INLAND/OCEAN WATERBORNE TRANSPORTATION INNOVATIONS AND PORT CHARGES[1]

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Containerization of transoceanic general cargo shipments was pioneered in 1966 when Sea-Land Service, Inc. initiated a containership service from the U.S. East Coast to Europe. Shipping of cargo in uniform-sized sealed containers of truck-trailer size revolutionized the marine transportation industry during the 1970s. The intermodal container enables the shipper to pack his cargo in the container at his own premises and deliver the cargo to a port to be transferred to an ocean vessel and delivered overseas to the foreign consignee, without the contents of the cargo being handled at each stage of the journey. Initially, the container was moved to an ocean port by rail or truck, but recently this leg of the movement has been adapted to inland river movement via the container-on-barge. Another alternative in intermodal waterborne transportation is the shipborne barge and barge-carrying vessel (BCV). The uniqueness of this intermodal form of waterborne transportation stems from the fact that the system directly bridges inland and ocean waterborne transportation. Specially designed shallow draft barges or lighters are directly loaded and discharged on an ocean-going mothership specifically equipped for that purpose. The two major design concepts of BCV that are currently employed are LASH (lighter aboard ship) and SEABEE.[2] The LASH version of BCV was analyzed in our study.

These technological innovations have brought a new dimension to the potential role of inland river navigation systems in the U.S. agricultural export distribution system. Traditionally, cargo river movements have consisted of low value bulk commodities such as grains, ores, gravels, logs, wood chips, fertilizer, and petroleum products. The two innovations allow the possibility of shipping commodities in smaller consignments classified as general cargo, where bags or other separate units are involved, or in certain cases as minibulk (small bulk consignments). Processed protein meal shipped in bags or smaller minibulk consignments, vegetable oils shipped in barrels, rice shipped in bags or minibulk consignments, cotton shipped in bales, forest products including paperboard and lumber, hides and skins, and canned fruits and vegetables are examples. Even refrigerated shipments can be made by such means, although the longer transit times associated with water shipments probably limit the feasibility of these modes for perishable commodities. Inland waterways such as the Mississippi, Sacramento, and Columbia Rivers as well as the navigable portions of their tributaries allow these technologies to reach a considerable portion of the United States hinterland that produces for export markets.

Minibridge is another relatively recent innovation in transportation that has developed as an extension of intermodal containerized shipping. This service combines a rail transcontinental and ocean container movement under one rate. For export shipments that originate near the West Coast but are destined to European markets, nonstop unitized trains move containers to East Coast ports where they are loaded on ocean vessels. Similarly, shipments originating near the East Coast or Gulf can be railed to West Coast ports for transshipment to ocean vessels destined for Asian ports. Two notable aspects of this mode of transportation are that it generates intercoastal competition among deep-sea ports as well as intracoastal competition and, second, that it is an important land alternative to all-water routes via the Panama Canal for transatlantic shipments originating in the West (or transpacific ship-

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[1]The study reported here is one of a series of studies at the University of Idaho analyzing the role of intermodal general cargo commerce on the Columbia/Snake navigation system. The project is supported by funds from Competitive Grant No. 616-15-85 provided by the Cooperative State Research Service of the U.S. Department of Agriculture; Grant Project Nos. R/UI-2 and R/UI-4 from the Oregon State University Sea Grant College Program in cooperation with the National Oceanic and Atmospheric Administration, U.S. Department of Commerce; and other funds provided by the Cooperative State Research Service and the University of Idaho Agricultural Experiment Station.

[2]The original version of the LASH system involved a barge-carrying mother vessel equipped with a 500-ton shipboard gantry crane designed for loading and offloading LASH barges over the stern. The barges are approximately 60 feet long, 30 feet wide and 13 feet high. The carrying capacity of these barges is approximately 400 tons. The SEABEE barge-carrying vessel concept differs from LASH in that the barges or lighters are designed differently and stowing barges on the vessel is different. The SEABEE barges have a greater carrying capacity and the mothership loads and offloads barges with an elevator device rather than a crane.

ments from the East in other situations).

We report the results of a transshipment linear programming analysis of the aforementioned modes applied to export shipments of dry peas via the Columbia/Snake navigation system in the Pacific Northwest (PNW). Similar analyses have been applied to bluegrass seed and lentil exports, but for the sake of brevity only the results for dry peas are reported here (Bahn and Jones, Belcher). The analysis identified least-cost modes and alternative routes encompassing combined inland and ocean movements under several alternative transportation conditions. It also identified inland origins of shipments and optimal port transshipment points.

The primary objective of our study was to examine intermodal transportation systems, specifically container-on-barge, barge-carrying vessel, and minibridge, by comparing them with traditional transportation systems. A secondary objective was to introduce two factors potentially affecting the rate structure—waterway users' fees and higher container handling charges—to assess the sensitivity of the model results to changes in rates or charges.

