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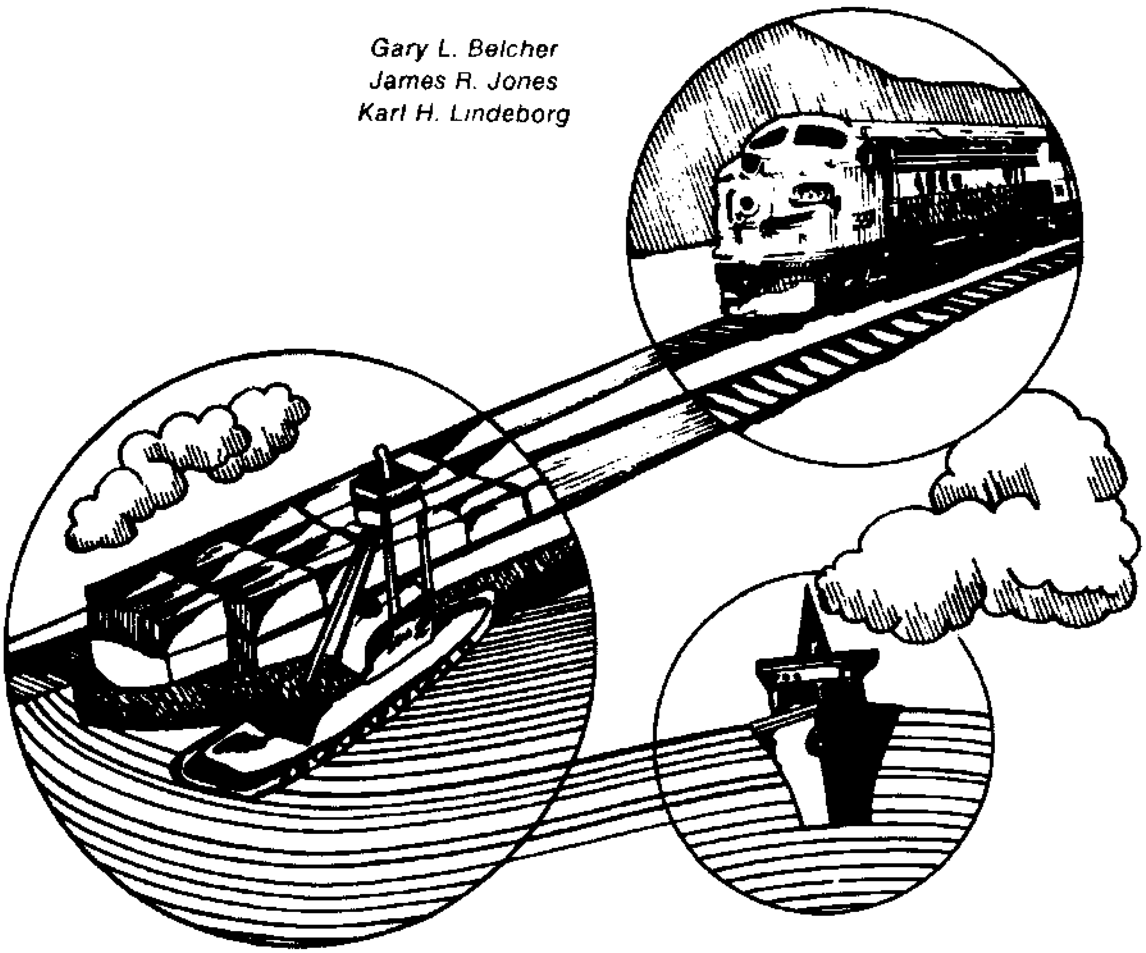

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Contents

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A Spatial Programming Model — Transit Time: Simulation Study of Dry Pea Export Shipments From the Pacific Northwest

Gary L. Belcher, James R. Jones and Karl H. Lindeborg

Spatial mathematical programming models have been used in several studies dealing with transportation issues.[1] Their usefulness lies in their ability to analyze the interdependent effects of freight rates, demand requirements and supply availabilities, all in conjunction with multiple availability of modes, routes and other considerations in moving commodities from surplus production regions to deficit markets in a least-cost framework. One criticism of studies based on programming models is that they ignore transit time considerations and focus exclusively upon freight rates in selecting the optimal shipping modes and routes for shipping commodities.

In an earlier phase of the study reported here, it was found that Pacific Northwest dry pea and lentil shippers choose among truck, rail and barge for containerized shipments and truck and rail for loosely-stowed, break-bulk shipments. Competition among these modes is keen in terms of freight rates. However, other decision criteria besides just the freight rate are of importance for modal choice; attention should also be given to transportation service quality.[2] While there are several dimensions of service quality, transit time is one major consideration that could affect the shipper's selection of transportation mode.

Study Objectives

This study developed a procedure for analyzing the cargo cost of transit time in spatial programming models. The procedure was applied to a model previously reported by Belcher et al. (1979) which looked at freight rates only for dry pea export shipments from the Pacific Northwest (PNW). Specific objectives were to:

1. Evaluate cost differentials of intramodal and intermodal shipping methods caused by incorporating the cargo cost equivalent of transit time in the rate structure of a transshipment mathematical programming model of dry pea export shipments from the PNW.
2. Analyze the sensitivity of least-cost shipping solutions (in terms of shipping volume, modes, routes, ports and transportation costs) to variations in interest rate levels and time delays.
3. Demonstrate the effects of time delays at Bonneville lock on the Columbia River upon least-cost shipping solutions.

Definition of Transit Time

Total transit time includes loading at the processing plant, movement to the river terminal, unloading and barge loading at the river terminal, movement to the ocean port, intraport movement, ship loading and ocean movement to the foreign port destination. It also includes storage time associated with availability of transportation service. Rail or direct truck shipments to the ocean port omit the river terminal. Transit time varies according to the mode, handling method, route and distance.

An economic analysis of transit time involves several considerations. Most importantly, a shipment represents an investment with an attendant financial cost to the shipper. That is, the shipper has paid the producer for the raw product (in this case dry peas) and, therefore, holds title to the commodity. A time interval exists between payment to the producer upon purchase and payment from

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[1]The varieties of these models that are applicable here include transportation and transshipment linear programming models and quadratic and reactive programming spatial equilibrium models. While the actual model employed is a transshipment model, the same procedure developed in this study can be applied to other mathematical programming models in like fashion.

[2]Of 11 shippers responding to a preliminary survey conducted on whether transportation cost or service quality is most important, six cited cost, two cited service quality, and two assigned them equal importance. The other shipper who responded to the survey indicated he would "pay more for reliable, good service if the cost difference is not too great, (although) the most expensive (service) is not always the best service either."

the consignee upon delivery. A relatively fixed portion of this time interval involves processing, handling, packaging and warehousing operations. The remaining portion of the time interval — in-transit time — is variable depending upon modal choice. The shipper has money tied up in the goods, and until he obtains payment, the shipper must bear an interest charge to finance the shipment.

Previous Work Incorporating Transit Time

Most transportation economists have approached the transit time cost problem similarly. Meyer (1959) stated that "a dollar value may be assigned to more rapid transit time. The costs involved in a longer time in transit are interest, risk and obsolescence." Meyer further asserted that "such costs depend not only on the time in transit but also on the value of the shipment since risk, obsolescence and interest per unit of time are properly computed as a percentage of this value per weight unit of the commodity." (Obsolescence would mean perishability or deterioration.)

In a more recent work, Roberts (1971) stated that "the opportunity costs of the goods while traveling is merely the interest on the money tied up during travel time. The money involved could have been invested at the prevailing interest rates during this time to produce an income." Roberts omitted risk and deterioration from the opportunity cost analysis.

Goss (1977) developed a succinct statement of the problem:

> "Goods in transit are financed, explicitly or implicitly, by working capital. With explicit finance charges payable and the greater the transit time, the greater will be the interest charge. With implicit finance, either the importer or the exporter will be using his own money, and there will be, except in terms of an opportunity cost, no identifiable interest charge. But either way capital is being employed, and it has an opportunity cost. Regardless, therefore, of the explicit or implicit form, extent and terms (for example, as regards the interest rate) of this finance, the social opportunity cost of capital is again the relevant measure."

