DATA COLLECTION FOR TWO DISTINCT SUPPLY CHAINS: FOOD DISTRIBUTION AND WHEAT

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INTRODUCTION

The second Strategic Highway Research program (SHRP 2) is a partnership of FHWA, AASHTO, and TRB that develops solutions to enhance transportation efficiencies. A Washington State Department of Transportation (WSDOT) priority for SHRP2's third round was the Freight Demand Modeling and the Freight Data Improvement (C20) product grants[1]. In 2014, WSDOT was awarded funding from this program. This research has a focus on two important supply chains in Washington State: the cross-state, primarily rural wheat supply chain; and the urban-area food distribution supply chain in the central Puget Sound.

Purpose

The purpose of this research is to develop knowledge of food distribution supply chains in Washington State through application of novel data collection approaches. This will allow WSDOT to provide the necessary information to support ongoing development and refinement of the Washington State Supply Chain Model, and will allow USDOT to develop recommended data collection approaches in support of the SHRP C20 freight data and modeling program.

This research meets SHRP2 C20 goals by: using interviews and questionnaires to collect information on characteristics of business and likely behavioral responses (route and mode choice) to various conditions; and supporting truck trip modeling by collecting truck count data at food distribution facilities under a variety of land use scenarios.

Results Washington

Results Washington, a statewide strategic framework for defining goals and managing performance, was launched in 2013[2] by Governor Jay Inslee. One of the five high-level goals is focused on Sustainable Energy and a Clean Environment, where the aim is to reduce transportation-related greenhouse gas emissions. This goal was further defined in April 2014, when the Governor signed an executive order to reduce carbon pollution in Washington State[3]. WSDOT is tasked with planning activities aimed at promoting clean transportation, including strategies to increase efficiency and reduce greenhouse gas emissions. This initiative has led WSDOT to examine diesel use in freight transportation.

Supply Chain Model

In order to accurately predict how companies will route shipments during a disruption, a statewide multimodal freight model was developed in 2009. The model was limited in scope and purpose, with a basic structure for a more fully developed state freight model to be developed in the future. The model is a GIS-based portrayal of the state's freight highway, arterial, rail, waterway and intermodal network and can help the state prioritize strategies that protect industries most vulnerable to disruptions. The model, when provided with sufficient supply chain data, can: predict how shipments will be re-routed during disruptions; and analyze the level of resiliency in various industry sectors in Washington State.

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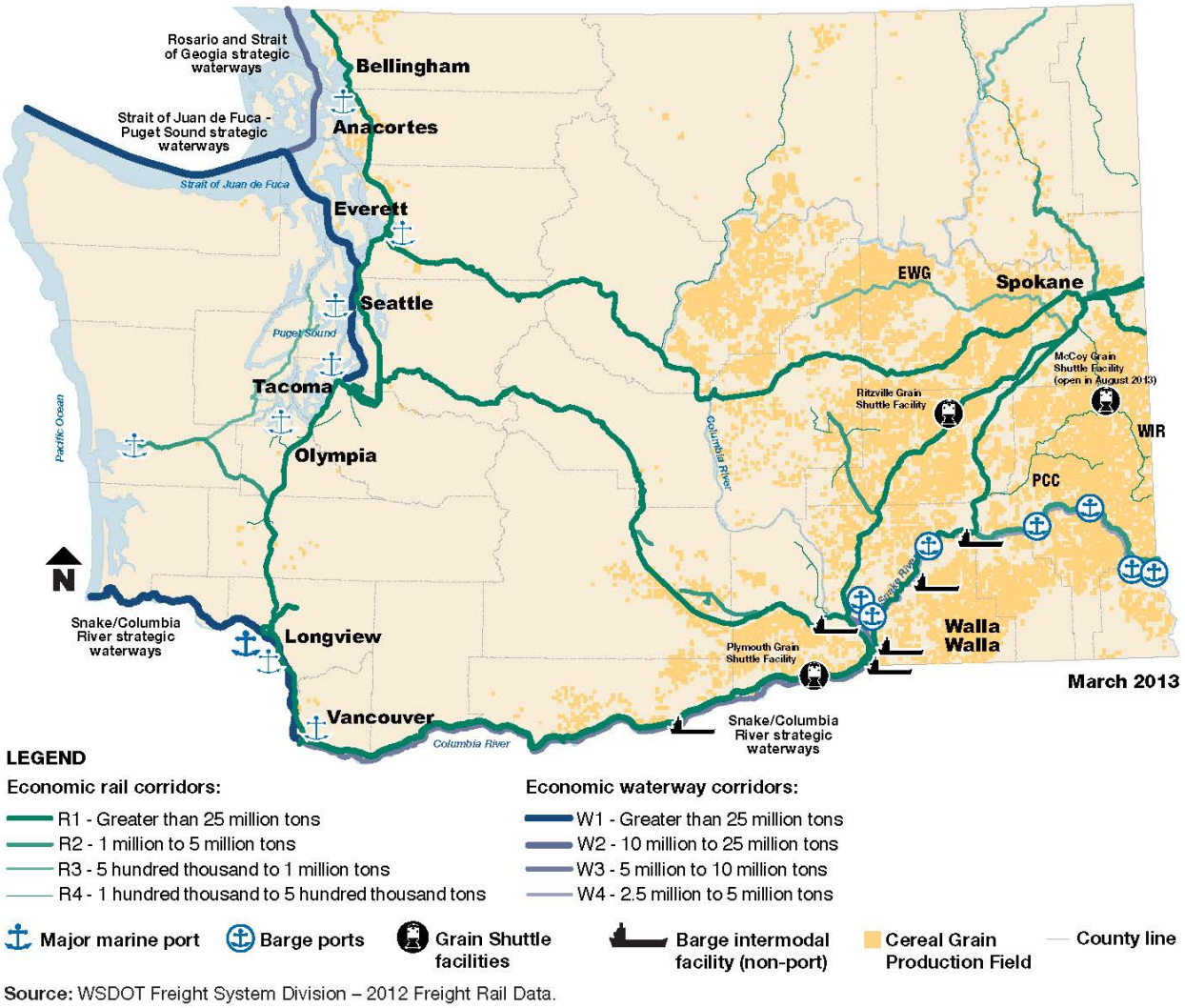
[1] https://www.fhwa.dot.gov/goshrp2/Solutions/All/C20/Freight_Demand_Modeling_and_Data_Improvement
[2] http://www.results.wa.gov/
[3] http://www.governor.wa.gov/sites/default/files/exe_order/eo_14-04.pdf

Supply Chain Planning in Washington

Freight transportation plays a key role in supporting supply chains in Washington State. As part of the 2014 Washington State Freight Mobility Plan[4], WSDOT developed maps to better understand supply chains that support international trade, regional economies, and the delivery of goods to Washington businesses and residents. The wheat supply chain is shown in Figure 1.

Figure 1: Wheat Supply Chain



A supply chain is defined as the movement of materials and information as they flow from the production source to the end consumer. Thus, it is made up of the people, activities, and resources involved in moving a product from supplier to consumer. The research in this report develops a better understanding of the rural nature of the wheat supply chain, and the urban nature of the food distribution supply chain. Summaries if these distinct research efforts are summarized below, followed by detailed reports.

[4] http://www.wsdot.wa.gov/freight/freightmobilityplan.htm

Wheat Supply Chain Data Collection

This research seeks to understand the wheat supply system and its transportation characteristics, as well as potential behavioral responses by wheat suppliers to changes in policy and market conditions; particularly that of the feasibility of alternative fuel adoption. To accomplish this, the research team has conducted both new interviews within the wheat supply chain actors, as well as identified existing data sources that help broaden the picture of wheat movement. Results suggest that research is needed to better understand and develop both the power generation of alternative fuel engines as well as the logistics of fuel distribution infrastructure. This is particularly evident for rural freight networks that move heavy agricultural or natural resource based products.

Food Distribution Supply Chain Data Collection

Supply chain firm interviews and truck counts were conducted in order to better understand the Food Distribution System in the Puget Sound. Interviews explored key business challenges, operations, and potential responses to natural gas incentives. Truck counts were conducted at grocery stores, and observations included truck type, time of day, stop duration, and parking behavior. The report includes a description of truck activity at grocery stores, and a summary of industry responses to natural gas incentives. The research contributes to the design of future freight data collection and the development of policy responsive freight models.

WHEAT SUPPLY CHAIN DATA COLLECTION

SUMMARY

By and large, wheat movement of the Pacific Northwest is geographically driven by the relative location of the production region to the rail and barge infrastructure. All production has at least some highway truck component to it; however, that segment is often rather short as the ton-mile expense of moving a heavy, bulk commodity like wheat on truck can be prohibitively expensive over long distances. As such, the segments made by truck are in effort to support and stage the movement of the wheat for the longer rail or barge movements.

Despite the short movements, the importance of the truck segment should not be understated. Wheat production, like that of many agricultural products, takes place across a dispersed landscape, thus requiring the utilization of many of the region's roads. Many of these roadways often do not rise to the level of perceived freight corridors when considered on a volume bases. They are however significant collector routes for much of the regional freight of southeast Washington. As policy scenarios or infrastructure investments are considered in the future, it is important in the context of wheat movement that the entire supply chain, across modes, be considered prior to assuming significant shifts in truck utilization.

The enclosed report seeks to summarize the necessary considerations that should be accounted for when attempting to consider specific supply chains in the development of statewide freight models. The wheat industry of Washington State offers a unique opportunity to visualize the potential shortcomings of a blanket freight category that assumes all freight decision makers respond in unison to policy or market changes. As we advance our understanding of potential responses, several key lessons learned arise:

- While there are a large number of farms and thus farmers, there are rather few actors making major transportation decisions. Many farmers throughout the region belong to a farmer cooperative that serves to aggregate the individual production of the numerous farmer members. Currently, there are roughly 26 buyers/shippers operate 300+ elevators.
- Wheat is too expensive to routinely move long distances by truck. Truck legs of wheat movements have historically been quite short and continue to be most often less than 20 miles.
- Potential shifts in movement are most likely to be induced by market conditions – Price, freight availability, rail and barge rates, customer location and need.
- Unlike other industries where production is concentrated and may be readily located on or near major freight corridors, wheat is heavily dispersed and has a significant reliance on rural and county roads.
- With wheat supply chain movements and importance better understood, the logistic realities of policy alternatives like implementation of alternative fuel networks may be better modeled for their practicality and potential adoption by the users. Implementation considerations should account for the necessary fueling infrastructure to reach dispersed rural locations with limited demand.

INTRODUCTION

Wheat is among the primary commodities produced in Washington State, ranking third behind only apples and milk. Among the highly favorable soils and climate of Eastern Washington, Whitman County has traditionally been one of the largest wheat producing counties in the nation[5]. Beyond Whitman County, much of southeastern Washington has significant acreage in wheat production. The history of grain development in Washington has largely gone hand-in-hand with technological development and the evolution of transportation within the region. Whether it has been steam boats on the Snake River, railroads around its falls and rapids, or the development of the highway system, all have served to support one of the highest density wheat producing regions in the world.

In excess of 80 percent of the wheat grown in Washington is destined for export. Given the commodity characteristics of wheat, it is most frequently transported to export terminals via barge or rail. Decisions on whether to use barge or rail as the primary means of movement is multifaceted, though rely largely on the geographic relationship of the farms and elevator storage areas to the modal loading facilities. Independent of use of rail of barge, truck movements are always a component of the total supply chain, even if for only a few miles.

As the Washington State Department of Transportation's (WSDOT) interest in developing a statewide freight model has grown, so too has the need to better understand potential responses of major industries to different policy and market scenarios aimed at reducing freight emissions. This research seeks to understand the wheat supply system and its transportation characteristics, as well as potential behavioral responses by wheat suppliers to changes in policy and market conditions. To accomplish this, the research team has conducted both new interviews within the wheat supply chain, as well as identified existing data sources that help broaden the picture of wheat movement.

The information presented in this report is intended to coincide with that similarly developed for food distribution in the Puget Sound region, thus providing a diverse pair of case studies from which to observe a spectrum of potential behavioral responses to policy and market condition changes. The overriding intent of these combined reports is to:

- Elaborate upon the relationship between data collection efforts and subsequent availability and accurately modeling key state supply chains' behavioral responses to different state policy scenarios aimed at reducing freight emissions and their impacts on the freight system in Washington State.
- Examine the interplay between policy scenarios and market forces driving key supply chains involvement with the transition to natural gas fuels for freight systems.

Using the above points as a basis of discussion, the remainder of this report summarizes the relationship between truck trip generation rates across the wheat producing regions of Washington and potential changes to such generation and volume of movement based on potential responses to policy and market changes. This discussion includes that of data needed to support the inclusion of wheat supply chain information in a statewide freight model including availability of existing data sources. We conclude with

[5] http://www.agcensus.usda.gov/Publications/2012/

a discussion of experiences, successes, challenges, and lessons learned with implementation of this innovative local freight data collection project.

THE NEED FOR DATA DEVELOPMENT

At least since the passage of MAP-21, a renewed interest in performance based investments has taken center stage among transportation agencies in the prioritization of infrastructure projects. Specifically, WSDOT has undertaken several overlapping research efforts to better capture the benefits and impacts of improved truck transportation to the regional economy of Washington. These research efforts include the development of a freight benefit/cost methodology for project planning by Sage et al (2013)[6]. These benefit-cost and economic impact methodologies rely on modeled responses of the freight system to changes in the network that may allow more efficient movement. However, a generation of expected benefits or impacts is directly dependent upon the quality of output from models used and thus upon the assumptions made about travel behavior. The methods and results identified by Sage et al (2013), are significantly driven by the relationship between congestion relief and travel cost, and as such are largely only applicable to the more urban regions of the state. Sage and Abdel-Rahim (2015) have expanded upon these results to suggest mechanisms to better include and account for the significant number of freight miles that occur outside urban centers, particularly as they relate to intermodal transportation[7]. Both of these reports build on themes produced for WSDOT to the effect of developing a better understanding of the movement of goods on Washington's roadways and the subsequent effects that roadway and other asset quality has on the utility of the state's transportation system. These earlier studies include efforts by Casavant et al (2004) to establish a series of attributes that facilitate viable intermodal truck facilities[8], as well as a full exploration by Simmons and Casavant (2010), of the interplay of modal transportation in the state when the river system experiences an extended outage[9].

In order to effectively advance the discussion and consideration of freight efficiency impacts from transportation investment, the anticipated response of the freight community to those investments must be known. The transportation community readily has commuter based travel models that permit an anticipated response measure based on origin-destination parameters, as well as trip purpose and other traveler attributes. However, we frequently lack similar level of disaggregation when considering freight movement. This lack of detail generates important limitations for several reasons:

- The nature of the freight being moved may dictate potential travel response to policy or market based changes that result in changes in cost structure;
- Market conditions of the commodity may dictate the feasibility of modal shifts;
- Freight transport characteristics such as bulk movement and weight play significant factors in truck type usage and power needs and thus potential adoption of new technologies;

[6] Sage, J.L. et al. 2013. Development of a Freight Benefit/Cost Methodology for Project Planning. WA-RD 815.1.
[7] Sage, J.L. and Abdel-Rahim, A. 2015. Performance-Measure Based Asset Management Tool for Rural Freight Mobility in the Pacific Northwest. Report submitted to PacTrans, August 2015.
[8] Casavant, K., Jessup, E., and Monet, A. 2004. Determining the Potential Economic Viability of Inter-modal Truck-Rail Facilities in Washington State. Report Submitted to the Washington State Department of Transportation. December 2004.
[9] Simmons, S. and Casavant, K. 2010. Historical Waterborne Commerce on the Columbia-Snake River System: Commodity Movements Up and Down River, 1991-2010. FPTI Research Report #1. November 2010.