Another important aspect of the model was that it permitted the inclusion of port charges in the analysis of export movements by specifying shipments from interior land points to overseas destinations. This feature was essential to analyzing the two transportation innovations as their merits depend heavily on cost savings achieved during handling at the port. Both technologies purportedly minimize these costs via reduced and automated handling involving intermodal containers or barges transferred by shoreside or shipboard cranes. The study is thought to have methodological merit for other transportation and trade researchers in that it incorporates all the various transportation and handling charges of a cargo from the time it leaves the inland shipper through all the transshipment points to the overseas port of destination. In particular, to the authors' knowledge, no other transportation studies of export movements have identified interfacing port charges in the detail encompassed in our study. Most similar studies have traced movements only to the ocean port, or have begun at that point, without including the various charges incurred at the port interfacing these two movements (e.g. Koo and Cramer, Schmitz, Thayer).

METHOD

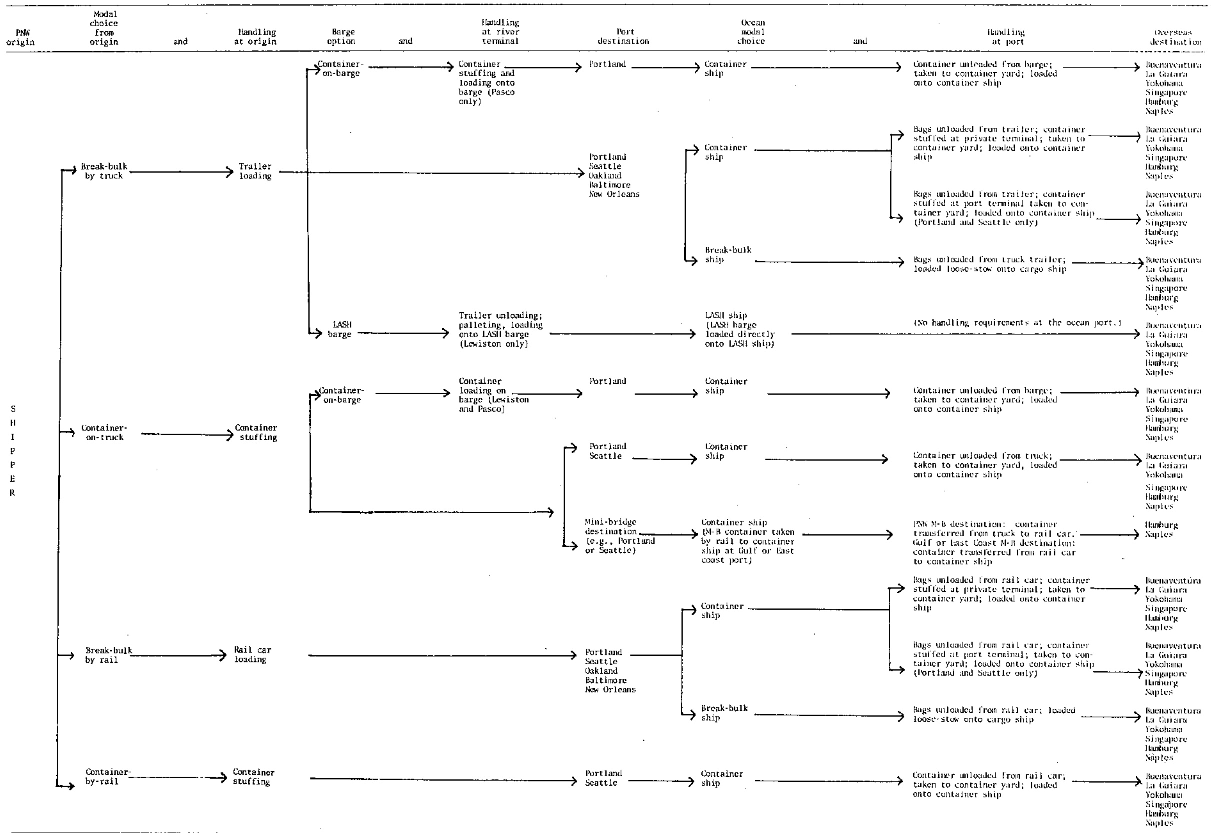
A detailed mathematical description of the linear programming transshipment model used in the analysis is presented in the appendix to summarize and illustrate the complexity of intra- and intermodal relationships and alternative routings encompassed in the study[3] (Belcher, Belcher et al.). The focus of the model was on whether the intermodal barge technologies—container-on-barge and shipborne barge—can effectively compete in the export distribution and transportation of an agricultural product that has traditionally not been shipped by barge when inland river navigation is available. Five additional types of inland shipping modes were specified as alternatives with which container-on-barge and shipborne barge river modes compete—break-bulk truck, container-on-truck, break-bulk rail, container-on-rail, and minibridge. Three types of ocean transportation were specified for dry pea exports—break-bulk vessel, container vessel, and barge-carrying vessel. Each type can call on all suitable U.S. and foreign ocean ports, although BCV is uniquely suited for ports situated along navigable rivers. Figure 1 is a flow chart of the dry pea transportation system.

The dry pea export trade network was spatially delineated into six production origins in the Pacific Northwest region where more than 90 percent of U.S. production occurs (nearly 70 percent of this production is traditionally exported). Major foreign market areas for dry peas were represented by six destinations: Buenaventura, Colombia; La Guiara, Venezuela; Yokohama, Japan; Singapore; Hamburg, Germany; and Naples, Italy. Five intermediate transshipment ocean ports were selected—Seattle, Portland, Oakland, New Orleans, and Baltimore. Lewiston, Idaho and Pasco, Washington were designated as inland river transshipment ports.