In a similar study, Mohring (1976) found that "most shippers would likely prefer faster to slower transit time. At the very least, faster deliveries reduce the interest costs to holding inventories." This is an alternative manner for perceiving the transit time cost problem (i.e., the cargo is essentially unpaid-for inventory which remains so even while in transit). These costs end at the geographic point of title exchange.[3]

[3]The point of exchange depends on the terms of sale (e.g., F.O.B., C.I.F., etc.) which determines the time span that the shipper must bear the interest costs. On an F.O.B.-ocean port term of sale — a typical term of sale for the pulse shipper — the title exchange and payments occurs at the U.S. ocean port. Another common term of sale is C.I.F. This means to delay title exchange and payment until the shipment arrives at the foreign port destination. In our study, the C.I.F. term is used.

Other work on transit time has focused on:

1. The economic cost of human transit time.
2. The cost of delay to the mode rather than the cargo.
3. Transit time as one of many measures of transportation service quality.
4. The conditions for demand for slower transit times.
5. Shipper use of transport modes as substitutes for storage.

Although the data base and application for the economic cost of human transit time are quite removed from this study, the methodology is similar. To measure the gain or loss to the individual in the instance of upgrading a road, for example, the concept of opportunity cost can be applied. The cost of a mode's time has also been studied. For example, Goss and Mann (1977) analyzed the cost of time delay to ocean vessels (port changes, foregone cargoes, etc.) and concluded, "the total cost of delaying a ship with cargo on board is: the cost of delaying the ship and the cost of delaying the cargo."

Other recent studies approached transit time as one of many measures of transportation service quality. Johnson (1976) estimated the influence of transportation service quality upon transportation demand for grain shipments. Transit time, in terms of railroad speed, was one of 10 factors considered. Miklius, Casavant and Garrod (1976) estimated demand for agricultural transportation for cherry and apple shipments. Variables used in the cherry model were rail and truck freight charges, transit times for both modes, shipment value and age of pack. Results from the cherry model indicated that for highly perishable commodities, "the choice of transport mode is much more sensitive to the transit time than freight charges."

Four problems encountered in estimating the impact of transit time on modal choice are the variances experienced in actual transit times among modes, "slow-steaming," scheduling and instances where the mode of transportation may be viewed as a storage facility. Variances in transit time can be significant.

Daughety and Inaba (1976) noted that "variance in scheduled transit time increases the risk of incurring penalties due to late arrival of goods and future loss of customers." Information about variability was gathered from a shipper survey (in terms of estimating minimum, average, maximum and variance of time in transit). Complete data were not forthcoming, so use of this data was restricted to average time in transit.

Miklius, Casavant and Garrod (1976) observed that there may be a difference between actual variability of transit time and the variability perceived by shippers. A related problem is one of "interlining -- where a shipment is handled by more than one carrier between the origin and destination" (Piercy and Ballou 1978).

You must break down the transit time into each carrier component for this study. "Slow-steaming" is a phenomenon which is a response to higher bunker prices. Fuel consumption is less at slower speeds, especially with diesel engines. This presents a problem for a transit time study because conflicting motives exist for lessening transit times. Also if the shipper views the mode as substitute storage, slow transit may be preferred to rapid transit. Both the study by Johnson and by Miklius et al. found evidence of this.

To arrive at precise times, the monitoring of actual shipments is possible if money and time were available to gather a statistically meaningful sample. Studies have been conducted which monitored actual shipments comparing the physical and cost performance of competing shipping systems, principally break bulk and containers (Hutchinson, Hoffman and Parlett 1976; Mongelli and Lederer 1975; and Nicholas and Breakiron 1974). Transit time was one factor for comparison, but variances in time were not analyzed in these studies.

The timing of shipment must coincide with inland mode availability and ocean vessel scheduling at the U.S. port. Shipping deadlines and rigid scheduling can cause failures in linking up inland and ocean modes. Moreover, an advantage exists in tight scheduling to exploit frequent sailings. The short distance from PNW ports to Japan relative to other U.S. ports loses its advantage if goods must wait on the quay. At most ports, limited time in free storage is usually allowed. Following that, however, demurrage penalties are assessed. In another study, surveyed shippers cited that lack of regularly scheduled rail service was more displeasing than relatively slow transit times (Hutchinson et al. 1976).

An additional transit time problem exists in port of call scheduling. Generally, the ocean vessel does not go directly from the U.S. port to the foreign port of shipment destination. Other U.S. ports of call and intermediate foreign ports of call may be encountered. For example, shippers on the Great Lakes report it takes an additional week to ship from Chicago to Rotterdam because the vessel has to stop at too many ports on the way to get enough cargo (Journal of Commerce 1979).

It might be argued that transit time is already accounted for in the transportation rate (i.e., that faster transit time will command a premium rate). Obviously, moving cargo becomes increasingly expensive with progressively faster rail, truck and air service. Time can be minimized according to a shipper's willingness to pay a higher rate for the increase in the motive power required. However, although transit time may be implicitly accounted for in the freight rate, transit time is not implicitly accounted for in cargo that is this study's objective.

Inland transit time can also be a substantial factor in the selection of ports. The geography of the U.S. tends to favor California ports for cargoes to and from the East Coast and the central and southern Midwest areas, while the northern Midwest areas favor the PNW. Palouse area shippers cite little difference in inland transit time by the same mode to regional ports such as Seattle or Portland.

Study Assumptions

1. The study assumes that faster transit is preferable to slower transit. Pulse shipments are assumed to be destined for near-term consumption rather than to supplement inventory.
2. The study assumes that both the pre-shipment planning period and the frequency of inland transportation services allow enough time for the shipper to choose among barge, truck and rail modes and avoid storage or demurrage charges.
3. The study assumes that all shipments go directly to destinations.
4. Frequency, availability, the size of consignment and product perishability are other factors that affect modal choice that are ignored.

A Transshipment Model Incorporating the Cargo Cost Equivalent Of Transit Time into the Freight Rate Structure

A methodology was developed to incorporate transit time considerations into the traditional, transshipment, linear programming model. The adapted model is mathematically formulated as:

(1) Minimize DPTC =

$$\sum_{i=1}^{5} \sum_{j=1}^{13} \sum_{k=1}^{5} \left[X_{ijk}\right] \left[[R + (\frac{r}{365} \cdot T \cdot V)]_{ijk}\right]$$

where:

DPTC = transportation cost of dry peas

i = origin area index

j = destination area index

k = mode index

X_{ijk} = hundredweights of dry peas transported from origin area i to destination area j by mode k.

(2) $C = [R + (\frac{r}{365}) \cdot T \cdot V]_{ijk}$ = the transportation cost (per cwt), including cost of transit time, from origin i to destination j by mode k

where:

R = freight rate

r = interest rate

r/365 = daily interest rate

T = transit time in days

V = value of per cwt shipment

This term is denoted as C in traditional transshipment models.

subject to:

(3) $\sum_{k=1}^{5} \sum_{j=1}^{13} X_{ijk} \leq S_i$

(4) $\sum_{k=1}^{5} \sum_{i=1}^{5} X_{ijk} \geq D_j$

(5) $X_{ijk} \geq 0$

(6) $\Sigma S_i = \Sigma D_j$

where:

S_i = supply of dry peas at origin i

D_j = demand for dry peas at destination j

Transit time is included in the transshipment model in the cost term defined in equation 2. Transit time is considered in the model as a cost component of shipping and is expressed in terms of an interest charge for the commodity during the time it is in transit.

The potential effects of transit time interest charges can be demonstrated with a simple example. Suppose that a rail shipment taking 4 days at 60 cents per cwt transportation rate and a truck shipment taking 1 day at 80 cents per cwt rate are moving to the same destination. If interest costs on the value of the cargo were 10 cents per cwt per day, the effective cost of transportation becomes $1.00 per cwt for rail and 90 cents per cwt for truck. Thus, in such a situation, the truck mode is actually cheaper when considering cost of transit time.

Data Requirements

Transit time data were gathered from ocean steamship conferences and lines, railroads, truck companies and shippers. A mail questionnaire was used to record the answers concerning transit time observations for specific modes over the various routes included in the model.

Lack of complete sets of transit time observations led to the necessity of estimating missing observations. A linear regression of time against distance [T = f(D)] was developed for each type of mode. The transit time was the dependent variable and distance the independent variable. The actual data from the questionnaire and the estimated data are tabulated in Appendix Tables 1 to 12. The tables show the costs of transit time with varying interest rates that are then added to the original costs of the model activities. The estimates of transit time obtained from the linear regression were used in subsequent analysis even where actual data were available. In this way, the estimated transit times for various routes were presumably more mutually consistent because these estimates abstract from random variation and other factors such as visits to unknown ports of call before final destination and other scheduling variables not accounted for.

