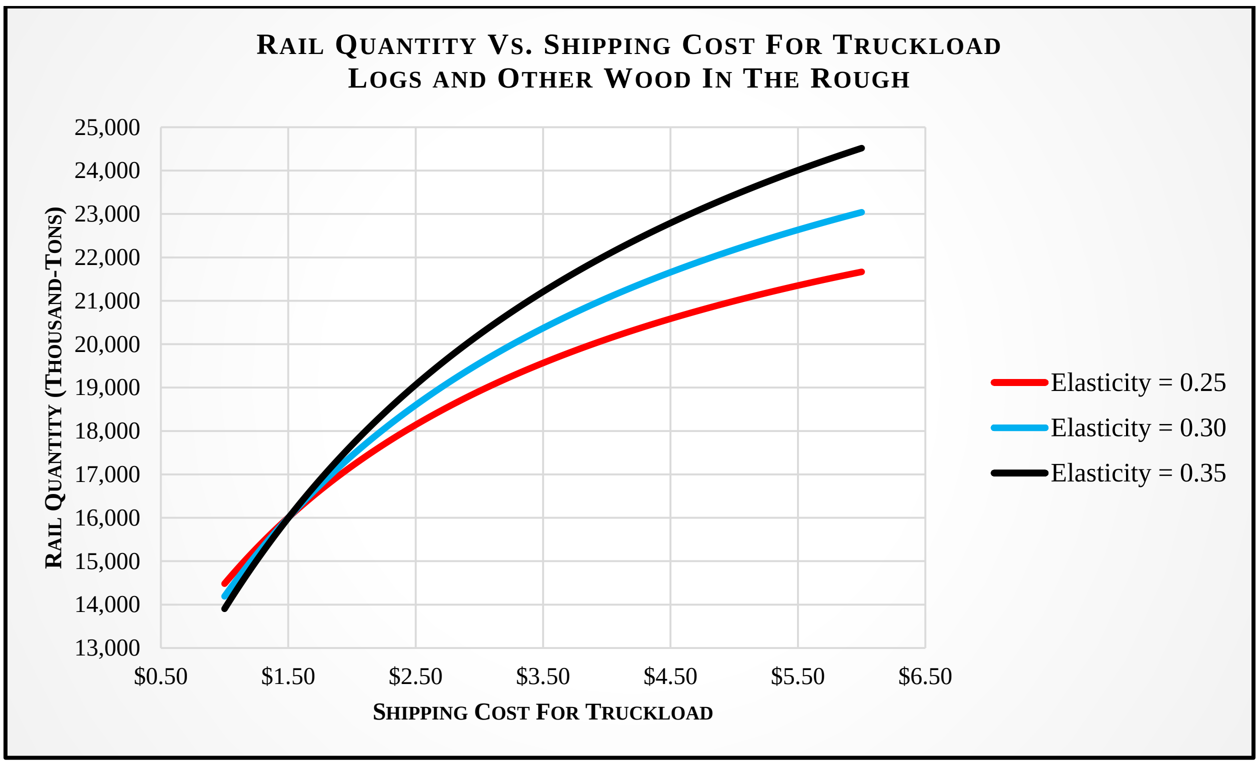

Figure 4.10: Change in Rail Quantity Due to Shipper Cost for Truckload – Logs and Other Wood in the Rough

Table 4.21: Best Fit Equations for TL Elasticity Curves – Logs and Other Wood in The Rough

Elasticity	Best Fit Equation	R^2
0.25	y = 4109.8[ln(x)] + 14,380	0.9997
0.30	y = 5088.1[ln(x)] + 13,973	0.9997
0.35	y = 6131.4[ln(x)] + 13,532	0.9994

Table 4.22: Equivalent TL Truckloads by Elasticity – Logs and Other Wood in The Rough

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	115,998	164,488
0.30	145,741	206,666
0.35	178,281	252,808

The change in rail quantity of Non-Metallic Mineral Products as truckload shipper costs increases to \$6.00 is displayed in Figure 4.11. Based on the current quantity of 6,592 thousand tons, when shipper cost reaches \$6.00 the potential shift to rail is tantamount to roughly 70 thousand truckloads for the 7-axle truck and 100 thousand truckloads for the 5-axle truck. Best fit equations for the elasticity curves can be seen in Table 4.23, and the number of equivalent truckloads are shown in Table 4.24.

