# TECHNICAL AND ECONOMICAL ASPECTS OF CONTAINER TRANSPORT BY FLUVIAL-MARITIME LINES

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## I. Present Situation and Future Development of the Container Transport

The considerable development of the container maritime transport since 1960 by large specialized ships has created large harbour terminals and adapted handling devices.

The container was mainly used for high cost goods, but because handling costs are growing more and more different products are transported in containers : we can say that now around 80 % of goods are moved in containers. The container transport on waterways can be made by adapted material; so several river terminals are under development. Well adapted inland boats can connect these terminals with sea harbours. If the distances are small, sea-river going vessels can be used to reach other sea harbours : an economic study in this case is necessary to decide the final solution.

In the container transport the handling cost is important. In order to avoid as often as possible this kind of operation, the use of sea-river going vessels is very interesting.

In the next chapters, we shall compare the transport costs of a container if it is transported by an inland boat, by a sea-river going vessel or by a truck.

## II. Transport Cost Computation

### II.1. Introduction

The transport of a container from an inland port to a destination located in another continent or along a sea coast can be done by several transport modes :

- by truck with transfer to a ferry-boat;
- by truck up to the inland port, then by an inland boat up to a sea harbour, and by a sea vessel wlth redistribution by truck;
- by truck up to the inland port, then by sea-river going vessel and redistribution by truck.

We have not taken the railway into account because in our country this mode is more expensive for the transport of containers. It is necessary now to answer by an economical computation the two following important questions :

- is the waterway competitive in comparison with the road transport if we consider only continental transport ?

- in a transfer which needs a travel on sea, what are the economical conditions assuring profit of a sea-river going vessel ?

Before answering these questions, we have to define the general equations used to do the economical computation of the waterway transport and the terms taken into account in the road transport.

## II.2. Transport economical computation

### 2.1. Inland Navigation

The more general case is to consider a self propelled boat with a capacity of Z containers which is moving during a certain time on the following successive distances :

$$d_1,\ d_2,\ d_3\ \ldots.\ \text{km}$$

in different waterway cross-sections.
We suppose that the following parts

$$n_1d_1,\ n_2d_2,\ n_3d_3,\ \ldots..\ \text{km}$$

are done in loaded condition at the relative speeds of

$$v_1,\ v_2,\ v_3,\ \ldots.\ \text{km/h}$$

The boat is than unloaded. The rest of each distance, it means :

$$(1-n_1)d_1,\ (1-n_2)d_2,\ (1-n_3)d_3\ \ldots\ldots\ \text{km}$$

is covered in light condition with the relative speeds

$$w_1,\ w_2,\ w_3,\ \ldots.\text{km/h}$$

The renumerated distance for the considered time is thus

$$D = \Sigma\, nd$$

The number of navigation days in loaded conditions is

$$N = \Sigma(nd/hv)$$

where h is the number of navigation hours per day
and v is the relative speed in loaded condition.

The number of navigation days in light conditions is

$$I = \Sigma\left[\frac{(1-n)d}{hw}\right]$$

The number of days spent in harbours is computed by the following formula

$$H = \Sigma(Z/T_d) + \Sigma(Z/T_c)$$

where $T_d$ is the rate of unloading in the successive ports (containers/day)

$T_c$ is the rate of loaded (containers/day).

The number of waiting days is equal to

$$J = \Sigma j$$

where j is the number of waiting days in each part of the travel.
The transport of Z.D container.km needs fixed expenses during a number of days equal to

$$X = N+I+M+J = \Sigma\left(\frac{nd}{hv}\right) + \Sigma\left[\frac{(1-n)d}{hw}\right] + \Sigma\left(\frac{Z}{T_d}\right) + \Sigma\left(\frac{Z}{T_c}\right) + \Sigma j$$

The amount of fixed expenses per container.km is :

$$\Phi_f = \frac{F+F'}{Z.D} \quad . X$$

where F : fixed expenses per day for a towed boat,
F' : fixed expenses per day for the propulsion installation.

In fact :

$$F = \frac{Au+S}{365}$$

where A : boat construction cost without the engine,
u : rate of fixed expenses corresponding to this cost (in %);
S : annual total salary of the crew.

The fuel expenses are defined by the following expression :

$$\Phi_c = \frac{Q.c.p.N.h + Q'.c'.p.I.h}{Z.D} = \frac{Q.c.p. \quad \Sigma(\frac{nd}{v}) + Q'.c'.p. \quad \Sigma\frac{(1-n)d}{w}}{Z. \ \Sigma \ (nd)}$$

where Q : shaft power in loaded condition (HP);
c : specific consumption in loaded condition (kg/HP/h);
P : fuel cost per kg;
the index (') is concerning the navigation in light condition.

Finally, the total amount of exploitation expenses per container.km is :

$$\Phi = \Phi_f + \Phi_c + d + d' \ \frac{\Sigma(1-n)d}{\Sigma nd} + 2 \ \frac{\Sigma f}{\Sigma nd}$$

where d : navigation dues/container.km;
d' : navigation dues in light condition;
f : port dues in light condition.

The number of containers.km realized per year is given by :

$$Z_a = Z \ (365/x) \ \ \Sigma \ (nd)$$

2.2. Sea Navigation

The annual cost of the vessel exploitation has three main parts :

- a term proportional to the investment aI (financial costs, insurances, maintenance costs)
- a term depending on the exploitation degree, including :
  1. the fuel and oil expenses given by :

$$C = n.j_m.c.P$$

where n = annual number of trips;
$h_m$ = number of days on the sea/trip;
c = consumption in tons/day;
P = mean cost of fuel taking into account also the oil.

  2. the harbour fees : harbor dues, towing costs and pilotage ... excluding handling cost.