Empirical Examples of Use of Transit Time

Parametric Variation of Interest Rate — As indicated in Appendix Tables 1 to 12, rate data from a previous study (Belcher et al. 1979, pp. 22-93) were augmented with the cost of transit time. In essence, the interest per day on a $30 value per cwt of cargo, multiplied by the time the cargo was in transit, was added to the transportation rate. Interest rates were set at 10, 15 and 20 percent. The augmented transportation rates were incorporated into a transshipment linear programming model (Belcher 1978). The model minimizes transportation costs and concurrently selects least-cost modes and routes.

Four simulations were developed for the parametric variation of interest rates. The first simulation represents a zero percent interest rate. Simulation runs 2, 3 and 4 represent interest rates of 10, 15 and

20 percent respectively. The zero percent simulation is conceptually equivalent to omitting transit time cost and is used as a base to analyze the impact of including transit time as a cost component on the model solution.

Parametric Variation of Bonneville Time Delay — A specific transportation delay problem concerning the Bonneville Lock on the Columbia River was analyzed using the transshipment model incorporating transit time costs. The Bonneville Lock is smaller in size than the newer locks further upriver; consequently, multibarge tows must be broken up and barges towed individually through the lock. The problem is in the time delay the single tows cause. Costs are incurred by the barge company for the additional fuel and labor required and for the cargo's owner in terms of interest costs on in-transit cargo.

The additional barging costs will be absorbed initially into the prevailing barge rate, although over time the rate could be expected to rise. The costs to the cargo, however, are directly affected by the increase in transit time, and the adapted transshipment model can be used to ascertain the impact of these costs.

Proponents of a new lock argue that the delay and costs are too high. Opponents of a new lock contend that the delay is not so serious, and the cost of the new lock is too high.

To estimate the impact of delay at the Bonneville Lock on cargo costs, the time element of the transit time cost equation ($r \div 365 \times t \times v/cwt$) was increased by 3, 6, 12 and 24 hours to represent delays of those amounts. The delays were applied only to the 15 percent interest rate model.

Interpretation of Results

Transit Time Consideration — The results of the four simulations from varying the interest rates are given in Table 1. A distinct effect of including transit time in the model solution emerged from Table 1. As interest rates increase, containerized modes increase their share of dry pea movements while break-bulk movements decrease. This result is expected since one of the main advantages of containerization is a unitized cargo which does not need to be rehandled or repacked beyond the original container stuffing. Individual bags are restowed at each modal interface for the break-bulk modes. Consequently, containerization of cargo generally saves time over break-bulk movement. This result suggests that omission of transit time in programming models tend to understate the advantage of containerized shipments as opposed to break-bulk shipments.

The transit time observations for break-bulk ship were generally much longer than for container ship. The greater time results from at least two reasons:

1. Break-bulk vessels may have more ports of call.
2. The additional handling causes break-bulk ships to spend more time in port than container vessels.

As one researcher found, "Conventional break-bulk cargo vessels typically spend only about 40 percent of their time at sea and 60 percent in port" (Whittaker 1975). The additional costs because of transit time considerations for the break-bulk modes caused those modes to decrease their share of cargo relative to container modes. The transit time observations for break-bulk ship ranged from 8 to 82 days depending on the route compared to a 8- to 31-day range in container ship transit time observations (Appendix Tables 7 and 10).

Table 1. Results of impact of cost of transit time for dry peas at 0, 10, 15 and 20 percent interest rates[1] (Least-cost solution of transshipment linear programming model).

Route	Mode	Quantity transported (cwt) under the four alternative solutions			
		(0%)	(10%)	(15%)	(20%)
Spokane to Seattle	container on truck (COT)	348,170	348,170	348,170	348,170
Moscow to Seattle	container on truck (COT)	206,900	0	0	0
Colfax to Seattle	break-bulk truck (BBT)	704,958	94,670	94,670	0
Colfax to Seattle	container on truck (COT)	0	206,900	206,900	206,900
Colfax to Portland	container on barge (COB)	0	403,388	403,388	498,058
Moscow to Portland	container on barge (COB)	172,879	379,779	379,779	379,779
Kendrick to Portland	container on barge (COB)	26,056	26,056	26,056	26,056
Craigmont to Portland	container on barge (COB)	201,947	201,947	201,947	201,947
Seattle to Buenaventura	break-bulk ship (BBS)	94,670	94,670	94,670	94,670
Seattle to La Guiara	break-bulk ship (BBS)	96,248	0	0	0
Seattle to Yokohama	break-bulk ship (BBS)	470,180	0	0	0
Seattle to Singapore	break-bulk ship (BBS)	43,860	0	0	0
Seattle to Hamburg	mini-bridge (MB)	408,080	408,080	408,080	408,080
Seattle to Naples	mini-bridge (MB)	146,990	146,990	146,990	146,990
Portland to La Guiara	container ship (COS)	400,882	497,130	497,130	497,130
Portland to Yokohama	container ship (COS)	0	470,180	470,180	470,180
Portland to Singapore	container ship (COS)	0	43,860	43,860	43,860
Total shipments via Seattle		1,260,028	649,740	649,740	555,070
Total shipments via Portland		400,882	1,011,170	1,011,170	1,105,840

[1]Original transportation costs plus cost of transit time at different interest rates are shown in Appendix Tables 1 to 12.

With only the freight rate considered in the base model, break-bulk modes are competitive with container modes over certain routes (particularly those distant from river transportation yet with more than one ocean port equally accessible). However, the cost of transit time, in addition to freight rates, causes break-bulk modes to drop out of the solution as the transit time costs increase.

In the base model (0 percent) in Table 1, break-bulk truck is the least-cost transportation mode from the major supply point -- Colfax -- which is also the only user of the break-bulk mode. As cargo transit time costs are incorporated into the model, Colfax is served less by break-bulk truck (from 100 percent of the origin's supply down to 13 percent and eventually to 0 percent when the highest levels of transit time costs are considered) in the least-cost solution and more by container modes, which rise from 0 to 87 percent and then to 100 percent of the origin's supply.

An unexpected result emerged from the model results. Despite the fact that inland transit time for container on barge is longer than truck or rail, container on barge increases significantly in the overall solution as the cost of transit time increases, from 24 percent in the base model to 61 percent and then to 67 percent. In conjunction with this result, the share of shipments going through Portland as opposed to Seattle increased from about one fourth to nearly two thirds of the total.

Since the transshipment model examines each route and all of the route's possible modal combinations which transport the cargo at least cost from origin to foreign destination, it is possible to have a relatively slow inland mode combined with a relatively fast ocean mode (e.g., container on barge and container ship) that would have a shorter combined transit time than a relatively fast inland mode combined with a slow ocean mode (e.g., break-bulk truck and break-bulk ship). Container on barge, however, is not faster than container on truck which conceivably could combine with container ship and be faster than the container on barge - container ship combination. Therefore, a second reason that container on barge (including its initial truck component) comes to dominate is that it has a rate advantage over competing modes.

The additional cost because of transit time is not large enough (caused by the low value of the dry pea cargo) to decrease that advantage. Additionally, container on truck or rail face different types of port charges than container on barge that gives container on barge a further advantage. Thus, container on barge maintained its advantage over containerized truck movement.

Sensitivity Analysis The standard, linear programming, sensitivity analysis presents a range in the transportation rate in which the solution holds. By dividing the cost per day of transit time (r ÷ 365 × $30) into the amount of the range of a particular rate, a range in terms of days in transit is obtained. Such information measures how sensitive the solution is to transit time. The information could also be useful in an analysis of scheduling or delays. For example, the activity of Spokane to Seattle by container truck was in the 10 percent interest rate model solution. The transportation rate is $0.719 and could rise to $0.755 at which point this activity drops out of the solution. The difference in range is $0.036. By dividing the range by the cost of transit time per day at 10 percent interest ($0.008), the number of days that could have been used additionally before the activity drops out of the solution is 4.4. This calculation is performed at the 10, 15 and 20 percent interest levels for each alternative situation in Table 1.

Fig. 1 shows the shipping pattern of dry peas under an interest rate of zero, that is, with no transit time considered in the model. Fig. 2 considers the sensitivity of transit time under 10 and 15 percent interest rates. The numbers in parentheses indicate the range in transportation rates converted into transit days. For example, the activity of Spokane to Seattle by container truck can increase 4.4 days of transit time before the solution changes. On the other hand, the transit time can decrease to infinity before the solution changes. In reality, this means that the activity will remain in the solution regardless of how low the rates become.