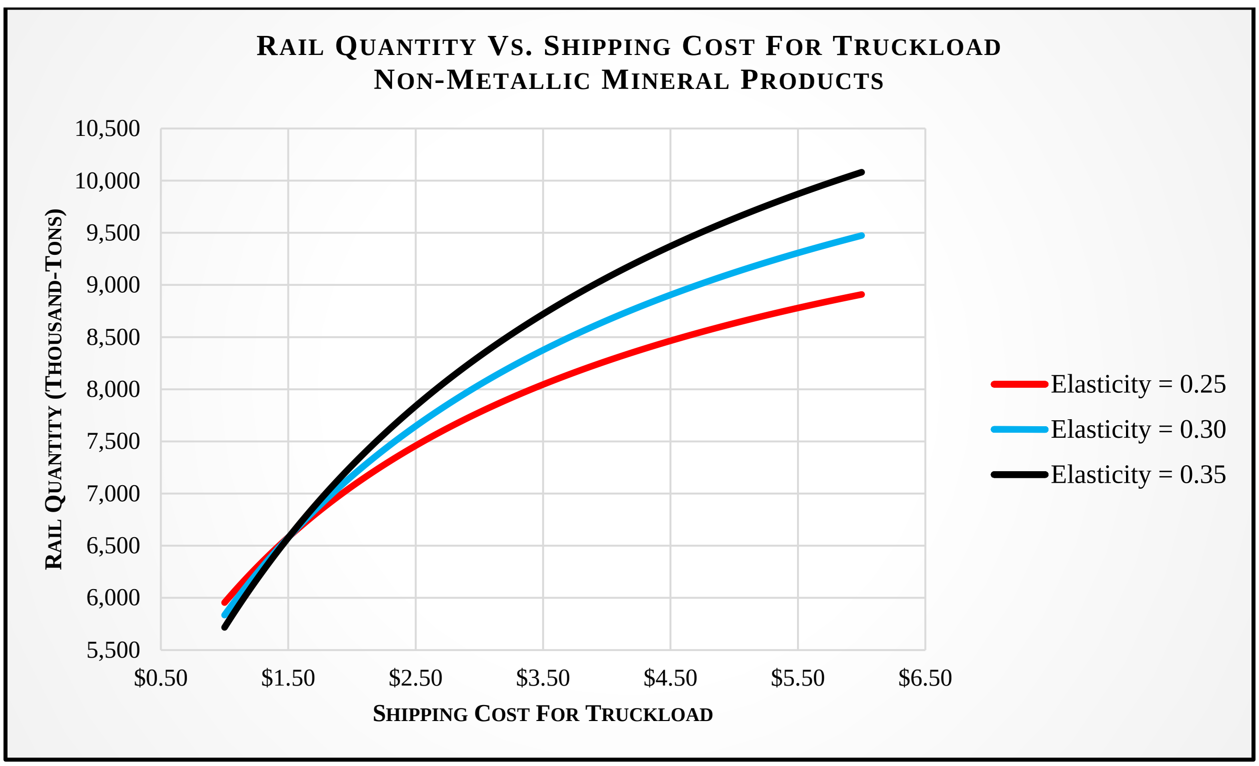

Figure 4.11: Change in Rail Quantity Due to Shipper Cost for Truckload – Non-Metallic Mineral Products

Table 4.23: Best Fit Equations for TL Elasticity Curves – Non-Metallic Mineral Products

Elasticity	Best Fit Equation	R^2
0.25	y = 1689.8[ln(x)] + 5912.7	0.9997
0.30	y = 2092.1[ln(x)] + 5745.2	0.9997
0.35	y = 2521.1[ln(x)] + 5564.0	0.9994

Table 4.24: Equivalent TL Truckloads by Elasticity – Non-Metallic Mineral Products

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	45,961	64,791
0.30	57,468	81,491
0.35	70,375	99,794

The change in rail quantity for Waste and Scrap is illustrated in Figure 4.12. As truckload shipper cost rises to $6.00 with a current quantity of 4,610 thousand tons, the number of truckloads with mode shift potential for the 7-axle and 5-axle truck are about 49 thousand and 70 thousand respectively. Best fit equations for the elasticity curves in Figure 4.12 are shown in Table 4.25, and the equivalent number of truckloads by elasticity are given in Table 4.26.

