

Estimating the Value of Rail Car Accessibility for Grain Shipments: A GIS Approach

EWITS Working Paper Number 5

by

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EWITS Research Reports: Background and Purpose

This report is the fifth in a series of Working Papers current topics related to the mission of the Eastern Washington Intermodal Transportation Study (EWITS)) to accompany EWITS reports providing information on the multimodal network necessary for the efficient movement of both freight and people into the next century.

EWITS is a six-year study funded jointly by the Federal government and the Washington State Department of Transportation as a part of the Intermodal Surface Transportation Efficiency Act of 1991. Dr. Ken Casavant of Washington State University is Director of the study. A state-level Steering Committee provides overall direction pertaining to the design and implementation of the project. The Steering Committee includes Jerry Lenzi, Regional Administrator (WSDOT, Eastern Region), Richard Larson (WSDOT, South Central Region); Don Senn (WSDOT, North Central Region); Charles Howard (WSDOT, Planning Manager), and Jay Weber (Douglas County Commissioner Pat Patterson represents the Washington State Transportation Commission on the Steering Committee. An Advisory Committee with representation - from a broad range of transportation interest groups also provides guidance to the study. The following are key goals and objectives for the Eastern Washington Intermodal Transportation Study:

- *Facilitate existing regional and state-wide transportation planning efforts.*
- *Forecast future freight and passenger transportation service needs for eastern Washington.*
- *Identify gaps in eastern Washington's current transportation infrastructure.*
- *Pinpoint transportation system improvement options critical to economic competitiveness and mobility within eastern Washington.*

For additional information about the Eastern Washington Intermodal Transportation Study or this Working Paper, please contact Ken Casavant at the following address:

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2. Gillis, William R. and Kenneth L. Casavant. "Lessons from Eastern Washington: State Route Mainstreets, Bypass Routes and Economic Development in Small Towns." EWITS Research Report Number 2. February 1994.
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4. Painter, Kate and Ken Casavant. "A Comparison of Canadian Versus All Truck Movements In Washington State With A Special Emphasis On Grain Truck Movements." EWITS Working Paper #4, March 1996.

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Introduction

The rural transportation problem is a matter of distance, as opposed to the urban transportation problem of congestion. The production of agricultural and natural resource products typically requires movement from remote, rural locations to manufacturing centers (either domestic or abroad) for processing and distribution. The marketing of grain is one example where the commodity must traverse considerable distance between the geographical locations of production and consumption activities. The cost associated with transporting grain from production locations to final destinations is directly reflected in the producer price, providing the incentive for producers to minimize this cost component.

Grain farmers often have access to several transportation options for grain shipment: truck, rail and barge transport. The availability of different modal choices provides producers with flexible shipping options and a competitive balance between shipping rates of each mode. With unlimited access to each shipping mode and equal service attributes, producers naturally select the mode (or combination of modes), which minimizes the total transportation cost of moving grain to market. The modal selection for grain shipment depends on (among other things) the locational proximity of the producer to elevators (with and without rail loading facilities) and river ports and the handling and storage charges associated with each modal usage. However, there are often external constraints, which limit the use of a particular modal choice at certain time periods, creating inefficient movement of grain at higher transportation costs. Railcar shortages are one external constraint which forces grain producers and handlers to utilize more costly truck transport.

The shortage of rail cars for grain shipments is a seasonal problem experienced by producers and grain handlers on an annual basis in Eastern Washington. The problem arises from the seasonality associated with grain production, harvest and transport. Favorable marketing conditions from September through February encourage producers to ship the majority of grain during these time periods, with considerably less grain movement the remaining six months. Consequently, the quantity of rail cars demanded is considerably larger during this time period.

Rail companies, however, invest in equipment (grain cars) with the anticipation of receiving a favorable return on investment, which is difficult if the rail car is not used throughout the year. Thus, to maintain a consistent return on investment railroad companies attempt to purchase and allocate grain cars on a monthly basis, supplying a base number of rail cars throughout the year rather than supplying cars to meet peak demand. Unfortunately, the demand for grain cars is not evenly distributed throughout the year.