Note that from the points of origin to the two intermediate shipping ports, the transshipment model is quite sensitive to transportation rate (transit time) changes. From the intermediate ports to the destinations in Europe, the transit time is much more stable with respect to changes in the model. When transit time becomes more expensive, as depicted by the 20 percent interest rate scenario, the model becomes very sensitive to changes in transit time both in shipping from the points of origin to the intermediate ports and to final destinations. This is shown in Fig. 3. If transit time becomes more expensive than in the last situation, the shipping patterns would be altered considerably with respect to route and mode.

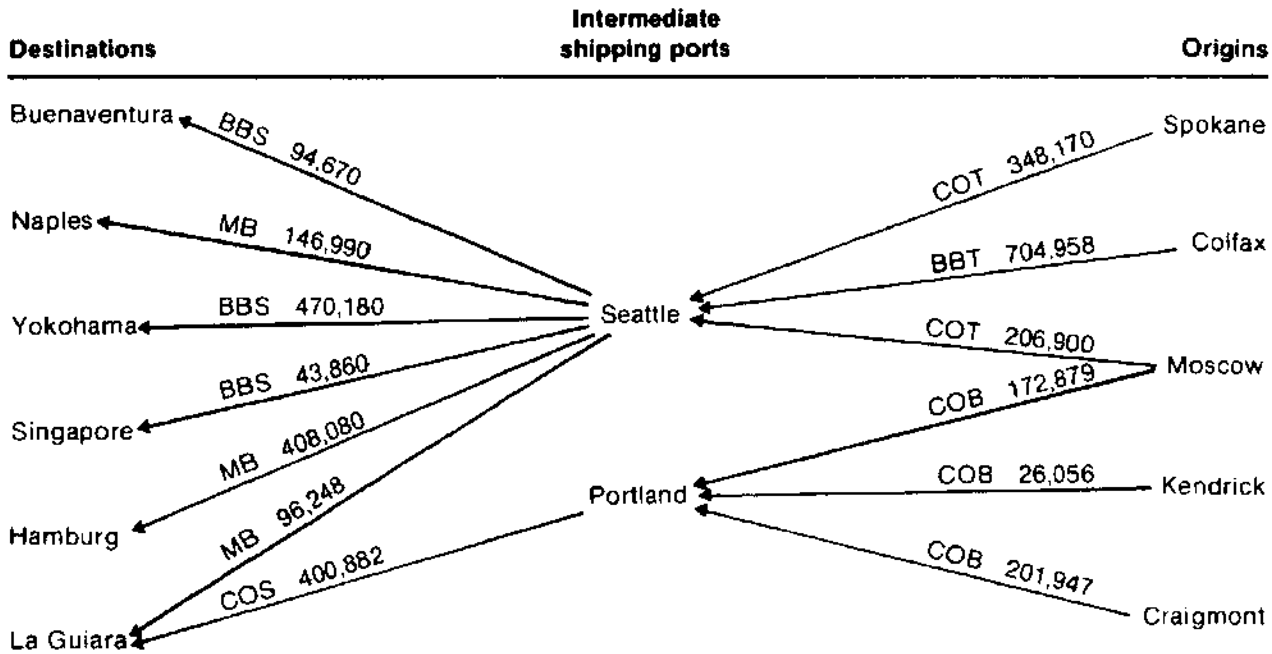
Table 2. Least cost solutions of the four simulations concerning transit time costs.

Alternative situations[1]	Total transportation costs[2]	Cost increase from base model
Base model (0%)	$7,795,375	
10% interest (transit time)	8,168,064	4.7%
15% interest (transit time)	8,346,438	7.1%
20% interest (transit time)	8,527,478	9.4%

[1]The costs of transit time are computed from the formulae: interest rate/365 × transit time in days × value/cwt (Appendix Tables 1 to 12).

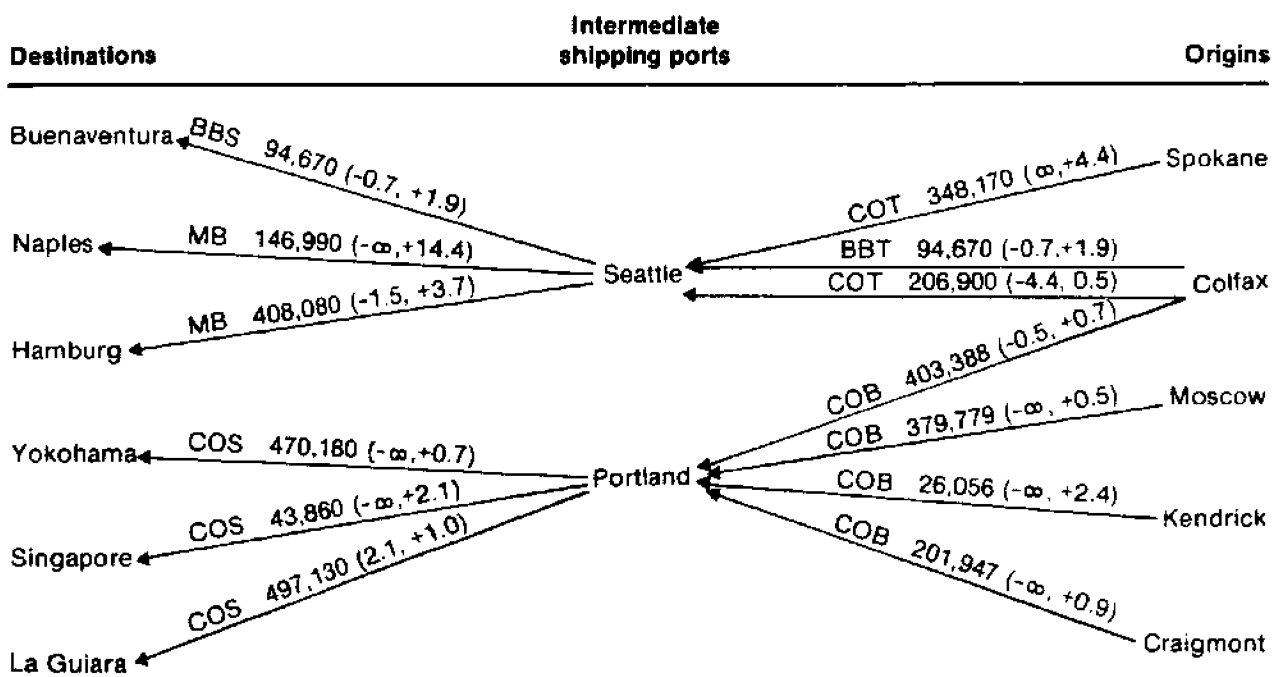
[2]Total costs of transporting the total supply of dry peas from the points of origins to the final destinations.

Fig. 1. Shipping patterns of dry peas (in cwt) under 0 percent interest rate.



Source: Table 1.

Fig. 2. Shipping patterns of dry peas (in cwt) under 10 and 15 percent interest rates (sensitivity of the transshipment model is indicated by the numbers in the parentheses).[1]



Source: Table 1.

[1]The transportation rates were converted into transit days by the formulae: $\frac{\text{transportation rate}}{0.10/365 \times 30}$

The positive numbers represent the upper range, and the negative numbers represent the lower range in transit days.

Table 2 depicts the additional costs of shipping the total supply of dry peas from the points of origin to the final destinations. The total costs of transportation increase by $732,103 or 9.4 percent when transit time cost is calculated at a 20 percent rate as opposed to being omitted entirely.

Bonneville Lock Time Delay — The results of time delay at the Bonneville Lock were simulated to analyze how the cargo cost equivalent of these delays affects the least-cost solution for dry pea export shipments from the PNW. The added cost of delay was computed by adding 3, 6, 12 and 24 hours of delay to the mode of transit passing through Bonneville Lock and calculating the new cost of transit time for that mode at an assumed 15 percent rate of interest. The solution of the basic model (given under 0 percent in Table 1) changed with 3 hours delay calculated at 15 percent, and then the new solution stayed constant for all the alternative situations (6, 12 and 24 hours of delays) analyzed. The sensitivity of the alternative situations was very similar to ones given in Figs. 2 and 3 under the parametric variation of interest rates used as a measure of transit time.

