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Inland Waterway User Charges, Port Development, and Research Methodologies

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Projecting the Demand for Ohio River Basin Waterway Traffic by Correlation and Regression

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The techniques used in projecting future commodity movements on the waterways of the Ohio River Basin and the manner in which these projections were assigned to the navigation projects in the region are presented. Historical data on commodity movements were collected and computer coded. Economic factors and associated projections that have some possible relation to commodity movements were selected, and a set of projected values was obtained for each commodity group by use of simple and multiple regression techniques. Recent trends in port-to-port commodity movements in conjunction with commodity group projections were then used to construct future origin-destination matrices for each commodity group. Finally, by using a traffic assignment program originally developed for urban transportation system modeling, a set of direction-specific and commodity-group-specific tonnages was assigned to each navigation project in the Ohio River Basin.

In 1976, nearly 163 million t (180 million tons) of commerce was carried on the waters of the Ohio River navigation system. Most of this consisted of bulk-type commodities such as coal, sand, gravel, crushed rock, and petroleum fuels. These materials constitute major inputs to the basic industrial and energy production processes of the United States.

To ensure the continued smooth flow of these commodities, the U.S. Army Corps of Engineers must continue to maintain and improve the conditions of the rivers and navigation projects in the Ohio River Basin (ORB). Since funds for this purpose are limited, the Corps of Engineers must develop a strategy for applying their financial resources in the way that will best achieve this goal.

As part of a systemwide study of commercial navigation in the ORB, the Huntington, West Virginia, District of the U.S. Army Corps of Engineers has retained the services of CONSAD Research Corporation to project future demand for ORB waterway traffic for the period from 1975 to 1990. (This is only one of three projection studies of the ORB that is being undertaken by the Corps of Engineers. The second study is based on surveys of shippers and receivers, and the third is examining a number of basic market conditions and trends.) The primary study area is defined to be the main-stem Ohio River and all of its commercially navigable tributaries, including the Monongahela, Allegheny, Kanawha, Kentucky, Green, Cumberland, and Tennessee Rivers. This analysis has consisted of the following tasks:

1. By use of correlation and regression techniques, future waterway traffic for the Ohio River navigation system was estimated for the period 1975 to 1990 for the following commodity groups:

Number	Commodity Group
1	Coal and coke
2	Petroleum fuels
3	Crude petroleum
4	Aggregates
5	Grains
6	Chemicals and chemical fertilizers
7	Ores and minerals
8	Iron ore and iron and steel
9	Other

Historic data on waterway traffic to be used in this task were collected from a report by the Corps of Engineers (1).

2. By use of 1969 to 1975 "PE to PE" and "BEA to BEA" flow data provided by the Corps of Engineers, the forecasts from task 1 were allocated to the Bureau of Economic Analysis (BEA) areas and river reaches within and outside the ORB by commodity group. [PE stands for port equivalent and refers to a stretch of river that exhibits a composite of port characteristics. The term was defined as part of the Inland Navigation Systems Analysis (INSA) program of the Corps of Engineers as an aid in water simulation projects. BEA area refers, in this paper, to any of the 173 economic areas into which BEA has divided the United States.] These future movements were then aggregated by direction of movement to the main stem of the Ohio River, each navigable tributary, and each of the 71 navigation projects in the Ohio River navigation system.