In addition to increased road damage, excessive energy utilization and safety concerns, rail car shortages have a negative impact on grain shippers through higher transportation cost and decreased service. More expensive truck shipments are utilized to either transport grain to river ports for barge transport or directly to final destinations. Increased time intervals for shipping grain from production areas to final destinations also limits the producers ability to supply domestic and international grain market demands.

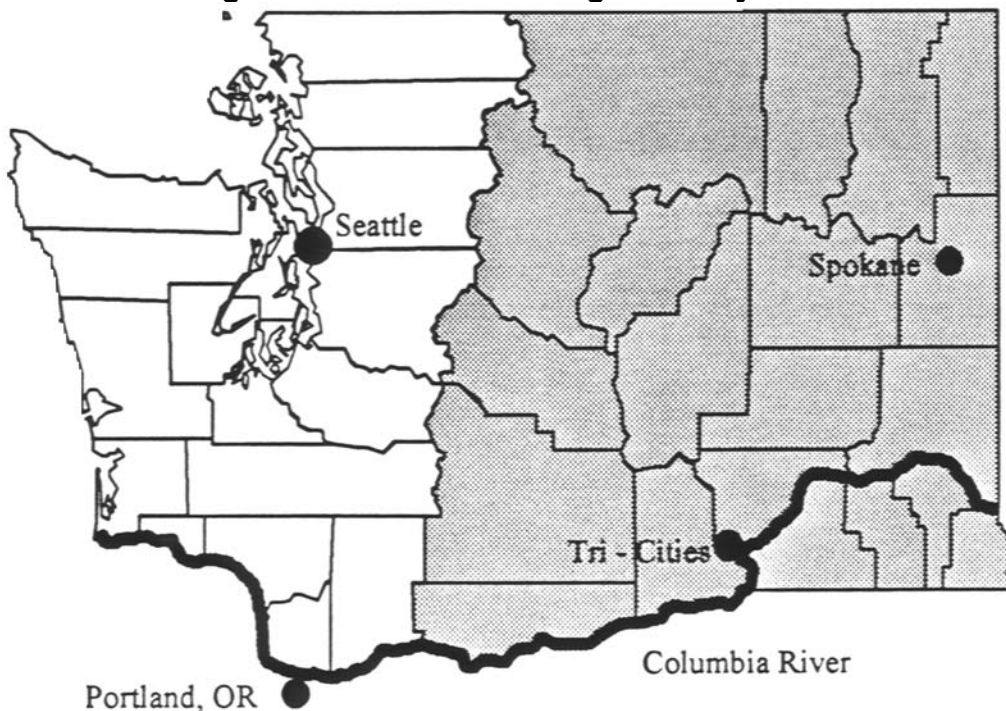
Objective and Approach

This study's purpose is to empirically estimate the value of rail car accessibility to producers. Changes in transportation flows for different levels of rail usage in the 20 county grain production region of Eastern Washington (see Figure 1) are also determined. A transportation optimization model, implemented through a Geographical Information System (GIS) incorporating grain movements originating from 695 township centers and passing through over 400 grain elevators en route to final destinations, is descriptively and analytically developed. Impacts on producer's (private) cost of transportation are estimated. Producer's cost is estimated by constraining the volume of grain shipped on rail, thereby generating shadow prices reflecting the marginal value associated with relaxing rail constraints. Description of the data acquisition and modification procedures are first presented, followed by the transportation optimization model description.