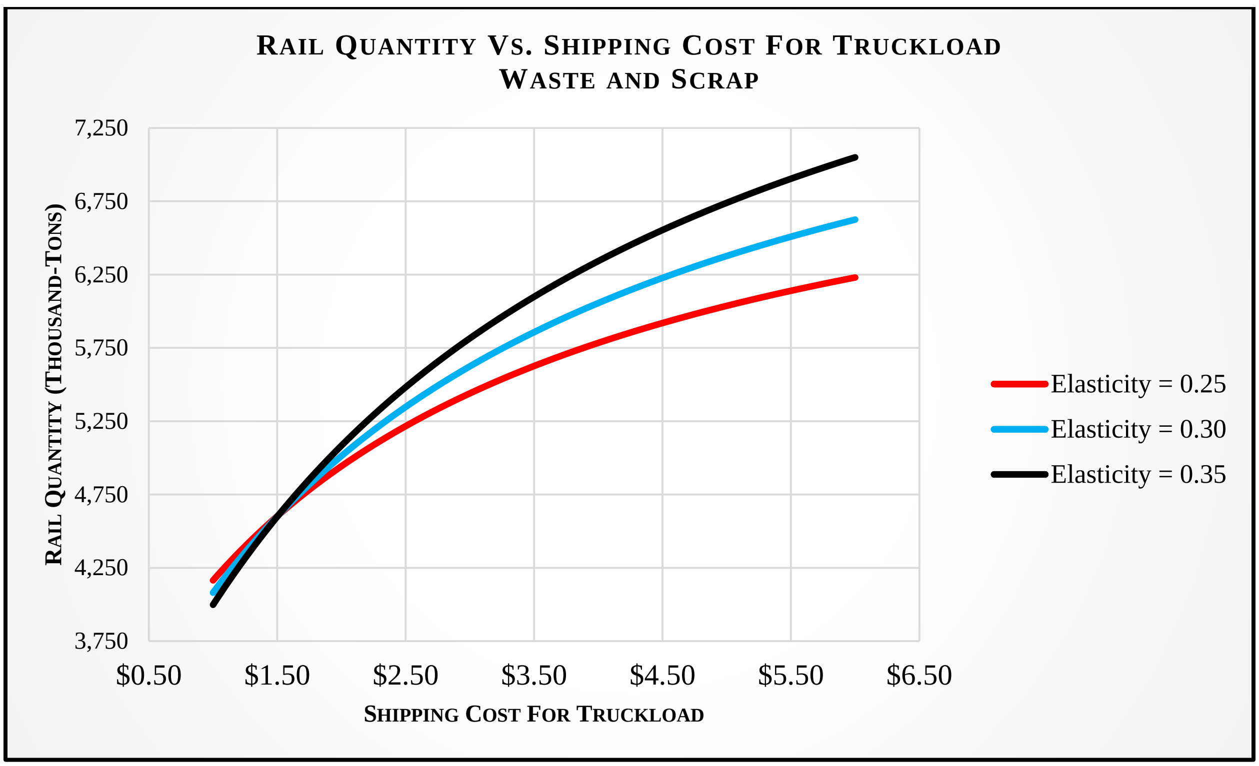

Figure 4.12: Change in Rail Quantity Due to Shipper Cost for Truckload – Waste and Scrap

Table 4.25: Best Fit Equations for TL Elasticity Curves – Waste and Scrap

Elasticity	Best Fit Equation	R^2
0.25	$y = 1181.8[\ln(x)] + 4135.0$	0.9997
0.30	$y = 1463.1[\ln(x)] + 4017.8$	0.9997
0.35	$y = 1763.1[\ln(x)] + 3891.1$	0.9994

Table 4.26: Equivalent TL Truckloads by Elasticity – Waste and Scrap

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	31,923	45,310
0.30	40,189	56,989
0.35	49,215	69,789

4.2.2.3 Specialized (SP) Shipping Cost

The effect of shipping cost for specialized shipments was analyzed for mode shift potential using the elasticity method from Section 4.2.1. For example, Figure 4.13 shows the potential increase in rail quantity of Gravel and Crushed Stone as specialized price rises to $6.00. Based on a current quantity of 9,200 thousand tons, the largest possible amount of truckloads is equal to approximately 103 thousand and 146 thousand for the 7-axle and 5-axle truck respectively. For the best fit elasticity curve equations and the number of equivalent truckloads by elasticity, see Table 4.27 and Table 4.28.

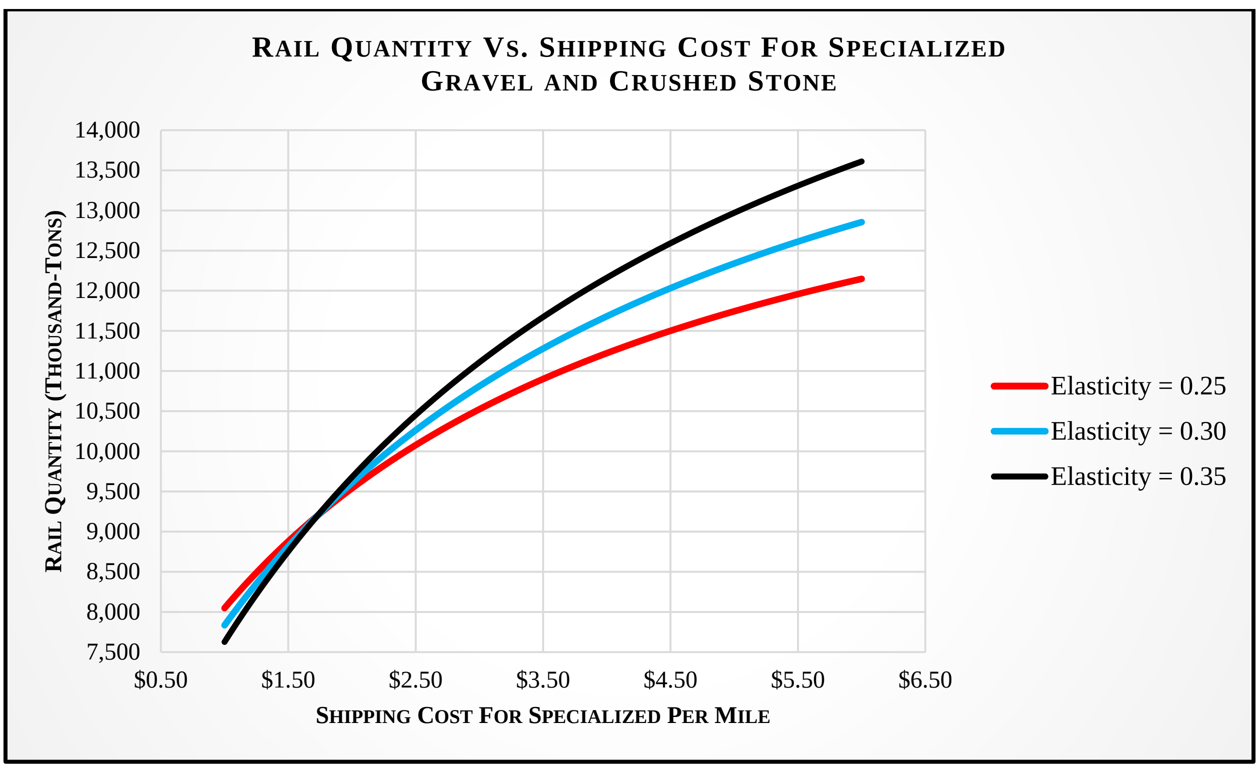

Figure 4.13: Change in Rail Quantity Due to Shipper Cost for Specialized – Gravel and Crushed Stone