The expenses depend on the tonnage (J)

$$P = P_o + bJ \text{ per trip}$$

$$P = n(P_o + bJ) \text{per year.}$$

3. a fixed term (F) per vessel for the crew cost, various expenses or general costs of the vessel. This term is fixed because it is not depending on the exploitation degree, the speed, and the dimensions,
4. a fixed term per service (G) representing administration costs, central general expenses supported by the service.
   If N vessels are necessary, the annual exploitation cost of a service is defined by the following relation :

$$N(a.I + nj_m.c.P + n(P_o + bJ) + F] + G$$

2.3. Road Transport

The cost price of road transport includes the following terms :

1. The annual fixed costs including :
   - the redemption and financial fees depending on the mean purchase cost, the pneumatic value, on the value without pneumatic (V) and on the residual value (R);
   - the annual redemption is computed by the formula (V-R)/n (n = number of life years of the truck). The financial fees are given by the expression (V+R/2).i (i = rate in %);
   - the insurances including burning of the vehicle and goods;
   - the drivers' salaries and their fees;
   - taxes.

2. The kilometric expenses (fuel, oil, pneumatic, repairing ....);

3. General fees.

## III. Computation Example

### III.1. Continental Transportation

In order to illustrate the preceeding theory, I will apply it to the case of the Port of Liege, the third inland port in Europe.
This port is located at 120 km from the sea harbour of Antwerp.
We shall compare the transfert costs of containers from Liege to Great-Britain, Ireland and Scandinavian countries.
First of all we have to define the handling cost of a container (see table I).

Table I

| | HANDLING COST (BEF) | |
|---|---|---|
| TRANSPORT MODE | INLAND PORT | SEA HARBOUR |
| Truck | 500 | 2500 |
| Inland Boat | 1000 | 5000 |
| Sea-River going vessel | 1000 | |

The transport by road, up to or from a port in a maximum radius of 30 km, costs 3000 BEF.

The first question to solve is to know in which conditions the waterway can be competitive in comparison with the road if we consider only continental transport.
The following table II is giving a first comparison between different transport modes : it defines the container.km costs taking into account the mean annual distance normally realized by each mode and the different loading rates.

Table II

| Modes of Transport | Loading rates | | | | |
|---|---|---|---|---|---|
| | 50 % | 60 % | 80 % | 90 % | 100 % |
| Road | 70,9 BEF | | | | 35,45 |
| Self-propelled boat | | | | | |
| 300 T | | 86,8 | | | 52,1 |
| 600 T | | 35,4 | | | 19,7 |
| 1200 T | | 25,6 | | | 14,4 |
| Pushed convoy | | | | | |
| 2250 T | | 26,5 | | | 14 |
| 4500 T | | 16,23 | | | 7,5 |
| 5000 T | | 14,41 | | | 7,1 |
| Sea-River going vessel | | | 31,2 | 27,7 | |

The mean cost per container.km for the waterway transportation takes into account that 75 % of containers have 20' length and 25 % of them have 40'. The number of crew for a inland boat is around 4 men and 8 men for a sea-river going vessel.

The results show that in general the waterway transport is more interesting than the road for displacements higher than 600 T, if we consider non stop travels. It will be assumed that the loading rate for the waterway is 60 %. The following table III defines the kilometer number over which the waterway is competitive in comparison with the road for two loading rates (50 and 100 %) and if we take into account or not the road transport up to the inland port.

Table III

| Type of boat | Kilometer number over which the waterway is competitive | | | |
|---|---|---|---|---|
| | 50 % | | 100 % | |
| | Road rapprochement | | Road rapprochement | |
| | With | Without | With | Without |
| 300 T | never | never | never | never |
| 600 T | 85 | 169 | never | never |
| 2250 T | 68 | 135 | 336 | 673 |
| 3500 T | 55 | 110 | 156 | 312 |
| 9000 T | 53 | 106 | 143 | 285 |

If the loading rate for the road transport is 100 %, the inland boat with a loading rate of 60 % will never be competitive for a line between Liege Port and Antwerp harbour. To be competitive with the road transport, the breaking of load at Antwerp Harbour must be avoided.

We have then to study now in which conditions the use of sea-river going vessels will be interesting.

III.2. Transportation from an Inland Port to a Sea Harbour with a Travel on Sea

As examples (see table IV) we consider several lines between the Port of Liege and Great-Britain (London, Liverpool), Ireland (Dublin) and Scandinavian countries (Oslo, Stockholm, Helsinki).
The rapprochement cost to Liege Port by road and the distribution by road from the arrival harbour is taken into account in the following computations of the sea-river going vessel cost of a container transport.
We assume that the loading rate of the trucks is 100 %.
For the sea-river going vessel we consider two rates : 80 and 90 %.

Table IV

| Transfer cost - BEF | | | | | |
|---|---|---|---|---|---|
| Lines | Truck+container Ship+truck | Truck+ferry boat + truck | Sea-River | | Railway |
| | 50 % | 100 % | 80 % | 90 % | |
| Liege-London | 35 900 | 30 200 | 24 500 | 22 900 | |
| Liege-Liverpool | 43 000 | 53 800 | 54 500 | 49 500 | |
| Liege-Dublin | 52 750 | 62 700 | 50 000 | 45 500 | |
| Liege-Oslo | 52 000 | 60 000 | 56 600 | 46 000 | 84 200 |
| Liege-Stockholm | 56 550 | 61 500 | 60 400 | 55 000 | 80 000 |
| Liege-Helsinki | 55 000 | 102 350 | 73 000 | 66 000 | 90 000 |

## IV. Conclusion

Following these results, it clearly appears that the sea-river going vessel transportation from Liege Port is almost the best one for all the destinations even when we have not considered the best conditions for this transportation mode. These conclusions can apply for other countries which have container traffic on inland waterways to sea ports with a certain travel on sea (coastal traffic).