Sources of Information

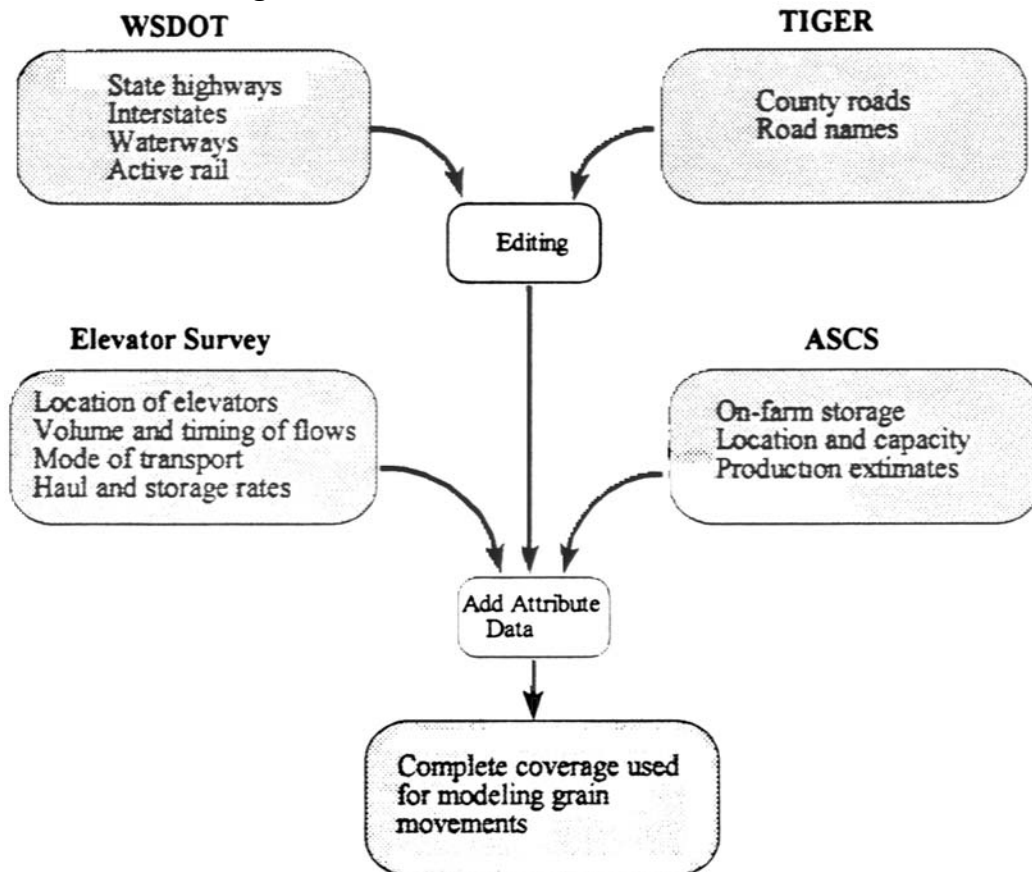
The transportation and marketing system being modeled involves grain movements from production areas in eastern Washington to feedlots and ocean ports for processing, consumption and export. Intermediate destinations, such as elevators and river ports, serve as short (and long) term storage facilities, transfer stations and points of consolidation. Hence, information from each component of the system was needed on a common platform to facilitate investigation and analysis. The one common element in each component of the system being modeled is geography. The production areas, elevators, river ports, ocean ports and transportation infrastructure (roads, highways, rail lines, barges) are all connected through geography, creating an ideal environment for a Geographical Information Systems approach.

Figure 1: Eastern Washington Study Area



The GIS coverages were constructed primarily from four sources, as illustrated in Figure 2. The Washington State Department of Transportation (WSDOT) provided GIS coverages for most county, state, U.S., and Interstate highways, in addition to active rail lines and navigable waterways. However, these files weren't entirely complete; missing road names and lower density county roads were added from U.S. Bureau of Census Topologically Integrated Geographic Encoding and Referencing (TIGER) files. WSDOT and TIGER file coverages were merged and edited to remove any coinciding arcs or needless road coverages, resulting in a complete and non-duplicative coverage of the road and highway transportation network.