Transportation rates and charges were obtained from surveys and by statistical methods. Break-bulk truck, break-bulk rail, and container-on-barge rates were gathered from a confidential field survey of 18 dry pea shippers, three truck firms, and three barge firms. Missing rate observations (for routes designated in the transshipment model) were estimated from the survey data by a linear regression model. Container-on-truck rates were contributed by a trucking firm and missing observations were estimated. LASH rates were estimated by a steamship agency official. River port charges were gathered from appropriate port tariffs. Ocean port charges and ocean freight rates were obtained from a mail and telephone survey of ocean steamship conferences and ocean steamship lines. (For further description of data and sources, see Belcher, pp. 22-93.)

[3]A standard transshipment linear programming model was used to minimize total transportation cost and identify least cost modes and routes under several simulated transportation settings. There were 410 to 450 activities in the transshipment model, the number depending on the particular transportation setting being analyzed. It was assumed that no short-run anomalies, such as heavy seasonal demand for transportation of other commodities, were occurring at that time which might distort the rates gathered for the study. Also, no mode or port capacity constraints were considered.

FIGURE 1. FLOW CHART OF MODAL ALTERNATES FOR PNW DRY PEA EXPORTS



[a]These six destinations are only potential destinations for LASH service at this time.

TAXONOMY OF PORT CHARGES

The incorporation of port charges into transportation models has been neglected in past studies. One possible reason is that port handling and shipping terminology and costing are complicated. However, port charges can be significant in terms of overall transportation costs. In our study, rail charges to Portland, Oregon from Lewiston, Idaho were 54¢/cwt whereas handling charges involved in transferring the commodity to a containership at Portland totaled \$1.32/cwt. The cost of barging containers to Portland was estimated to be 36¢/cwt, the river terminal charges were 9¢/cwt, and Portland's handling charges were 33¢. No studies that included an analysis of port charges were found in the literature search. This dearth of information was also cited by Admunsen who recently conducted a port pricing study for the U.S. Maritime Administration.

Our discussion of port charges is based on interviews with port officials and a review of published port tariffs. Port charges were included in the total freight bill according to both operating and nonoperating port pricing systems. At the two operating ports, Portland and Seattle, the port charges incorporated into the linear programming model were based on ocean steamship conference pricing of port services. The operating port performs the actual handling of cargo through the port to shipside. The operating port bills the ocean steamship line which, in turn, bills the account of cargo (i.e., the shipper or consignee depending on the terms of the sale). The steamship line can be a member of an ocean steamship conference. The conference sets common freight rates, and common port charges at operating ports, for its member lines. (Conference rates were used in this study rather than nonconference tramp or charter rates.)

Deriving port costs is difficult because operating ports and ocean steamship lines have their own separate terminology and pricing method. Unfortunately (for research purposes), there is no neat juxtaposition of ocean steamship company pricing and operating port pricing.

At the three nonoperating ports, Oakland, New Orleans, and Baltimore, private stevedoring companies perform port services and bill the account of cargo. A nonoperating port leases port space to stevedoring companies. An essential difference between a nonoperating port and an operating port is that the former assesses charges against the ocean vessel, such as wharfage, whereas the latter assesses charges against both the vessel and the cargo moved through the port. An operating port publishes a port tariff which covers all services offered and the rates thereof. Private terminal operators at nonoperating ports establish competitive rates for services.

TABLE 1. PORT PRICING OF PORT SERVICES FOR TWO OPERATING PORTS: SEATTLE AND PORTLAND[a]

	Seattle		Portland	
break-bulk by truck to loose-stow on ship	break-bulk assessment $6.50 MT[b]	.295	break-bulk assessment $6.50 MT	.295
	service and facilities $3.16 ST[b]	.180	service and facilities $3.16 ST	.180
		.475		.475
break-bulk by rail to loose-stow on ship	rail unloading $9.88 ST	.494	rail unloading $9.88 ST	.494
	break-bulk assessment $6.50 MT	.295	break-bulk assessment $6.50 MT	.295
	service and facilities $3.16 ST	.180	service and facilities $3.16	.180
		.969		.969
break-bulk by truck to privately stuffed container to container ship	private container stuffing $0.28/cwt[b]	.280	private container stuffing $0.25/cwt	.250
	throughput $58.25/c[b]	.150	throughput $78.00/c	.202
	wharfage $2.60 ST	.130	wharfage $2.60 ST	.300
	service and facilities $37.25/c	.096		
		.656		.582
break-bulk by rail to privately stuffed container to container ship	rail unloading and private container stuffing $0.31/cwt	.310	rail unloading and private container stuffing $0.31/cwt	.310
	throughput $58.25/c	.150	throughput $78.00/c	.202
	wharfage $2.60 ST	.130	wharfage $2.60 ST	.130
	service and facilities $37.25/c	.096		
		.686		.642
all container by truck, barge (Portland only), or rail to container ship	throughput $58.25/c	.150	throughput $78.00/c	.202
	wharfage $2.60 ST	.130	wharfage $2.60 ST	.130
	service and facilities $37.25/c	.096		
		.376		.332

[a]Price per cwt in right hand column of each cell.
[b]MT = metric ton; ST = short ton; LT = LONG TON: C = twenty foot container; cwt = hundredweight.