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COST RESPONSIBILITY IN NORTHWESTERN UNITED STATES: CASE STUDY OF THE RECOVERY OF OPERATING COSTS AND ENERGY LOSSES BY WATERWAY USER FEES

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## Introduction[3]

It appears that user fees and a cost responsibility policy on inland waterways will be a reality of the 1980's and later in the United States and world. However, the political process has not settled on the type of user fee to be imposed or the level of cost recovery to be attained. Thus, both the form and level of user fees are policy variables worthy of study.

The question of cost responsibility for waterways is particularly acute for the wheat industry in the Northwest United States[4] because some 70-90 percent of the wheat is exported. Moveover, the region is a major contributor to total United States wheat production and exports. Therefore potential transportation cost impacts on the competitive position of Northwest U.S. wheat have significant regional and national implications.

In summary, then, both the wheat industry and the transportation industry which serves it are vitally interested in the form and level of waterway user fee policies on both transportation modal share and on the transportation costs born by wheat growers.

Three aspects of user fee policy are specifically addressed in the study. First, what form should a user fee take? The study explores three types of user fees: a fuel tax imposed uniformly throughout the United States, a fuel tax based on costs specific to a river segment (i.e. specific waterway), and (river segment) lockage fees. The second issue concerns how costs should be defined, where the presumed goal of user fee policy is some proportion of cost recovery. What costs should be recovered: operations and maintenance (variable costs), capital (fixed costs), opportunity costs (foregone opportunities) and indirect costs (and benefits)? Once costs are defined, the third issue is the level at which these costs should be recovered. Traditionally, the U.S. cost recovery level has been set at zero. The impact of changing from zero to 100 percent might be substantial. Prudence and political realities may indicate intermediate levels of cost recovery.

The study explores all three of these issues. A special feature of the study is the explicit consideration of opportunity costs. Opportunity costs are defined as the value of a resource in an alternative use. Thus, while no cash payments are made for the water used to fill the locks, this resource might (and does) have value in an alternate use, in this case in the generation of hydroelectric power.

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[3]Joanne Buteau, Research Associate, assisted in the preparation of model results reported in this paper.

[4]Northwest United States is herein defined as Idaho, Montana, Oregon, and Washington.

while opportunity costs are often overlooked, clearly a total cost accounting requires they be incorporated.

A final feature of this study is an analysis of the impact of the deregulation of the rails (the Staggers Rail Act) on the wheat transportation system. The impact of rail deregulation has been a major focus in other studies (e.g., 3). It is included here mainly as a standard by which to measure the relative significance of the user fees policy issues.

The body of the paper comprises a short discussion of some theoretical issues in user fee assessment and transportation subsidies, a review of the basic model, the presentation of results, and a conclusion assessing the significance of the results and major shortcomings in the model.

Economic Analysis of Cost Responsibility: Fees and Subsidies

Waterways and most other transportation modes have traditionally been subsidized, although the extent of such subsidies have varied greatly over time and between modes. In this section we look briefly at the economic logic behind waterway subsidies in order to gain insight into practicable and desired levels of cost recovery versus subsidy.

A waterway is a decreasing cost industry. Once large initial capital costs are expended, increasing traffic can be supported with minimal increases in costs up to the point of congestion. The situation is represented in Figure one. We assume a large initial fixed cost and a constant marginal variable cost (MC curve) for additional units of waterway services. The combination of large fixed cost and low and constant marginal costs implies an average unit cost that starts extremely high and curves down to approach the marginal cost curve (the AC curve).

According to economic theory, the (Pareto) efficient quantity of waterway service occurs at price $P^*$ and quantity $Q^*$, which is where marginal cost equals price (demand). But production at ($P^*$, $Q^*$) covers only marginal costs. The initial, large fixed costs are not covered. Therefore, the logic of economic efficiency suggests that cost recovery be set at 100 percent of operations and maintenance (variable) costs and that capital costs be subsidized.

This raises the controversial question of who subsidizes the capital costs. One solution is not to subsidize, resulting in inefficiently low production levels and high prices. This is the regulated utility solution of setting price equal to average cost ($\bar{P}$, $\bar{Q}$). Note that in efficiency terms the regulated utility approach is still superior to the private monopoly who would produce much less service, $Q^m$, for much higher price, $P^m$. The final option is for the government to pay the subsidy from general revenues. This facilitates efficient production and pricing of waterway services, but obviously shifts the problem to other shoulders.

Taking stock, we see that the logic of economic efficiency provides no perfect answer to the difficult problems of a decreasing cost industry, but can support either the regulated utility or the subsidized capital cost policy. In fact, as noted earlier, waterway subsidies have traditionally included both capital and operating and maintenance costs, i.e. 100 percent subsidy. Part of the logic of such subsidy is that waterways, and certain other "infrastructure" investments, stimulate and support economic growth. Such "indirect" benefits are extremely difficult to measure, but were surely very important in earlier years in

