Activity Modeling of Freight Flows in Washington State: Case Studies of the Resilience of Potato and Diesel Distribution Systems

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Anne Goodchild
Assistant Professor
121E More Hall, Box 352700
Department of Civil and Environmental Engineering
University of Washington
Seattle, WA 98105
Phone: (206) 543-3747
Fax: (206) 543-1543
annegood@u.washington.edu

Sunny Rose (corresponding author)
MS Candidate
More Hall
Department of Civil and Environmental Engineering
University of Washington
Seattle, WA 98105
Phone: (206) 331-2900
Fax: (206) 543-1543
sunnyr@u.washington.edu

Derik Andreoli
Ph.D. Candidate
413 Smith Hall, Box 353550
Department of Geography
University of Washington
Seattle, WA 98195
Phone: (206) 543-5843
Fax: (206) 543-3313
dohne@u.washington.edu

Eric Jessup
Associate Research Professor
Transportation Research Group
School of Economic Sciences
Washington State University
Pullman, WA 99164
Phone: (509) 335-5558
Fax: (509) 335-1173
eric_jessup@wsu.edu

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ABSTRACT

This paper describes the development and use of a network model using publicly available industry data to analyze the resilience of two important Washington state industries. Modeling of freight activity in support of the potato and diesel industry in Washington state demonstrates how individual industries utilize the road network and how they are affected by a transportation disruption. We estimate the potato industry, which relies entirely on trucks for intra-state deliveries, generates about 50 cross-Cascade truck trips per day. Roughly 90 percent of the trucks deliver potatoes from processing facilities on the east side of the state to markets on the west side, while 10 percent carry fresh potatoes from the west to the east for processing. The coupled origins and destinations do not vary unless there is a disruption to the network. The diesel distribution system in Washington state also relies heavily on trucks, but only for the final segment of the logistics chain because both barge transport and pipelines are more cost effective modes. By necessity, trucks deliver from terminals to racks, but there is an established flexibility in these distribution operations as routes and travel distances regularly change because of variations in commodity price at each terminal and the presence of multiple terminals. As a consequence, we demonstrate that the diesel distribution system is much more resilient to roadway disruptions, especially those which occur along the cross-Cascades routes. These examples demonstrate the necessity of understanding industry practice as it relates to analyzing needed infrastructure and operational improvements to reduce economic impacts resulting from transportation disruptions.

INTRODUCTION

Without knowledge of individual industry use of infrastructure, it is not clear how different industries use the transportation system, and how each industry will be affected by network changes; for example, whether specific failures will disrupt their activities or if improvements will be beneficial to their logistics. Through modeling of truck activity and the use of a network model, we evaluate two specific industries in Washington state to demonstrates that industries do vary in their use of transportation infrastructure, and how differently they are affected by a specific transportation disruption. The impact of the closure of the cross-Cascades corridor, a particularly common disruption that occurs seasonally in Washington state, is evaluated through the development of a GIS network model, identification of freight generators, and estimation of freight activity.

The finding that freight industries can be very different in their response to a disruption is important because it demonstrates the necessity of understanding industry practice as it relates to analyzing needed infrastructure and operational improvements to reduce economic impacts resulting from transportation disruptions.

DATA COLLECTION

A detailed investigation was undertaken of each industry to identify origins and destinations, estimate trip volumes, and understand industry operations. Publicly available resources were thoroughly reviewed for this data and interviews conducted with experts in each industry. Statewide vehicular flows in service of the potato industry are generated so that cargo-specific flows and trip logistical properties can be identified for any roadway segment. Diesel distribution activity is modeled by identifying origin-destination pairs assuming shortest travel times on the road network.

MODELING POTATO FLOWS

Potato movements are estimated for origin-destination and product specific vehicle trips. An example is the daily truck trips of fresh potatoes from the Skagit Valley to the Seattle consumer market. There are three main potato-growing regions within Washington state: the Skagit Valley, the Lower Basin, and the Upper Basin (Figure 2).

Potatoes are processed at 16 facilities within Washington state, as shown in Figure 1. All processing facilities are located on the east side of the state, with the exception of two potato chip processing plants. These plants are located on the west side of the state due to higher costs of transporting processed potato chips and their proximity to larger markets in Seattle and Portland.