Table 4.27: Best Fit Equations for SP Elasticity Curves – Gravel and Crushed Stone

Elasticity	Best Fit Equation	R^2
0.25	$y = 2360.7[\ln(x)] + 7935.6$	0.9996
0.30	$y = 2903.5[\ln(x)] + 7646.8$	0.9993
0.35	$y = 3475.2[\ln(x)] + 7342.7$	0.9986

Table 4.28: Equivalent SP Truckloads by Elasticity – Gravel and Crushed Stone

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	67,873	96,246
0.30	84,696	120,102
0.35	102,870	145,873

The change in rail quantity of Logs and Other Wood in The Rough due to specialized shipper cost per mile is shown in Figure 4.14. As shipper cost increases to $6.00 with a current quantity of 16,032 thousand tons, the potential rail quantity becomes greatly notable. For the 7-axle truck, the potential quantity in terms of truckloads is roughly 179 thousand. The quantity in terms of truckloads for the 5-axle truck is much larger at approximately 254 thousand. Best fit elasticity equations are shown in Table 4.29 and the number of equivalent truckloads by elasticity are displayed in Table 4.30.

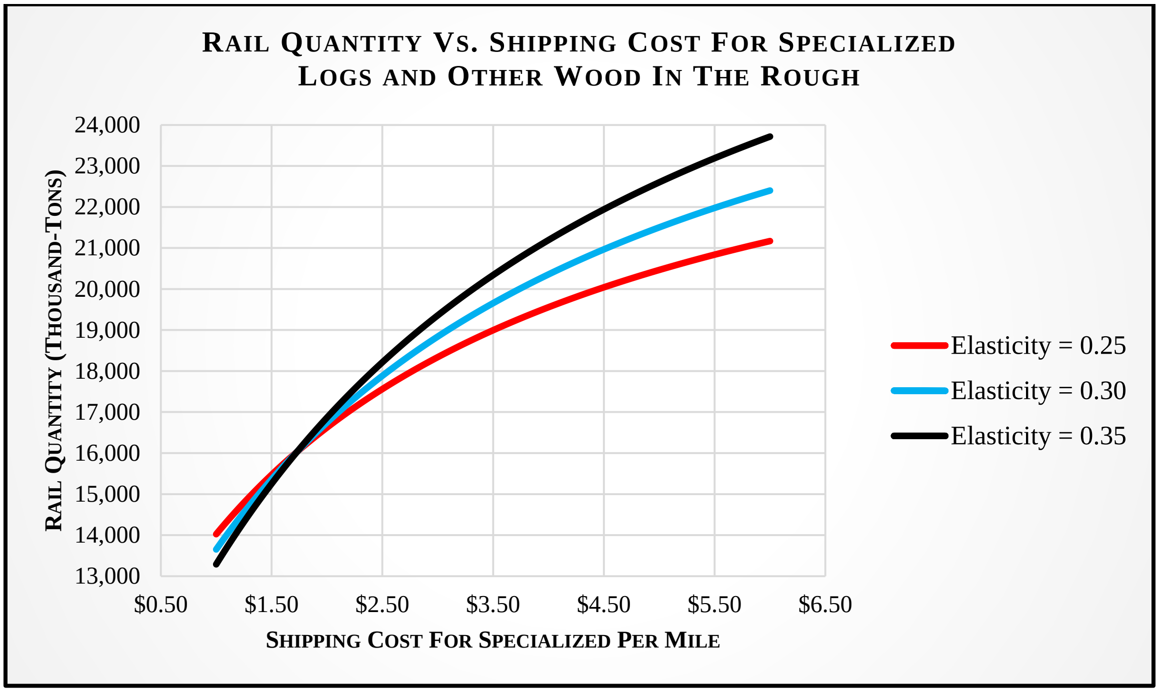

Figure 4.14: Change in Rail Quantity Due to Shipper Cost for Specialized – Logs and Other Wood in the Rough

Table 4.29: Best Fit Equations for SP Elasticity Curves – Logs and Other Wood in the Rough

Elasticity	Best Fit Equation	R^2
0.25	y = 4113.8[ln(x)] + 13,829	0.9996
0.30	y = 5059.7[ln(x)] + 13,325	0.9993
0.35	y = 6056.0[ln(x)] + 12,795	0.9986

Table 4.30: Equivalent SP Truckloads by Elasticity – Logs and Other Wood in The Rough

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	118,276	167,719
0.30	147,592	209,290
0.35	179,263	254,200

The change in rail quantity of Non-Metallic Mineral Products due to specialized shipper cost is seen in Figure 4.15. When the cost to ship reaches $6.00, the largest number of truckloads that are potentially shifted to rail are roughly 70 thousand for the 7-axle truck and 100 thousand for the 5-axle truck during a one-year period. For best fit elasticity equations and the number of equivalent truckloads by elasticity, refer to Table 4.31 and Table 4.32.