TABLE 2. PORT PRICING OF PORT SERVICES FOR THREE NON-OPERATING PORTS: OAKLAND, NEW ORLEANS, AND BALTIMORE[a]

	Oakland		New Orleans		Baltimore	
break-bulk by truck to loose-stow on ship	truck unloading $0.72 ST	.036	truck unloading $4.73 ST	.237	truck unloading $5.95 ST	.298
	break-bulk charge $19.33 ST	.967	wharfage $0.90 ST	.045	wharfage $1.00 ST	.050
	wharfage $2.60 ST	.130	terminal charge $4.00 LT	.180		
		1.133		.462		.348
break-bulk by rail to loose-stow on ship	rail unloading $12.25 ST	.613	rail unloading $4.73 ST	.237	rail unloading $3.80 ST	.190
	wharfage $2.60 ST	.130	wharfage $0.90 ST	.045	wharfage $1.00 ST	.050
	break-bulk charge $19.33 ST	.967	terminal charge $4.00 LT	.180		
		1.710		.462		.240
break-bulk by truck to privately stuffed container to container ship	truck unloading $0.72 ST	.036	private container stuffing $10.00 LT	.447	truck unloading $5.95 ST	.298
	private terminal throughput $125/c (stuffing $82/c) (stevedoring $43/c)	.325	terminal charge $4.00 LT	.180	private container stuffing and handling $175.00/c	.455
	wharfage $2.60 ST	.130	wharfage $0.90 ST	.045	wharfage $1.00 ST	.050
		.491		.672		.803
break-bulk by rail to privately stuffed container to container ship	rail unloading $12.25 ST	.613	private container stuffing $10.00 LT	.447	rail unloading $3.80 ST	.190
	private terminal throughput $125.00/c (stuffing $82/c) (stevedoring $43/c)	.325	terminal charge $4.00 LT	.180	private container stuffing and handling $175.00/c	.455
	wharfage $2.60 ST	.130	wharfage $0.90 ST	.045	wharfage $1.00 ST	.050
		1.068		.672		.695

[a]Price per cwt in right hand column of each cell.

Tables 1 and 2 show the port pricing of port services. Nine types of port interfaces were identified for bagged dry pea shipments. The first type of interface, "break bulk by truck to loose stow on ship," is available at each of the five selected ports. Seattle and Portland, which are in a common marine terminal conference, denote the costs for the requisite port services as a "break bulk assessment" and a "service and facilities" charge. The former charge includes the movement from where the cargo is first removed from the truck (the "first point of rest") and the wharfage charge. The latter charge is a general fee for using the port facilities and includes such services as receipt, delivery, checking, care, custody, and control of cargo moving through the port. At Oakland, New Orleans, and Baltimore, private terminals apply a truck unloading charge and wharfage charge. The break-bulk charge in Oakland and the terminal charge in New Orleans are similar to the break-bulk assessment described heretofore. We did not ascertain whether such a charge is used in Baltimore or how it would function. In addition, for all interfaces a ship-loading cost was involved and was absorbed into the ocean freight rate. Rail unloading was the only additional port cost factor for the second type of interface, "break bulk by rail to loose stow on ship."

Rail and truck unloading charges are usually paid by the shipper. Port charges after the first point of rest are billed by the port or private marine terminal to the steamship line. The steamship line presents the actual bill for port services to the shipper or the consignee. Most dry pea exports are sold "FOB-dock" which obliges the shipper to deliver to the first point of rest at the U.S. port of discharge. The consignee pays port charges (as billed by the steamship line) and ocean freight.

To different degrees, port charges may be billed separately and/or "absorbed" into the ocean freight rate. Pacific Northwest steamship conferences use both methods. Seattle and Portland port officials stated that the steamship conferences' "handling" and "wharfage" charges are billed independently of the ocean freight bill, but that some of the costs for port services are absorbed into the freight rate. The other ports had terminal and wharfage charges for the bagged cargo. Some port charges, such as dockage, apply only to services required by the vessel aside from the cargo. Such charges are incorporated into the ocean freight rate.

All of the other types of interfacings involve container movements and have mostly common charges. Depending on the type of container interfacing and port, there are truck or rail unloading charges and private or port stuffing charges. Wharfage is a charge common to all container interfacings and ports.

The movement of the container from first point of rest to shipside incurs a "container throughput" charge at Seattle, Portland, and Oakland. In Oakland, a nonoperating port, private terminals also include container stuffing in this cost item. A specific cost item for container movements from first point of rest to shipside was not determined for Baltimore and is probably incorporated into the ocean rate. Steamship lines bill and/or absorb these charges.

The port charges at the representative upriver ports are for container interfacings between truck and barge. Three inland charges are incurred: the round trip container-on-barge movement, a terminal ("throughput") charge, and the trucking charge for the delivery of the empty container and return of the "stuffed" container from the inland source.

Shipborne barge costs at upriver ports would probably include unloading the bags from the truck, palletizing, and loading into the barge. Because shipborne barges are loaded directly onto the ocean vessel, ocean ports can be bypassed.