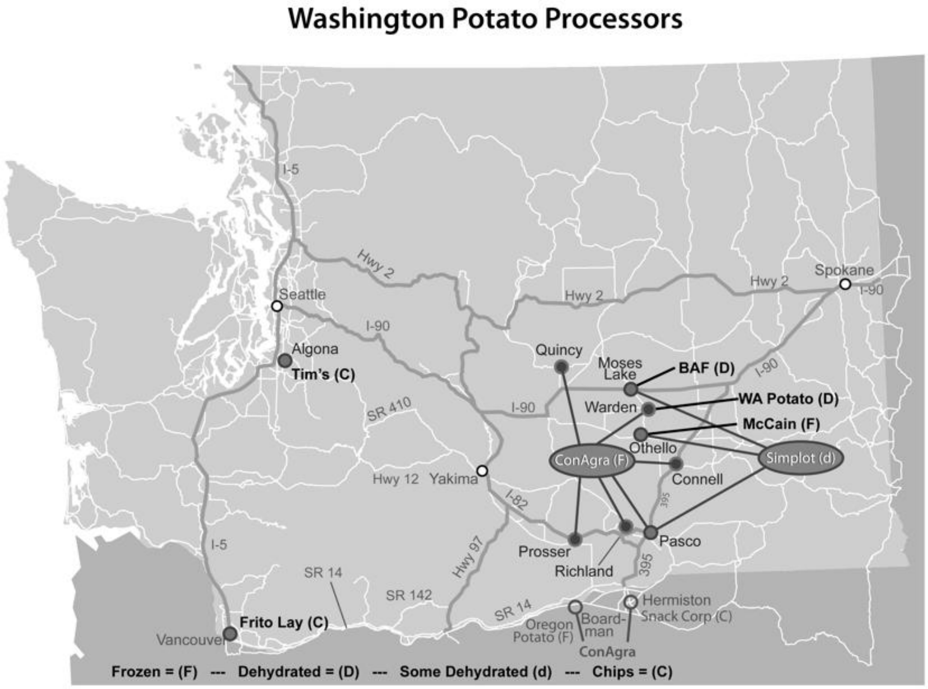

FIGURE 1 Potato processors in Washington state.

A GIS transportation network was developed that identifies routes used in serving each origin-destination pair by using a shortest travel time assumption as a function of length and average speed. Impedance factors are obtained from the TeleAtlas road network (as is used by Google Maps). Truck volumes are estimated through careful consideration of production in each region, truck capacities, product loss, and conversion from fresh product to processed potatoes.

Using the results of the least cost routing, the pattern of movements within the state include the movement of potatoes and potato products from western Washington to eastern Washington, and vice-versa. We estimate 250 truck trips are generated by potato growers and processors, of which about 50 traverses the Cascade Mountain passes each day.

During the last few years, heavy snowfall and avalanches in Washington state have frequently caused the closure of I-90 at Snoqualmie Pass. During the 2007-2008 winter season, Snoqualmie Pass was closed for roughly 370 hours (2). The closures are distributed approximately equally between eastbound and westbound lanes. The closure of I-90 also impacts the other mountain routes of HWY 2 and HWY 12. In addition, SR-410 and HWY 20 are closed seasonally every winter, leaving SR-14, the southern-most east-west route as the only east-west connection.

Figure 2 shows the routes and daily truck trips for origins and destinations located on opposite sides of the Cascades. The “Normal” scenario shows truck trips when the mountain passes are open. I-90 westbound serves approximately 33 daily trips, SR-410 westbound almost 11, and HWY 2 eastbound nearly five. Using the GIS transportation network, the links on I-90, HWY 2, and HWY 12 are disabled to replicate the impact of a severe winter storm. These closures result in truck trips re-routed to the new least cost route connecting origins and destinations.