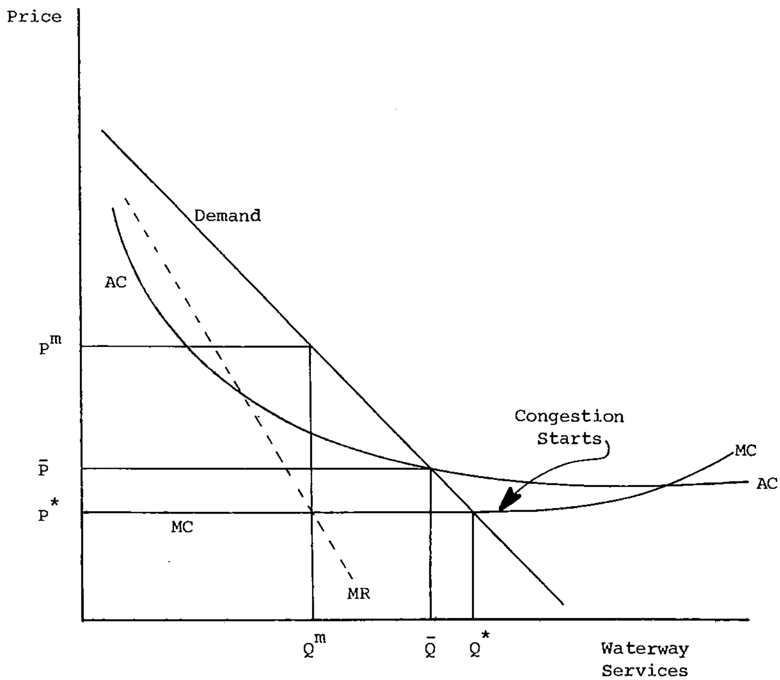


Figure 1: Costs and Subsidies for a Decreasing Cost Industry (Waterways) with Congestion

U.S. development. Note also that they are external benefits not easily captured by the waterway enterprises. In a mature economy a waterway no longer opens up new areas to development; it provides one among several alternative transportation modes. There is a demonstrable benefit to providing competition , but it certainly pales by comparison to the opening of new development (4).

A second economic justification for total subsidization of waterways stems from the non-rival (public good) characteristic of waterways. One flotilla's use of the waterway does not reduce the amount of waterway available to another--up to the point of congestion. If the cost of the marginal user is zero, then the price (user fee) should be zero from an efficiency perspective.[5] According to this logic user fees should be charged for only two purposes: (1) the cost directly attributable to lockage, and (2) rationing use in the event of congestion (currently a problem at one facility--Bonneville Dam).

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[5]The earlier graph showed that the quantity of waterway service varies with the level of operations and maintenance. But once provided, a given level of waterway services is available to all users without reducing the levels available to others--subject to congestion.

Consider the cost of lockage. Most operations and maintenance costs are for general maintenance of system capacity. The major input which can be directly tied to lock use is the water for the lockage. Water used in lockage does not have a price. If it had no alternative use its economic value would be zero. However, water not used for lockage could spin turbines to produce electricity. Therefore, the economic value of the water (opportunity cost) is the value of hydro electric power which would otherwise have been produced, the energy foregone.

In summary we have briefly considered four economic factors affecting what might serve as recoverable costs for waterway services. The logic of the large fixed cost-decreasing cost industry suggests user costs to cover operations and maintenance but not capital costs. The logic of indirect benefits suggests that at one time zero cost responsibility may have been appropriate, but no longer. The logic of non-rival good suggests cost responsibility for that portion of operations and maintenance directly attributable to lockage and for water opportunity costs (hydropower foregone) also attributable to lockage. These arguments provide partial justification for the approach to cost accountability adapted in the remainder of this paper: capital costs are excluded, operations and maintenance costs are evaluated at several recovery levels, and hydropower opportunity costs are evaluated, also at several levels. Note also that current user fees are designed to recover a portion of operations and maintenance costs (Inland Waterways Revenue Act of 1978, P.L. 95-502).

## Research Methods

The study employed a simple transportation model (linear program) to identify least cost shipping alternatives for Northwest U.S. wheat under the different user fee assumptions.[6] Formally:

$$\text{Minimize WTC} = \sum_{i=1}^{66} \sum_{k=1}^{4} S_i T_{ik}$$

where:

WTC = wheat transportation cost
$i$ = origin area
$k$ = transportation mode
$S_i$ = tons of wheat transported form origin area i
$T_{ik}$ = transportation rate from origin area i to Portland by mode k.

$$\text{subject to: } D = \sum_{i=1}^{66} S_i$$

where:

D = demand at Portland

Major wheat growing areas were divided into 66 production regions or supply areas with centrally located shipping points identified as the supply area. All wheat produced was assumed to be exported, a reasonable assumption since exports have recently approximated production. Northwest wheat is shipped for export from a variety of

[6] See Casavant, (2) for full discussion of model, data sources, and user fee calculation.

Columbia River ports. For simplicity, and since transportation rates vary little, Portland was assumed to be the sole destination (demand point). Transportation costs were assumed to be the transportation rates including handling charges and wheat inspection fees. User fees were added as surcharges on transportation rates. Rates were assumed to be constant regardless of volume (i.e. supply of transportation services was assumed to be perfectly elastic). The base rates (before user fees) comprised single and multiple car rail rates, truck rates, and truck-barge rates. Single car rail rates were available for all but a few areas, but multiple car rates were not available to 30 of the 66 supply areas.

There are two basic types of user fees: system wide (uniform) fees and waterway-specific segment fees. Under the uniform fee, users throughout the United States pay a tax at the same rate. Under the segment tax, user fees reflect the operations and maintenance costs of the specific waterway. Both types of user fees can be implemented in a variety of forms including ton-mile, fuel tax, lockage fee, license (vessel) fee. In this study, we examine the uniform fuel tax[7] which is the existing form of user fee. We also evaluate the segment fuel tax and segment lockage fee. The original study also examined the ton-mile tax, but under the simplifying assumptions of the model employed, the ton-mile and fuel tax produce virtually identical results (since distance is the dominant factor in determining the cost impacts of both).