Figure 2: Data and Information Sources



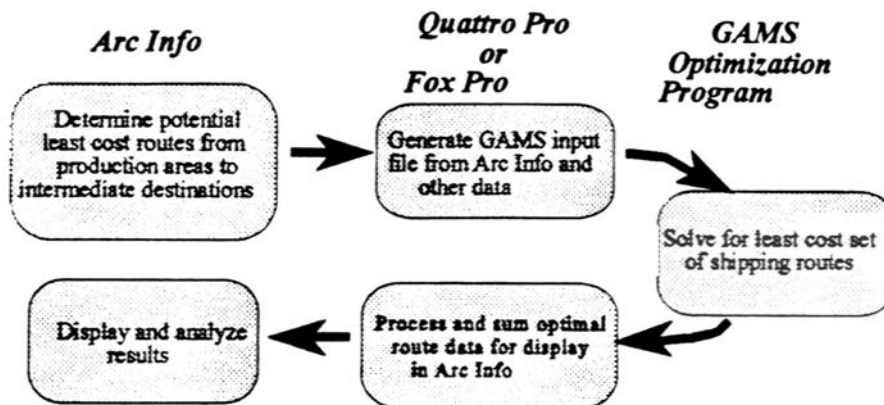
Additional information relating to the grain production areas and intermediate destinations (elevators and river ports) was obtained from the Agricultural Soil and Conservation Service (ASCS) and from an elevator survey sent to each of the 400 plus grain elevators in the study area. Detailed data concerning on-farm storage locations and capacities, in addition to acreage and production estimates within each township, were obtained from the ASCS. Elevator locations, capacities, handling and storage rates, and modal usage were acquired from the brief survey sent to all elevators in the study area. Over 90% of the surveyed elevators (96% of volume) returned completed questionnaires, providing valuable information on grain movements from production locations to final destinations and the modes utilized in the process. Transport rates for truck shipments were also obtained from the elevator survey. Rail rates were collected from Burlington Northern and Union Pacific, the two class I railroad companies operating in the region, and barge rates were collected from barge companies operating on the river.

Optimization Modeling Procedure

Several GIS software packages designed for transportation modeling and analysis do provide some limited internal optimization features. However, the approach implemented in this analysis utilizes, for flexibility and robustness, an optimization package, which is external to the GIS software. The process being modeled consists of one product (wheat), utilizing multiple modal options and passing through multiple intermediate designations along several route options to different final destinations. The complexity associated with this transportation system necessitates a modeling procedure with tremendous flexibility at each phase of the transport process. Therefore, the optimization software used to allocate grain shipments on various modes and routes is called GAMS, an acronym for Generalized Algebraic Modeling System, and is external to the GIS software, Arc Info.

The method used to combine the GIS with the minimum cost transportation model is presented in Figure 3. Arc Info is used to generate a collection of minimum distance node combinations from township centers to elevators, township centers to ports, elevators to elevators, and elevators to ports. These distance tables are then exported to an intermediate program, such as Quattro Pro and Fox Pro, to generate cost coefficients, which are used as an input file in the GAMS optimization model. At each phase of the transportation process, multiple shipment alternatives are incorporated into the optimization model to provide maximum flexibility. The nearest three intermediate destinations for each shipping point whether shipping from township centers or elevators, are included in the choice set. Hence, should an optimization run, preclude use of one of the three routes, the model still has several routing alternatives from which to choose. Once the set of minimum distance routes are compiled in ArcInfo, and associated cost components incorporated in Quattro Pro, the GAMS optimization software is used to determine the least cost set of shipping routes.

Figure 3: Optimization Methodology using GIS and external optimization program, GAMS



The GAMS model is a linear programming model where the objective is to ship known quantities of grain from production points (township centers) to predefined destinations, while minimizing total transportation cost. The volume of grain supply (and demand) at each township (and final destination) is known. However, the volume of shipments on given routes and modes to reach the final destination is not known. The complexity increases with the introduction of intermediate destinations (elevators and river ports). The movement from production areas is predominately confined to truck shipments, which generally haul directly to either river ports for barge transport or to elevators. Once the grain reaches the elevator, several possibilities exist for where and how it may move. If the elevator has rail access, the grain may be loaded onto rail for shipment to final destinations. If the elevator doesn't have rail access, then grain may be transshipped to another elevator with rail access or trucked to a river port for barge transport. The GAMS optimization model incorporates each of these modal shipment and route options at each stage of the grain marketing process, with the decision criteria at each juncture being cost minimization.