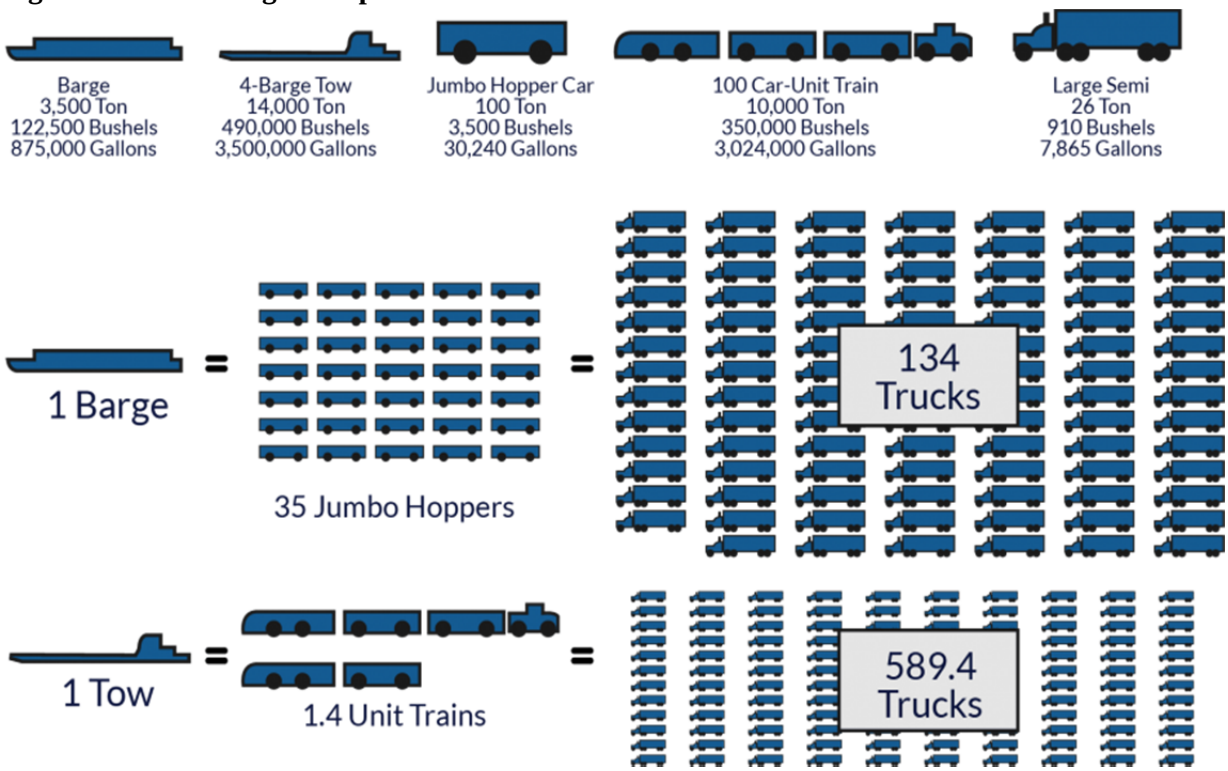
- Agricultural freight, in particular, has significant seasonality that may not be captured in Annual Average Daily Truck Traffic Counts (AADTT);
- Agricultural production is greatly dispersed, thus relying on a broader set of roadway assets than most industries.

For the reasons above, amongst others, the development of freight travel models should be done with an ability to account for potential discrepancies created by unique industries such as agriculture, particularly when those industries make up significant portions of the AADTT within a region. The remainder of this report highlights several key facets of the wheat supply chain that are needed to accurately model behavioral responses to varying state policy scenarios aimed at reducing freight emissions and their impacts on the freight system in Washington State. It also examines the interplay between policy scenarios and market forces driving key supply chains involvement, or lack thereof, with the transition to natural gas fuels for freight systems.

CHARACTERIZING THE WHEAT SUPPLY CHAIN

Given the dispersed nature of wheat production, and its transport characteristics (e.g. bulk, weight), the current transportation system supporting the wheat and other agricultural industries of Washington is highly intermodal and comprised of all three major freight modes: rail (both Class I and Short Line); trucks using the highway/county road system; barges using the inland waterway system (Figure 2); as well as a set of intermodal facilities to enable the transfer of commodities between modes (Figure 3).

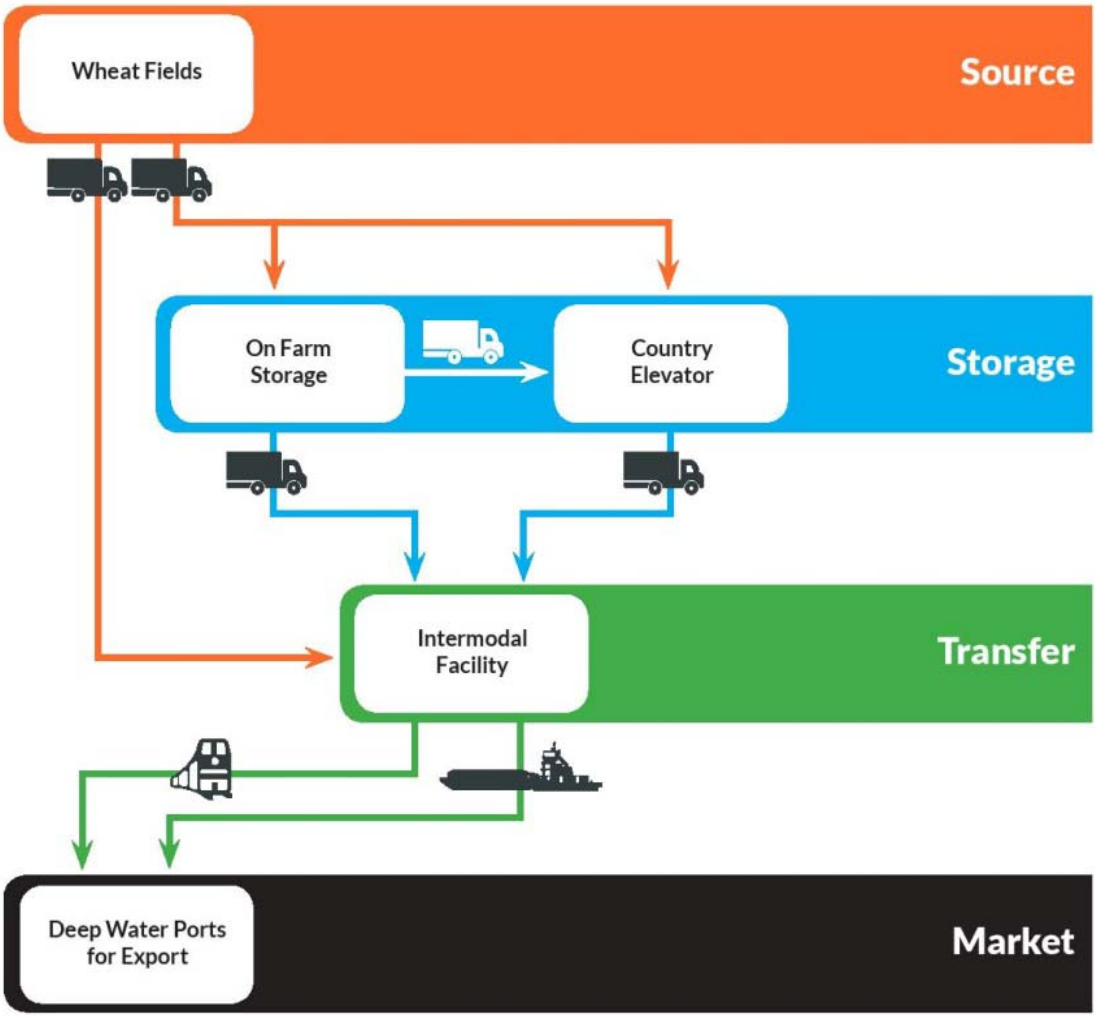
Figure 2: Modal Cargo Comparison[10]



[10] Port of Lewiston

Each of these modes serves its part in moving much the wheat of Eastern Washington to the coastal ports for bulk export. The capacity and cost efficiencies garnered by either rail or barge movement for longer distances dictate the movement of wheat from field to nearby storage or intermodal facilities by truck for future movement by rail or barge. Note: The Country Elevator and Intermodal Facility may be one and the same.

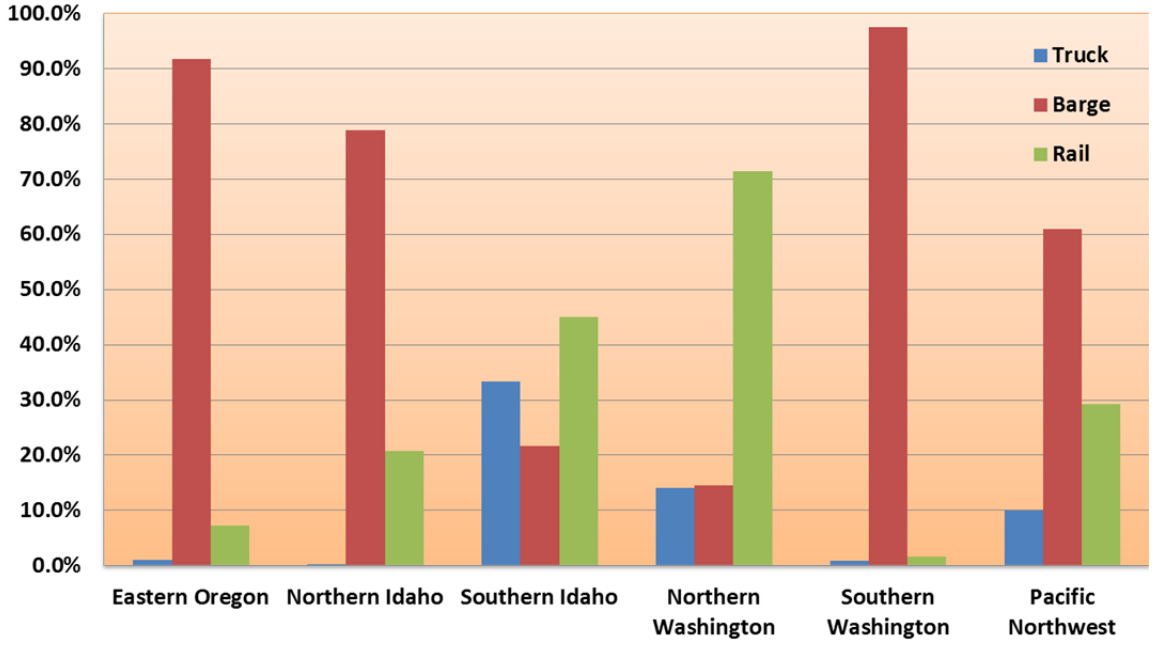
Figure 3: Typical Wheat Supply Flow from Farm to Export



As wheat and other cereal grain production is a land intensive practice, an effective and dynamic transportation system is vital to the ability of those farmers to compete in a global marketplace. The competition among, and capacity of, these modes has provided efficient and market responsive service in the region. Though the state's transportation system is quite mature, continual development and adaptation is necessary to maintain any competitive advantage held by the region. Such adaptation requires ready flexibility to changing market conditions, demands, as well as changes to the transportation system itself – both planned and unforeseen. While geography is a major driver of the direction and modal usage within the wheat supply chain (Figure 4), those directional movements are not static. Case in point was the 2011 lock closure along the Columbia-Snake waterway in which all grain movement was

halted for three months while repairs were made[11]. Typical movements along the waterway had to be adjusted either by time of movement or direction of movement onto other modes. The supply chain was able to effectively adjust. While the lock outage may be an anomaly within the movement of wheat in the region[12], the necessity to adjust to changing conditions is ever present. Other such conditions include recent deployments of new multi-car loading facilities for rail transport. One such facility, McCoy, has now been in operation for several years, while another, Highline, is in the development process. These large loading facilities have the potential to shift the relative cost of transport between rail and barge for some farmers.

Figure 4: Typical Percentage of Wheat Shipped via Various Modes in the Pacific Northwest[13]

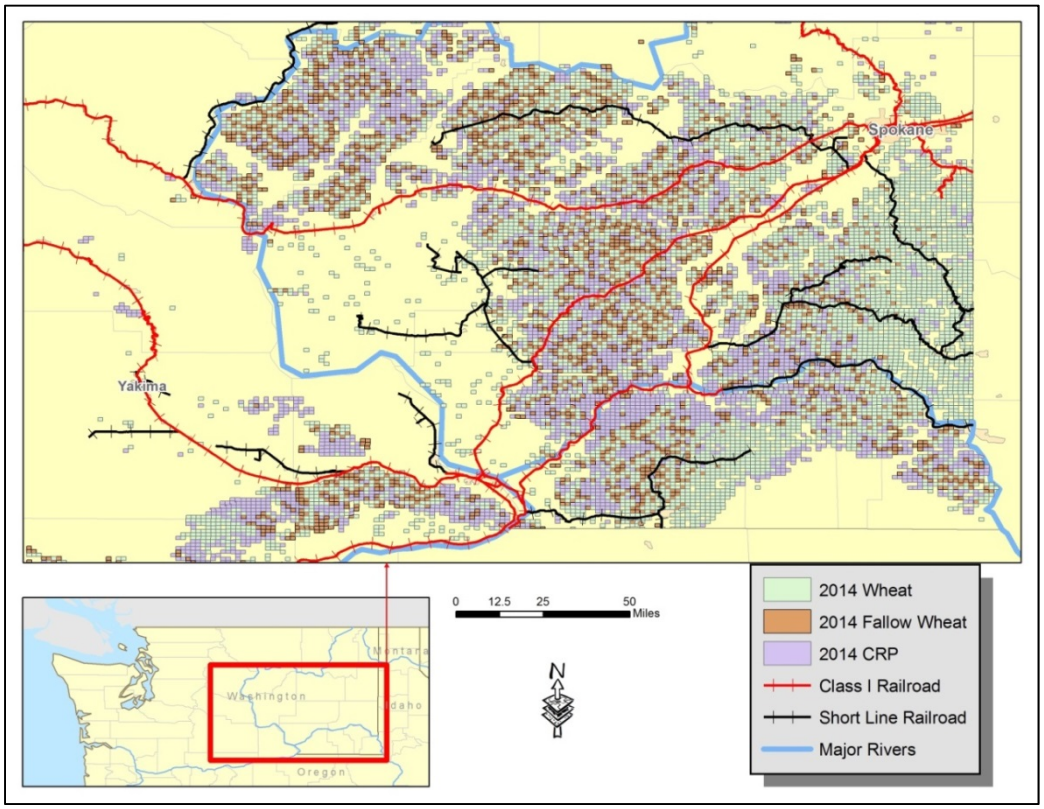


Farm Origins

In 2012, the most recent Census of Agriculture, wheat was grown on more than 2.1 million acres throughout Washington, primarily in the southeast region. These acres produced 141 Million bushels, or nearly 65 bushels per acre[14]. Significant additional acreage is left fallow in any given year to promote soil health, while other parcels of potential wheat producing lands are currently maintained in the Conservation Reserve Program. Under the CRP, farmers are paid yearly rental payments by the USDA to remove environmentally sensitive lands from production for up to 15 years per contract. As evident from Figure 5, the major wheat production area of Washington is expansive, covering significant portions of 10 southeastern counties.