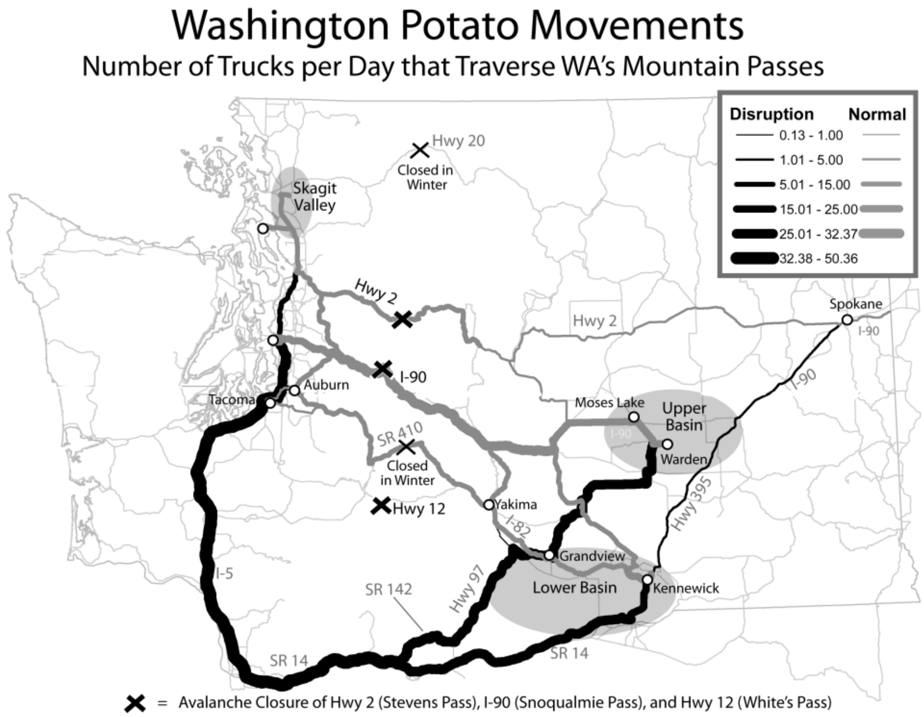

FIGURE 2 Truck trips per day on cross-Cascades routes under the normal and disruption scenario.

The new routes are classified as the "Disruption" scenario in Figure 2. Re-routing is required to the only remaining east-west freight route, SR-14, and utilization of I-5 for the north-south portion of the trip. In the "Normal" scenario, no trucks use this route to cross the Cascades.

We can conclude that the re-routing impacts just over 50 truck trips per day; five trips in the eastbound direction, and about 45 trips in the westbound direction, or nearly 20 percent of total truck trips moving potatoes in Washington state. Under normal conditions trucks transporting potatoes travel an estimated 11,000 miles each day. Under the disrupted conditions, if all trucks re-route, truck miles traveled increases to almost 21,000 miles, an almost 80 percent escalation. This result signifies that the potato industry is vulnerable to a transportation network disruption to the cross-Cascades corridor.

MODELING DIESEL DISTRIBUTION

The diesel distribution network in Washington state incorporates the interests of multiple agents and transportation by pipeline, waterway, and tanker truck to transport diesel from refineries to consumers.

Figure 3 summarizes flows within the Washington state diesel distribution network. It can be observed that the movement of diesel around the state is qualitatively different when compared to the movement of potatoes. Diesel moves into the state from the perimeter, traveling as far as possible via barge or pipeline, only traveling by truck for the last segment from terminal location (where diesel is delivered by barge or pipeline) to cardlock racks (where trucks purchase fuel). While there are only three origins for fresh and processed potatoes, there are 27 terminal racks that function as origins in the diesel truck distribution network.

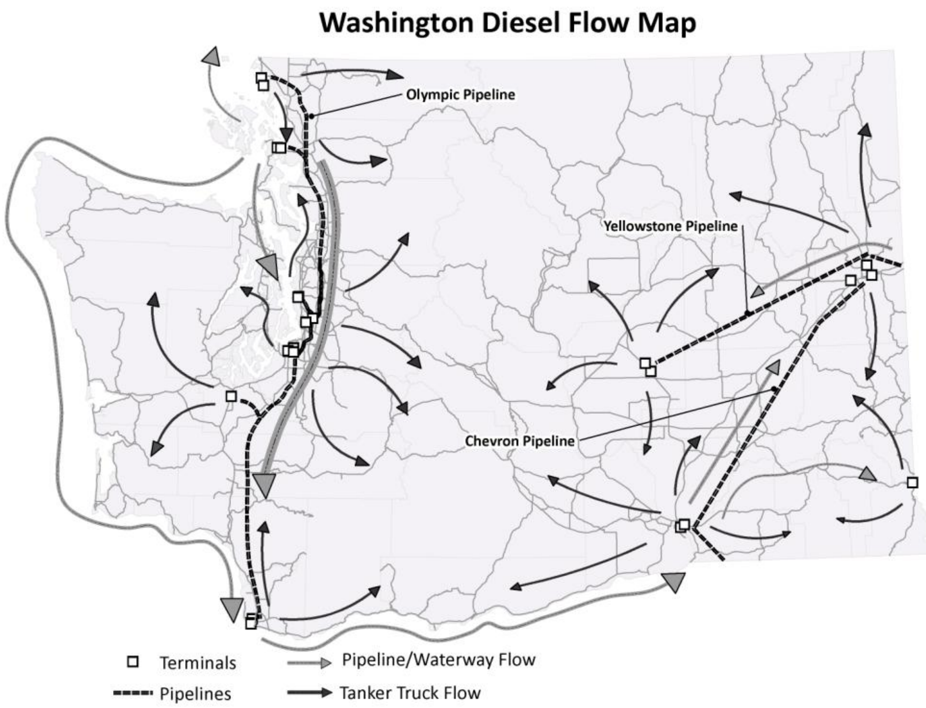

FIGURE 3 Washington state diesel flow.

Our analysis considers the truck movements of diesel. Using the locations of the terminals and cardlock facilities, the origin-destination pairs that use each link in the diesel distribution network are identified (Figure 4) based on the assumption that cardlock facilities are served by the terminal with the shortest travel time from that cardlock facility, and trucks use the shortest travel time path between origin and destination.