TRANSPORTATION SETTINGS AND RESULTS

Four alternative transportation scenarios that were analyzed with the transshipment model are reported here. Dry pea shipping without container-on-barge (Model Ia) and dry pea shipping with container-on-barge (Model Ib) were run to analyze the impact of the introduction of container-on-barge general cargo transportation on the transportation system.[4] Models II and III assess the potential effect of waterway users' fees and increased container-handling charges at Portland, respectively, on the results obtained in Model Ib. Models IVa, IVb, and IVc introduce shipborne-barge BCV service as an additional river mode along with container-on-barge under three sets of assumptions regarding the treatment of handling costs at the inland river port where the barge is first loaded. Table 3 lists the linear programming solutions of cargo distribution among modes for the transit from an inland point to the ocean port. The modal distributions for the ocean transit are given separately in Table 4. Minibridge is incorporated into each scenario and its relative role can be seen in this table where it is presented as an alternative to all-water shipments from the West Coast.

Comparing Model Ia with Model Ib shows that, upon its introduction, container-on-barge

[4]General cargo shipments of peas and other commodities are differentiated from bulk-shipped commodities such as grain because shipping consignments are smaller and the commodity is generally shipped in bags, cartons, barrels, or some other unitized means such as bales rather than in loose form.

TABLE 3. LINEAR PROGRAMMING SOLUTIONS: INLAND MODAL SHARES OF PACIFIC NORTHWEST DRY PEA EXPORTS

Model		Break-Bulk Truck quantity[b] (%)	Break-Bulk Rail quantity (%)	Container on Truck quantity (%)	Container on Rail quantity (%)	Container on Barge-Pasco[a] quantity (%)	Container Via Barge-Lewiston quantity (%)	BCV Barge from Lewiston quantity (%)	Total quantity (%)
Ia	Dry pea shipping with out container on barge	1,105,840 (67%)	----	555,070 (33%)	----	N.A.	N.A.	N.A.	1,660,910 (100%)
Ib	Dry pea shipping with container on barge (BASE MODEL)	704,958 (42%)	----	555,070 (33%)	----	----	400,882 (25%)	N.A.	1,660,910 (100%)
II	Base Model with 12¢/g user fee and 30% increase at Portland	1,105,840 (67%)	----	555,070 (33%)	----	----	----	N.A.	1,660,910 (100%)
III	Base Model with 30% increase in container handling charge at Portland	1,105,840 (67%)	----	555,070 (33%)	----	----	----	----	1,660,910 (100%)
IVa	Base Model with BCV, including loading and palletization costs at Lewiston	704,958 (42%)	----	555,070 (33%)	----	----	400,882 (25%)	----	1,660,910 (100%)
IVb	Base Model with BCV, with loading but without palletization costs at Lewiston	514,000 (31%)	----	539,088 (32%)	----	----	15,981 (1%)	591,800 (36%)	1,660,910 (100%)
IVc	Base Model wtih BCV, not including loading or palletization costs at Lewiston	----	----	146,990 (9%)	----	----	----	1,513,920 (91%)	1,660,910 (100%)

[a]The barge modes also require truck transportation from the shipper to the river.
[b]Quantity is in terms of hundredweight bags.
N.A.: not applicable.

TABLE 4. LINEAR PROGRAMMING SOLUTIONS: OCEAN MODAL SHARES OF PACIFIC NORTHWEST DRY PEA EXPORTS

Model		Mini-Bridge quantity[a] (%)	BCV Vessel quantity (%)	Break Bulk Ship quantity (%)	Container Ship (excluding Mini-Bridge) quantity (%)	Total quantity (%)
Ia	Dry pea shipping without container on barge	555,070 (33%)	N.A.	1,105,840 (67%)	----	1,660,910 (100%)
Ib	Dry pea shipping with container on barge (BASE MODEL)	555,070 (33%)	N.A.	704,958 (42%)	400,882 (25%)	1,660,910 (100%)
II	Base Model with 12¢/g. user fee and 30% increase at Portland	555,070 (33%)	N.A.	1,105,840 (67%)	----	1,660,910 (100%)
III	Base Model with 30% increase in container handling charge at Portland	555,070 (33%)	N.A.	1,105,840 (67%)	----	1,660,910 (100%)
IVa	Base Model with BCV, including loading and palletization costs at Lewiston	555,070 (33%)	----	704,958 (42%)	400,882 (25%)	1,660,910 (100%)
IVb	Base Model with BCV, with loading but without palletization costs at Lewiston	539,088 (32%)	591,800 (36%)	514,040 (31%)	15,982 (1%)	1,660,910 (100%)
IVc	Base Model with BCV, not including loading or palletization costs at Lewiston	146,990 (9%)	1,513,920 (91%)	----	----	1,660,910 (100%)

[a]Quantity is in terms of hundredweight bags.
N.A.: not applicable.

captures 25 percent of the total shipments and the share of break-bulk truck falls from 67 to 42 percent. Minibridge-destined container-on-truck movements are projected a 33 percent share in both models. During the latter course of the study barging companies announced a reduced rate on container-on-barge service on the Columbia/Snake navigation system. The container-on-barge mode alternative was re-examined in light of the lower rate (not shown in Tables 3 and 4) and the container-on-barge share increased to 79 percent. In another development a minibridge ocean carrier announced that Port of Portland handling charges of transferring containers from barges to the rail terminal for minibridge rail shipment to the East Coast would be absorbed within its freight charge. A run of Model II with this rate resulted in 100 percent of dry pea shipments from the Pacific Northwest moving by container-on-barge on the Columbia/Snake navigation system.