[11] Refer to FPTI reports: 1, 2, 9, 10, and 12 for full details on industry response to the closure.
[12] The 2011 lock closure lasted approximately 11 weeks. A 14-week closure is currently planned for the end of 2016.
[13] Simmons, Sara and Ken Casavant. FPTI Research Report #12. "Economic and Environmental Impacts of the Columbia-Snake River Extended Lock Outage." August 2011.
[14] http://www.agcensus.usda.gov/Publications/2012/

Figure 5: Regional Production Area for Washington Wheat[15]



Roughly progressing sequentially from southwest to northeast, wheat harvest occurs throughout late summer as the crop becomes ready. Upon harvest, much of the wheat is moved by farm truck to local storage. Until recent decades, such movements were conducted by more, smaller trucks; however those trucks are now frequently replaced by larger trucks moving up to 26 tons of wheat at a time. One bushel of wheat weighs approximately 60 pounds, making the entire weight of the 2012 harvest roughly 4.23 million tons. This yield thus generates an estimated 162,716 truck trips between farm and grain elevator, shown in Table 1.

Table 1: Farm Truck Trips to Support Wheat Harvest

Factor	Quantity
2012 Wheat Acres Harvested	2,186,813
2012 Wheat Yield (Bu)	141,020,565
Weight per Bushel (lbs.)	60
2012 Weight Yield (tons)	4,230,617
Tons Hauled per Truck	26
Truck Trips Needed to Support Harvest	**162,716**

[15] Washington State Department of Agriculture, Agricultural Land Use Maps. http://agr.wa.gov/PestFert/NatResources/AgLandUse.aspx

As previously identified, wheat production takes place over a dispersed geography. Such dispersion places the generated truck trips on numerous roadways throughout the region. Figure 6 below highlights an approximation of the dispersed nature of truck trips generated by harvest throughout the Palouse region, based on the calculations above. The Palouse area is used as an example, given its high density of wheat production and access to multiple modes. Trucks may be expected to begin on the network at the point near the field where they can access a roadway suitable for truck traffic. Each truck collects wheat from approximately 13 acres; actual value depends upon truck size used and crop yield. Using the U.S. Department of Agriculture's CropScape Data Layer[16], accurate estimates of annual production of specific crops may be generated. Note: Grid cells represent 1 square mile.

Figure 6: Wheat Harvest Truck Trips Generated (Whitman, Asotin, Garfield, Columbia Counties) 2014

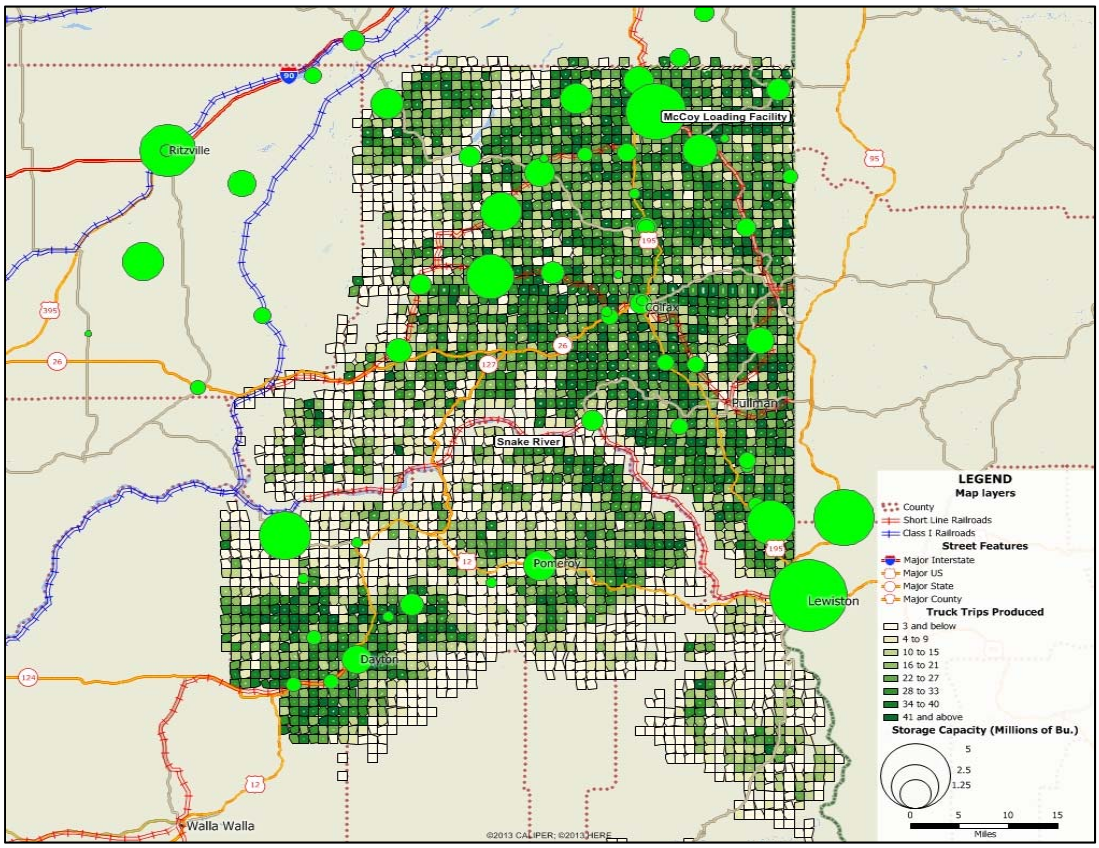


Figure 4 demonstrated that for Washington wheat farmers, truck movement constitutes a small portion of travel, yet a vital one as wheat does not grow directly on the rail line or the river. From the farm, most trucks are destined for nearby storage either to be moved again later by truck, to be loaded onto the rail or barge for its longer segments to export ports.

After the Farm

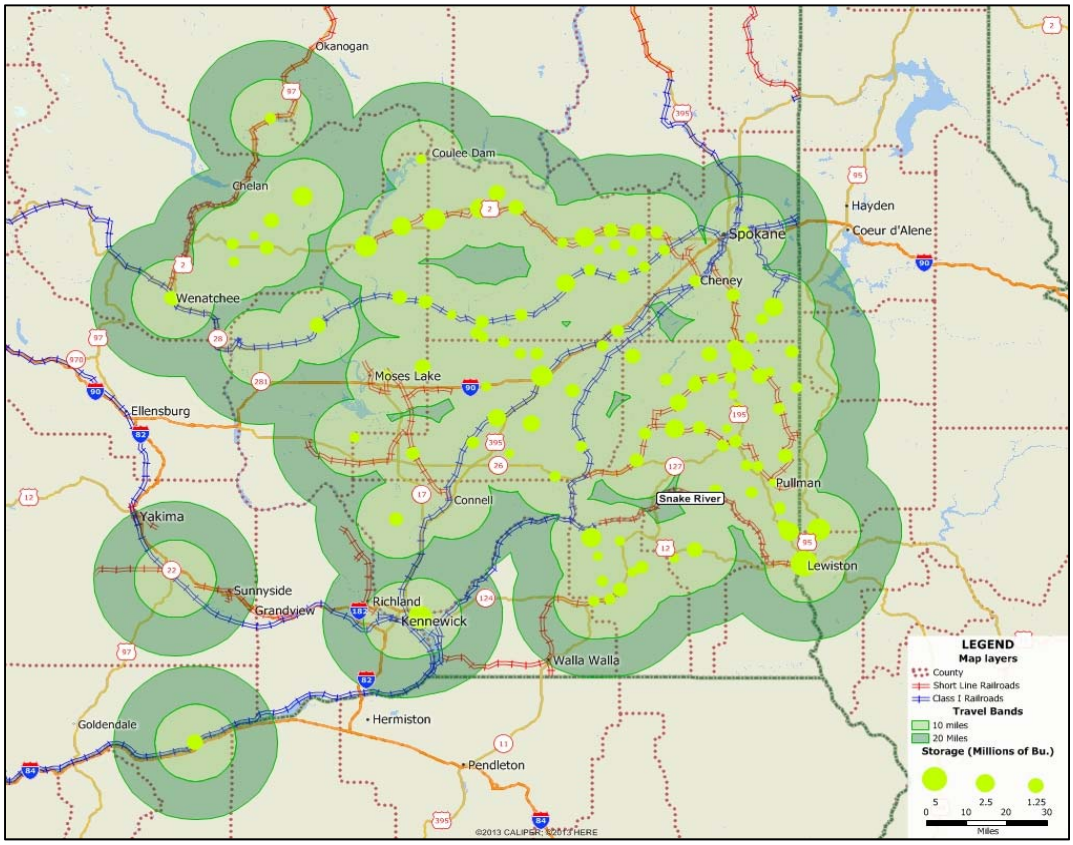
As one moves up the wheat supply chain, the number of actors quickly diminishes. While there were 2,871 wheat farms in Washington in 2012, there were less than 30 major wheat suppliers and buyers with

[16] http://nassgeodata.gmu.edu/CropScape/

grain storage capacity in the state. These elevators (mostly cooperatives) have grain elevators storage for just over 131 million bushels of wheat plus additional capacity through ground piles. The storage facilities throughout the region vary considerably in size and access to rail or river connections (Figure 6). More storage can also be found on farm.

Historically, the average elevator attracted farms located 10 to 20 miles from any one of their facilities. Some larger facilities with direct access to rail or barge possessed a slightly larger catchment. Assuming the catchment falls within this range, Figure 7 displays the approximate coverage of the region's wheat production by the known locations of the storage facilities. At a travel band of 20 miles, full coverage of the major wheat production area is captured, while 10 mile bands capture a substantial majority of the producing region.

Figure 7: Grain Storage Facility Catchment Areas (10 and 20 mile Buffers)



WHEAT SUPPLY CHAIN STAKEHOLDER ENGAGEMENT

Survey of Wheat Suppliers

As a substantially homogeneous commodity, the wheat grown by one farmer is largely indistinguishable from that of any other. From the farm, the wheat harvest is collected by, or shipped to, a small set of wheat suppliers. Mostly cooperatives, these suppliers function to serve as an aggregating actor to identify markets and promote the sale and typically export of Washington's wheat harvest on behalf of their

farmer members. Given their central role in the supply chain of Washington wheat, these suppliers serve as the primary points of contact in this study. Further, these firms have routinely served as valuable and highly knowledgeable sources of information for the movement of wheat in Washington. A prime example of such insight is the previously conducted research surrounding the 2011 extended lock closure in which the Freight Policy Transportation Institute (FPTI) researchers were able to engage in open communication with the wheat suppliers to ascertain their traditional movements and expected reactions to the closure.

In this round of survey and interview efforts, FPTI successfully contacted 19 of 26 suppliers (73 percent). These suppliers may be found on the Washington Grain Commission Website. We excluded suppliers identified as seed companies. Survey respondents were asked to identify the primary reasons for their modal choice decisions. Of the 19 responses collected, eight indicated that costs were the primary factor, while another seven indicated that the availability or relative location of the mode was a primary consideration. Market price also played a smaller role, two responses, in modal choices.

Responses to the modal choice questions fall in line with the observations shown in Figure 1 that suggest discrete geographic differences in modal usage. These differences reflect the availability and relative rates of the rail and barge modes and the distance required to move the wheat to the nearest access points by truck. Further, these responses are reflective of the relative ton-mile expenses faced in a multimodal supply chain such as wheat. Tables 2 and 3 show the relative equivalencies of the three modes of transport in terms of cargo capacity (Table 2) and costs (Table 3).

Table 2: Standard Modal Capacities

Modal Freight Unit	Standard Cargo Capacity
Highway - Truck	26 tons
Rail - Bulk Car	111 tons
Barge - Dry Bulk	1,750 tons

Table 3: Modal Equivalencies[17]

Equivalent Units	Mode of Transportation		
Equivalence By Mode	1 Barge	16 Rail Cars	70 Trucks
Cost per Ton-Mile (cents)	0.72	2.24	26.61
Ton-Mile per Gallon of Fuel	616	478	150

[17] Texas Transportation Institute. A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001-2009. http://nationalwaterwaysfoundation.org/study/finalreporttti.pdf. February 2012.

The survey and supplementary follow-up discussions couched economic decision making with respect to transport costs and emissions reductions within a series of questions aimed to reveal stated concerns or reactions by the respondents related to:

- Identified market condition changes in the preceding three years;
- Firm responses to market condition changes;
- Action taken to minimize impact of future market condition changes or uncertainty;
- Identified government policy changes in the preceding three years;
- Firm responses to policy changes;
- Action taken to minimize impact of future policy changes or uncertainty.

In addition to the primary lines of questioning above, the disseminated online survey also sought information from the respondents in regards to catchment area of each of their elevator facilities. Such information is used to generate estimated roadway usage during harvest as wheat is moved from farm to elevator. Respondents in this 2015 survey remained consistent with those previously identified by Clark et al (2003) and used to generate the travel bands in Figure 7.

Responding to Market Conditions

Market conditions routinely impact commodity movements and transportation decisions. "Market conditions," is a broad term covering multiple potential avenues of impact. Such scenarios covered include changes in relative transportation rates between modes, changes in market demand or commodity prices. Survey respondents were asked in a yes or no question to identify whether their operations were effected by any changes in market conditions in the previous three years. Of those responding to the question, 47 percent indicated that market conditions necessitated an alteration of their transportation decisions. Of those making such alterations, 86 percent indicated the need to shift some movement of their product from rail to barge, while 43 percent indicated a shift at some point from barge to rail. The high level of fluidity between barge and rail movements suggests the potential sensitivity of many wheat suppliers to the relative rates and availability (rail cars) of transportation by mode. While actual rates can vary in time and location, approximate ton-mile costs by mode are .7 cents by barge, 2.2 cents by rail, and 26.6 cents by truck (Table 3).

Roughly 86 percent of those taking action to alter their transportation decisions identified a change in their timing of shipment. Again, this may be related to both transportation costs as well as market prices for wheat. Respondents were given the opportunity to select any of the following response actions and then elaborate on their reasons for action:

- Shifted some movement from rail to barge;
- Shifted some movement from barge to rail;
- Transported wheat entirely by truck;
- Altered timing of shipment;
- Held more wheat in storage than usual;
- Held less wheat in storage than usual;
- Took other actions.