The uniform operations and maintenance (O&M) fuel tax was calculated by simply dividing total national O&M expenditures by estimated total national fuel consumption. Operations and maintenance charges for segment fees were based on wheat's share of the total navigational O&M cost for each lock on the Columbia-Snake waterway. Wheat's share of O&M was assumed to be proportionate to wheat shipments as a percentage of total traffic.[8] These costs were then converted to a tonnage charge from each of the 66 supply regions. The tonnage charge could then be directly added to the base transportation rate from the supply area to destination (Portland). Fuel (uniform and segment) user fee rates were calculated based on estimated fuel consumption per mile, with the fuel tax rate a simple quotient of total grain O&M costs divided by fuel consumption. Lockage fees were calculated under the assumption of a uniform charge per vessel per lock.[9] The total grain O&M costs were then distributed over the total number of vessels locked. The transportation cost on a tonnage basis was then calculated based on the capacity of the barges and the number of lockages between the supply area and the destination point (Portland).

Determination of energy opportunity costs required calculation of the amount of energy which would have been produced by the water had it gone through the turbines instead of the lock. Hydroelectric energy production depends on the quantity of water and the height the water

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[7] Data on O&M for each lock were provided by the Corps of Engineers. Total O&M was $6.686 Million in 1980. Grain O&M was $4.824 million. (2, p.14, table 2).

[8] For these and the calculations which follow see (2, pp 12-25).

[9] There are any number of forms for a lockage fee. We assumed the administratively simplist form.

falls ("head").[10] Energy loss per lockage was calculated for each of the eight locks. Energy loss in kilowatt hours multiplied by the number of lockage cycles and the price of electrical energy produced a total dollar cost of lost energy at each lock. The total energy loss (sum of the losses at eight locks) was then be converted to a cost per ton of wheat shipped in the manner outlined above for total operations and maintenance costs.

A critical feature of the energy loss costs is obviously the price attached to energy. The study assumes a price of 40 mills per Kwh. This price is based on the cost of replacing the energy from another source. Major alternative sources are coal and nuclear power plants with costs ranging from 30-60 mills per Kwh (1980 dollars), which makes the 40 mills price fairly conservative (1). This assumes that the electrical system is operating at or near capacity. No surplus exists so that replacement electricity comes from newly constructed power plants. For a baseline, long run analysis as in this study, this is the appropriate assumption. But in the short run, the Northwest U.S. now has an energy surplus. Under surplus conditions the value of lost hydropower is equal to the amount which could be saved by shutting down an existing thermal plant, in the neighborhood of 20-30 mills. Therefore, if lost energy costs were to be assessed to navigation on the basis of short run annual conditions, the energy costs would currently be about one-half to two-thirds of that used in the study. These costs would rise as the energy surplus disappears in the 1990s to the (inflation adjusted) prices of 30 to 60 mills.

## Results: Market Share Shifts

We initially consider the impact of user fees on transportation modal market shares. First consider conditions before railroad deregulation when only the single car rail rates are available. Table 1 shows base line market shares without user fees to be: rail 43.4 percent, truck-barge 32.9 percent and truck 23.7 percent. The imposition of waterway user fees induces some shifts in market shares away from truck-barge. The lowest user fee, the uniform fuel tax at the 25 percent recovery for operations and maintenance and no energy recovery charge produces a decrease in truck- barge market share of one percentage point. This corresponds to a loss of about three percent in the wheat volume moved by truck-barge. The one percentage point market share loss is stable over a wide range of increases in operations and maintenance recovery levels. However, when the segment specific taxes are imposed at full recovery level truck barge endures a dramatic loss in market share, to 18.8 percent, with the truck mode capturing most of the shift.

Imposition of user fees to recover energy costs produces similar results. Table 2 shows various combinations of the three O&M recovery user fees (uniform fuel tax, segment fuel tax, and segment lockage fee) and two energy cost recovery fees. The energy recovery fees apply only to the Columbia-Snake waterway, so there is no analogue to the uniform fuel tax. We assume, however, that each of the two energy fees can be imposed on top of any of the three O&M user fees. We also assume that no energy fee would be charged unless some level of O&M fee were levied.

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[10] These range from 2,913 Kwh at Bonneville to 12,765 Kwh at John Day. (5, 6, 7).

Table 1. Pacific Northwest Transportation Market Shares, O&M Charges Only, Single Car Rail Models

| Fee Type | Percent Cost Recovery Level (%) | Percent of Market Shares | | |
|---|---|---|---|---|
| | | Single Rail (%) | Truck-Barge (%) | Truck (%) |
| Base Model One | 0 | 43.4 | 32.9 | 23.7 |
| Uniform Fuel | 100 | 44.4 | 31.9 | 23.7 |
| | 50 | 44.4 | 31.9 | 23.7 |
| | 25 | 44.4 | 31.9 | 23.7 |
| Segment Fuel | 100 | 47.3 | 18.8 | 33.9 |
| | 50 | 44.4 | 31.9 | 23.7 |
| | 25 | 44.4 | 31.9 | 23.7 |
| Lockage | 100 | 47.3 | 18.8 | 33.7 |
| | 50 | 44.4 | 31.9 | 23.7 |
| | 25 | 44.4 | 31.9 | 23.7 |

Imposition of even 100 percent energy recovery level on the 25 and 50 percent O&M recovery level fee uniform fuel produces no additional market shift. However, the energy recovery fee on top of the 100 percent uniform fuel fee produces significant modal shifts. Truck-barge modal shares falls to 21.1 percent (line 4) with a 50 percent recovery level energy lockage tax and 24.0 percent (line 10) with a 50 percent level energy fuel fee on top of the uniform O&M recovery fee. With the 100 percent level energy fee, truck-barge share falls to 18.2 and 18.8 percent.

When the energy recovery fees are imposed on top of either of the two segment O&M recovery fees, larger market share shifts occur at any combination of 50 percent recovery level for O&M or energy and 100 percent level for the other. In the worst case, truck-barge share drops to 15.7 percent with 100 percent recovery levels for both O&M segment fuel tax and energy fuel tax. Again the bulk of the market shift is captured by the truck mode which gains an additional 12.7 percent of the market.