The optimization model also includes a variety of constraints, which are constructed to maintain realism in the modeling process. A true optimization system would identify the origin points and the quantities to be shipped, the collection of possible routes on various modes, the cost associated with each route option, and the final destinations and then allow the linear program to solve for the least cost optimal solution. However, there are capacity constraints at the intermediate destinations, which limit the amount of grain, which can be handled at each location. There are also capacity constraints associated with usage of certain modes of transport, particularly for rail shipments. Therefore, to insure that these capacities and others relating to the origins and destinations are not exceeded, the following constraints are included in the optimization model.

Supply Balance Equation

Equation (1)
$$\sum_{i=1}^n s_{ij} \leq S_j \quad \forall \quad j$$

Where s_{ij} is the i th grain shipment from township j and S_j is the available grain supply produced in township j . Thus, the supply balance equation prevents the total amount of shipments from any township from exceeding the available supply produced within that township.

Node Balance Equation

Equation (2)
$$\sum_{i=1}^n x_{ij} = \sum_{i=1}^n y_{ij} \quad \forall \quad j$$

Here x_{ij} is the i th grain shipment into the j th intermediate location (river ports and elevators) and y_{ij} is the i th shipment leaving the j th intermediate location. Therefore, the total volume of grain flowing into intermediate locations must equal the amount flowing out of each location. This constraint abstracts from reality somewhat by preventing any grain storage. However, the analysis utilizes grain production and consumption volumes for the year and the majority of grain produced in a given year is marketed before the next harvest period.

Destination Balance Equation

Equation (3)
$$\sum_{i=1}^n d_{ij} \geq D_j \quad \forall j$$

This constraint verifies that the sum of all shipments (d_{ij}) to the j th final destination is greater than or equal to the grain demanded at each final destination.

Elevator Capacity Equation

Equation (4)
$$\sum_{i=1}^n x_{ij} \leq C_j \quad \forall j$$

This constraint assures that elevator capacity is not exceeded at any individual elevator. Here x_{ij} is the i th shipment into the j th elevator and C_j is the grain capacity at elevator j . Therefore, the sum of all shipments into a given elevator cannot exceed the capacity of the elevator.

Rail Capacity Equation

Equation (5)
$$\sum_{i=1}^n r_{ij} \leq R_j \quad \forall j$$

The rail capacity constraint controls the amount of grain, which may be shipped, on rail from any given elevator with rail access. The variable r_{ij} represents the i th shipment on rail from elevator j and R_j is the rail capacity at elevator j . Without a constraint on rail usage, the total volume of grain entering elevators with rail loading facilities would likely be shipped on rail due to cheaper rates associated with rail transport. In reality, elevators in eastern Washington are forced to truck various amounts of grain due to market conditions and the limited availability of rail cars. Thus, by constraining the amount of grain shipped on rail at each elevator, the optimization model closely represents actual grain movements in the region, and more importantly, produces shadow prices reflecting the marginal dollar value associated with relaxing rail constraints, the primary focus of this investigation.

The rail capacity constraint for each individual elevator represents the historical annual volume shipped on rail, as reported in the elevator survey. These values represent the "base" scenario with increases and decreases applied later. Modifications to this constraint allow investigation of the sensitivity of shadow prices to changes in the quantity of rail shipments. The shadow price in this context represents the marginal value to the producer or grain shipper associated with relaxing the rail constraint (increasing the amount) one unit (bushel, ton, carload, etc.) Thus, increases and decreases of 10, 20, 30, 40 and 50 percent of the base value are examined to determine changes in shadow prices and the total transportation cost.