Most respondents (79 percent) have taken action to seek to minimize impact of market based fluctuations. The nature of the wheat market necessitates a significant degree of long range planning in production,

sales and transportation alternatives, thus suppliers routinely seek opportunities to minimize the effects of small market based fluctuations on their larger operations. They indicate they have done so through increased storage, increased access to all modes, and more efficient warehousing operations. Several specific comments from respondents include:

- Cost and availability of rail transportation dictates much of our transportation decisions;
- Freight costs and availability along with crop quality change from year to year, thus changing the way we move our products;
- The largest issues are with the Ports and Longshoremen;
- We move wheat as needed for storage quality and then make movement decisions based on market direction;
- Prices for different shipment periods changed or supported one shipment period over another. Varying market conditions may cause farmer to sell more of their grain and carry over less.

The actions taken in recent years by the respondents is reflective of their sensitivity to fluctuations and reliability of freight modes. These actions include:

- Hedging against fuel surcharges;
- Maximize mill and feedlot direct shipments;
- Improve facilities to receive bigger trucks and improve ability to load rail;
- Direct exporting instead of delivering grain to competitors;
- Continue to ship on the short line to ensure that they will be here in the future;
- Leasing of rail cars to improve availability;
- Ensuring multiple modes of delivery are available;
- Improving warehousing for more efficient trucking.

Responding to Policy Conditions

In a similar style to the questions posed to respondents about previous responses to changes in market conditions, they were also asked to respond to questions regarding their responses to changes in policy conditions. Slightly fewer, 43 percent, of respondents indicated that over the last three years government policies (federal, state, or local) have caused a shift in their transportation decisions. These questions were intentionally left open ended to permit the respondent to identify the policies that were most likely to generate a response by their operation. Unlike a change in market conditions, no single response was highly common among respondents. Fifty percent of those making some sort of change indicated that they altered the timing of their shipments. Few indicated that a policy generated any type of modal shift, and those that did appear to be temporary as the respondents were making decisions based on road or rail closures for short durations of time, such as seasonal weight restrictions.

Similar to preparing for market based changes, respondents indicated they attempt to buffer themselves from government based actions by ensuring quality access to multiple modes. By possessing access to multiple modes, the respondents indicated their ability to be responsive to customer demands and ensure timely delivery in the event of unforeseen issues on a particular mode or area of production.

Considering Fuel Alternatives

Most survey respondents operate with some combination of their own trucks and the hiring of independent trucks and drivers. They used a variety of compensation mechanisms for the trucks they

hired out, these include: per bushel hauled, per unit weight, and per mile. Several indicated that fuel costs are directly tied to driver compensation contracts.

When provided information as to the relative costs of fuel to the marginal costs of trucking (about 38 %), and asked whether they have considered alternatives to diesel, only two respondents indicated they have, though neither have attempted or experimented with alternatives. The cost and availability of the fuel, cost of maintenance, and unit power to navigate the hilly region were significant concerns of those who did consider alternatives.

Recognizing that fuel costs are significant to their operations, several respondents utilize typical market based mechanisms to control fuel spending. These mechanisms include the purchase of large quantities at times of perceived low prices, as well as fuel hedging. When contracting permits, many costs associated with a rise in fuel costs are passed along to the customer and/or grower. However, this pass along is not always feasible. Such cases arise when grain is purchased and sold for three months in the future. If fuel prices fluctuate significantly over that time, what was a good buy and sell may become less so if fuel costs rise. In the broader scheme, fuel prices affect the competitiveness of northwest wheat globally.

The importance of both the dispersed nature of wheat production in rural landscape and the transport characteristics of the commodity being moved are perhaps two of the most important considerations in the potential application of alternative fuel usage by the wheat supply chain. On the one hand wheat is a heavy commodity that often relies on truck transport for its first mile movements. In response to increasing demand for efficient transportation, the industry has moved towards larger trucks capable of moving more wheat in fewer trips. These attempts at efficiency gains have necessitated significant power generation from its trucks. The power needs are further desired to navigate the hilly terrain of the major wheat production areas. Secondly, the rural nature of wheat production place truck movement across large landscapes, adding infrastructure constraints to the potential implementation of alternative fuels. Without easy and ready access to the fuels, adoption by the wheat industry would not be practical.
With power needs and the dispersed nature of agriculture in mind, several items of consideration should be included in moving forward on alternative fuels policies and potential adoption recommendations.

Technological Barriers

While support and evidence for the emission reducing potentials of alternative fuels (LNG and CNG) continue to grow, questions remain as to the power generation capability of these fuels on par with that of diesel engines. As such, policies aimed to incentivize the development of higher power output generation of heavy duty trucks running on alternative fuels should be explored. Natural resource and agricultural production based trucks frequently require the capability to move some of the heaviest trucks on the roadway, thus placing their power needs at the higher end of the spectrum[18]. These trucks will frequently weigh out before they cube out.

Where (or when) output is on par with diesel trucks, a program to increase awareness, and thus potential adoption may be encouraged. Based on interviewee responses, such an awareness, when presented to owners and/or operators of trucks involved in wheat movement should be directed towards the

[18] Sage, J. L. and Casavant, K.L. 2014. Freight Commodity Flows: Selected Washington State Highways. WA-RD 825.1. http://www.wsdot.wa.gov/research/reports/fullreports/825.1.pdf

identification of the potential return on investment (ROI) for alternative fuel based trucks. Key components of such an ROI may include:

- Evaluation based on the seasonal use of many farm trucks (impacts miles per year and assumed loading characteristics);
- Owners likely to own few trucks (many are owner operators);
- Fuel costs in relation to fuel efficiency;
- Positive ROI with and without subsidy support;
- Necessary payload reductions to offset NG vehicle weight increases;
- Ability (and cost) to perform self-repair of NG vehicles;
- Operators are not likely located on or near major freight corridors (See Logistic Barriers below)

Unlike larger truck firms with many trucks, or retail firms with their own fleets, small owner/operators have a reduced incentive to purchase based on social cost or green marketing. This reduced incentive is not a statement of lacking environmental concern; rather, it is a statement of the homogeneity of the wheat industry in which no single farm, driver, or shipper is distinguishable from the others. As such, there is little to no individual marketing advantage to promotion of emissions reductions.

Logistic Barriers

As stated in the list above, most operators within the trucking leg of the wheat supply chain are not operating on major freight corridors. They are running the majority of their miles from farm to elevator in geographically disparate regions of the state. As such, these locations are likely to be late adopters of the infrastructure necessary to support LNG or CNG refueling. Subsequently, any discussion of wheat supply chain adoption of such fuels hinges on the identification of the feasibility of rurally located service station capacity to store and handle alternative fuels. Key considerations include the physical facilities, as well as the economic incentives (e.g. are subsidies or tax incentives needed or warranted?) to transition and make the fuels available in lower density regions.

Further investigation and research is warranted on the minimum facility location needs to ensure adequate accessibility for rural users without necessitating significant off route travel to refuel. This research includes the identification of the potential for distribution systems for independent or onsite fuel storage.

Technologic and Logistic Needs: Chicken and Egg

The above discussions as to the technologic and logistic needs to entice adoption of alternative fuels within the wheat supply or other agriculturally based supply chain are not new, and are intimately related. In fact, the two discussions should be held simultaneously. The adoption of the new fuels is inherently dependent upon multiple groups of actors making business decisions that affect one another. One the one hand, there is little sense in marketing well performing engines to these owner operators if there are not convenient refueling options available to them. While on the other, there is little incentive to develop the necessary infrastructure for CNG or LNG if the major fuel consumers do not have a viable engine to use that meets their power needs.

CONCLUDING DISCUSSION

By and large, wheat movement of the Pacific Northwest is geographically driven by the relative location of the production region to the rail and barge infrastructure. All production has at least some highway

truck component to it; however, that segment is often rather short as the ton-mile expense of moving a heavy, bulk commodity like wheat on truck can be prohibitively expensive over long distances. As such, the segments made by truck are in effort to support and stage the movement of the wheat for the longer rail or barge movements.

Despite the short movements, the importance of the truck segment should not be understated. Wheat production, like that of many agricultural products, takes place across a dispersed landscape, thus requiring the utilization of many of the region's roads. Many of these roadways often do not rise to the level of perceived freight corridors when considered on a volume bases. They are however significant collector routes for much of the regional freight of southeast Washington. As policy scenarios or infrastructure investments are considered in the future, it is important in the context of wheat movement that the entire supply chain, across modes, be considered prior to assuming significant shifts in truck utilization.

Lessons Learned

The preceding report has sought to summarize the necessary considerations that should be accounted for when attempting to consider specific supply chains in the development of statewide freight models. The wheat industry of Washington State offers a unique opportunity to visualize the potential shortcomings of a blanket freight category that assumes all freight decision makers respond in unison to policy or market changes. As we advance our understanding of potential responses, several key lessons learned should be considered:

- While there are a large number of farms and thus farmers, there are rather few actors making major transportation decisions. Many farmers throughout the region belong to a farmer cooperative that serves to aggregate the individual production of the numerous farmer members. Currently, there are roughly 26 buyers/shippers operate 300+ elevators.
    - Several actors spend significant amount of time buying/selling transportation (e.g. rail cars).
    - In terms of truck transport, despite few actors making major decisions, they must draw from a variety of independent owners and operators of trucks to accomplish their movements. In this sense, there is often not a fleet of trucks with central direction or ownership. Subsequently, policies aimed at incentivizing conversion to alternative fuels should be done at an appropriate economic scale of owners with only a few trucks at most. This additionally has direct implications for the types of fueling infrastructure required.
- Wheat is too expensive to routinely move long distances by truck. Truck legs of wheat movements have historically been quite short and continue to be most often less than 20 miles. The elevator/storage presence in the major wheat growing areas effectively cover all productive lands.
- Potential shifts in movement are most likely to be induced by market conditions – Price, freight availability, rail and barge rates, customer location and need.
- Unlike other industries where production is concentrated and may be readily located on or near major freight corridors, wheat is heavily dispersed and has a significant reliance on rural and county roads.

- Most wheat movement estimates are frequently made at the county level, however to increase the network understanding and needs of movement, analysts can utilize USDA CropScape data layer to generate truck trip generation from the farm level. Additionally, most storage facilities (elevators) are licensed by the State of Washington and can thus be geocoded to create an origin destination pair from the farm to the elevator.
- With Origin and Destination knowledge, we can estimate truck volume and thus roadway importance to wheat movement.
- With wheat supply chain movements and importance better understood, the logistic realities of policy alternatives like implementation of alternative fuel networks may be better modeled for their practicality and potential adoption by the users. Implementation considerations should account for the necessary fueling infrastructure to reach dispersed rural locations with limited demand.

FOOD DISTRIBUTION SUPPLY CHAIN DATA COLLECTION

SUMMARY

This report summarizes the work completed under the SHRP2 Local Freight Data program for the Washington State Department of Transportation (WSDOT) completed between August 1, 2014, and December 15, 2015.

The project had multiple goals. The first was to understand the Puget Sound's food distribution supply chain's transportation, logistics, and fleet characteristics, as well as the industry's experience and expectations with natural gas vehicles and natural gas policies or programs. The second was to test relevant data collection approaches for measuring and understanding this industry, so as to inform future data collection and modeling efforts.

Following consideration of the research problems, available resources, and current state of knowledge, a data collection program was designed that included qualitative interviews, online surveys, and manual truck counts. Data collection instruments were designed for each data collection effort, including an interview script, online survey, and activity description. An approach was designed that included urban, suburban, and rural locations, as well as grocery stores, food distributors, and food processors.

To begin, we spoke to twelve employees involved in the food distribution supply chain at ten diverse companies in the Puget Sound area. These included two large grocery stores, two large food distributors, and six smaller food processing, distribution, and import operations. They were asked about the nature of their business and their attitudes about government policy and market conditions. We also asked them about their experiences with alternative fuels, how they managed fuel use, and the issues in the supply chain to which they paid the most attention. The emphasis was on knowledge generation and exploration, given the limited existing understanding. Given this, the interview script included many open ended questions, which were asked prior to more narrow questions.

We then conducted truck counts at twelve grocery stores in the Puget Sound area from two major grocery marquees. The counts were conducted at stores in urban, suburban, and rural areas in the morning hours between 6:00 am and 12:00 pm. This data collection strategy was necessary due to the desire to understand both the number and timing of truck trips, but also truck driver and parking behavior.
From the counts and interviews, we found that large grocery store firms used larger trucks, travelled longer distances, and travelled more highway miles than local street miles. Large food distributors travelled a larger variety of routes, with a more diverse truck fleet. In contrast, smaller food distributors used smaller trucks, travelled shorter routes, and travelled mostly in urban areas, with less highway driving.

Smaller firms with smaller trucks delivered goods through the front door of the store, and used the customer parking lot. Larger firms, with larger trucks unloaded goods through the loading dock in the

back of the store. Smaller, local firms also made more frequent deliveries, delivering goods every weekday, while large firms made deliveries three to four times per week.

In urban stores, there was often a lack of a dedicated store parking lot. These urban stores often had covered garages, with loading docks inside the garage. Once again, many drivers, particularly from smaller firms, and those with smaller trucks, still preferred to use the front door for deliveries. However, they had to park their trucks in parallel spot, left turn lanes, or the travel lane. Deliveries at urban stores occurred earlier in the morning than at suburban and rural stores, when there was traffic on urban streets.

With respect to the adoption of alternatively fueled vehicles by the food delivery sector in the Puget Sound, we discovered the following:

- Smaller (with respect to number of trucks), independent companies could benefit more from alternative fuel trucks
- Public Incentives are not sufficiently tailored for or marketed to these small companies
- Natural gas trucks are currently too expensive to have a sufficient return on investment
- Firms reported that natural gas pilot programs brought out the performance deficiencies of current natural gas trucks
- Firms with shorter routes in urban area are ideal candidates.
- Firms with a customer oriented business model

In regards to natural gas, we found that three of the five large food distributors had implemented natural gas pilot programs, while none of the smaller food distributors (with fleets of fewer than 40 trucks) had implemented or considered natural gas truck engines, particularly for operating large trucks at highway speeds. The companies that had instituted natural gas pilot programs reported that the trucks lacked power and range.

Firms that began natural gas pilot programs are:

- Customer facing
- Have more than 40 trucks
- Use large trucks
- Operate on highways

Firms that began natural gas pilot programs stated the following issues:

- Lack power
- Short range
- Lack of refueling infrastructure
- High cost of trucks

Small food distribution firms place importance on fuel use reductions and emissions reductions. However, they do not have the resources to procure natural gas technology. The government grant and tax credit process is also cumbersome to navigate for smaller enterprises. These issues, together with the lack of refueling stations, means that alternative fuel vehicles are not a viable option for smaller firms.

Firms that did not began natural gas pilot programs are:

- Less than 40 trucks in fleet
- Business facing
- Characteristics conducive to natural gas include:
- Short routes
- Travel on urban roads
- Small trucks

At the same time, these small firms operate trucks and service routes that would be most conducive to reductions in fuel use and emissions if they switched to natural gas trucks, without any detriment to performance. Larger firms experimenting with natural gas trucks have found that while they benefit from fuel use and emission reductions, the trucks they use and routes they service are limited by natural gas engines. Care should be taken with new alternative fuel incentives so that they reach smaller firms that have been left out of the alternative fuel marketplace.