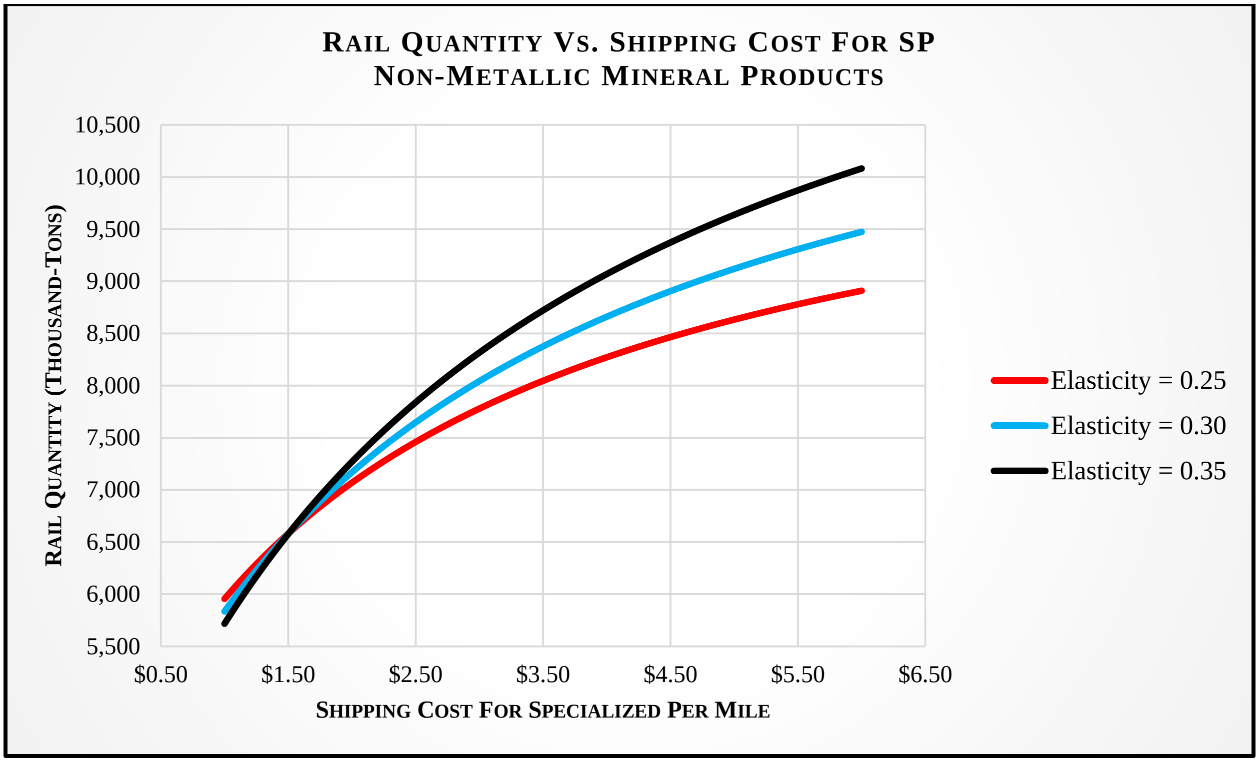

Figure 4.15: Change in Rail Quantity Due to Shipper Cost for Specialized – Non-Metallic Mineral Products

Table 4.31: Best Fit Equations for SP Elasticity Curves – Non-Metallic Mineral Products

Elasticity	Best Fit Equation	R^2
0.25	y = 1689.8[ln(x)] + 5912.7	0.9997
0.30	y = 2092.1[ln(x)] + 5745.2	0.9997
0.35	y = 2521.1[ln(x)] + 5564.0	0.9994

Table 4.32: Equivalent SP Truckloads by Elasticity – Non-Metallic Mineral Products

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	45,691	64,791
0.30	57,468	81,491
0.35	70,375	99,794

As shipper cost for specialized shipments increases, the corresponding change in rail quantity of Waste and Scrap is illustrated in Figure 4.16. When shipper cost reaches $6.00 and there is a current quantity of 4,610 thousand tons, several thousand truckloads are shifted to rail. In terms of the 7-axle truck, roughly 50 thousand truckloads have mode shift potential over the period of one year, and in terms of the 5-axle truck, about 70 thousand truckloads have mode shift potential spanning a one-year period. Table 4.33 shows the best fit equations for the elasticity curves in Figure 4.16 and Table 4.34 displays the number of equivalent truckloads by elasticity.