Results

Rail transport of grain is often cheaper than other modal options for most producers and grain handlers, except for those located within close proximity of a navigable waterway, such as the Snake/Columbia river system. These producers often truck grain directly to river ports for barge loading, usually avoiding handling and storage cost associated with movement through elevators, while realizing the full benefit of extremely low cost river transport. Those producers located long distances from the river are limited by time and logistics during harvest season to either ship grain by rail, truck-barge, or storing the grain for future marketing. Rail car shortages for these producers and handlers increase the cost of transporting their crop to market, resulting in cost increases from storage, handling and transport rates.

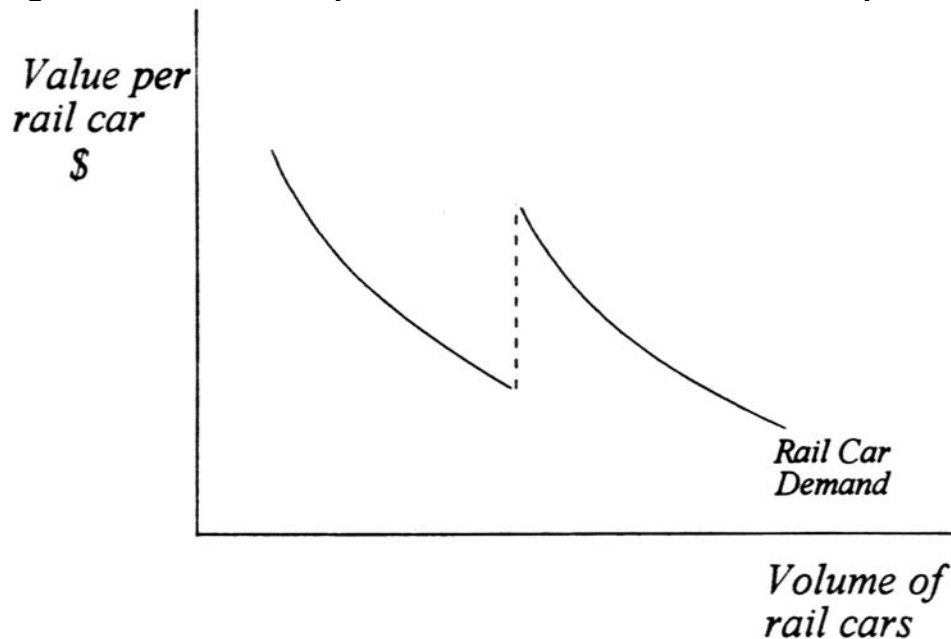
It is not surprising, therefore, that the total cost of transporting all wheat produced in Eastern Washington to market consistently declines as the allowable amount of rail shipments increase, as displayed in Table 1. Transportation costs of \$66.6 million with the most stringent rail constraint scenario decreases to about \$66.06 million under the least rail constraining scenario, producing a savings of over \$570,000. It is interesting to note the marginal changes associated with the total transportation costs for each rail use situation. When rail capacity is heavily constrained to only 50 percent of historical volumes, the decrease in total transportation costs associated with relaxing the constraint 10 percent is over \$67,000. However, each additional increase in allowable rail shipments has a steadily decreasing impact on the magnitude of transportation cost savings. Increasing the rail constraint from 40 percent to 50 percent above the base scenario decreases total transportation cost only \$44,098. Stated differently, rail car shortages increase transportation cost at an increasing rate. The cost, for example, to producers associated with a rail car shortage of one car is more than doubled when the rail car shortage increases to two cars. Grain producers and handlers, therefore, are severely impacted by large, prolonged rail car shortages.

Table 1--Estimated value of rail car accessibility, rail volume and total transportation costs for different rail usage scenarios.