Alternative fuels technology is continually improving, and future advances may bridge the gap between diesel and natural gas in performance and range. We were recently told that one major manufacturer had brought to market liquefied natural gas trucks that were on par with diesel trucks of the same category in terms of performance. It is currently finalizing a deal with a major grocery store chain to sell these trucks. However, it is still important that the market for alternative fuels be as broad as possible, and small-to-medium food distribution firms remain priced out of the market despite government grants encouraging the adoption of these fuels.

INTRODUCTION

Washington State has a robust food distribution industry that provides food to residents of the Puget Sound region. This food must be transported from farms to processing plants, to warehouses, and finally to stores for consumption. Although this freight system helps sustain economic growth in the state, it also has significant impacts on traffic congestion, and carbon emissions.

The Washington State Department of Transportation (WSDOT) is interested in better understanding the food distribution system, and its potential responses to different policy and market scenarios aimed at reducing freight emissions. This research sought to understand the Puget Sound region's food distribution system and its transportation characteristics, as well as potential behavioral responses of food distribution supply chain companies to changes in public policy and market conditions. To do so, the research team conducted both interviews with food industry representatives and truck counts in the Puget Sound.

LITERATURE REVIEW

There is an active body of literature considering cost effective ways to understand goods movement. Here we discuss the most relevant segments of this literature.

Truck Data Collection

The most commonly used methods of data collection on truck activity are; travel diaries or surveys, manual counts, and GPS data collection. Here we briefly describe key approaches in each of these areas. Location counting and travel diaries have been used longest, with GPS data collection only becoming available in more recent years.

Clark et al. (2002) used the U.S. Census Vehicle Inventory and Use Survey collected from registered truck owners to model freight truck origins and destinations in Washington State. Using existing data is the least expensive way to predict the truck trips generated by distributors (Jessup & Lawson, 2004). However, it may not have the desired characteristics, so compromises in project design may need to be made. McCormack and Hallenbeck (2006) looked at the effectiveness of using truck windshield mounted transponders that are read at weigh-stations. They also tested the performance of GPS trackers mounted on volunteer trucks.

Fischer and Han (2001) outlined the advantages and drawbacks of vehicle classification counts, roadside surveys, and travel diary surveys for truck trip generation. Vehicle classification counts were found to be good for small survey areas, where driveways could be monitored and all traffic into and out of an area could be accounted for. In larger, neighborhood-wide studies, they were less effective. State agencies and contractors often use them to perform engineering analyses. However, the need for expensive, automated counting equipment made such counts less viable for this study. Fischer and Han also found that travel diaries had have very low response rates and tended to under-report trips.

Shin and Kawamura (no date) suggested initiating the research with simple supply chains, with only one or two origins for the freight traffic. In fact, focusing on one distribution center is ideal. Kawamura et al. (2005) also recommended that simple supply chains be studied, particularly those serving large volume stores, as there are fewer origins and destinations involved.

Surveys

Survey data allows us to understand driver or organizational behavior. Survey distribution can be a challenge, and generating sufficient responses is always so. Here we describe several ways that survey data is collected in freight transportation. Sample size and response rate were important considerations when planning surveys.

Jessup and Lawson (2004) conducted an extensive evaluation of various truck trip data collection methods. They found that telephone surveys had a very high response rate but limited the length of the survey. Managers were unwilling to spend large amounts of time on the phone. Mail-out surveys were less costly and time-consuming for the researchers, but response rates were lower and less representative of the trucking population. Small truck owners were poorly represented, while response rates from owner/operators were better.

Combined telephone and mail surveys solved many of the issues of mail-only and phone-only surveys stated above, but they were considerably more expensive and time-consuming to conduct (Jessup and Lawson 2004). Roadside interviews had the highest response rated and best sample control. However, they were disruptive to truckers, beholden to weather and time of day, and geographically limited. However, according to Samuel Lau (1994), these combined surveys are the most common.

Online surveys such as those facilitated by SurveyMonkey.com are an affordable and convenient solution to some of the above issues. However, controlling for knowledge of the respondent, quality of response, and response rate are ongoing challenges. WSDOT has used the method to administer user-satisfaction surveys for the SR 167 HOT lanes and found them to be successful, with a 10 percent response rate (Ukrainczyk, 2013).

In a separate study, McCormack et al. (2010) used telephone interviews and manual truck counts to investigate relationships between freight trip generation and land use for grocery stores. They used telephone surveys and manual data collection to ensure a high response rate and reliable and unbiased survey respondents. Kawamura et al. (2005) also reported that survey questionnaires and store visits provided the most detailed data, and only validatable data, particularly regarding the amounts and the types of goods moved.

Natural Gas Vehicles

Conversion of freight vehicles to natural gas presents a number of challenges. Heaslip et al. (2014) identified the difficulties associated with adopting natural gas engines for heavy-duty truck fleets. The large amount of fuel used by these trucks means that the adoption of natural gas as a fuel would significantly reduce carbon emissions. However, the large power requirements of these trucks would create fuel efficiency penalties, and limitations in access to refueling stations and the greater expense of natural gas engines are further reasons for trucking companies' reluctance to adopt natural gas as a fuel. Jaffe et al. (2015) also observed that the lack of refueling infrastructure is an impediment to widespread natural gas adoption. However, Utah has found success in encouraging conversion to natural gas trucks with a tax credit that provides 35 percent of the incremental cost of a new natural gas engine. Jaffe et al. (2015) found that the most compelling case for natural gas trucks could be made for long distance fleets that travel in excess of 120,000 miles per year, in order for the fuel savings to pay for the natural gas truck premium.

In addition, diesel has been shown to produce 75 percent more PM exhaust during stop and go city driving than during highway driving (Ayala et al). Converting local delivery trucks to natural gas would therefore yield additional savings in PM emissions. These savings in PM emissions would be less significant on highway routes. Step-vans can be both gasoline powered and diesel, although diesel step-vans are more common. A search of two local online classified websites revealed that 80 percent of listed trucks were diesel, while 20 percent were gasoline powered.

Wolmarans (2014) suggested using Regulatory Impact Assessments (RIAs) to measure the economic benefits and costs of regulations on businesses. Assessments conducted in California in response to the California Air Resources Board's Alternative Fuel Vehicle Incentive Programs did not find evidence of loss of business. However, this may have been a result of California's prominent status in the movement of goods. Washington's position may not be as favorable, indicating the need for RIAs.

Wolmarans (2014) suggested funding alternative fuels adoption through tax credits, grants, and pilot programs, as well as promotion of low-emissions branding. These approaches were included in this project's hypothetical policy scenarios.

These previous studies informed our choice of the best data collection approach for this study. Relationships have been established with food distribution firms, and we interviewed managers at these firms on their business practices. Qualitative interviews were the only appropriate approach with such limited knowledge of the current decision making framework. This approach allows the researchers to listen and learn, and then create the decision framework, rather than applying one a priori. We then conducted truck counts at some of these locations, using knowledge gained from the interviews to inform our counts. Again, this is the only appropriate approach with such complex location design (multiple access and egresses and multiple parking locations), and such broad information requirements (truck type, good, parking location, dwell time, etc.).

METHODOLOGY

Interviews

Qualitative interviews were selected to understand the food industry's response to potential policy and market condition changes aimed at reducing freight emissions. This approach is best when the key decision elements and perspectives are not well understood, and need to be explored through open-ended questions, as opposed to a context with higher levels of initial problem understanding, when a fixed-question survey approach may be more appropriate. The number of interviews conducted allowed for saturation—a sense that respondents were converging on similar topics or opinions— and stayed within project budget.

Identifying Interview Candidates

Interview candidates were identified through online research as well as existing WSDOT contacts in the freight transportation industry. Ten firms involved in the distribution of food in the Puget Sound were chosen to represent a diverse sample of distributors, retailers, and producers at the local and national geographic scales. Candidates were selected because of their location in the Puget Sound, their willingness to be interviewed, their availability, and their involvement in food distribution as their primary business. Only food retailers and producers that were also involved in distribution were interviewed. The interviews provided the most in-depth source of information and were the most convenient way for individuals from the businesses to provide that information. It took only one hour of their time, with no further effort beyond talking.

With each interview, a phone meeting was set up to determine whether the individual had sufficient knowledge to participate in the in-depth interviews. If the contacted employee was not suitable, then an alternative employee was sought. If no one at the firm was suitable, a new firm was found to replace it. Employees at three firms were found to be unsuitable. One was replaced by another employee at the same firm, while the two others were replaced by other firms.

In order to increase response rates, the research team arranged for interviews to take place at the respondent's place of business. In order to improve the quality and completeness of information, questions were designed to make interviewees as comfortable as possible. For example, all interviewees were asked for permission to record interviews. Questions were designed to be reasonable and easy to answer on the spot.

Employee knowledge required for the long-term strategy interviews included:

- Corporate attitudes to new policies aimed at reducing emissions and actions taken to comply with those policies
- Approaches to future changing market conditions, especially concerning the price of various fuels, consumer attitudes toward sustainable companies
- Strategies for selecting service and route corridors
- Technological innovation and investment
- Emission reduction practices
- Alternative fuel use
- Corporate attitudes to new policies aimed at reducing emissions and actions taken to comply with those policies
- Approaches to future changing market conditions, especially concerning the price of various fuels, consumer attitudes toward sustainable companies

Employee knowledge required for the day-to-day operation interviews included:

- Distribution center location
- Customer location
- Fleet size
- Trucks in fleet
- Truck replacement policy
- Selection of truck type by destination
- Amount of goods coming or going to a particular zone
- Who are their contractors (owner-operators, logistics firms, etc.)
- Categories and classification of facilities

Individuals selected for the interviews were involved in the logistics management and warehouse operations. Their job titles and descriptions are provided in Table 4.

Table 4: Individuals Selected for Interviews

Title	Role
Vice president of logistics	Manages strategy for warehousing and transportation. Warehouse managers and transportation managers report to the VP of logistics.
Vice president of transportation	Manages strategy and high-level operations for trucking and shipping, both upstream and downstream. Transportation managers report to the VP of transportation.
Vice president of depot operations	Manages strategy and high-level operations at warehouses. Warehouse managers report to the VP of depot operations.
Director of transportation	Manages strategy and operations at warehouses. Found at medium sized firms, does long-term and day-to-day management.

Operations manager	Managed transportation and storage in addition to other duties at the factory or warehouse.
Warehouse manager	Managed storage, incoming deliveries and outgoing shipments at a single warehouse.
Plant manager	Managed production and outgoing shipments at the site of production.
Driver	Made deliveries from warehouse to stores, managed stock at stores and cultivated relationship with store managers.

Table 5: Types of employees that were sought, according to size and type of business

Type	Producer	Distributor	Retailer	Carrier
Large firm (>40 trucks)	VP of transportation Warehouse manager	VP of logistics Warehouse manager	VP of logistics Operations manager	VP of transportation Operations manager
Small firm (<40 trucks)	Plant manager	Warehouse manager	Director of transportation	Operations manager

In-Depth Interview Script

An outline of discussion topics and open-ended questions was used during the in-depth interviews. The outline addressed the following topics:

- What changing market conditions have you had to adapt to in the last 3 years?
- What actions did you take to adapt to those changing market conditions?
- What actions are you taking to minimize the adverse impacts of future changes in the market?
- What government policy changes have you had to adapt to in the last 3 years?
- What actions did you take to adapt to those changing government policies?
- What actions are you taking to minimize the adverse impacts of future government policies?

The interviews emphasized emission reduction and economic decisions and opened discussion about the participants' perspectives on policies for reducing emissions and promoting natural gas. These questions allowed the researchers to explore the effects of government policies, how well those policies are received, and how to best construct future policies to guarantee maximum effectiveness and adoption. During the interview, questions from the interview script were asked, and open discussion was encouraged. Efforts were made to address all candidate policy changes and to focus the conversation on the most relevant topics. Interviewees were told that any answers they provided were confidential. The results of these interviews are discussed in Results. Topics were brought up in the following order:

1. Market conditions and general opinions

2. Policy questions
3. Voluntary actions that the firm had taken to reduce emissions
4. Public perception in decisions concerning carbon, particulate matter (PM), and NOx emissions

The following items were addressed to increase impartiality and accuracy:

- Leading questions about potential market and policy scenarios were avoided
- Policy changes likely to happen and their effect on the firm and its competitors.
- The importance of emission reduction and technological innovation for the benefit of air quality.

Supply Chain Firm Interviews

Eleven employees from ten firms were interviewed, with many of the business connections provided by WSDOT's Freight Systems Division. Five participants were employed in a management role and five were employed in an operations role. Those in a management role answered questions about fleet acquisition and strategic planning, those in an operational role about operational tactics. The interview script is found in Appendix A.

The businesses interviewed are shown in Table 6.These stakeholders represent the food supply chain from producer to finished product, as well as along the spectrum of product volume. Product volume is important, as it is strongly correlated with the ability to consolidate and efficiently use intermediate facilities and equipment.

Table 6: Interview summary

Title	Type	Scale	Method
Operations manager	Distributor	National	Phone screen and in person
Director of transportation	Distributor	National	Phone screen and in person
Operations manager	Distributor	Local	Phone interview
Operations manager	Grocery Retailer	National	Phone screen and in person
Vice President, Transportation	Grocery Retailer	National	Phone screen and in person
Director of transportation	Grocery Retailer	Local	Phone interview
Vice president, depot operations	Warehouse Retailer	National	Phone screen and in person
Director of transportation	Retailer	Local	Phone screen and in person
Warehouse manager	Distributor	Local	Phone screen and in person
Operations manager	Producer	Local	Phone screen and in person
Owner/operator	Producer	Local	Phone interview

Large food distributors were full service operations that provided food to:

- Restaurants
- Large corporate offices
- Educational and healthcare campuses
- Grocery stores

One such large food distributor had warehouses in Kent and Edmonds; the other had a single Seattle area warehouse in Kent.

The national grocery stores selected received bulk goods in the supply chain, and they commanded fleets of 1400 to 1800 trucks. The national grocery store chain had a 15 percent market share in the region. That chain had also already replaced 40 of its Oregon-based diesel trucks with natural gas trucks and had seen a 23 percent drop in greenhouse gas emission for those trucks. Their employees were asked what the impetus for that decision was, and what conditions in Washington would encourage them to adopt a similar change here (Golbraith 2011).

The grocery store chains interviewed control 45 percent of the market (Beaman & Johnson, n.d.). Market share was not calculated among food distributors and smaller food producers due to a lack of industry data. All of the major firms interviewed had operations in the Kent valley region of Puget Sound.

Survey

Following the in-depth interviews, the outcomes of the interviews were summarized and used to inform the design of a survey. Hypothetical policy scenarios and four market force scenarios focused on carbon, PM, and NOX emissions were presented to the respondent. The policies were designed to address the weaknesses of previous policies discussed during the in-depth interviews and incorporated any suggestions given by the supply chain firm or grocery store employees. These scenarios include:

- Public financial incentives or disincentives
- Changes in the cost of diesel and natural gas
- Competitors actions on natural gas technology

In addition to the scenarios, the survey asked fundamental questions about the operation of the business. These questions can be found in Appendix A.