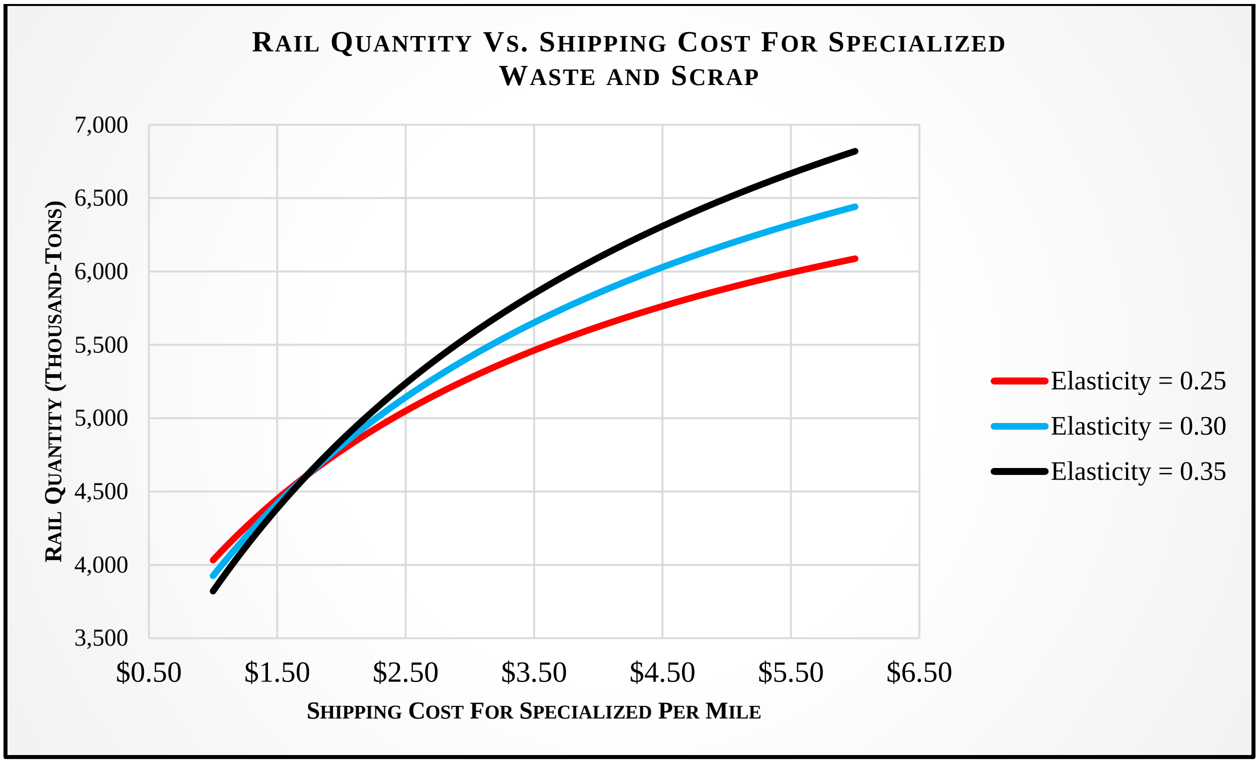

Figure 4.16: Change in Rail Quantity Due to Shipper Cost for Specialized – Waste and Scrap

Table 4.33: Best Fit Equations for SP Elasticity Curves – Waste and Scrap

Elasticity	Best Fit Equation	R^2
0.25	$y = 1182.9[\ln(x)] + 3976.4$	0.9996
0.30	$y = 1454.9[\ln(x)] + 3831.7$	0.9993
0.35	$y = 1741.4[\ln(x)] + 3679.3$	0.9986

Table 4.34: Equivalent SP Truckloads by Elasticity – Waste and Scrap

Elasticity	7-Axle Truckloads	5-Axle Truckloads
0.25	32,624	46,262
0.30	40,753	57,789
0.35	49,551	70,264

4.3 MODE SHIFT "TIPPING POINT"

Although unable to quantify a precise value at which shipping firms begin to lose money, it can be assumed that at that point shippers are likely to look elsewhere for distributing their goods. To definitively determine a "tipping point," data involving profit margins of distributors is needed—see Section 3.5 for further discussion. However, it is known that shippers can utilize benchmarks[3] to better understand their shipping costs, and as a result, their profits. Among the benchmarking metrics are the following *(Robinson 2015; Cass Information Systems undated)*:

- On-Time Pickups
- Outbound Freight as a Percentage of Net Sales
- Inbound Freight as a Percentage of Purchases
- Origin/Destination Regions
- Weight of Shipment
- Distance of Shipment
- Cost per Shipment
- Miles per Shipment

These "points of reference" provide insight into the market conditions and allow the decision makers to make informed decisions regarding mode choice. The benchmark metrics are likely to contribute to and impact the "tipping point" for a modal shift. In consummation, if shipping by truck induces a profit loss for distributors, it is likely to consider an alternate mode to meet distribution needs. In the end, if a mode shift were to take place, the number of truckloads—based solely on fuel price and shipper cost by type of shipment—shifted to rail are acutely noteworthy.

4.4 CASE STUDY

Two potential rail lines in Oregon could provide an opportunity for mode shifting, one in Southern Oregon and one in Northern Oregon. The Central Oregon & Pacific Railroad (CORP) that runs from Weed, CA to Eugene, OR can be considered. Based on the GIS data, there are intermodal facilities in Ashland, OR and Eugene, OR, providing the infrastructure needed to shift modes. In addition, the FAF data showed that the four commodities considered in this study are shipped between Oregon's two FAF regions, or within the same FAF region. This line would allow goods to be shipped via rail from Southern Oregon to Central Oregon. Most importantly, the two intermodal facilities are located in towns that I-5 passes through. With this in mind, goods can be shifted with very little rerouting on behalf of the trucks and the rail line runs parallel to the existing path, I-5.