Scenario	Value Per Car \$/Carload	Rail Volume (number of rail cars)	Total Transportation Cost (\$)
50% ↓	128.9	2730.6	66,642,916
40% ↓	124.7	3248.9	66,545,471
30% ↓	121.1	3764.2	66,510,397
20% ↓	120.9	4279.4	66,447,949
10% ↓	114.2	4491.6	66,386,076
Base	126.3	5224.1	66,327,885
10% ↑	124.3	5648.1	66,270,066
20% ↑	122.6	6067.9	66,213,671
30% ↑	120.5	6465.4	66,159,093
40% ↑	111.6	6835.6	66,110,003
50% ↑	109.8	7171.6	66,065,905

The value per rail car associated with relaxing the rail constraint one car for each scenario is also included in Table 1, along with the volume of rail shipments in number of cars. In a sense, this schedule of values and quantities is an estimate of the demand relationship for rail cars used for grain transport. Each scenario represents a point on the demand curve, representing the quantity of rail cars for various rail car values. And, if the value per rail car were assigned to the vertical axis and the quantity of rail cars attached to the horizontal axis and each of these points plotted, a downward sloping curve would result as expected for demand relationships. It would be downward sloping to the right except for one noticeable "lump". The value per rail car declines as the rail constraint is relaxed up until the base scenario. Here the value per rail car has a dramatic jump in value, then declines again as rail volume is increased. This relationship, characterized generally in Figure 4, is unlike the smooth, continuous demand relationship we usually expect. The question to be answered is why does the value of rail accessibility increase as the amount of rail usage increases.

Figure 4: General shape of rail car demand for wheat shipments

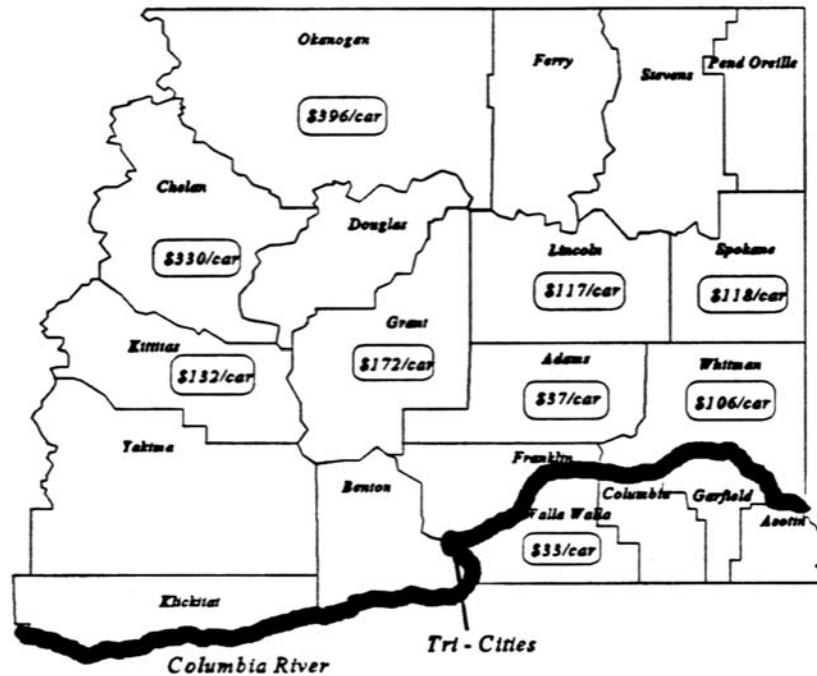


The explanation for this phenomenon rests in the procedure used for estimating the value of rail car accessibility and the nature of rail shipments and rail car allocation in the region. Each elevator in the region is limited to the historical annual amount of grain for rail shipments, as identified in the grain survey. Whenever this constraint is binding for an individual elevator, a shadow price is generated representing the difference between transporting grain via rail and the next cheapest method of reaching the final destination. Whenever this constraint is not binding the value associated with having access to an additional rail car has no value since there is currently unused rail capacity. Only elevators with binding rail constraints, and therefore shadow prices, are used in evaluating the value of rail car accessibility. Elevators with rail capacity and no shadow prices are not incorporated into the estimation process because excess capacity at one elevator does not necessarily translate into additional rail cars for those elevators with car shortages. Each elevator is allocated rail cars by rail companies based upon their historical use, with limited opportunities for car transfers. There are opportunities for arbitrage through the purchase of certificates of transport (COTS) from rail companies at a premium, similar to buying an option to purchase or sell rail cars at a future date. There could also be some internal transferring of grain cars among elevators owned by a single firm. The extent of this practice and the additional price premium for COTS, difficult to implement into this modeling procedure, therefore causing these estimates to potentially over estimate, to some degree, the true value of rail car accessibility.