Survey distribution:

- 224 firms are listed in the ReferenceUSA.com database as involved in food distribution, production, or sale in the Puget Sound area.
- The survey was sent by email to the 61 individuals for whom contact information was found on ReferenceUSA.
- 2 additional reminders were sent requesting the recipient to complete the survey.
- Five responses to the survey were received.
- This 8 percent response rate is typical for email surveys.

Unfortunately, the low response rate, combined with the small sample size, resulted in insufficient data collected from the survey. If either the sample size or the response rate could be significantly improved,

such as expansion to a national population, then enough businesses might be reached to retrieve an adequate response. However, our qualitative interviews achieved a 20 percent response rate.

Truck Counts at Food Distribution Facilities

Single facility counts during working hours were the most reliable way to gather data on truck arrivals at grocery stores. This allowed us to count every truck that arrived at that store during counting hours. To understand truck behavior involved in food distribution, truck arrivals and departures were counted and observed at Puget Sound area grocery stores. We chose to count truck arrivals at grocery stores because they are a major component of the end-user side of the supply chain.

Additionally, grocery stores are a centralized food destination, with many deliveries occurring throughout the day, allowing for effective use of the researchers' time for counting trucks. Restaurants and cafes were excluded due to the large number of restaurants and their operational diversity. Overall, these counts augmented our understanding of area food distribution supply chains based on the qualitative surveys, allowing us to confirm anecdotal data, as well as draw new conclusions about the supply chain and its transportation characteristics.

Use of human counters was the most appropriate approach, given the complexity of truck maneuvers around grocery stores. Typically, a truck can access the store through several parking lot and loading bay entrances and exits. In addition, drivers do not all approach the same door of the facility; some enter through the loading bay and some enter through the front door. Finally, trucks may not always use the same parking locations, depending on other vehicles and traffic. These complexities prevented use of a fixed location technology solution. Furthermore, additional behavioral observations could be made with human observers, including driver behavior.

Tour-based data collection was considered and trialed. Due to the large variation in travel time between locations, this method could not produce statistically reliable results.

To summarize, the following features of truck activity and behavior were captured by human observers:

- Time of truck arrival
- Time of truck departure
- Trucks' parking behavior
- Types of trucks
- Photograph

Counts at the 12 stores were conducted at rural, suburban, and urban locations. Urban grocery stores were defined as located in central Seattle neighborhoods, inside mixed-used developments, and accompanied by parking garages rather than parking lots (see Figure 8). Note the garage, lack of open parking lot, and high density mixed use development (google.com). Data collection point of view is on the left.

Figure 8: Urban grocery store

Suburban grocery stores were defined as sites with large setbacks from wide arterials and surrounded by neighborhoods of predominantly single-family homes, which formed contiguous development with the city of Seattle (see Figure 9). Note the adjacent large arterial street, large parking lot, single story, and single use development (google.com). Data collection point of view is on the left.

Figure 9: Suburban grocery store.

Rural grocery stores were located in small towns separated from contiguous urban development by farmland and open space (Figure 10). At first glance, characteristics are similar to the suburban grocery store. However, this store is in a remote area 20 miles from central Seattle. The surrounding land uses are agricultural, and the city is not contiguous with development in the Seattle metro area (google.com). Data collection point of view is on the left.

Figure 10: Rural grocery store

All facilities required one counter to be present for data collection. The following items were also needed: University vehicle, orange safety vest, clipboard, pen/pencil, data collection sheet, camera, annotated facility map, and watch.

Counting was conducted on twelve weekdays between June 4 and September 28, 2015. Counts were conducted between 6:00 am and 1:00 pm because this is the period of most significant truck activity (Store Manager interview, McCormack, Ta, Bassok, & Fishkin, 2010). These counts can be seen in Appendix B.

The counter would park in a location where both the loading dock and parking lot were visible. If it was not possible to see both the loading dock and parking lot from a single location, the counter would watch the driveway entrances to the facility and follow every truck entering the driveway to its final destination, whether that was the loading dock or some other location in the parking lot. Whenever a truck arrived at the grocery store and settled into its loading location, the counter would take a time-stamped picture of the vehicle; the photograph provided a record of the truck and the time it arrived. Counters took additional notes about the truck dwell time and any other details that they deemed important.

For truck counts, six mid-market chain grocery stores and six upscale chain grocery stores were selected for counting. All stores belonged to two national grocery store conglomerates with a combined market share of 41 percent of Seattle area customers. The upscale chain controlled 12 percent of the market and the mid-market chain controlled 27 percent. These stores were the most common grocery stores in the Puget Sound area, used by consumers of all income levels for day-to-day grocery needs. Stores from each of three land uses and two market levels were selected for data collection to account for differences in vehicle accessibility, parking, and congestion (Table 7). We hypothesized that stores in areas of less density would receive deliveries at more different times of the day in comparison to stores in high density urban areas. We also predicted that the types of trucks used and the number of trucks making deliveries would vary with the density of the store's surrounding development.

Table 7: Primary truck count summary

Store Type	Number surveyed	Land use
Upscale grocery store	2	Rural
	2	Suburban
	2	Urban
Mid-market grocery store	2	Rural
	2	Suburban
	2	Urban

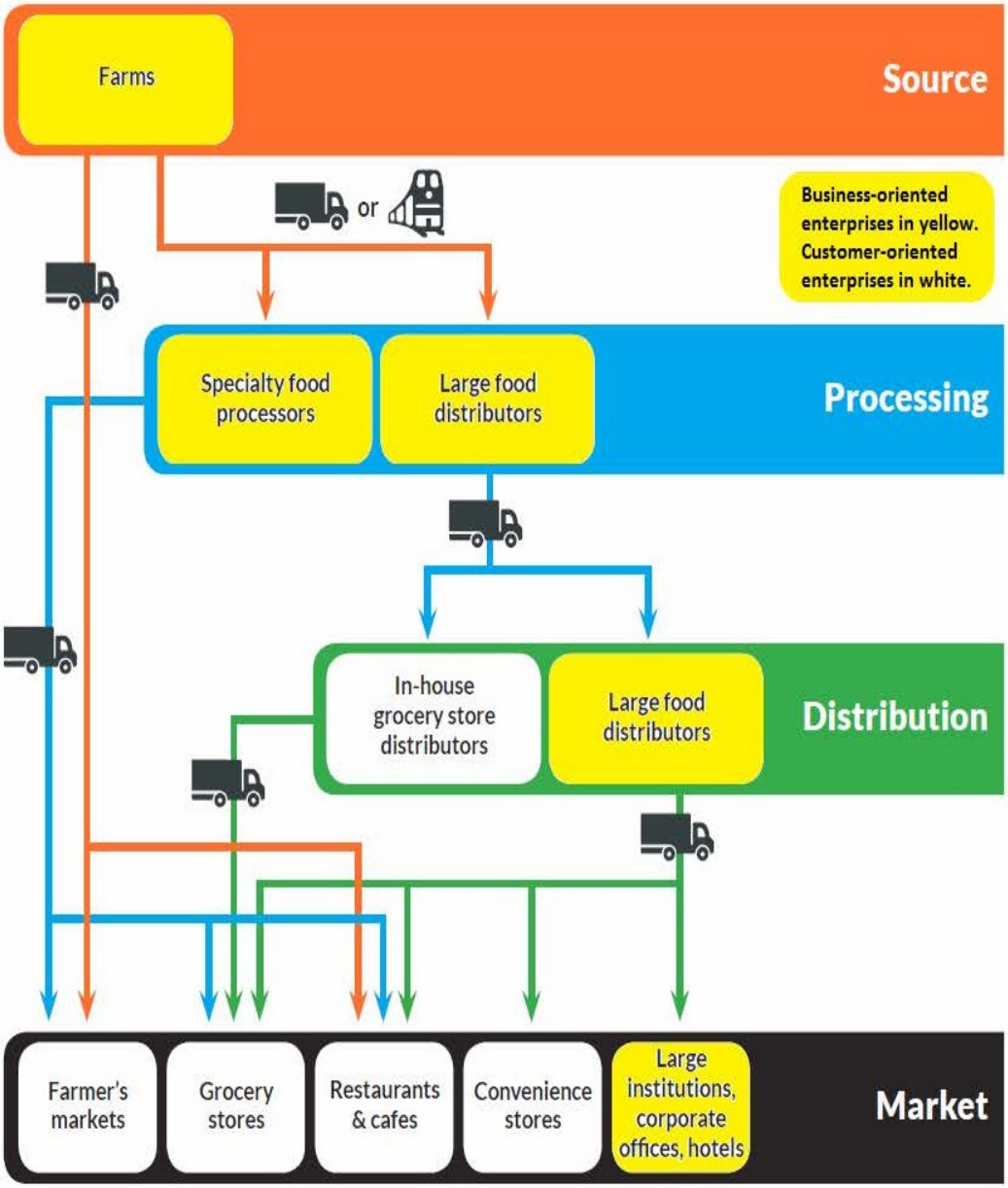
RESULTS

The Food Distribution Market

Figure 11 shows the food distribution system graphically, where goods flow from farms to food retailers in many cases stopping at food processors and, food distributors. Operations vary in size, from small specialty food producers to large operations. In this project, we focused on the last leg of the supply chain, from food distributors to the point of consumption. while also surveying food producers who distributed their products directly to the retailers.

We define smaller producers and distributors as those operating fleets of 40 or fewer trucks with a single facility, and larger producers and distributors with more than 40 trucks and multiple facilities. Note: Arrows denote the movement of food goods. The dark black line divides consumer oriented firms from nosiness-oriented firms.

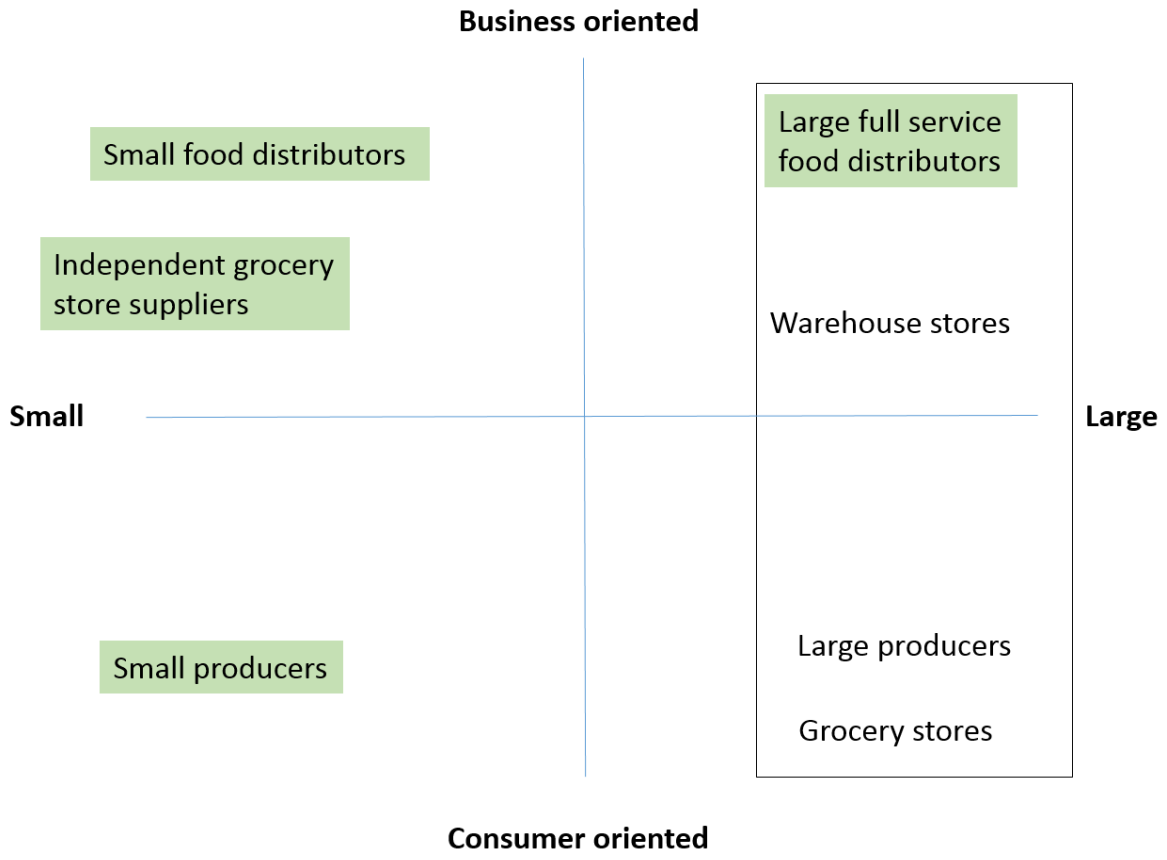
Figure 11: Food Distribution Supply Chain



Classification of Food Distribution Companies

We can classify our food distributors by their customers. Business oriented distributors see others businesses as their customers. Consumer oriented distributors see individual consumers as their customers. Figure 12 maps the interviewees across business-consumer orientation, and size.

Figure 12: Business-Consumer Orientation



Business oriented distributors

Because these distributors serve a small number of customers, each customer influences significant power over distributor behavior and decision-making. For example, one large distributor purchased a new truck when the large educational institution it serviced requested that it make deliveries to them using a natural gas truck. Customers are typically large institutions such as hospitals and prisons, national chain restaurants, and other large buyers. Products include prepared and semi-prepared foods. Two of the businesses interviewed were major dedicated full-service distribution firms, and both firms expressed the need for flexibility when making deliveries to clients.

Consumer oriented distributors

Consumer oriented distributors see the end user as their customer. Although the food delivery occurs at a grocery store, the end-user influences distributor decision making. This is in contrast to business-oriented distributors who see the destination of the goods as the customer. From the consumer's perspective, the distributor and the grocery store are the same entity. Although end-users are customers, and influential, there is a large number, and individual customers may exhibit little power.

In-house grocery store distributors are consumer oriented. They serve their own stores. Customers are individual end-consumers, so individual customers have little power. Grocery store distributors were much less likely to change their practices in response to customer demand.
Warehouse membership grocery stores reported being particularly inflexible and went to great length to preserve the homogeneity of their fleet. This led to great savings in their maintenance and purchasing, but made them less flexible for new technologies and sustainability strategies. These stores are similar to grocery stores, and have their own in-house distribution centers, but with amplified tendencies.

Note: This diagram shows the placement of different players in the food distribution industry on an axis defined by business size and proximity to the end user. For small distributors, the distribution center was often in the same building as the production facility, if they were producers or refiners of food products. Small distributors Most often their fleets had fewer than five trucks.

Direct Store Delivery

Direct store delivery (DSD) drivers are a unique category of grocery store delivery that combines the roles of salesman and delivery driver. Based on the testimony of the driver/salesman for a large bread company, we learned that these employees make visits to the same stores every day, deliver goods, check stocks, order merchandise for the store, and maintain a working relationship with the store manager on behalf of the supplier.

Because they serve both of these roles, they have some different behavioral characteristics than those serving only the delivery driver role. DSD employees will visit the same five to ten stores every day to maintain good relationships with the manager. The store manager will decide where in the store the DSD can display product, and the amount of shelf-space the DSD employee is allocated. DSD employees earn revenue on commission by the units of product sold, so good shelf-space and location can increase earnings. In order to develop and maintain relationships with store managers, DSD employees spend more time at the store, in addition to visiting more frequently. Smaller truck dwell times ranged from 45 to 60 minutes, while large trucks took longer, ranging from 45 to 90 minutes, as shown in Table 8.