We see that in the era before deregulation, imposition of user fees potentially created some significant market shifts away from truck-barge, although generally speaking only where both O&M and energy recovery levels exceeded 50 percent. The emergence of multiple car rail rates with the coming of of deregulation changes the situation significantly. Table 3 shows base level market shares with multiple car rates but no user fees to be 9.7 percent for single car rail, 58.7 percent multiple car rail, 16.2 percent truck barge and 15.4 percent truck. Multiple car rail captures the bulk of the market, with truck-barge falling to a level below any of the losses induced by the imposition of user fees. In fact, table 3 shows that the imposition of user fees for O&M recovery induce only one additional percentage point market share loss even at the highest level of recovery for the two segment specific user fees. The model shows truck-barge losing this single point whether O&M recovery levels are at their lowest or highest.

Table 2. Pacific Northwest Transportation Market Shares, O&M Charges and Energy Costs Inclusive, Single Unit Rail Models

| Fee Type | | Percent of Market Shares | | |
|---|---|---|---|---|
| | | Single Rail (%) | Truck-Barge (%) | Truck (%) |
| O&M Fee | Energy Fee | | | |
| 100% Uniform Fuel | 100% Lockage | 47.9 | 18.2 | 33.9 |
| 50% Uniform Fuel | 100% Lockage | 44.4 | 31.9 | 23.7 |
| 25% Uniform Fuel | 100% Lockage | 44.4 | 31.9 | 23.7 |
| 100% Uniform Fuel | 50% Lockage | 47.3 | 21.1 | 31.6 |
| 50% Uniform Fuel | 50% Lockage | 44.4 | 31.9 | 23.7 |
| 25% Uniform Fuel | 50% Lockage | 44.4 | 31.9 | 23.7 |
| 100% Uniform Fuel | 100% Fuel | 47.3 | 18.8 | 33.9 |
| 50% Uniform Fuel | 100% Fuel | 44.4 | 31.9 | 23.7 |
| 25% Uniform Fuel | 100% Fuel | 44.4 | 31.9 | 23.7 |
| 100% Uniform Fuel | 50% Fuel | 44.4 | 24.0 | 31.6 |
| 50% Uniform Fuel | 50% Fuel | 44.4 | 31.9 | 23.7 |
| 25% Uniform Fuel | 50% Fuel | 44.4 | 31.9 | 23.7 |
| 100% Lockage | 100% Lockage | 47.9 | 18.2 | 33.9 |
| 50% Lockage | 100% Lockage | 47.3 | 18.8 | 33.9 |
| 25% Lockage | 100% Lockage | 44.4 | 31.9 | 23.7 |
| 100% Lockage | 50% Lockage | 47.9 | 18.2 | 33.9 |
| 50% Lockage | 50% Lockage | 44.4 | 31.9 | 23.7 |
| 25% Lockage | 50% Lockage | 44.4 | 31.9 | 23.7 |
| 100% Segment Fuel | 100% Fuel | 47.9 | 15.7 | 36.4 |
| 50% Segment Fuel | 100% Fuel | 47.3 | 21.1 | 31.6 |
| 25% Segment Fuel | 100% Fuel | 44.4 | 31.9 | 23.7 |
| 100% Segment Fuel | 50% Fuel | 47.9 | 18.2 | 33.9 |
| 50% Segment Fuel | 50% Fuel | 44.4 | 31.9 | 23.7 |
| 25% Segment Fuel | 50% Fuel | 44.4 | 31.9 | 23.7 |

Table 3. Pacific Northwest Transportation Market Shares, O&M Changes Only, Multiple Car Rail Models

| | Percent Cost Recovery (%) | Percent of Market Shares | | | |
|---|---|---|---|---|---|
| | | Single Rail (%) | Multiple Rail (%) | Truck-Barge (%) | Truck (%) |
| Base Model Two | 0 | 9.7 | 58.7 | 16.2 | 15.4 |
| Uniform Fuel | 100 | 10.7 | 58.7 | 15.2 | 15.4 |
| | 50 | 10.7 | 58.7 | 15.2 | 15.4 |
| | 25 | 10.7 | 58.7 | 15.3 | 15.4 |
| Segment Fuel | 100 | 10.7 | 58.7 | 15.2 | 15.4 |
| | 50 | 10.7 | 58.7 | 15.2 | 15.4 |
| | 25 | 10.7 | 58.7 | 15.2 | 15.4 |
| Lockage | 100 | 10.7 | 58.7 | 15.2 | 15.4 |
| | 50 | 10.7 | 58.7 | 15.2 | 15.4 |
| | 25 | 10.7 | 58.7 | 15.2 | 15.4 |

Table 4. Pacific Northwest Transportation Market Shares, O&M Charges and Opportunity Costs Inclusive, Multiple Unit Rail Models

| Fee Type | | Percent of Market Shares Single Rail | Multiple Rail | Truck-Barge | Truck |
|---|---|---|---|---|---|
| | | % | % | % | % |
| O&M Fee | Energy Fee | | | | |
| 100% Uniform Fuel | 100% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Uniform Fuel | 100% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Uniform Fuel | 50% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 100% Uniform Fuel | 50% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Uniform Fuel | 50% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Uniform Fuel | 50% Lockage | 10.7 | 48.7 | 15.2 | 15.4 |
| 100% Uniform Fuel | 100% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Uniform Fuel | 100% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Uniform Fuel | 100% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 100% Uniform Fuel | 50% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Uniform Fuel | 50% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Uniform Fuel | 50% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 100% Lockage | 100% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Lockage | 100% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Lockage | 100% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 100% Lockage | 50% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Lockage | 50% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Lockage | 50% Lockage | 10.7 | 58.7 | 15.2 | 15.4 |
| 100% Segment Fuel | 100% Fuel | 10.7 | 58.7 | 12.7 | 17.9 |
| 50% Segment Fuel | 100% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Segment Fuel | 100% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 100% Segment Fuel | 50% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 50% Segment Fuel | 50% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |
| 25% Segment Fuel | 50% Fuel | 10.7 | 58.7 | 15.2 | 15.4 |

Even the imposition of additional user fees to recovery energy costs has little effect on market shares. As table 4 shows, only under one scenario is there an additional shift in market shares. Where 100 percent recovery levels are imposed for both energy loss and O&M costs, truck-barge loses an additional 2.5 percentage market share, with the gain going to truck.

