Contact Information

Development and Analysis of a GIS-Based Statewide Data Flow Network
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Research Note

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Building freight transport resilience through GIS-based data

Washington State
Department of Transportation

Washington's economy depends on freight movement

Washington's economy is dependent on the movement of freight for delivering and distributing raw materials, products and goods regionally, nationally and internationally. Our transportation infrastructure is a major element in this chain and, as such, disruptions to the transportation network have a significant impact on businesses that depend on freight. Recent examples include the weather-related closures of I-90 and I-5 in the winter of 2007 – 2008, which stymied freight movement across the state for several days causing nearly $75 million in losses due to freight delay.

Disruptions in the transportation network have significant economic impact

Management techniques for freight supply chain and transportation have created lean supply chains, which rely on just-in-time delivery. Because infrastructure development has not kept up with growing demand, when disruptions occur to essential pieces of the network, such as freight corridors or port facilities, they cause significant impacts to the state's economy.

This research builds the groundwork for transportation system resiliency

The relationship between infrastructure and economic activity is not well understood. This research helps to increase our understanding of how sensitive the economy is to disruptions in infrastructure availability. It lays the groundwork for reducing this sensitivity and improving the resilience of the transportation system by improving the ability of the infrastructure to move people and goods in the face of transportation disruptions. Resilience tends to increase if a system can prioritize resources to improve those areas where disruptions would cause the most economic harm.

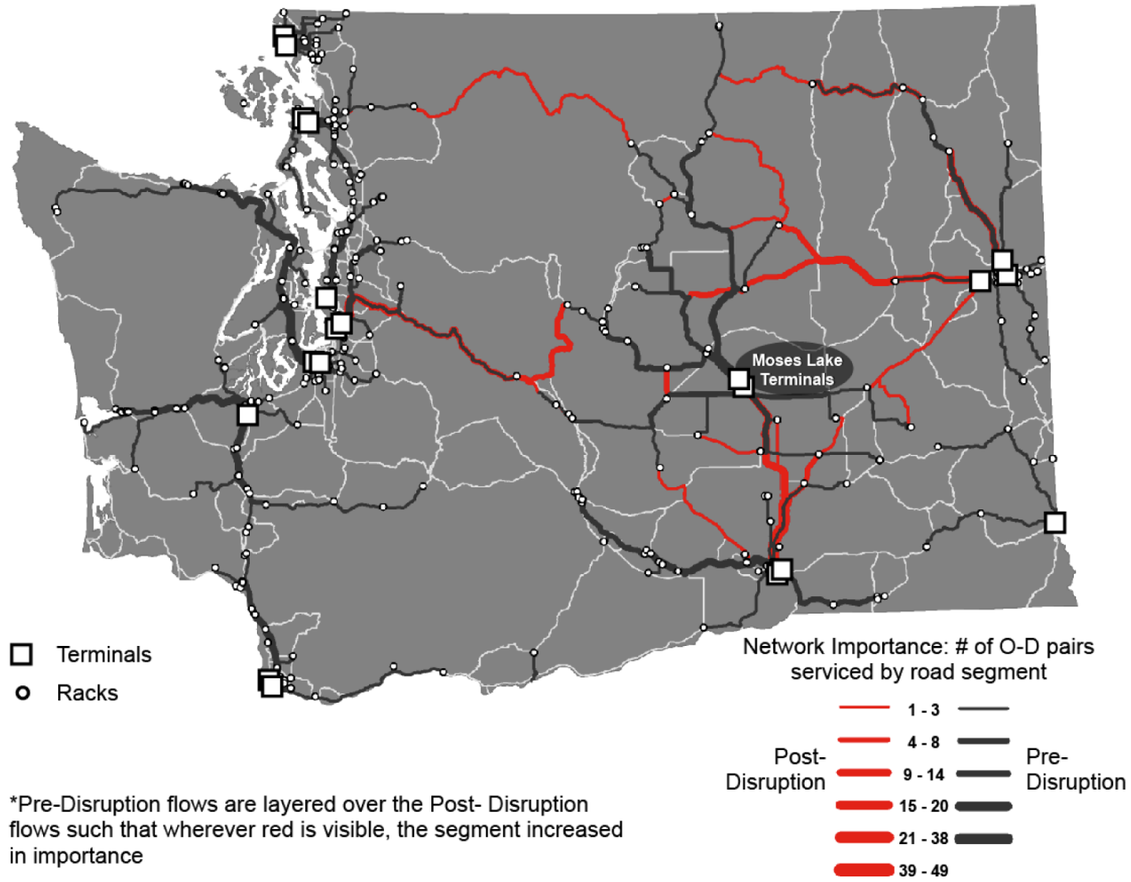
Methods used for this research

Literature review: Our research team carried out an extensive review of literature about resilience, including the literature from disciplines outside transportation. This review allowed us to begin the research with clear definitions for features of resilience and a framework for developing useful tools. We define resilience in the context of freight transportation systems, and identify behaviors of resilient enterprises, managing organizations, and features of resilient infrastructure.

In order to accurately predict how companies will route shipments during a disruption, this research developed the first statewide multimodal freight model: The model is a geographic information system (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.

Case studies - diesel fuel distribution and potato growing and processing: The report features two case studies showing the model's capabilities. These case studies show how the statewide freight model can predict the routing of shipments during disruptions and analyze the level of resiliency in various industry sectors in Washington State.