Increasing the allowable amount of rail usage generates more elevators with zero shadow prices, especially for elevators within close proximity of barge transport. When the rail constraint was increased from a 10 percent decrease to the base scenario those elevators located fairly close to the river (and not desiring to use rail) generated zero shadow prices, with the remaining shadow prices from further north of the river being

considerably higher. Since the zero shadow prices are not included in the estimation process, the result is a higher value for rail car access. This situation is illustrated in Figure 5 where the value of rail car access is calculated for each county for the base scenario. Those counties without estimates were either void of elevators with rail access or the rail constraint wasn't binding. However, the value of rail access for those counties close to the Snake/Columbia river is less, compared to those counties further from the river. The difference in rail value is directly proportional to the distance from the river. Larger distances require increased trucking cost to reach the river or ship directly to market, thus producing larger shadow prices. The value of an additional rail car to an elevator who can use barge without incurring much additional cost is small compared to someone who must truck grain long distances in the absence of rail.

Figure 5: Estimated Value of Rail Car Accessibility for Wheat Shipments in Eastern Washington, by county



The estimated value per car for each scenario in Table 1 also represents a market for rail service above the current rail rates. While most of this value represents the additional transportation cost (trucking and barge rates) associated with transporting grain to market in the absence of rail, this value also includes storage, handling and interest cost from grain that must be stored for some period while waiting for shipment. Hence, this value also offers some measure of the opportunity cost associated with rail car shortages. Additionally, these estimates may provide producers, grain handlers and Washington State DOT officials with information regarding potential rail car investment opportunities.

Summary and Conclusions

This study has taken an unconventional approach to investigating the annual occurrence of rail car shortages in Eastern Washington. The approach is unconventional in the sense that both GIS and classical linear optimization technologies are used, but maintained separately, to model grain movements from production to final market and investigate the value of rail car access under different rail usage scenarios. This procedure offers considerably more flexibility in modeling transportation systems, which require powerful optimization capabilities such as modeling grain movements in Eastern Washington. The GAMS optimization software is used in this analysis and is external to the Geographic Information System, Arc Info. Many different types of policy analyses involving transportation modeling, planning and infrastructure investment decisions are natural using the approach incorporated in this study. Issues such as rail line abandonment road closures, highway impact analysis and river drawdowns are more completely evaluated and addressed using this type of modeling framework.

Eleven different rail usage scenarios are considered for estimating the value associated with rail car accessibility. Rail transport at each elevator is constrained within the optimization model to historical levels and increases (and decreases) of 10, 20, 30, 40 and 50 percent of this base level are analyzed. Total transportation costs decline considerably with each allowable increase in rail transport as expected. However, the decrease to total transportation cost becomes smaller for each successive increase in rail access. Therefore, the adverse impacts to grain producers and handlers, in terms of increased transportation cost storage and handling cost, and interest cost increases substantially as rail car shortages become more severe.

The value of rail car access varied from \$128.9 per rail car in the most restrictive rail use scenario to \$109.8 per rail car when rail constraints are increased to 50 percent above historical levels. These estimates disregard elevators without binding rail constraints, assuming no transferring of cars between elevators, which may exaggerate these values of rail access somewhat. However, these rail car values represent a market for additional rail cars above the current rail rate. Rail companies operating in the region may utilize these estimates to develop car allocation systems, which serve this market more effectively while increasing profits.

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