Among the ocean modes, container ships take 58 percent, 25 percent directly from West Coast ports and 33 percent as minibridge shipments. Break-bulk ships handle 42 percent. The dominance of container ship ocean transit over break-bulk shipping is consistent with the shift from break-bulk to containerized shipping in the past decade. The result for minibridge shipments is interesting as it suggests that this form of intermodal shipping is a feasible alternative to all-water shipments through the Panama Canal.

A waterway users' fee was introduced in Model II to ascertain whether imposition of such a fee would significantly alter the competitive position of container-on-barge. The fee was assumed to be completely passed through in the form of higher freight rate structures. A parametric programming procedure brought in a range of a 0-42¢/gal fuel tax user fee which represents a range of up to 4.41¢ added cost per hundredweight in the shipping rate. The user fee has an initial effect at 27.6¢/gal. If the incidence of the fee were not borne entirely by shippers in higher rates, the level of impact would be commensurably higher. Because the recently enacted user fee on waterway barge operators to partially cover navigational maintenance and operation charges reaches a maximum of 10¢/gal by 1985, user fees are estimated to have no significant impact on the competitive position of container-on-barge.

Model III incorporates a 30 percent increase in the ocean conference container handling charge at Portland which reportedly was being considered at the time the study was conducted. Although conference port charges are approximately equalized in practice at U.S. West Coast ports, this sort of charge hypothetically could affect modal shares if it were implemented. Adding it to the freight charge of transporting cargo by container-on-barge through the Port of Portland, according to the linear programming results, causes container-on-barge to be eliminated. This finding indicates that variations in port charges at one port in relation to another can have significant implications for the method and route of least-cost shipment.

In general the results of the analysis suggest that, with the rate structure in effect at the time of the study, container-on-barge is a competitive modal alternative for shipping dry peas into export markets. Its share of the traffic is shown to be sensitive to freight rate variations including increased port handling charges. Waterway users' fees, however, are discounted in importance because of their minimal effect on rates.

When container-on-barge is evaluated in terms of potential savings to shippers as an alternative to traditional rail and truck shipping, its significance is not overwhelming. Before container-on-barge is introduced for dry pea transportation the total freight bill is $7,809,634. After the introduction of the mode, total cost decreases by $14,259 (0.18 percent) under the rate structure included in the solutions in Table 3 and 4, and by $83,554 (1.0 percent) after the reduced container-on-barge rates and new minibridge via container-on-barge services are incorporated.

Shipborne-barge/barge-carrying vessel services as represented by LASH are entered into the linear programming analysis in Models IVa, IVb, and IVc. In the late 1960s and early 1970s this concept in inland/ocean waterborne intermodal shipping was much heralded. In-port economies were claimed for the system by virtue of the fact that the vessel could avoid port delays and costly labor charges by cargo being loaded directly aboard the ocean vessel in barges without docking at a deepwater ocean port. A cost comparison of shipborne-barge services and container-on-barge services verified that the former could reduce handling expenses by 54-57¢/cwt at the deepwater port (Jones). However, loading and palletization costs of transferring dry peas to the lighter barge from trucks at the upriver port were estimated to be as much as 59-63¢/cwt more than if the cargo had been shipped by container.

The scope of our study did not permit a full evaluation of the true economies of shipborne barge. Rather, the three models (IVa, IVb, and IVc) were run to ascertain the potential impact of shipborne barge when loading and palletization costs at the representative inland river port are paid by the shipper in addition to the in-transit freight charge (Model IVa), when palletization charges are absorbed by water carriers in the freight rate (Model IVb), and when both loading and palletization costs are absorbed into the in-transit freight charge by carriers (Model IVc). Alternatively, these models could also be used to demonstrate the sensitivity of BCV's feasibility if ways of eliminating or reducing loading and/or palletization costs could be devised. For example, larger 1-ton capacity plastic bags or minibulk handling techniques or other less expensive loading and handling techniques might be adopted. If the original warehousing/processing facility were located on the river, the original costs of loading the truck inland would be removed, offsetting some of the costs of loading the barge. The results prove the issue to be pivotal in the share of shipping captured by shipborne barge.

In Model IVa shipborne barge does not enter the solution. Absorption of palletization costs into the in-transit rate results in 36 percent of dry pea shipments being in shipborne barge, and complete absorption of upriver costs in the in-transit rate results in 91 percent of the modal share going to the system. The scenario represented by Model IVc reduces the total export shipping bill by $452,000 (6 percent) compared with Model Ib.

A sensitivity analysis of the transportation rates and port charges was conducted to ascertain the range in which those rates or charges can increase or decrease before changing the optimal solution of the linear programming model. The sensitivity results associated with Model IVb are reported because all three modal systems of interest—container-on-barge, minibridge, and barge-carrying vessel (LASH)—appear in the optimal solution of that modal alternative. Models II and III are also, in a sense, sensitivity analyses of the base model (Ib) because they demonstrate at which point the model solution changes as a result of additional fees or charges.