## Results: Transportation Cost Increases

The shift in modal share indicates the impact of user fees on the transportation industry. We are also interested in the impact of user fees on those who pay the transportation bill. Again we consider first the situation before deregulation, with only single car rail rates available.

Table 5 shows the base level transportation bill before user fees and the increases in transportation costs caused by adding various levels and combinations of user fees. Increases are shown in dollar amounts and as a percentage increase over the base. The imposition of

Table 5. Pacific Northwest Transportation Costs, O&M Charges and Energy Costs Inclusive, Single Unit Rail Models

| Fee Type | | Total Cost ($) | Dollar Change From Base Model One ($) | Percentage Change From Base Model One (%) |
|---|---|---|---|---|
| Base Model One | | 22,568,848 | 0 | 0 |
| O&M Fee | Energy Fee | | | |
| 100% Uniform Fuel | 0 | 229,026,240 | 2,457,392 | 1.09 |
| 50% Uniform Fuel | 0 | 227,802,736 | 1,233,888 | 0.55 |
| 25% Uniform Fuel | 0 | 227,191,056 | 622,208 | 0.28 |
| 100% Segment Fuel | 0 | 230.247,520 | 3,678,672 | 1.62 |
| 50% Segment Fuel | 0 | 228,527,680 | 1,958,832 | 0.87 |
| 25% Segment Fuel | 0 | 227,553,456 | 984,608 | 0.44 |
| 100% Lockage | 0 | 230,125,392 | 3,556,544 | 1.57 |
| 50% Lockage | 0 | 228,525,728 | 1,956,880 | 0.86 |
| 25% Lockage | 0 | 227,552,336 | 983,488 | 0.43 |
| 100% Uniform Fuel | 100% Lockage | 230,398,216 | 3,820,368 | 1.69 |
| 50% Uniform Fuel | 100% Lockage | 229,627,712 | 3,058,853 | 1.35 |
| 25% Uniform Fuel | 100% Lockage | 229,015,824 | 2,446,976 | 1.08 |
| 100% Uniform fuel | 50% Lockage | 229,895,360 | 3,326,512 | 1.47 |
| 50% Uniform Fuel | 50% Lockage | 228,715,232 | 2,145,384 | 0.95 |
| 25% Uniform Fuel | 50% Lockage | 228,103,632 | 1,534,784 | 0.68 |
| 100% Uniform Fuel | 100% Fuel | 230,448,624 | 3,879,776 | 1.71 |
| 50% Uniform Fuel | 100% Fuel | 229,629,120 | 3,060,272 | 1.35 |
| 25% Uniform Fuel | 100% Fuel | 229,017,504 | 2,448,656 | 1.08 |
| 100% Uniform Fuel | 50% Fuel | 229,918,672 | 3,349,824 | 1,48 |
| 50% Uniform Fuel | 50% Fuel | 228,715,936 | 2,147,088 | 0.95 |
| 25% Uniform Fuel | 50% Fuel | 228,104,256 | 1,535,408 | 0.68 |
| 100% Lockage | 100% Lockage | 231,006,528 | 4,437,608 | 1.96 |
| 50% Lockage | 100% Lockage | 230,064,496 | 3,495,648 | 1.54 |
| 25% Lockage | 100% Lockage | 229,377,344 | 2,808,496 | 1.24 |
| 100% Lockage | 50% Lockage | 230,567,264 | 3,998,416 | 1.76 |
| 50% Lockage | 50% Lockage | 229,438,288 | 2,869,440 | 1.27 |
| 25% Lockage | 50% Lockage | 228,464,848 | 1,896,000 | 0.84 |
| 100% Segment Fuel | 100% Fuel | 231,146,448 | 4,577,600 | 2.02 |
| 50% Segment Fuel | 100% Fuel | 230,174,752 | 3,605,904 | 1.59 |
| 25% Segment Fuel | 100% Fuel | 229,279,888 | 2,811,040 | 1.24 |
| 100% Segment Fuel | 50% Fuel | 230,724,160 | 4,155,312 | 1.83 |
| 50% Segment Fuel | 50% Fuel | 229,440,736 | 2,871,888 | 1.27 |
| 25% Segment Fuel | 50% Fuel | 228,466,656 | 1,897,808 | 0.84 |

user fees to recover only O&M costs has a maximum impact of 1.62 percent on the transportation bill. When energy recovery fees are added, the transportation bill increases by a maximum of 2.02 percent or 4.6 million dollars. In both cases maximum increases occur under segment fuel taxes. Note, there are changes in transportation costs where the model shows no change in market shares. For instance increasing the recovery of O&M from 25 to 100 percent (with no energy recovery) had no effect on market shares, but increases the transportation bill from $.6 million to $2.5 million dollars. This occurs when transportation cost increases are less than the threshold needed to motivate shifts in transportation mode.