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[3] Benchmarking is a point of reference, both internal and external, that allows decisions makers to compare and contrast metrics to make the best decision in their interest *(31)*.

The second potential rail line is the BNSF rail line that runs from Portland, OR to Bend, OR. The line runs parallel to the Columbia River from Portland, OR to near The Dalles, OR, then runs south to Bend. This line would provide an alternate mode for commodity groups being shipped within the Portland FAF region and commodity groups being shipped from one of Oregon's FAF region to the other. Alike the CORP line, the BNSF line runs near existing highway infrastructure; I-84 and US-97. The current infrastructure parallel to the BNSF rail line would also allow goods to be shifted to rail with little to no rerouting on behalf of the trucks.

For example, Logs and Other Wood in The Rough being shipped from Oregon (Remainder of State) to Portland, or vice-versa, can be shipped via the BNSF rail line that runs from one FAF region to the other. If mode shifting could occur between these regions, up to 254,204 truckloads based on the less-than-truckload shipper cost elasticity analysis and 105,783 truckloads based on the fuel price elasticity analysis can be taken off the highway system over the span of one year. Likewise, Gravel and Crushed Stone being shipped from Southern Oregon to the Willamette Valley, or vice-versa, can be shipped via the CORP rail line that runs from Southern Oregon to Eugene. This mode shift could remove up to 145,875 truckloads based on the less-than-truckload shipper cost elasticity analysis, and 60,704 truckloads based on the fuel price elasticity analysis, from the freight highway system over a one-year period. Unfortunately, due to lack of data a precise case cannot be identified—see Section 4.5 for further details.

Although both locations appear to be worthy candidates for mode shifting, last-mile logistics must be considered. Last-mile is a term used to define the final segment of the shipment, the portion of the trip in which the commodities are reaching their destination *(Dablanc et al. 2013)*. In the case of the present study, this specifically refers to the logistics leading up to the location that the modal shift would take place. For instance, if a commodity being shipped from Oregon (Remainder of State) to Portland is to shift modes in Bend, OR, last-mile logistics are going to be a major factor. The shifting commodity may require deliveries at specific times or have constraints on routing. The facility where the commodity is to be transferred from truck to rail, or rail to truck, may not have the equipment or capacity to meet the needs of the shipment. In addition, last-mile logistics are often considered the most expensive aspect of the supply chain and can account from 13% to 75% of the total logistics cost *(Macharis and Melo 2011)*.

4.5 DATA CHALLENGES AND LIMITATIONS

Data used for this study was public, readily attainable data. As a result, data challenges and limitations were encountered. The FAF data, although comprehensive, provides a macro picture of freight movement. The macro nature of this data works well when analyzing freight flow from state to state, but has its limitations when considering in-state freight flow. The data simply states if a commodity group was shipped from or shipped to an Oregon FAF region. It can be seen if the commodity group is being shipped from and sent to the same Oregon FAF region, or from one Oregon FAF region to the other, but no further inference from the data can be made. With a more disaggregated set of freight movement data, commodity group flow can be identified from city to city. Knowledge of city-to-city freight flow may result in different commodity groups with mode shift potential, as well as determine the exact location (e.g. Klamath Falls, OR to Eugene, OR) that the shifting can take place.

The competitive nature of the shipping industry results in a lack of distinct data. For instance, the two rail lines discussed for the case study were contacted on multiple occasions, yet no response was received. Contact with the two rail lines could have provided vital information, such as the frequency of rail shipments, the available space to ship goods, firms that ship some goods by rail and could ship more if conditions were right, the most shipped commodity group by ton and/or ton-miles from one city to another. With a need for the aforesaid data, a possible solution could be to issue a survey to rail lines of interest and several shipping firms within the state of Oregon.

To identify a tipping point for mode shifting, knowledge of shippers' profit margins and the point at which firms begin to lose money is essential. Unfortunately, this data is not readily attainable and is difficult to acquire. This is likely the most difficult data to collect, as shipping firms may not be willing to disclose any financial information. Financial data regarding shippers in the state of Oregon would serve as a viable solution. Ultimately, if no financial data regarding profits for distributors is available, the best "tipping point" can be no more than an assumption or approximation. However, there are private databases (e.g., FleetSeek) for sale that provide information at the trucking industry level and can provide revenues, shipment type, and industry information that can be used in developing a clearer picture of Oregon freight movements.

With such limitations and challenges, the most accurate solution to the problem was attained. Without micro level freight data, four commodity groups were identified to have mode shifting potential. With lack of information regarding the case study rail lines, the location and routes of the lines provide an ideal situation for mode shifting. Although no financial information concerning distributors' profit margin was available, the assumption that mode shifting would be considered when profits are negative was made. To alleviate these challenges and offer a tangible "tipping point" and location, the data missing from this study is crucially needed.