Table 8: Driver dwell time

Truck Type	Dwell Time
Large trucks (over 26,000 lbs.)	45 to 90 minutes
Small trucks (under 26,000 lbs.)	45 to 60 minutes

Driver Concerns

In interviews, drivers and logistics managers expressed several concerns about driving and parking trucks while making deliveries. For trucks serving food delivery in the Puget Sound region, the majority of route time is spent parked at a stop. Additionally, it can be difficult for drivers in urban locations to find a place to park. Drivers reported to be willing to make only one trip around the block to look for parking locations. If no spots were available, drivers would:

- Park in the left turn lane
- Park in the right turn lane (such as in Figure 13)
- Park in the traffic lane (such as in Figure 14)

Figure 13: Parking in the left-turn-lane, Capitol Hill, Seattle

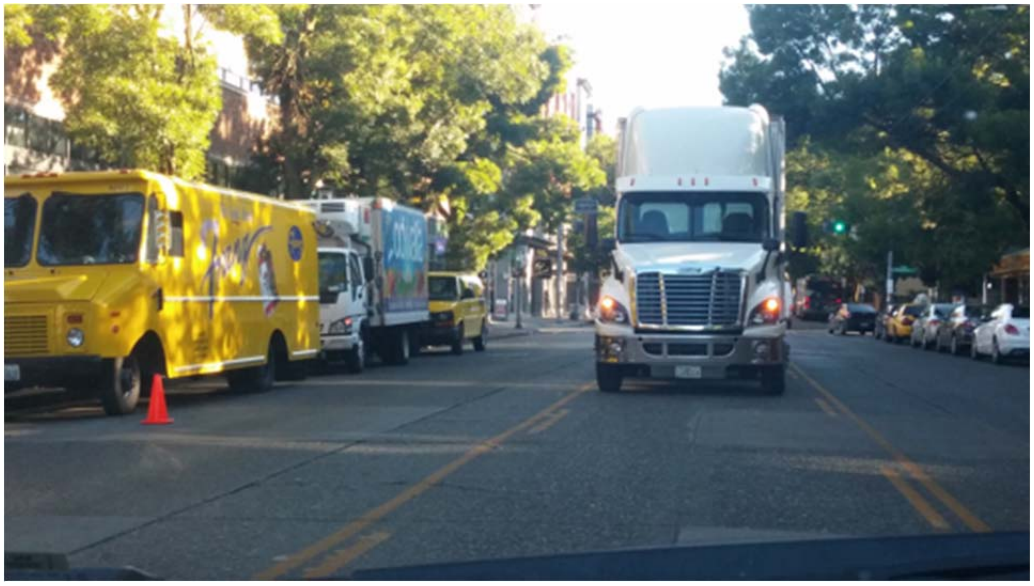
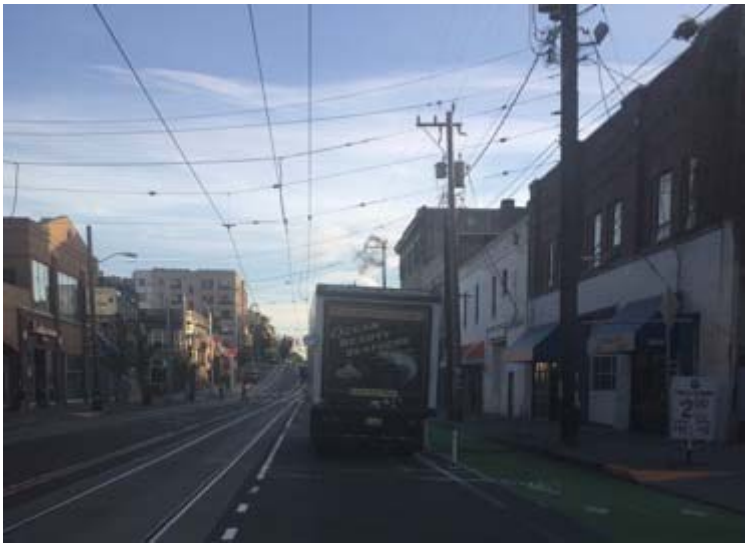


Figure 14: Blocking the traffic lane



One driver reported that they avoided garages, as they are difficult to maneuver inside. Drivers avoid backing out of any space. The driver is uncomfortable because of concern about surrounding traffic, pedestrians, and vehicles, as truck driver's sight is severely limited (see Figure 15).

Figure 15: Congestion at Queen Anne, Seattle, grocery store loading dock

Parked cars can narrow the traffic lane, causing difficulty for trucks navigating the street. This may cause drivers to reroute. For example, MLK Boulevard is preferred to Rainier Avenue.
Delivery drivers reported occasionally accruing parking tickets. Drivers paid tickets out-of-pocket in most cases, although the company sometimes paid parking fees. One driver mentioned that he avoided idling in consideration for the company's image. This was particularly true for suppliers that produce sustainability minded and healthy products.

Drivers avoid local street congestion by visiting high traffic areas, such as the University District in Seattle, first in the morning. Highway congestion is avoided by arriving in the service area before morning rush hour and leaving after the morning rush hour. One driver stated that he never entered I-5 after 7:00 am and returned to the distribution center by noon.

Natural Gas Experience

Natural gas fuel has been making recent inroads into the food distribution supply chain. Several companies have experimented with these trucks, and have run into performance issues that hinder their further adoption. Several other companies have chosen not to try natural gas fuel, or are unable to afford it. There are several factors that determine the usefulness of the truck, due to:

- truck size
- route length and route type
- truck and fuel cost
- type of business (customer facing, business facing)

Both of the large grocery store chains had experimented with natural gas truck use, although both expressed reservations about the trucks' usefulness. Both firms expressed disappointment in the lack of

power and refueling infrastructure to support natural gas use. Both firms had purchased compressed natural gas trucks for a pilot program, although the grocery store purchased more trucks than the membership warehouse store. These grocery store chains operated large, Class 8 semi-trailers in excess of 33,000 pounds (see Figures 16 and 17).

Figure 16: Truck classification chart (ctbsales.com)

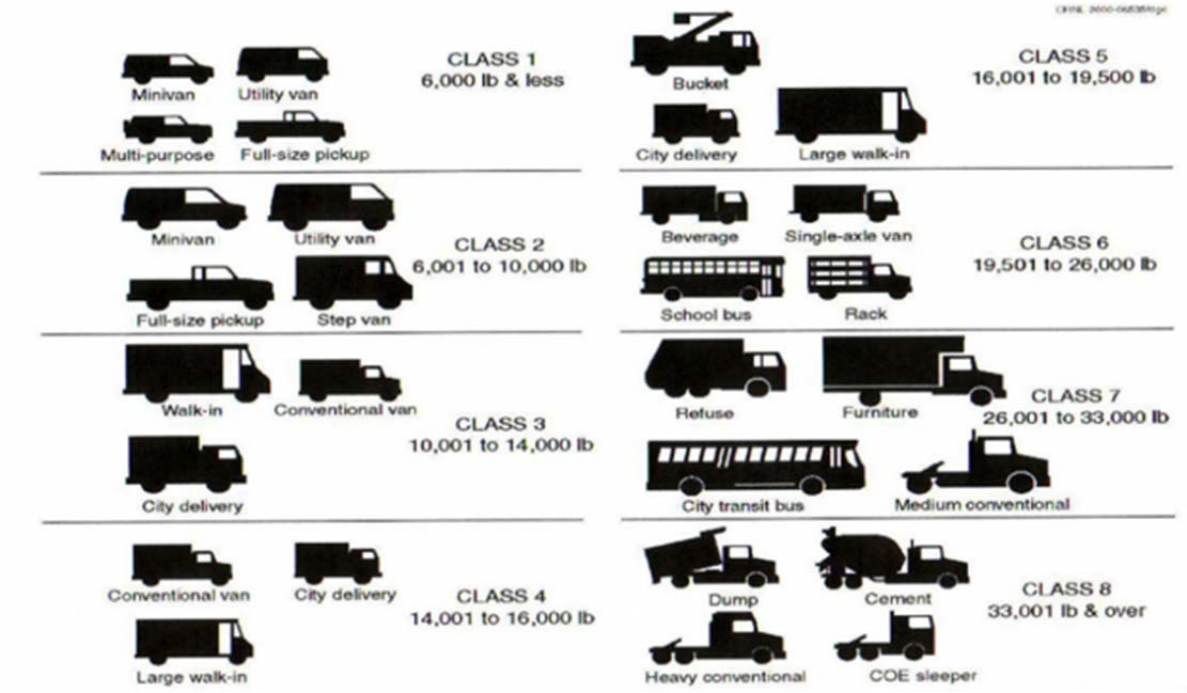


Figure 17: Liquefied natural gas large Class 8 truck used in grocery store pilot program (fleetsandfuels.com)

The businesses reported that natural gas powered engines could not produce the required power to propel the trucks up steep grades in the region, nor reach highway speeds in a timely manner. The reduced range of the trucks was also an issue, especially because of the lack of refueling stations.

The two major food distributors interviewed did not purchase any natural gas trucks; however, they did conduct an analysis of the benefits and costs. They concluded that the benefits did not outweigh the cost, and cited many of the same concerns as the grocery store chains: the range was insufficient, the trucks are underpowered, and the cost of conversion is too great.

Both of the major grocery store distributors said that, ultimately, there would not be sufficient return on investment for this technology. The fuel savings attributable to the improved efficiency of natural gas and its lower price per gallon were not enough to offset the nearly 100 percent cost increase of the truck purchase.

The warehouse club store had also looked into the feasibility of using natural gas trucks. It researched the experience of other food distributors that had launched pilot programs. The interview participant stated that they were hesitant and cautious when considering the adoption of new technologies. The vice president of transportation mentioned that they had considered purchasing bio-diesel trucks in 2008 but decided against it because of the unproven nature of the technology. The company was taking a similar approach to natural gas truck adoption. The warehouse club company also maintains a very homogenous truck fleet to control costs and ease maintenance. Its entire fleet of 600 trucks is produced by one manufacturer through a long-term contract agreement. All of the trucks have the same engine. Procuring a pilot fleet of natural gas trucks would introduce variances in maintenance and operation procedures that would complicate operations and increase costs.

The smaller food distributors and producers interviewed reported that they had not seriously considered adopting natural gas trucks because of the high cost of buying a natural gas truck or converting an existing diesel truck to run on natural gas. One specialty food importer said that its 30 trucks were all bought used, in the age range of 5 to 10 years, and at an average cost of $25,000. A new comparable natural gas truck would cost $100,000. The manager of one import business reported that it was not feasible to buy even one such natural gas truck as a test.

The smaller food distributors served shorter routes, with less highway use and more urban driving than larger distributors. Smaller distributors used smaller trucks, Class 6 and below, under the 26,000-lb. weight limit requirement for a commercial driver's license (see Figure 18). These trucks are not as susceptible to the shortcomings outlines by transportation managers. They spend less time traveling at highway speeds, require a shorter fuel tank range, and carry less weight. Larger food distributors also operate small trucks on shorter, urban routes in a similar manner for some of their deliveries.

Figure 18: Class 4 truck used by many smaller food producers

Smaller food distributors, small food producers, and larger food distributors on certain routes would be good candidates for fleet conversion to natural gas trucks. Smaller food distributors operate largely in dense urban areas, where the emissions from diesel vehicles are particularly harmful to individuals who live near major thoroughfares that are used by delivery vehicles. Changing the fuel that is used on these routes would have the biggest benefit to carbon emissions, as well as local air quality and in turn the health of local residents. However, small food distributors and producers are least financially able to procure expensive natural gas engines, and do not have the resources to navigate the federal, state, and local grants and financial incentives for natural gas vehicles.

Overall, the fuel was more conducive for use in smaller trucks, on short routes in urban areas. Operators of large trucks on long routes found that the performance of the natural gas engines was insufficient. Smaller food operators were unable to afford the large costs of procuring the truck. Despite natural gas fuel being cheaper than diesel, diesel trucks could be operated for a fraction of the cost.

Truck Counting

Table 9 and Figure 19 show the average arrivals per hour by land use type. As can be seen by the green line in Figure x, the number of suburban truck arrivals peaked at 9:00 am with nearly four trucks per hour per location. Deliveries were most frequent between 7:00 am and 10:00 am. Few deliveries were counted at 6:00 am or after 11:00 am. However, suburban stores received significant numbers of deliveries at 6:00 am.

Urban stores arrivals were more concentrated in the morning, we conjecture that drivers aim to avoid the morning rush hour in congested urban areas. Deliveries in rural areas were more consistent throughout the day, peaking at two trucks per hour in the late morning period. Interviews with food distribution operators indicated that this is to avoid congestion in urban areas.

Table 9: Average truck arrivals

Type	6:00	7:00	8:00	9:00	10:00	11:00	12:00	Average	Median
Overall Average	1.4	2.1	2.2	2.5	2.3	1.4	0.2	11.1	26.0
Urban Average	0.7	3.7	2.0	2.0	2.0	1.7	0.3	12.3	24.0
Suburban Average	2.7	2.0	2.7	3.7	2.7	0.7	0.0	14.3	24.0
Rural Average	1.0	1.0	2.0	2.3	2.3	1.3	0.0	9.8	36.0

Figure 19: Average truck arrivals by hour at store

Table 10: Types of trucks by prevalence, in arrivals per day

Type	All	Urban	Suburban	Rural
All	14	13	17	15
Box Truck	7	44%	51%	37%
Semi-Trailer	3	13%	12%	28%
Step Van	2	15%	13%	20%
Pick Up	1	0%	4%	5%
Van	2	17%	19%	7%

Urban and suburban stores had similar median dwell times, around 24 minutes. Rural stores had significantly longer dwell times, with a median of 36 minutes. Because deliveries to rural stores are steadier throughout the day, drivers may be able to take their time when unloading goods at rural stores. Table 11 shows large distributors represent a larger percentage of deliveries in rural areas, and vice versa, small distributors represent a larger percentage in urban areas. Locals relied heavily on DSD drivers and close driver relationships to store managers. Locals rarely used docks. They used the front door 80 percent of the time to allow foster relationships between the delivery person and store manager. In contrast, trucks delivering products from nationals, such as Pepsi, Coors, and Kraft, made use of the dock for nearly all deliveries (70 percent dock vs front door). Locals delivered product every day; nationals delivered product a few times per week according to store managers at the location surveyed. Locals used box trucks and vans; nationals were more likely to use step-vans and semi-trailer trucks (see Table 12).

Table 11: Number of daily trucks by operator size, and percentage of total truck arrivals

Type	All	Urban	Suburban	Rural
Local company	9	8	11	9
	63%	62%	66%	60%
National company or subsidiary	6	5	6	6
	37%	38%	34%	40%

Table 12: Proportion of all trucks by type and operator company size

Type	Local company	National company or subsidiary
Box truck (class 7 and below)	33%	13%
Semi-trailer (class 8)	9%	10%
Step-van (class 3)	2%	15%
Pick-up (class 1)	3%	0%
Van (class 2)	15%	1%

Other Stakeholder Concerns

The most cited concerns among food distributors are: Hours of Service regulations; driver labor shortages; fuel efficiency and fuel use reduction; and particulate matter filter regulation.