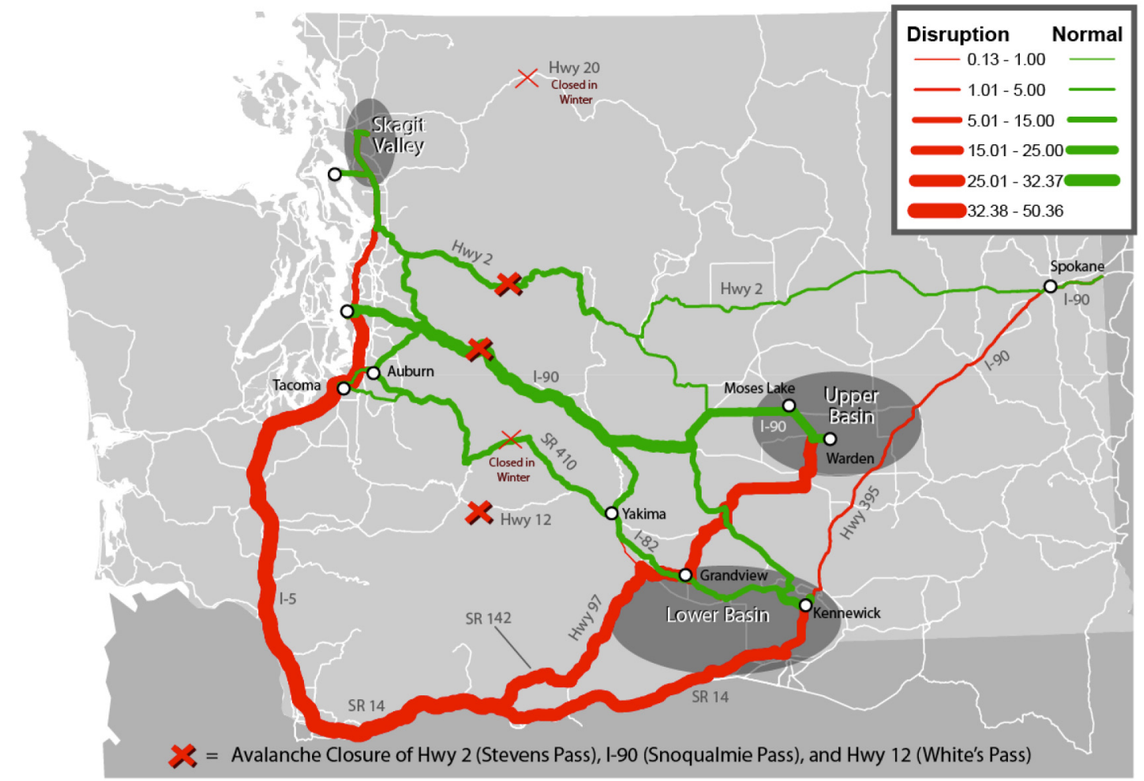
Diesel Network Flow Map: Pre- and Post- Disruption



*Pre-Disruption flows are layered over the Post- Disruption flows such that wherever red is visible, the segment increased in importance

Washington Potato Movements

Number of Trucks per Day that Traverse WA's Mountain Passes



What we learned

Resilience related to transportation is relatively new

Outside of transportation, resilience is a well-studied topic. Within the context of transportation, researchers have only begun to address the issue. The GIS tool developed through this project lays the groundwork for a more comprehensive, statewide freight-modeling tool, as well as immediately providing insights into the two industries studied. The two industries studied provide good examples of how differently industries use the transportation infrastructure and are affected by disruptions.

Diesel distribution in Washington is flexible and resilient

The diesel distribution system in Washington state relies heavily on barge transport and pipeline. Trucks are used for the final leg of the trip from terminal racks, where fuel is dispensed into a truck, to self-serve fueling facilities (cardlocks) used by commercial customers. Because profit is tied to the purchase price of diesel fuel, marketers have flexible sourcing locations and are regularly changing routes and travel distances. This flexibility makes the diesel distribution system very resilient to roadway failure and in particular to disruptions along the cross-Cascades routes.

Potato distribution relies heavily on roads

In the case of potato distribution, all of the produce is transported by truck, and the industry is therefore more dependent on the highway mode. This makes the potato industry particularly sensitive to highway disruptions. A closure of the cross-Cascades corridor would cost the potato industry from $275 to $640 per truck.

Above: Comparison of flow between terminals and cardlock facilities with and without the Moses Lake terminals

These differences demonstrate the value of understanding how industries use the infrastructure. Without these case studies we would have to assume a closure would affect the industries similarly, and it would likely be assumed that diesel trucks were harder hit because of the necessity of the product for the economy.

Recommendations to promote freight resilience:

The model developed in this project was used to evaluate the impact of transportation disruptions to two specific industries. The results contributed significantly to WSDOT's understanding of goods movement and vulnerability to disruptions. As origin-destination data for other freight-dependent sectors is added to the model, WSDOT will be able to evaluate the impact of freight system disruptions on each of them. This will improve WSDOT's ability to develop optimal strategies for highway closures and prioritize improvements to the system based on relative economic impact of the disruption.

WSDOT should continue to learn, in operational detail, about the key supply chains within Washington state. This information will inform decisions and help prioritize freight transport needs. These strategies will improve the knowledge and operations of users, which in turn will improve the state of the system during a disruptive event.

Additional detailed research should also be performed to:

- improve the functions, currently embedded in the model for routing purposes, to be more reflective of travel times for trucks
- characterize supply chains with similar logistical behavior
- prioritize industries important to Washington state and do additional case studies
- define and map geographic locations which generate freight trips

Above: Truck trips per day on cross-Cascades routes under disruption scenario

- build an automated tool within GIS to map "origin and destination" pairs on infrastructure
- integrate GPS data from the current WSDOT Truck Performance Measures research project
- ensure compatibility of statewide model with existing and future regional models.