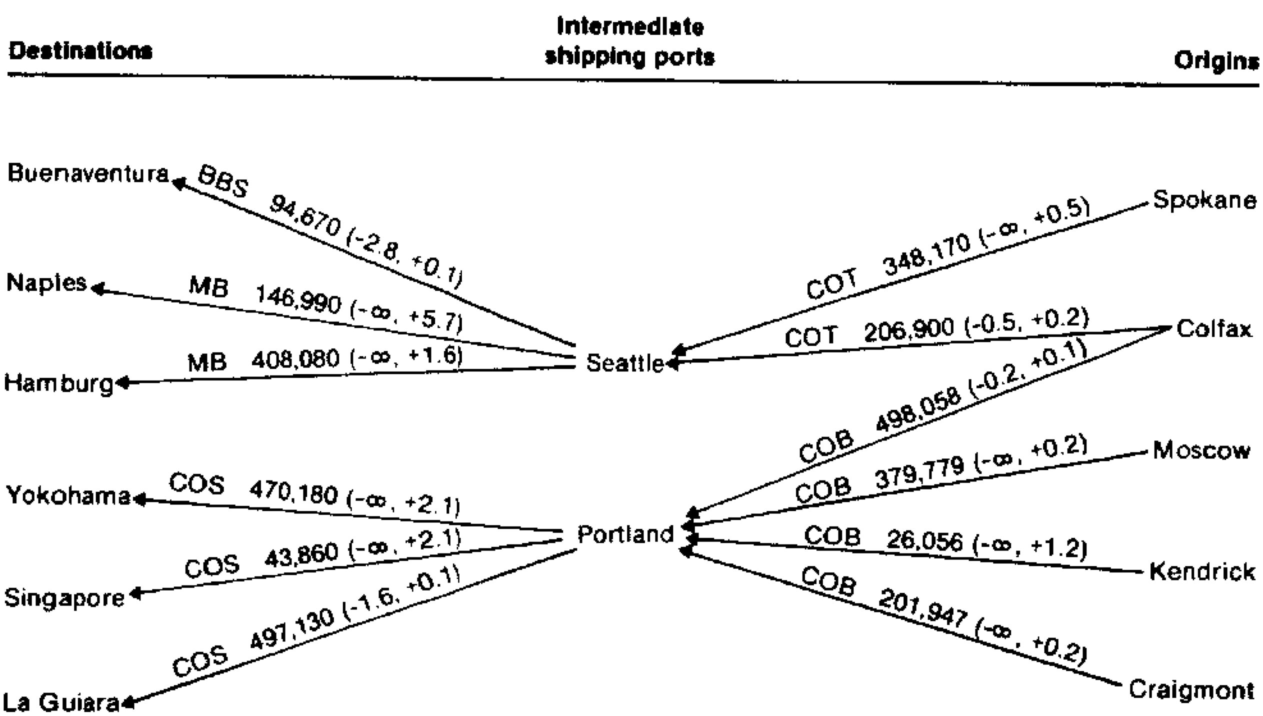
Table 3 shows the increase in total costs associated with the alternative delays. The total costs of transporting in terms of cargo transit time costs increase by $13,100 or less than .2 percent when average delays of 24 hours occur. This aspect of delays appears to be relatively small, but it is important to remember that this procedure ignores the transit time cost equivalent of mode and crew costs.

Table 3. Least-cost solutions of the five alternative situations concerning the time delay at the Bonneville Lock.

Alternative situations	Total transportation costs[1]	Annual cost of delay
No delay at Bonneville Lock	$8,346,483	
3 hours delay	8,348,460	$1,977
6 hours delay	8,350,077	3,594
12 hours delay	8,353,490	7,007
24 hours delay	8,359,583	13,100

[1]Total annual costs of transporting the total supply of dry peas from the points of origin to the final destinations assuming a 15 percent rate of interest.

Fig. 3. Shipping patterns of dry peas (in cwt) under 20 percent interest rate (sensitivity of the transshipment model is indicated by the numbers in the parentheses).[1]



Source: Table 1.

[1]The transportation rates were converted into transit days by the formulae: $\frac{\text{transportation rate}}{0.20/365 \times 30}$

The positive numbers represent the upper range, and the negative numbers represent the lower range in transit days.

Conclusions and Recommendations For Future Research

The inclusion of transit time considerations in terms of a cargo interest cost equivalent resulted in significant changes in the final least-cost solution obtained in the mathematical programming model. Container-on-barge shipments were allocated 24 percent of inland shipments when transit time was ignored, but the least cost solution allocated 67 percent of these shipments to that mode when cargo transit time costs were incorporated into the mathematical programming solution at an assumed 20 percent rate of interest. Shipments via alternative ports were also radically affected in the solution when transit time was included.

The procedure for incorporating transit time into spatial programming models that was reported in this study is relatively straight forward. However, further refinement and study are needed on the appropriate procedure to incorporate this consideration into programming studies.

A commodity's perishability can be a factor in modal choice and routing. A temperature-controlled fresh vegetable shipment has only a short marketable timespan to reach the consumer before spoilage begins to occur. Short transit time thus increases in importance for increasingly perishable goods. As Miklius et al. (1976) note, "For a highly perishable commodity, where costs associated with time in transit are high, the probability that a particular mode is chosen is expected to be negatively correlated with its own transit time and positively correlated with the transit time of competing modes." This factor is not as critical for semiperishable commodities such as dry peas and lentils.

Shippers disagreed over a specific maximum allowable transit time, with responses ranging from 6 to 9 months to "indefinite." Transit time would be only a small portion of total marketable life for dry peas. However, where perishability is considered to be important, the methodology could be extended to incorporate marketable life into the transshipment model. A charge analogous to a depreciation schedule could be applied to the shelf life of the commodity and then be entered into the cost matrix of the spatial model. This concept was not applied to this study since dry peas are not susceptible to deterioration as discussed earlier.

The procedure adopted in this study also ignored situations where shippers in the case of CIF transactions, or buyers in the case of FOB transactions, substitute transit for time in storage, thus reducing outlays for storage facilities. Evidence of this occurring was reported by Johnson (1976) where he found that speedier rail service resulted in less rail demand in the case of grain shipments. Similar results were found by Miklius et al. (1976) with regard to apple shipments and Mohring (1976) with regard to lumber shipments. This may suggest a need to account for this occurrence directly in determining the costs of shipping.

Another consideration ignored in this study is a charge to reflect situations where risks of damage or loss and concomitant insurance charges are greater if goods take longer in transit. Faster transit time might lead to lower insurance premiums, but this proposition cannot be verified or reputed on the basis of information that the authors of this study have.

Finally, this study assumes that transit time considerations are not directly incorporated into the market freight rate structure which is, to say the least, subject to question. The procedure would be more justifiable if cost of service rates rather than actual market rates were used in the spatial model. In addition, the availability of cost of service data by mode would allow the interest equivalent of transit time delays in terms of equipment and crew costs to be included. Unfortunately, these data were not available in this case. The reader is reminded that the results of this study must be interpreted as being illustrative only of the cost of transit time in terms of cargo.

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Appendix

Appendix Table 1. Derivation of cost for transit time for break-bulk truck ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Spokane to Seattle	278	1, 2.5	1.5	012	.018	.024	575	.587	593	.599
Spokane to Portland	348	1, 2.5	1.6	.013	.020	.026	.575	588	.595	.601
Spokane to Oakland	882	2	2.4	.020	.030	.040	1 155	1.175	1.185	1.195
Spokane to New Orleans	2,343	4	4.6	.038	.057	.076	3 000	3.012	3.057	3.076
Spokane to Baltimore	2,403		4.7	.039	.058	.078	3.133	3.172	3.191	3.211
Colfax to Seattle	296	1, 1.25, .66, 2	1 5	.012	.018	.024	.543	.555	.561	.567
Colfax to Portland	345	1, 1.25, 1, 2	1.6	.013	.020	026	.603	615	.623	.629
Colfax to Oakland	997	2, 3	2.6	.021	.032	.042	1 405	1.426	1.437	1.447
Colfax to New Orleans	2,401	4	4.7	.039	.058	.078	3.131	3.170	3.189	3.209
Colfax to Baltimore	2,520	6	4.8	039	.059	.078	3.277	3.316	3.336	3.355
Moscow to Seattle	301	1.5, 2	1.5	.012	.018	.024	.650	.668	.668	.674
Moscow to Portland	326	1.5, 2	1.6	013	.020	.026	.650	.663	.670	.676
Moscow to Oakland	978		2.5	.021	.031	.042	1.381	1.402	1.411	1.423
Moscow to New Orleans	2,418		4.7	.039	.058	.078	3.151	3 190	3.209	3 229
Moscow to Baltimore	2,500		4.8	.039	.059	.078	3.252	3.291	3.311	3.330
Kendrick to Seattle	349	2	1.6	.013	.020	.026	.635	.648	.655	.661
Kendrick to Portland	319	2	1.6	.013	.020	.026	.635	.648	.655	.661
Kendrick to Oakland	971	3	2.5	.021	.031	.042	1.373	1 394	1.404	1.415
Kendrick to New Orleans	2,410		4.7	.039	.058	.078	3.142	3.181	3.200	3.220
Kendrick to Baltimore	2,492		4.8	.039	.059	.078	3.242	3 281	3.301	3.320
Craigmont to Seattle	367		1.6	.013	.020	.026	.600	.613	.620	.626
Craigmont to Portland	336		1.6	.013	.020	.026	.600	.613	.620	626
Craigmont to Oakland	988		2.6	.021	.032	.042	1.393	1 414	1.425	1.435
Craigmont to New Orleans	2,433		4.7	.039	.058	.078	3.170	3.209	3 228	3 248
Craigmont to Baltimore	2,510		4.8	.039	.059	.078	3.265	3.304	3.324	3.343

[1] $Time_{days}$ = 1.082 + .00149D; R^2 - .76; F = 71.0; standard error = .00018

[2] Cost of transit time = interest rate ÷ 365 days × $30 × estimated days in transit.