The results of the sensitivity analysis of Model IVb are tabulated in Table 5 for all nonzero activities in the optimal solution. Table 5 indicates that nearly all the modes are very sensitive to changes in the actual rate. In several instances, only slightly higher or lower transportation rates or port charges could cause an alternative activity to enter the optimal solution. Of course, if the charge that varies is a minor component of the total transfer cost, such as waterway user charges, large percentage variations will not necessarily affect the stability of the model results.

TABLE 5. SENSITIVITY ANALYSIS

Activities in Optimal Solution of Model IVB			Actual Rate ($/cwt.)	Range in Rates			
Origin	Mode	Destination		Low	(% Change)	High	(% Change)
Spokane	Container-on-truck	Seattle	$0.707	0	100	0.749	6
Colfax	Container-on-truck	Seattle	0.743	0.721	3	0.479	1
Colfax	Break-bulk truck	Seattle	0.543	0.490	10	0.565	4
Moscow	Truck-LASH barge	LASH vessel	0.859	0	100	0.862	0.3
Kendrick	Truck-LASH barge	LASH vessel	0.845	0	100	0.858	2
Craigmont	Truck-LASH barge	LASH vessel	0.871	0.868	0.3	0.881	1
Craigmont	Truck-container-barge	Portland	0.571	0.565	1	0.574	0.5
Seattle	Break-bulk ship	Yokohama	2.770	2.770	0	2.770	0
Seattle	Break-bulk ship	Singapore	5.216	5.216	0	5.216	0
Portland	Container ship	Hamburg	4.480	4.474	0.1	4.483	.07
Seattle/Portland	Mini-bridge	Hamburg	4.302	4.299	0.07	4.308	.14
Seattle/Portland	Mini-bridge	Naples	4.044	0	100	4.140	2.4
Ship barge[a]	Barge carrying vessel	Buenaventura	4.897	0	100	5.122	5
Ship barge[a]	Barge carrying vessel	La Guiara	4.259	3.006	42	4.482	5

[a]A LASH barge is loaded onto the LASH vessel near the mouth of the Columbia River.

CONCLUSIONS

Container-on-barge shipment of bagged dry peas is suggested to be competitive with land modes in terms of the freight rate structure incorporated into the transshipment model. However, two qualifications bear consideration. The model does not explicitly incorporate other considerations such as transit time, adequacy of facilities, steamship scheduling, or service reputation that may also influence the selection of modes and routes. Moreover, the rates used are those actual rates prevailing around January 1978 in the study region. Whether these rates reflect long-run costs of each mode is subject to question. Market imperfections (rates distorted by monopoly or noneconomically regulated rates, imperfect information regarding actual costs, etc.) are often the rule rather than the exception where transportation rates are concerned, and thus long-run equilibrium costs can be very different from actual rates at a point in time. Whether carriers are quoting container-on-barge rates that will be fully compensatory is particularly uncertain given the relatively brief experience they have had with that mode. In light of the fact that the optimal solutions obtained in the transshipment modeling are very sensitive to changes in many of the rates, as shown in the sensitivity analysis, the assumption that the rates incorporated in the study are reflective of relative rates over time is tenuous. These qualifications apply to the other modes considered as well. Use of cost of service transportation charges rather than actual rates theoretically would be desirable, but the practical problems of prorating costs associated with so many modes and port facilities to a specific commodity precluded our taking that approach.

The results of the analysis suggest that the purported advantage of BCV being able to circumvent ocean port charges does not compensate for the higher inland port loading costs of this system in relation to containerization under present rate structures. The fact that the transshipment analysis permits the identification of the importance of this interfacing link in the overall transportation system is considered a major advantage of the type of method employed in our study. It is demonstrated that, barring the absorption of these costs by water carriers or their reduction by innovations in loading procedures, BCV will be minimally important. A recent study completed after our analysis gives further reason to doubt that BCV will be a significant alternative mode (UNCTAD). It is extremely difficult to load barges into or discharge them from a mother vessel moored at an offshore anchorage. For this and other reasons this operation is being carried out in most instances inside the port itself, and thus the main purported advantage of BCV shipping is negated. Several other issues regarding BCV also bear consideration but are beyond the scope of our article. They are discussed by one of the authors elsewhere (Jones).

APPENDIX 1

TRANSSHIPMENT MODEL

$$\begin{aligned}\text{Minimize PTC} = & \sum_{\eta=1}^{5}\sum_{\beta=1}^{5} A_{\eta\beta}Z_{\eta\beta} + \sum_{\eta=1}^{5}\sum_{\beta=1}^{5} B_{\eta\beta}Y_{\eta\beta} + \sum_{\eta=1}^{5}\sum_{\delta=1}^{5} C_{\eta\delta}J_{\eta\delta} \\ & + \sum_{\eta=1}^{5}\sum_{\delta=1}^{5} D_{\eta\delta}W_{\eta\delta} + \sum_{\eta=1}^{5}\sum_{\varepsilon=1}^{5} E_{\eta\varepsilon}V_{\eta\varepsilon} + \sum_{\eta=1}^{5}\sum_{\psi=1}^{1} F_{\eta\psi}U_{\eta\psi} \\ & + \sum_{\varepsilon=1}^{2}\sum_{\mu=1}^{1} G_{\varepsilon\mu}T_{\varepsilon\mu} + \sum_{\psi=1}^{1}\sum_{\lambda=1}^{1} H_{\psi\lambda}S_{\psi\lambda} + \sum_{\eta=1}^{5}\sum_{\partial=1}^{2} N_{\eta\partial}R_{\eta\partial} \\ & + \sum_{\beta=1}^{5}\sum_{\alpha=1}^{6} O_{\beta\alpha}I_{\beta\alpha} + \sum_{\delta=1}^{5}\sum_{\alpha=1}^{6} P_{\delta\alpha}M_{\delta\alpha} + \sum_{\lambda=1}^{1}\sum_{\alpha=1}^{6} Q_{\lambda\alpha}K_{\lambda\alpha}\end{aligned}$$