Worker Hours

Hours of Service Regulations are the policy issue of most concern to Puget Sound food distribution. Every large food distribution and grocery company mentioned that state and federal legislation restricting worker hours had affected their business. The warehouse manager for one major food distribution

company said that the restrictions contributed to the driver labor shortage, and that ensuring their drivers meet government policy was challenging. The same manager mentioned that the regulations had changed three times in the past ten years, requiring frequent revisions to documentation and scheduling. Complying with the law required constant changes to driver education and training. Respondents described the resources required to comply with the law:

1. Two of the four larger companies had implemented computerized driver logs.
2. Driver- education efforts among all large the companies interviewed to ensure that all drivers were aware of the policies.

However, respondents also recognized that implementing these technologies has improved their ability to monitor their driver's work and performance.

In contrast to the larger distributors, smaller food distributors and food manufacturers did not mention hours of service regulations are unaffected by these policies because of the local nature of their operations. Their drivers do not spend the majority of their working hours driving; rather, they spend a large amount of time moving goods from the trucks and interacting with employees at the destination facility. In addition, their vehicles operate inside a 300-mile radius of their facilities and therefore are not affected by Hours of Service Regulations. While large companies are very concern about any changes to Hours of Service Regulations, smaller companies are not as concerned and would be unaffected by any changes or incentives.

Fuel Efficiency

Fuel efficiency was the second most commonly cited cost concern among all of the food distribution companies. They had all made efforts to improve the efficiency of their vehicles to reduce fuel costs, particularly by fully loading trailers to minimize truck trips. Grocery store companies made a great effort to ensure that every trailer was maximally loaded to optimize fuel spending per ton-mile. All firms also attempted to incorporate back-hauls, or loaded return trips, into their schedule, thereby minimizing the miles travelled by empty trucks. The four major firms stated that 15 percent of their capacity was back-haul.

The major carriers also made efforts to purchase fuel with pricing agreements and to negotiate fuel prices with fuel distributors. Preventative maintenance for trucks was also a major concern, as well maintained trucks use less fuel. Efficiency often went hand-in-hand with emissions goals.

The smaller firms reported giving less attention to reducing fuel consumption. Fuel costs were considered a constant cost of doing business. They did not have the resources to purchase sophisticated fuel-efficient trucks or the resources to track fuel consumption across routes. The smaller the truck fleet being operated, the less attention was paid to fuel consumption.

Fuel efficiency did take a back seat to labor costs for every food distribution company. Worker pay and compensation were brought up more often among food distribution firms.

Particulate Matter

Two of the four large distributors stated that they were focused on exceeding state regulations on truck emissions. None of the smaller distributors considered emissions when considering truck purchases or retrofitting. One large grocery distributor was concerned with emissions depositing soot on its white

trailers. This distributor made a collaborative effort with its truck engine supplier to improve the emissions of its engines, to great success. Current versions of its truck engine do not leave a sooty deposit on its trailers.

Three of the distributors complained about the detrimental effects of state requirements for the use of diesel particulate filters and diesel emissions filters. Interview participants mentioned that these impeded truck performance, and their change cycles complicated truck maintenance. The transportation manager for one large warehouse store mentioned that they struggled to find the ideal time to change the filter to minimize power and efficiency loss, as well as down time. He mentioned that there was a trade-off between fuel efficiency and particulate emissions.

DISCUSSION

Natural Gas Conversion

There is a disconnect between 1) the delivery methods, routes, and trucks that make viable candidates for natural gas conversion and 2) the resources and motivations of the companies that utilize the different delivery methods, routes, and trucks. The defining factors in determining the feasibility of a natural gas program for a given company are company size and its business orientation to its customers. Small companies are prime candidates. In particular small companies who serve other businesses may overlook natural gas pilot programs despite their suitability to them. Such programs would results in fuel cost savings and reduction in particulate matter, NOx, and carbon emissions

Large firm characteristics

Large national food producers, food distributors, and grocery chains (most often a national company or its subsidiary) operate large trucks, with large loads and infrequent deliveries to stores. Larger, national firms, and dedicated grocery store fleets delivered goods two to three times per week. Whereas local firms use step-vans and smaller sub-26,000 lb. box trucks for grocery store deliveries, the national food distribution firms use box trucks and semi-trailers. This was confirmed by a delivery driver who had worked for both national and regional food production firms. A summary of the characteristics of each type of company is found in Table 13.

Table 13: Company characteristics by relative size

Characteristic	Large companies	Small companies
Route length	Longer	Shorter
Route type	Highway	Local street
Truck size	Larger on average	Smaller on average
Stop per route	More	Fewer
Dwell times	45 minutes	35 minutes

The truck size and heavier loads make the larger trucks less desirable candidates for natural gas conversion. According to the directors of operations at one large food distribution company interviewed and one large grocery store chain, current natural gas engines are not powerful enough to carry large loads at highway speeds and up steep grades.

Small firm characteristics

Local companies, comprising regional food production and distribution firms, operate smaller trucks that are less often loaded to capacity. All of the regional firms interviewed for this study used step-vans and small, sub-26,000 lb. box trucks. They visited each store more frequently, on a daily basis, and delivered smaller volumes of goods. Local firms utilized local roads more and made use of peak traffic hours. This makes their trucks excellent candidates for natural gas conversion. They do not need the extra power that diesel provides over natural gas.

Invectives can be targeted at companies that are being overlooked

Despite the benefit of natural gas to smaller vehicles, national companies are the ones that have the resources to establish natural gas pilot programs, as well as reputations to protect. These pilot programs often bring prestige or cachet to their firms, allowing them to advertise their environmental friendliness to customers. Many of the national firms we interviewed established these pilot programs only to find that natural gas trucks were not a good fit for their needs. In contrast, smaller, local firms do not have the resources to invest in pilot programs. They operate only a fraction of the number of trucks that national firms do, and they cannot afford to convert a substantial portion of that fleet to natural gas. Since these local firms rarely adopt pilot programs, they don't get to see the potential benefits of natural gas.

For these reasons, incentives for natural gas conversion should be aimed at local producers and distributors, particularly those without the resources to fund expensive pilot programs. Educational sessions, presentations, and websites can be aimed at independent food producers. Large national companies already have additional incentives, as well as additional corporate image benefits, for adopting pilot programs. Their command of multiple markets allows them to test natural gas in one market with minimal disruption to company resources as a whole. In contrast, local producers serve only one or two markets, and cannot afford sweeping changes in that crucial market.

Overall, the adoption of natural gas trucks will be an outcome of:

- policy
- fuel cost
- vehicle cost
- infrastructure

Any policy that reduces operating costs and increases ease of operation will help increase the adoption of natural gas trucks. So far, however, firms have not reported having good experience with the natural gas trucks they have tried, and they are wary to expand their natural gas trucking fleets.

In October 2015, we received news from a Kroger logistics executive that Freightliner had developed a new, improved liquefied natural gas truck that effectively closes the gap in range and power that affected the natural gas trucks in Kroger's previous pilot project. Kroger is purchasing a fleet of these new trucks.

We could not find any press releases or white papers on these new vehicles, but we plan to review how they affect the adoption of natural gas in the future.

Experiences, Interviews, Data Collection, and recommendations for future work

In person and phone interviews were the best way to gather data on the attitudes of industry stakeholders and food distribution operators. Online surveys went unanswered despite frequent reminders for completion. The relatively small pool of potential respondents involved in food distribution in a given metro area means that a large response rate is necessary to gather sufficient data for analysis.

Identifying candidates for data collection

We identified 224 businesses in the Puget Sound area that were involved in the production and distribution of food. Only 61 of those businesses could be reached through email. Five responses were received after three reminders to complete the survey. We would have needed at least 20 responses to have an adequate sample from which to draw conclusions. See Table 14.

Table 14: Response rate

Factor	Value
Businesses identified	224
Business able to be contacted	61
Return surveys	3
Response rate	5%
Responses required	20
Additional businesses to be reach	400

It is important to have an established relationship with employees at food distribution facilities. Store managers were generally willing to speak to interviewers, even on cold calls. However, transportation managers at warehouses and distribution facilities were difficult to reach with cold calls. Without a direct connection to the company, calls and emails were often routed back and forth; it sometimes took as many as two weeks and five emails to reach a person who could help with the interview. Most email inquiries were dead ends. Of 30 people contacted about interviews, only nine interviews were conducted. Scheduling interviews was also difficult, as the employees' time is valuable, and the facilities were located far from Seattle.

It is important to attend interviews in person whenever possible. While phone interviews provided useful information, interviewees were more reluctant to volunteer information and engage in unstructured conversation over the phone. Phone interviews were always shorter and curter than in-person interviews. In-person interviews also occasionally allowed for tours of the facility, which provided valuable insight into operations.

Additionally, it was important to makes thing as convenient and comfortable as possible for the interviewees. This included meeting the interviewees at the location of their choosing, most often their company office. Interviews were scheduled whenever it was most convenient for them, and were kept short in order to not use up too much of their time. They were also assured that answer would not be linked to them, and their identities would be kept confidential. Their permission was obtained before any recording occurred. It was important to ask questions that could be quickly answered, without the need to look up data. For any questions that required data, interviewees were given the option to email their answers, after they had time to look up the relevant data.

The most useful data were gained when interviews were allowed to go off-script. Asking open-ended questions was an invaluable tactic, as interviewees volunteered much more information when they felt comfortable and settled into the conversation. Asking another question would often stall the interview. It was important to allude to the next appropriate question in conversation rather than ask outright.

Lessons learned from truck counting

The only cost effective way to gather data on truck trip generation was to station human counters outside facilities during business hours. We chose human counters as opposed to using a technology application for two important factors:

1. Physical complexity. Most grocery stores have multiple access and egress locations, multiplying the number of locations where sensors must be installed. In addition, truck drivers choose to park in multiple locations, including the front of the store, the back of the store, and in the street. Again, this multiplies the number of sensors that would be required should a technology solution be selected, and in some cases, would be entirely prohibitive.
2. Multiplicity of metrics. Not only were the number of trucks counted, but additional factors were collected including the type of truck, the good delivered, the dwell time, and the behavior of the trucker. Video cameras would be the only method that could obtain all of these data elements, but these were excluded due to factor 1.

Driving loops between facilities to encompass a larger area of stores was not a feasible way gather data, as too much time was wasted driving between facilities. The circuit method, in which five stores were visited many times throughout the day in a driven circuit, was not accurate enough. It was very easy to miss trucks stopped at one store while counting at another store, and the margin of error was 30 percent. We looked into building a laser sensor that would register the passage of a truck at a checkpoint. Development of the sensor is under way for a different project, but we were not able to implement the sensor in time to begin truck counts for this project.

As mentioned, consideration was given to conducting automated truck counts. Video camera installation, tube counters, and laser sensors were considered. While the data collection components of these approaches are less labor intensive. The physical configuration of stores and delivery locations meant these methods were infeasible within the project resource constraints. A small number of cameras or laser counters would not provide the detail we needed, with respect to truck type, truck size, and company affiliation. Additionally, most count sites had multiple entrances, which made setting up a cordon difficult. Many trucks also parked in the store parking lot and did not utilize the dock. The large variation in parking location required the watchful eye of a human counter.

It was important to provide some sense of comfort for the long counting hours, particularly for early morning counts. It was much more reasonable to spend 7 hours counting within the comfort of a car or coffee shop rather than on the street.

However, the method was also very labor intensive, as gathering data about one store required a whole day of counting by a person. An average of twelve trucks per day were counted, amounting to counting two trucks per hour. Thus the majority of the counter's time was spent idle.

We experimented with a tour-based counting method, where a counter would drive a loop of 3 to 4 stores in succession, and note trucks parked at each location. Then data from previous single location counts could be used to calibrate the truck numbers to account for trucks that were missed in counting. As dwell times for trucks average 30 to 40 minutes, and the length of the tour could be around 30 minutes, we assumed that a minimal number of trucks would be uncounted. This method allowed us to count at several locations at once, and gather more data in a shorter amount of time.

However, tour length widely varied according to time of day and traffic conditions, which made calibrating difficult and inaccurate, with a standard variation of 5 for total average counts of 20 trucks per day. This large variation was unacceptable.

Overall, the most important factors in gathering data were developing relationship with businesses associated with this supply chain, over a period of several weeks. Multiple phone calls and emails were needed before some managers were willing to sit down with us. The interviews should be open-ended and conversation in nature, but care must be taken to ensure they do not run long. Accurate truck counts required dedicating 8 hours of counting time to a single location, and care must be taken to see where trucks are parking, and which establishment they are delivering to. Collecting data in this field is a time-consuming process, and few shortcuts are available.

CONCLUSIONS AND FUTURE WORK

Food distribution companies are making efforts to reduce fuel consumption and emissions. They have been investing in new truck technologies, utilizing route optimization software, and rightsizing trucks. As stated early, there are five key things to consider:

- The performance needs of small firms and large firms differ
- Insufficient marketing to small firms
- High cost of trucks
- Large firm pilot programs identified deficiencies of natural gas as a fuel
- These needs and deficiencies must be addressed before making new incentives

These efforts have become more pronounced at larger companies that operate larger trucks, in larger fleets, on longer routes. Larger companies have the resources to analyze fleet fuel usage and keep current of new technologies. They also have a prominent public image that benefits from the public relations boost that cleaner burning technology can offer.

Small food distribution firms place importance on fuel use reductions and emissions reductions. However, they do not have the resources to procure natural gas technology. The government grant and tax credit process is also cumbersome to navigate for smaller enterprises. These issues, together with the lack of refueling stations, means that alternative fuel vehicles are not a viable option for smaller firms.

At the same time, these small firms operate trucks and service routes that would be most conducive to reductions in fuel use and emissions if they switched to natural gas trucks, without any detriment to performance. Larger firms experimenting with natural gas trucks have found that while they benefit from fuel use and emission reductions, the trucks they use and routes they service are limited by natural gas engines. Care should be taken with new alternative fuel incentives so that they reach smaller firms that have been left out of the alternative fuel marketplace.

Future work should focus on finding the quantitative effects that state policies have on the rise of alternative fuels. If the policies recommended here are implemented, data should be collected on new pilot projects started by food distribution companies in all segments of the market. Companies may be encouraged to report purchases of alternative fuel vehicles so that adoption rates can be analyzed.

While 12 interviews were enough for our purposes in this investigation, future work may attempt to talk to a majority of food distributors in the region. Stakeholders should be brought to the table before new incentives are implemented, during their implementation, and after implementation in order to measure progress.

Alternative fuels technology is continually improving, and future advances may bridge the gap between diesel and natural gas in performance and range. We were recently told that one major manufacturer had brought to market liquefied natural gas trucks that were on par with diesel trucks of the same category in terms of performance. It is currently finalizing a deal with a major grocery store chain to sell these trucks. However, it is still important that the market for alternative fuels be a broad as possible; small-to-medium food distribution firms remain priced out of the market despite government grants encouraging the adoption of these fuels.