[3] Cost of transportation, surcharges and port charges included.

Appendix Table 2. Derivation of cost for transit time for break-bulk rail ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Spokane to Seattle	310	3, 4, 3, 5, 3	3.8	.031	.047	062	.54	.571	.587	.602
Spokane to Portland	368	3, 3, 3.5, 3	3.9	.032	048	.062	.54	.572	588	.602
Spokane to Oakland	1,086	7, 8, 6	5.8	.048	.072	.096	1.43	1.478	1.502	1.526
Spokane to New Orleans	2,590	10, 8, 16.5, 10	9.7	.080	120	160	2.51	2.590	2.630	2.670
Spokane to Baltimore	2,628	10, 9, 14	9.8	.081	121	.162	3.15	3.231	3.271	3.312
Colfax to Seattle	384	4, 3, 3	4.0	.033	049	.066	.54	.573	589	.606
Colfax to Portland	442	4, 3, 2.5	4.1	.032	.051	068	.54	.574	.591	.608
Colfax to Oakland	1,160	8	6.0	.049	.072	098	1.43	1.479	1.504	1.528
Colfax to New Orleans	2,664	8, 7, 9	9.9	.081	.122	162	2.51	2.591	2.632	2.672
Colfax to Baltimore		9, 9	10.0	.082	123	164	3.15	3.232	3.273	3.314
Moscow to Seattle	412	3, 4, 4	4.0	.033	049	.066	.54	573	.589	.606
Moscow to Portland	470	3, 4, 4	4.2	.035	.052	.070	.54	.575	.592	.610
Moscow to Oakland	1,188	7, 8	6.0	.049	074	098	1.43	1.479	1.504	1.528
Moscow to New Orleans	2,692	10, 8	9.9	.081	122	.162	2.51	2.591	2.632	2.672
Moscow to Baltimore	2,730	10, 9	10.0	.082	123	164	3.15	3.232	3.273	3.314
Kendrick to Seattle	450	4, 5	4.1	034	051	.068	.54	574	.581	.608
Kendrick to Portland	508	4, 5	4.3	035	053	.070	.54	.575	.593	.610
Kendrick to Oakland	1,226	11	6.1	.050	075	100	1.43	1.480	1.505	1.530
Kendrick to New Orleans	2,730	11, 10	10.0	082	123	.164	2.51	2.592	2.633	2.674
Kendrick to Baltimore	2,768	11	10.1	.083	125	166	3.15	3.233	3.275	3.316
Craigmont to Seattle	505	4	4.3	035	053	070	.54	.575	.593	.610
Craigmont to Portland	563	4	4.4	.036	054	.072	.54	.576	.594	.612
Craigmont to Oakland	1,281	8	6.3	.052	078	.104	1.43	1.482	1.508	1.534
Craigmont to New Orleans	2,785	8	10.2	.084	126	.168	2.51	2.594	2.636	2.678
Craigmont to Baltimore	2,823	9	10.3	.085	127	.170	3.15	3.235	3.277	3.320

[1]$Time_{days} = 2.96 + .00259$ Distance; $R^2 = .73$; $F = 159.15$; standard error = .000205

[2]Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated)

[3]Cost of transportation, surcharges and port charges included

Appendix Table 3. Derivation of cost for transit time for container on truck ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Spokane to Seattle	278	1, 2.5	1.5	.012	018	.024	.707	.719	.725	.731
Spokane to Portland	348	1, 2.5	1.6	.013	020	.026	.707	.720	.727	.733
Colfax to Seattle	296	1, 1.25, 2	1.5	.012	018	.024	.743	755	.761	.767
Colfax to Portland	345	1, 1.25, 2	1.6	.013	.020	.026	.743	.756	.763	.769
Moscow to Seattle	301	1.5	1.5	.012	018	.024	.740	.752	.758	.764
Moscow to Portland	326	1.5	1.6	.013	020	.026	.740	.753	.760	.766
Kendrick to Seattle	349	2	1.6	013	.020	.026	.781	.794	.801	.807
Kendrick to Portland	319	2	1.6	.013	.020	.026	.781	.794	801	.807
Craigmont to Seattle	367		1.6	.013	020	026	.800	.813	.820	.826
Craigmont to Portland	336		1.6	013	020	.026	.800	.813	.820	.826

[1]The regression results were not significant ($Time_{days} = 1.356 + .000788$ Distance; $R^2 = .0016$; $F = .0187$; standard error = .00576). Therefore, an estimate of transit time was made by using the regression equation derived for break-bulk truck.

[2]Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated).

[3]Cost of transportation, surcharges and port charges included.

Appendix Table 4. Derivation of cost of transit time for container on rail ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Spokane to Seattle	310	3, 4, 3.5	3.7	.030	045	.060	900	.930	945	960
Spokane to Portland	368	3, 3, 3.5	3.8	031	046	062	900	.931	946	.962
Colfax to Seattle	384	4, 3	3.8	031	.047	.062	900	931	947	962
Colfax to Portland	442	4, 3	4.0	.033	.049	.066	900	933	949	966
Moscow to Seattle	412	3, 4, 4	3.9	032	.048	.064	900	.932	948	964
Moscow to Portland	470	3, 4, 4	4.0	.033	049	066	.900	933	.949	966
Kendrick to Seattle	450	4	4.0	.033	.049	066	900	.933	949	966
Kendrick to Portland	508	4	4.1	.034	.051	.068	900	.934	951	968
Craigmont to Seattle	505		4.1	.034	.052	.068	.900	934	952	968
Craigmont to Portland	563		4.2	.035	.052	.070	.900	.935	952	970

[1]$Time_{days}$ = 2.97 + .00223 Distance, R^2 = .80; F = 153.74; standard error = .000179

[2]Cost of transit time - interest rate ÷ 365 × $30 × days in transit (estimated).

[3]Cost of transportation, surcharges and days in transit included

Appendix Table 5. Derivation of cost for container-on-barge with container-on-truck feeder service ($ per cwt of dry peas).

Initial leg of route with ultimate destination of Portland	Distance in miles	Container-on-truck time in days[1]	Container-on-barge in days[2]	Total time[3]	Cost of transit time for $30 product at interest rate of[4]			Original cost of modal activity[5]	Total: Cost of transit time at interest rate of		
					(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Spokane to Lewiston	109	25	5.75	6.00	.049	.074	.099	.731	.780	.805	.830
Spokane to Pasco	132	.26	5.17	5.43	.045	.067	.089	.744	.789	.811	.833
Colfax to Lewiston	48	.21	5.75	5.96	.049	.073	.098	.578	.627	.651	.676
Colfax to Pasco	147	.29	5.17	5.46	.045	.067	.090	.766	.811	.833	.856
Moscow to Lewiston	35	.20	5.75	5.95	.049	.073	.098	.571	.620	644	.669
Moscow to Pasco	126	.26	5.17	5.43	.045	.067	.089	.734	.779	.801	.823
Kendrick to Lewiston	23	.19	5.75	5.94	.049	.073	.098	.558	.607	631	656
Kendrick to Pasco	176	.30	5.17	5.47	.045	.067	.090	.810	.855	877	.900
Craigmont to Lewiston	48	21	5.75	5.96	.049	073	.098	.571	.620	.644	.669
Craigmont to Pasco	194	33	5.17	5.50	.045	.068	.090	.837	.882	905	.927

[1]Estimates are based on 50 mph plus 4 hours loading and unloading and 3.5-day delay because of the one scheduled loading a week at the river ports. Since a delay could consequently take from 0 to 7 days, an average schedule delay would be 3.5 days.