Table 6 shows the transportation bill and changes under the multiple car transportation structure which followed deregulation. Availability of multiple car rates (Base Model Two) lowers transportation costs $8.9 million compared to the pre-deregulated structure (Base Model One, Table 5). Imposition of user fees only for O&M recovery raises the transportation bill by .12 percent to .71 percent ($.25 million to $1.55 million). The lowest increase under user fees for all costs occurs with the 25 percent uniform (O&M) 50 percent lockage (energy) where the bill rises by .26 percent or $.57 million. The maximum increase is 1.02 percent or $2.23 million with segment fuel for O&M and fuel tax for energy recovery.

Reviewing the transportation costs indicates that uniform fees impose the lowest cost. This result is expected because the Columbia-Snake River system is a high cost waterway. In general, for any level of cost recovery, lockage fees have a slightly smaller cost impact than segment fuel taxes.

## Conclusions

The imposition of user fees for the recovery of operations and maintenance and energy opportunity costs had a relatively small impact on modal shares and transportation costs. Under the prederegulation regime of single car rates the O&M user fee had minimum impact except at 100 percent cost recovery for the segment specific fees. Addition of energy cost recovery did have the potential for some shifts away from truck-barge demonstrating the competitive vulnerability of the mode.

The entry of deregulation has however preempted these potential changes. Multiple rail rates captured the lions share of the market and reduced the transportation bill substantially. The addition of user fees, post deregulation, produces very little modal shift, indicating that most of the potential shift away from barge is induced by the multiple car rates. Indeed where additional modal share shift occurs, it is to single rail or truck modes. Finally the transportation bill impact of user fees is less under deregulation because of the smaller base for the user fees (the smaller truck-barge modal share).

The last result indicates, however, one weakness of the modal. User fees were calculated to recover a given share of costs (O&M and energy) based on existing traffic levels. Decreases in truck-barge market share means that these same rates will recover less than the target level. If user fees were adjusted to recover the original level of costs at the new lower traffic base, additional modal share losses could occur. Whether additional iterations would result in a "death spiral" in which truck-barge lost more and more traffic or an equilibrium would be reached near the solutions given in this paper is not clear. However, the small shifts in the post deregulation models suggests the potential for shift has mostly been exhausted.

Table 6. Pacific Northwest Transportation Costs, O&M Charges, and Energy Costs Inclusive, Multiple Unit Rail Models

| Fee Type | | Total Cost ($) | Dollar Change From Base Model Two ($) | Percentage Change From Base Model Two (%) |
|---|---|---|---|---|
| Base Model Two | | 217,641,824 | 0 | 0 |
| O&M Fee | Energy Fee | | | |
| 100% Uniform Fee | 0 | 218,620,864 | 979,040 | 0.45 |
| 50% Uniform Fee | 0 | 218,136,528 | 494,704 | 0.23 |
| 25% Uniform Fee | 0 | 217,894,352 | 252,528 | 0.12 |
| 100% Segment Fuel | 0 | 219,194,768 | 252,528 | 0.71 |
| 50% Segment Fuel | 0 | 218,423,616 | 781,792 | 0.36 |
| 25% Segment Fuel | 0 | 218,037,808 | 395,984 | 0.18 |
| 100% Lockage | 0 | 219,012,080 | 1,370,256 | 0.63 |
| 50% Lockage | 0 | 218,332,208 | 690,384 | 0.32 |
| 25% Lockage | 0 | 217,992,176 | 350,352 | 0.16 |
| 100% Uniform Fuel | 100% Lockage | 219,258,416 | 1,616,592 | 0.74 |
| 50% Uniform Fuel | 100% Lockage | 218,774,064 | 1,132,240 | 0.52 |
| 25% Uniform Fuel | 100% Lockage | 218,531,872 | 890,048 | 0.41 |
| 100% Uniform Fuel | 50% Lockage | 218,939,664 | 1,297,840 | 0.60 |
| 50% Uniform fuel | 50% Lockage | 218,455,280 | 813,456 | 0.37 |
| 25% Uniform Fuel | 50% Lockage | 218,213,152 | 614,032 | 0.26 |
| 100% Uniform Fuel | 100% Fuel | 219,343,872 | 1,702,048 | 0.78 |
| 50% Uniform Fuel | 100% Fuel | 218,859,536 | 1,217,712 | 0.56 |
| 25% Uniform Fuel | 100% Fuel | 218,617,376 | 975,552 | 0.45 |
| 100% Uniform Fuel | 50% Fuel | 218,982,368 | 1,340,544 | 0.62 |
| 50% Uniform Fuel | 50% Fuel | 218,498,048 | 856,224 | 0.39 |
| 25% Uniform Fuel | 50% Fuel | 218,255,856 | 614,032 | 0.28 |
| 100% Lockage | 100% Lockage | 219,649,632 | 2,007,808 | 0.92 |
| 50% Lockage | 100% Lockage | 218,969,776 | 1,132,952 | 0.61 |
| 25% Lockage | 100% Lockage | 218,629,696 | 987,872 | 0.45 |
| 100% Lockage | 50% Lockage | 219,330,880 | 1,689,056 | 0.78 |
| 50% Lockage | 50% Lockage | 218,641,008 | 1,009,184 | 0.46 |
| 25% Lockage | 50% Lockage | 218,310,928 | 669,104 | 0.31 |
| 100% Segment Fuel | 100% Fuel | 219,871,088 | 2,229,264 | 1.02 |
| 50% Segment Fuel | 100% Fuel | 219,146,496 | 1,504,672 | 0.69 |
| 25% Segment Fuel | 100% Fuel | 218,760,864 | 1,119,040 | 0.51 |
| 100% Segment Fuel | 50% Fuel | 219,556,320 | 1,914,495 | 0.88 |
| 50% Segment Fuel | 50% Fuel | 218,784,960 | 1,143,136 | 0.53 |
| 25% Segment Fuel | 50% Fuel | 218,399,328 | 757,504 | 0.35 |

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