Subject to: $\sum_{\eta=1}^{5}\sum_{\alpha=1}^{6} X_{\eta\alpha} \leq \text{SUPPLY}_{\eta}$, and $\sum_{\eta=1}^{5}\sum_{\alpha=1}^{6} X_{\eta\alpha} \geq \text{DEMAND}_{\alpha}$

$$X_{\eta\alpha} \geq \emptyset$$

$$\sum_{\eta=1}^{5} \text{SUPPLY}_{\eta} = \sum_{\alpha=1}^{6} \text{DEMAND}_{\alpha}$$

where:

- PTC = dry pea transportation cost
- η = origin area index (Spokane, Colfax, Moscow, Kendrick, Craigmont)
- β = break-bulk port index (Seattle, Portland, Oakland, New Orleans, Baltimore)
- $A_{\eta\beta}$ = quantity moved from origin η to port destination β by break-bulk truck
- $Z_{\eta\beta}$ = unit transportation cost from origin η to port destination β by break-bulk truck
- $B_{\eta\beta}$ = quantity moved from origin η to port destination β by break-bulk rail
- $Y_{\eta\beta}$ = unit transportation cost from origin η to port destination β by break-bulk rail
- δ = container (by truck or rail) port index (Seattle, Portland, Oakland, New Orleans, Baltimore)
- $C_{\eta\delta}$ = quantity moved from origin η to port destination δ by container-on-truck (Seattle and Portland only)
- $J_{\eta\beta}$ = unit transportation cost from origin η to port destination β by container-on-truck
- $D_{\eta\delta}$ = quantity moved from origin η to port destination δ by container-on-rail (Seattle and Portland only)
- $W_{\eta\delta}$ = unit transportation cost from origin η to port destination δ by container-on-rail
- ε = river terminal-container facility index (Lewiston, Pasco)
- $E_{\eta\varepsilon}$ = quantity moved from origin η to river terminal ε by container-on-truck
- $V_{\eta\varepsilon}$ = unit transportation cost from origin η to river terminal ε by container-on-truck
- ψ = river terminal-LASH barge facility index (Lewiston)
- $F_{\eta\psi}$ = quantity moved from origin η to river terminal ψ by break-bulk truck
- $U_{\eta\psi}$ = unit transportation cost from origin η to river terminal ψ by break-bulk truck
- μ = container-by-barge receiving ocean port index (Portland)
- $G_{\varepsilon\mu}$ = quantity moved from river terminal ε to port μ by container-on-barge
- $T_{\varepsilon\mu}$ = unit transportation cost from river terminal ε to port μ by container-on-barge (includes river terminal charge for container and barge rate)
- λ = LASH vessel (at downriver location) index
- $H_{\psi\lambda}$ = quantity moved from river terminal ψ to LASH vessel λ by LASH barge
- $S_{\psi\lambda}$ = unit transportation cost from river terminal ψ to LASH vessel λ by LASH barge (includes loading and palleting costs at river terminal ψ and LASH barge rate)
- ∂ = overseas mini-bridge destination index (Hamburg and Naples)
- $N_{\eta\partial}$ = quantity moved from origin η to destination ∂ by mini-bridge
- $R_{\eta\partial}$ = unit transportation cost from origin η to destination ∂ by mini-bridge (includes container by truck rate to PNW transshipment point and mini-bridge rate, which includes container on rail rate to U.S. port and container vessel rate)
- α = overseas destination index (Buenaventura, La Guiara, Yokohama, Singapore, Hamburg, Naples)
- $O_{\beta\alpha}$ = quantity moved from port β to overseas destination α by break-bulk ship
- $I_{\beta\alpha}$ = unit transportation cost from port β to overseas destination α by break-bulk ship [includes handling, wharfage, rail or truck unloading (where applicable), ocean surcharges (where applicable) and ocean vessel break-bulk rate]
- $P_{\delta\alpha}$ = quantity moved from port δ to overseas destination α by container ship
- $M_{\delta\alpha}$ = unit transportation cost from port δ to overseas destination α by container ship [includes wharfage and container handling, rail or truck unloading (when applicable), container stuffing (when applicable), ocean surcharges (where applicable) and ocean container vessel rate]
- $Q_{\lambda\alpha}$ = quantity moved by LASH vessel λ to overseas destination α
- $K_{\lambda\alpha}$ = unit transportation cost for LASH vessel λ to overseas destination α (LASH vessel ocean rate)
- $X_{\eta\alpha}$ = hundredweights of dry peas transported from origin η to destination α
- SUPPLY_{η} = supply of dry peas at origin
- DEMAND_{α} = demand for imported dry peas at destination

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