[2]Estimates were obtained from a barge company official and includes 4 hours loading and unloading.

[3]Sum of container-on-truck time and container-on-barge time.

[4]Cost of transit = interest rate ÷ 365 × $30 × days in transit (estimated).

[5]Cost of transportation, surcharges and port charges included.

Appendix Table 6. Derivation of cost of transit time for break-bulk ship with break-bulk truck port interface ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle to Buenaventura	3,718	22, 18	21	.170	.260	.340	5.444	5.614	5.704	5 784
Seattle to La Guiara	4,904	14	30	.250	380	.500	4.804	5.054	5.184	5 304
Seattle to Yokohama	4,254		25	.210	320	.420	2 770	2.980	3 090	3.190
Seattle to Singapore	7,062	56	47	.390	.590	780	5.216	5.606	5.806	5 996
Seattle to Hamburg	9,125		63	520	780	1.040	5.240	5.760	6.020	6.280
Seattle to Naples	9,372		65	.530	.800	1.060	5.053	5 583	5.853	6.113
Portland to Buenaventura	3.561	21, 16	19	.160	.240	.320	5.444	5 604	5.684	5.764
Portland to La Guiara	4,753		29	.240	360	.480	4.804	5 049	5.164	5.284
Portland to Yokohama	4,323		25	.210	.320	.420	2.770	2 980	3.090	3.190
Portland to Singapore	7,142	57	48	.390	.590	780	5.216	5 606	5 806	5.996
Portland to Hamburg	8,974		62	.510	.760	1 020	5.240	5 750	6.000	6.260
Portland to Naples	9,221		64	.530	.800	1.060	5.053	5 583	5.853	6.113
Oakland to Buenaventura	3,386	17, 13	18	.150	.230	.300	5.480	5.630	5.710	5.780
Oakland to La Guiara	4,132	14	24	200	.300	400	4.840	5.040	5.140	5.240
Oakland to Yokohama	4,539		27	220	.330	.440	2.806	3.026	3.136	3.246
Oakland to Singapore	7,356	59	49	400	.600	800	5 252	5.652	5.852	6 052
Oakland to Hamburg	8,353		57	470	.710	.940	5.276	5.746	5 986	6.216
Oakland to Naples	8,600		59	.480	.720	.960	5.089	5.569	5.809	6.049
New Orleans to Buenaventura	1,785		5	040	060	.080	6.816	6 856	6.876	6.896
New Orleans to La Guiara	1,801		5	.040	060	080	3.665	3.705	3.725	3.745
New Orleans to Yokohama	9,115		63	.520	.780	1 040	4 400	4.920	5.180	5.440
New Orleans to Singapore	11,938		85	.700	1.050	1 400	6.972	7.672	8.022	8.372
New Orleans to Hamburg	5,111		32	.260	390	.520	3.061	3.321	3.451	3.581
New Orleans to Naples	5,549		35	.290	440	.580	4.245	4.535	4.685	4.825
Baltimore to Buenaventura	2,296	16	9	.070	.110	.140	6.703	6.773	6.813	6.843
Baltimore to La Guiara	1,813	8	5	.040	.060	.080	3.552	3.592	3.612	3 632
Baltimore to Yokohama	9,626		67	.550	.830	1.100	4.287	4.837	5.117	5.387
Baltimore to Singapore	12,449	82	89	730	1 100	1.460	6.823	7.553	7.923	8.283
Baltimore to Hamburg	3,977		23	.190	290	.380	8.085	8 275	8.375	8.465
Baltimore to Naples	4,471		26	.210	.320	420	7.731	7.941	8.051	8 151

[1] $Time_{days}$ = -8.86 + 0079 Distance, R^2 · 89; F · 93 47; standard error = 000814

[2] Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated).

[3] Cost of transportation, surcharges and port charges included.

Appendix Table 7. Derivation of cost for transit time for break-bulk ship with break-bulk rail port interface ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle to Buenaventura	3,718	22, 18	21	170	.260	340	5 938	6 108	6 198	6 278
Seattle to La Guiara	4,904	14	30	.250	.380	.500	5.298	5.548	5 678	5.798
Seattle to Yokohama	4.254		25	210	.320	.420	3 264	3.474	3 584	3 684
Seattle to Singapore	7,062	56	47	.390	.590	.780	5.710	6.100	6 300	6 490
Seattle to Hamburg	9 125		63	.520	.780	1 040	5.734	6 254	6 514	6.774
Seattle to Naples	9,372		65	.530	.800	1 060	5.547	6.077	6 347	6 607
Portland to Buenaventura	3,561	21, 16	19	.160	.240	320	5 938	6.098	6 178	6 258
Portland to La Guiara	4,753		29	.240	.360	.480	5.298	5.538	5.658	5 778
Portland to Yokohama	4,323		25	.210	.320	.420	3.264	3.474	3 584	3 684
Portland to Singapore	7,142	57	48	.390	.590	780	5.710	6.100	6.300	6 490
Portland to Hamburg	8,974		62	.510	.760	1 020	5 734	6.244	6.494	6 754
Portland to Naples	9,221		64	.530	.800	1.060	5 547	6.077	6 347	6.607
Oakland to Buenaventura	3,386	17, 13	18	.150	230	.300	6 057	6.207	6.287	6 357
Oakland to La Guiara	4,132	14	24	.200	300	400	5 417	5 617	5 717	5 817
Oakland to Yokohama	4,539		27	.220	.330	440	3 383	3.603	3 713	3 823
Oakland to Singapore	7,356	59	49	.400	.600	.800	5.829	6.229	6 429	6 629
Oakland to Hamburg	8,353		57	.470	.710	940	5.853	6.323	6 563	6.793
Oakland to Naples	8,600		59	480	.720	960	5 666	6 146	6 386	6 626
New Orleans to Buenaventura	1,785		5	.040	.060	.080	6.816	6.856	6 876	6 896
New Orleans to La Guiara	1,801		5	.040	.060	.080	3.665	3.705	3.725	3.745
New Orleans to Yokohama	9,115		63	.520	.780	1.040	4.400	4 920	5.180	5 440
New Orleans to Singapore	11,938		85	700	1.050	1 400	6.936	7 636	7 986	8 336
New Orleans to Hamburg	5,111		32	.260	.390	.520	3 061	3.321	3 451	3.581
New Orleans to Naples	5,549		35	.290	.440	.580	4 245	4 535	4 685	4.825
Baltimore to Buenaventura	2,296	18	9	.070	.110	.140	6 595	6 665	6 705	6 735
Baltimore to La Guiara	1,813	8	5	.040	.060	.080	3.444	3.484	3 504	3.524
Baltimore to Yokohama	9,626		67	.550	.830	1.100	4.179	4 729	5 009	5.279
Baltimore to Singapore	12,449	82	89	.730	1.100	1.460	6.715	7.445	7 815	8.175
Baltimore to Hamburg	3,977		23	.190	.290	.380	8.066	8.256	8 356	8 446
Baltimore to Naples	4,471		26	.210	.320	.420	7 623	7.833	7 943	8.043

[1] $Time_{days} = -8.86 + .0079$ Distance; $R^2 = .89$; $F = 93.47$; standard error = .000814.

[2] Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated)

[3] Cost of transportation, surcharges and port charges included

Appendix Table 8. Derivation of cost for transit time for container ship with operating port stuffing from break-bulk truck ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle to Buenaventura	3,718		14	.115	.173	.230	5.752	5.867	5 925	5.982
Seattle to La Guiara	4,904	17	17	.140	.210	280	5.112	5.252	5.322	5.392
Seattle to Yokohama	4,254	18, 11, 19, 11	16	.132	.197	264	3.078	3.210	3 275	3.342
Seattle to Singapore	7,062	28, 23, 21	23	.189	.284	378	5.524	5.713	5 808	5.902
Seattle to Hamburg	9,125	27, 28	28	.230	.345	.460	4.788	5.018	5 133	5.248
Seattle to Naples	9,372		29	.238	.358	.476	4.626	4 864	4.984	5.102
Portland to Buenaventura	3,561		14	.115	.173	.230	5.933	6.048	6.106	6.163
Portland to La Guiara	4,753	22	17	140	.210	280	5 295	5.435	5.505	5.575
Portland to Yokohama	4,323	13, 13, 15, 9	16	132	197	.264	3 529	3.661	3.726	3.793
Portland to Singapore	7,142	29, 25, 21	23	189	.284	.378	5 705	5.894	5.989	6 183
Portland to Hamburg	8,974	26, 27	28	.230	.345	460	4 969	5.199	5.314	5 429
Portland to Naples	9,221		28	.230	.345	.460	4 807	5 037	5.152	5.267

[1] $Time_{days}$ = 5.015 + .00251 Distance; R^2 = .66; F = 60.08; standard error = .000324.