Without disruptions, and assuming constant diesel pricing, there is only one origin destination pair using cross-Cascades route; however, a terminal east of the cascades will service this destination with an increase in travel time of 13.3 minutes per trip. This is in striking comparison to the potato case study where 20 percent of truck trips use the cross-Cascades routes. For the distribution of diesel, other links service almost 40 origin-destination pairs including SR-16 on the east side of the Olympic Peninsula, and SR-17/282 out of Moses Lake.

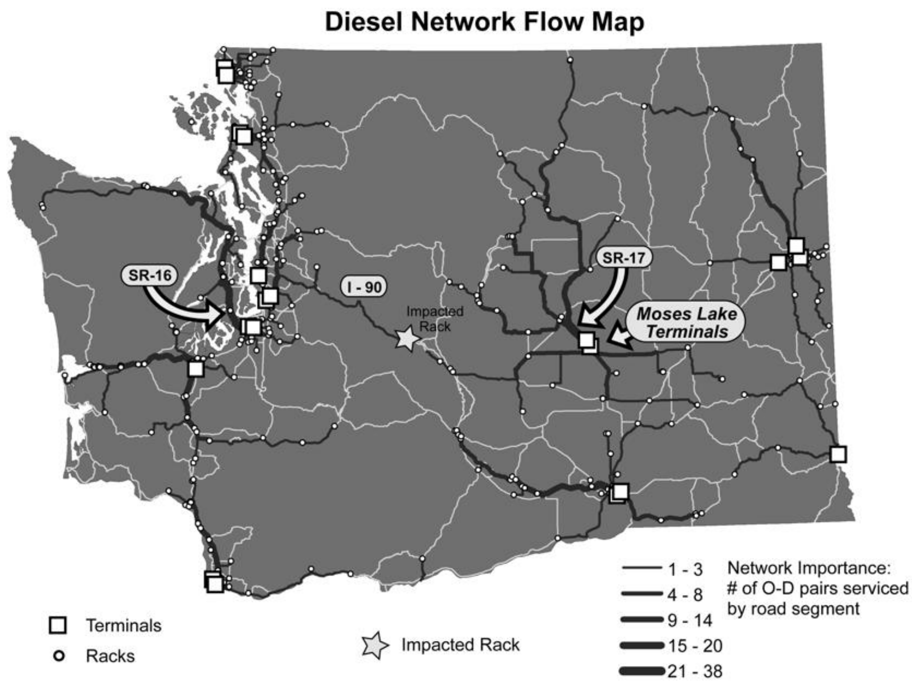

FIGURE 4 Diesel network flow map showing the number of origin-destination pairs using each link.

The initial distribution of diesel essentially avoids truck operations while depending on pipeline and barge movements from the boundaries of the state inland. Only the final leg of the distribution system uses trucks. Given the accessibility provided by the coast, the Columbia River, and the existing pipeline infrastructure, the cross-Cascades routes are not critical to the diesel distribution system under normal operations. In contrast to the distribution of potatoes, the diesel distribution system demonstrates significant modal redundancy.

While we model diesel distribution assuming shortest travel time pairings of terminals and cardlock facilities, some diesel truckers have an incentive to pursue the least cost, not only with respect to travel, but also with respect to diesel purchase price. In practice, this affects a proportion of routes and travel times, and requires diesel truckers to adjust the number of drivers and trucks that other industries do not contend with. These exposures to sourcing risk give the diesel truckers a natural flexibility that positions them well in responding to disruptions along the transportation network. Not only does the system demonstrate resilience to the cross-Cascades disruption as demonstrated by the model, but current industry practice improves on that network resilience.

CONCLUSION

Faced with a high probability that major disruptions will occur to the transportation system it is important to understand how disruptions of freight corridors affect various freight-dependent industries. With this knowledge, plans can be developed to protect freight-dependent sectors that are at high risk and future transportation investments can be prioritized. Although currently available data is limiting, through extensive data collection efforts, we are able to model product specific origin-destination truck trips in service of the potato industry. In the case of diesel distribution, we analyze activity but cannot estimate truck specific origin destination flow data. Future work will develop routing logic for a broader set of industries and methods for developing disaggregated flow data for these industries.

In order to accurately predict how companies will route shipments during a disruption, this research develops the first statewide multimodal freight model for Washington state. 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.

Through application of two case studies, we demonstrate that a closure of the cross-Cascade corridor will have a significant affect on the potato industry in Washington state, but not on the distribution of diesel. The operational difference exposed from this disruption demonstrates the necessity of understanding how different industries use transportation infrastructure when investing in network and operational improvements. Without these case studies it is unknown how such a road closure will impact these freight industries' ability to transport goods; the results identify that each freight industry must be considered independently when determining how the freight industry utilizes the transportation network.

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