5.0 SUMMARY AND INSIGHTS

This study identified key factors in mode choice decision by shipping firms, differences in mode choice decision by commodity characteristics, necessary market conditions for mode shifting, potential mode shifting commodity groups and an illustrative example if conditions permitted mode shifting within Oregon. Based on previous literature, the three primary components in freight mode choice are reliability and quality of transportation services, transportation costs, and the likelihood of damage and loss of goods. Although these three aspects are the driving force of mode choice decisions, certain commodity groups may result in different logistic decisions (e.g. high priced items with very little shelf life). It was determined through a cross-elasticity analysis, while considering only fuel price and shipper cost, the amount of freight with potential to move from truck to rail. As fuel price increases and/or shipper cost increases, the cross-elasticity analysis illustrated a significant number of truckloads with a potential shift. Although the number of equivalent truckloads are in the tens to hundreds of thousands, the percentage of the current quantity is less than 1% based on fuel price and from 1% to 1.5% based on shipper cost.

Using the publically available $FAF^{3.5}$ data, it was determined that the majority of freight is shipped by truck and rail. This indicated that the most probable shift would occur from truck to rail, hence became the focus of this study. Further analyzing the $FAF^{3.5}$ data, four commodity groups were identified for mode shifting potential: (1) Gravel and Crushed Stone, (2) Logs and Other Wood in the Rough, (3) Non-Metallic Mineral Products and (4) Waste and Scrap. These four commodity groups were the most shipped commodity groups by truck in terms of tons, as well as being shipped between Oregon FAF regions or from one Oregon FAF region to the other. Commodity groups being shipped primarily by truck and within the state of Oregon were accordingly leading candidates for potential mode shifting. A cross-elasticity analysis using fuel price and shipper cost market conditions was conducted for the four identified commodity groups to determine the quantities, in terms of truckloads, if a shift were to take place. The cross-elasticity analysis indicates that less-than-truckload shipper cost has the greatest effect on mode shift potential. The number of equivalent truckloads was largest for less-than-truckload costs. Specifically, Logs and Other Wood in The Rough had the largest shift and can be credited to the current quantity being shipped within Oregon. Table 5.1 summarizes the commodity groups and their maximum potential shift measured in truckloads of a 5-axle twin 28' truck and a 7-axle 40' + 28' truck. Specifically, Gravel and Crushed Stone and Logs and Other Wood in The Rough would be the most ideal candidates for mode shifting in Oregon. In addition to the aforesaid commodity groups having the largest potential shift, both commodity groups are exceptions to the general rule of thumb that shipments under 500 miles should be shipped by truck—both groups are very heavy and dense and can be shipped short distances via rail *(Brogan et al. 2013)*.

Table 5.1: Maximum Potential Shift in Truckloads by Commodity Group

Commodity Group	7-Axle Truckloads	5-Axle Truckloads
Gravel and Crushed Stone	102,872	145,875
Logs and Other Wood in The Rough	179,265	254,204
Non-Metallic Mineral Products	70,878	100,507
Waste and Scrap	49,567	70,288

After establishing the necessary market conditions and four potential commodity groups, two rail lines in Oregon were considered: (1) CORP and (2) BNSF. The CORP rail line runs from Southern Oregon to Eugene, OR, while not requiring major rerouting of trucks from I-5. This line is an ideal candidate for mode shifting of commodity groups being shipped along I-5 from Southern Oregon to Eugene, OR. Such a shift for Logs and Other Wood in The Rough would result in up to 254,204 truckloads over the span of one year based on the less-than-truckload shipper cost elasticity analysis, and up to 105,783 truckloads during a one-year period based on the fuel price elasticity analysis being removed from the highway system between Southern Oregon and Eugene. The BNSF line crosses FAF regions by running from Portland, OR, to Bend, OR. This line also runs near current freight corridors, I-84 and US-97, minimizing truck rerouting for mode shifting. If Gravel and Crushed Stone were to shift, up to 145,875 truckloads over one year based on the less-than-truckload shipper cost elasticity analysis and up to 60,704 truckloads over one year based on the fuel price elasticity analysis would be removed from the highway system. Although not considered for the present study, the Columbia River is considered an underutilized asset for east-west shipments in Northern Oregon and in future work should undergo an analysis for mode shift potential.

With all of these in mind, several challenges were incurred due to insufficient data. The four identified commodity groups may differ if a disaggregated freight movement dataset is used. The public FAF$^{3.5}$ data depicts freight flow at a macro level (e.g. FAF region to FAF region), while city to city freight flow can provide a more accurate picture of in-state freight flow and indicate better candidates for more shift potential. In addition, significant financial information used to determine definite market conditions for mode shifting was not available. Surveying shipping firms and/or access to aggregate financial data regarding freight distribution would omit the need to assume that mode shifting would occur when profit margins are low. Suitable financial data would allow for a more thorough analysis to determine the point at which mode shifting would take place. Lastly, critical knowledge of the CORP and BNSF rail lines could not be attained. Although the two rail companies were contacted on several occasions, no dialogue took place. To more confidently state that mode shifting could occur on these lines, factors like frequency of shipments, available shipping capacity and capacity of facility, and the most shipped commodity group by ton is needed to be known in order to comprehensively evaluate mode shifting viability using these two rail lines.

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