[2] Cost of transit time = interest rate ÷ 365 × days in transit (estimated).

[3] Cost of transportation, surcharges and port charges included.

Appendix Table 9. Derivation of cost for transit time for container ship with operating port stuffing from break-bulk rail ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle to Buenaventura	3,718		14	.115	.173	.230	6.246	6.361	6.419	6.476
Seattle to La Guiara	4,904	17	17	.140	.210	.280	5.606	5.746	5 816	5.886
Seattle to Yokohama	4,254	18, 11, 19, 11	16	.132	.197	.264	3.572	3.704	3.769	3.836
Seattle to Singapore	7,062	28, 23, 21	23	.189	.284	378	6.018	6.207	6.302	6.396
Seattle to Hamburg	9,125	27, 28	28	230	.345	.460	5 282	5.512	5.627	5.742
Seattle to Naples	9,372		29	238	.358	.476	5.120	5 358	5.478	5.596
Portland to Buenaventura	3.561		14	115	.173	.230	6.427	6.542	6.590	6.657
Portland to La Guiara	4.753	22	17	.140	.210	280	5.787	5.927	5.997	6.067
Portland to Yokohama	4,323	13, 13, 15, 9	16	132	.197	.264	3.753	3.885	3.950	4.017
Portland to Singapore	7,142	29, 25, 21	23	.189	284	.378	6.199	6 368	6.463	6.577
Portland to Hamburg	8,974	26, 27	28	.230	345	.460	5.463	5.693	5.808	5 923
Portland to Naples	9,221		28	.230	.345	.460	5.301	5.531	5.646	5.761

[1] $Time_{days}$ = 5.015 + .00251 Distance, R = 66; F = 60.08; standard error = .000324.

[2] Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated).

[3] Cost of transportation, surcharges and port charges included.

Appendix Table 10. Derivation of cost for transit time for container ship with private terminal stuffing from break-bulk rail or truck ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle to Buenaventura	3,718		14	.115	.173	.230	5.724	5.839	5.897	5.954
Seattle to La Guiara	4,904	17	17	.140	.210	.280	5.084	5.224	5.294	5.364
Seattle to Yokohama	4,254	18, 11, 19, 11	16	.132	.197	.264	3.050	3.182	3.247	3.314
Seattle to Singapore	7,062	28, 23, 21	23	.189	284	.378	5.496	5.685	5.780	5.874
Seattle to Hamburg	9,125	27, 28	28	.230	.345	.460	4.760	4.990	5.105	5.220
Seattle to Naples	9,372		29	.238	.358	.476	4.598	4.836	4.956	5.074
Portland to Buenaventura	3,561		14	.115	.173	.230	5.694	5.809	5.867	5.924
Portland to La Guiara	4,753	22	17	.140	.210	.280	5.054	5.194	5.264	5.334
Portland to Yokohama	4,323	13, 13, 15, 9	16	.132	.197	.264	3.020	3.152	3.217	3.284
Portland to Singapore	7,142	29, 25, 21	23	.189	.284	.378	5.466	5.655	5.750	5.844
Portland to Hamburg	8,974	26, 27	28	.230	.345	.460	4.730	4.960	5.075	5.190
Portland to Naples	9,221		28	.230	.345	.460	4.563	4.793	4.908	5.023
Oakland to Buenaventura	3,386		14	.115	.173	.230	5.555	5.670	5.728	5.785
Oakland to La Guiara	4,132	14	15	.123	.185	.246	4.915	5.038	5.100	5.161
Oakland to Yokohama	4,539	20, 12, 14	16	.132	.197	.264	2.881	3.013	3.078	3.145
Oakland to Singapore	7,356	31, 28	23	.189	.284	.378	5.327	5.516	5.611	5.705
Oakland to Hamburg	8,353	24, 25	26	.214	.321	428	4.591	4.805	4.912	5.019
Oakland to Naples	8,600		27	.222	.333	.444	4.429	4.651	4.762	4.873
New Orleans to Buenaventura	1,785		9	.074	.111	.148	5.180	5.254	5.291	5.328
New Orleans to La Guiara	1,801		10	.082	.123	.164	5.189	5.271	5.312	5.353
New Orleans to Yokohama	9,115		28	.230	.345	.460	4.542	4.772	4.887	5.002
New Orleans to Singapore	11,938		35	.288	.432	.576	7.146	7.434	7.578	7.722
New Orleans to Hamburg	5,111	16	18	.148	.222	.296	3.271	3.419	3.493	3.567
New Orleans to Naples	5,549	22	19	.156	.234	.312	4.455	4.611	4.689	4.767
Baltimore to Buenaventura	2,296	18	11	.090	.136	.180	5.010	5.100	5.146	5.190
Baltimore to La Guiara	1,813	8	10	.082	.123	.184	5.019	5.101	5.142	5.203
Baltimore to Yokohama	9,626	23	29	.238	.358	.476	4.372	4.610	4.730	4.848
Baltimore to Singapore	12,449		36	.296	.444	.592	6.976	7.272	7.420	7.568
Baltimore to Hamburg	3,977		15	.123	.185	.246	7.635	7.758	7.820	7.881
Baltimore to Naples	4,471		16	.132	.197	.264	8.704	8.836	8.901	8.968

[1]$Time_{days}$ = 5.015 + .00251 Distance; R^2 = .66; F = 60.08; standard error = .000324.

[2]Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated).

[3]Cost of transportation, surcharges and port charges included.

Appendix Table 11. Derivation of cost for transit time for container ship with container-on-barge, truck or rail as inland mode ($ per cwt of dry peas).

Route	Distance in miles	Actual time data	Transit time in days	Cost of transit time for $30/cwt product an interest rate of[2]			Original cost of modal activity[3]	Total: Original cost plus cost of transit time at interest rate of		
		(days)	(estimate)[1]	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle to Buenaventura	3,718		14	.115	.173	.230	5.444	5.559	5.617	5.674
Seattle to La Guiara	4,904	17	17	.140	.210	.280	4.804	4.944	5.014	5.084
Seattle to Yokohama	4,254	18, 11, 19, 11	16	.132	.197	.264	2.770	2.902	2.967	3.034
Seattle to Singapore	7,062	28, 23, 21	23	.189	.284	.378	5.216	5.405	5.500	5.594
Seattle to Hamburg	9,125	27, 28	28	.230	.345	.460	4.480	4.710	4.825	4.940
Seattle to Naples	9,372		29	.238	.358	.476	4.318	4.556	4.676	4.794
Portland to Buenaventura	3,561		14	.115	.173	.230	5.444	5.559	5.617	5.674
Portland to La Guiara	4,753	22	17	.140	.210	.280	4.804	4.944	5.014	5.084
Portland to Yokohama	4,323	13, 13, 15, 9	16	.132	.197	.264	2.770	2.902	2.967	3.034
Portland to Singapore	7,142	29, 25, 21	23	.189	.284	.378	5.216	5.405	5.500	5.594
Portland to Hamburg	8,974	26, 27	28	.230	.345	.460	4.480	4.710	4.825	4.940
Portland to Naples	9,221		28	.230	.345	.460	4.318	4.540	4.663	4.778

[1]$Time_{days}$ = 5.015 + .00251 Distance; R^2 = .66; F = 60.08; standard error = .000324.

[2]Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated).

[3]Cost of transportation, surcharges and port charges included.

Appendix Table 12. Derivation of cost for transit time for mini-bridge (Pacific Northwest to Europe via East or Gulf Coast port) ($ per cwt of dry peas).

Route	Observations	Simple average
PNW to East or Gulf Coast	7.5, 14.5, 10, 7.5, 12	10.3 days
East or Gulf Coast to Europe	14.5, 30, 16	20.2 days
Total		30.5 days

Route	Cost of transit time for $30/cwt product at interest rate of[1]			Original cost of modal activity[2]	Total: Original cost plus cost of transit time at interest rate of		
	(10%)	(15%)	(20%)		(10%)	(15%)	(20%)
Seattle/Portland to Hamburg	.25	.38	.50	4.302	4.552	4.682	4.802
Seattle/Portland to Naples	.25	.38	.50	4.044	4.294	4.424	4.594

[1]Cost of transit time = interest rate ÷ 365 × $30 × days in transit (estimated).

[2]Includes container-on-truck rate to Seattle/Portland and mini-bridge rate from Seattle/Portland to Europe.