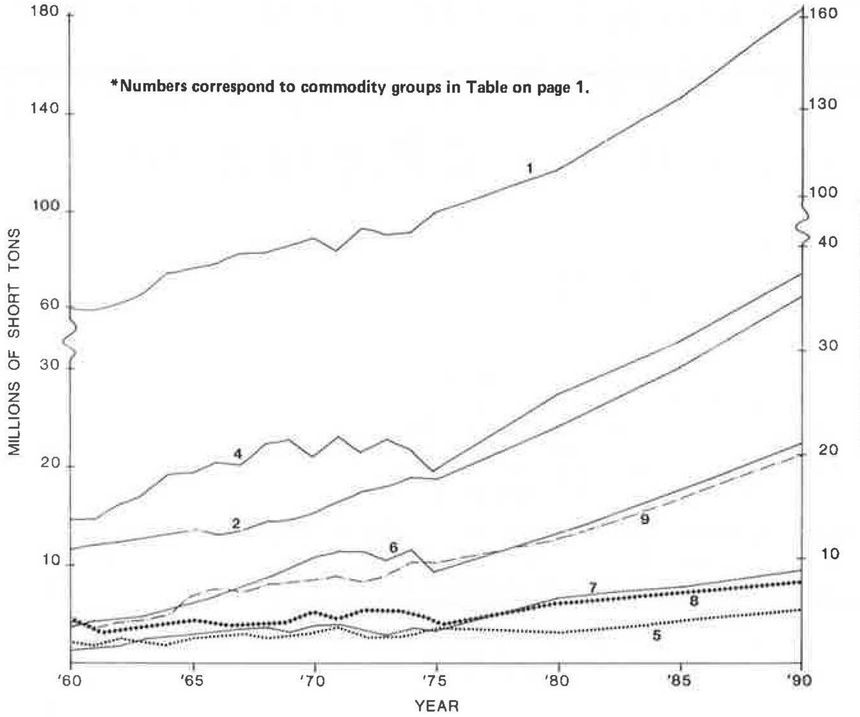
3. Independent projections of waterway traffic by commodity group and direction of movement (upbound-downbound) were also generated for the main stem of the Ohio River and each navigable tributary in an attempt to identify the degree of association between the behavior of the total system and its components. A similar analysis was performed for traffic that passes key navigation projects in the Ohio River system. These subsystem studies were intended to test the reliability of basinwide projections throughout the system.

This paper summarizes the analytical techniques and results, which are fully documented in the final report by the Corps of Engineers (2).

DATA AND ANALYSIS

Data on the movements of commodities on the rivers under investigation for the years 1953 to 1975 were collected from the Corps of Engineers report on U.S. waterborne commerce (1). Before 1953, back through 1940, this information appeared in the annual report of the Chief of Engineers. These data were computer coded in much the same way as they were in the later volumes of Waterborne Commerce (1). That is, for each commodity, the directional distinctions of upriver, downriver, in river, out river, and through river (up and down) were retained to provide the maximum amount of flexibility in the data file. River and year codes were also included. In addition to these data, CONSAD was provided with BEA-to-BEA and PE-to-PE movement

Figure 1. Observed and projected ORB traffic by commodity group.



*Numbers correspond to commodity groups in Table on page 1.

data on all commodities for the years 1969 to 1976 and data on the 71 lock-and-dam projects by commodity group and direction as far back historically as data existed.

Assuming that the patterns of past commodity flows bear some relation to their future flows, and also assuming that these commodities are moving in response to the economic demands of the nation, it is believed that quantitative relations exist between economic indicators and levels of waterway traffic. It is expected that these relations could be determined from historical data by using correlation and regression techniques and that these relations could then be applied to future economic projections to obtain projections of future demand for waterway traffic.

In the search for economic indicators that could logically be considered a driving force behind the movements of a particular commodity or commodity group on the waterways of the ORB, it was found that compatibility between annual historical data and the projected data was extremely rare. More specifically, we were able to locate many annual data series for all types of economic variables, but there were usually no projections in existence that were based on the annual series. The projections we were able to locate were not based on historical data that extended as far back as 1940.

Finally, it was decided that the best source would be BEA. The data tapes purchased from BEA included a 37-industry breakdown of earnings, total personal income, per capita income, and population. These categories were provided on an annual basis for the years 1965 to 1975 and included both national- and BEA-level data.

These data sources are compatible with the Office of Business Economics/Economic Research Service (OBERS) Projection Series (3) prepared by BEA in conjunction with the Economic Research Service of the U.S. Department of Agriculture for the U.S. Water Resources Council. In addition to such data as projected earnings and income for the years 1980, 1985, and 1990, this series also provides historical data for the years 1950, 1959, and 1962. This brings the number of available historical observations to 14.

Before any regression procedures could begin, the data set from the Corps of Engineers report on waterborne commerce (1) had to be converted from the river-specific format to a total system format that would take into account all traffic movements on the rivers of the ORB for each commodity group. This was accomplished by summing the tonnages for all six directions on the Ohio River together with the tonnages for the two intrariver directions (up and down) for each of the seven tributaries. All ORB traffic was thus aggregated without any double counting (see Figure 1 for historic traffic).

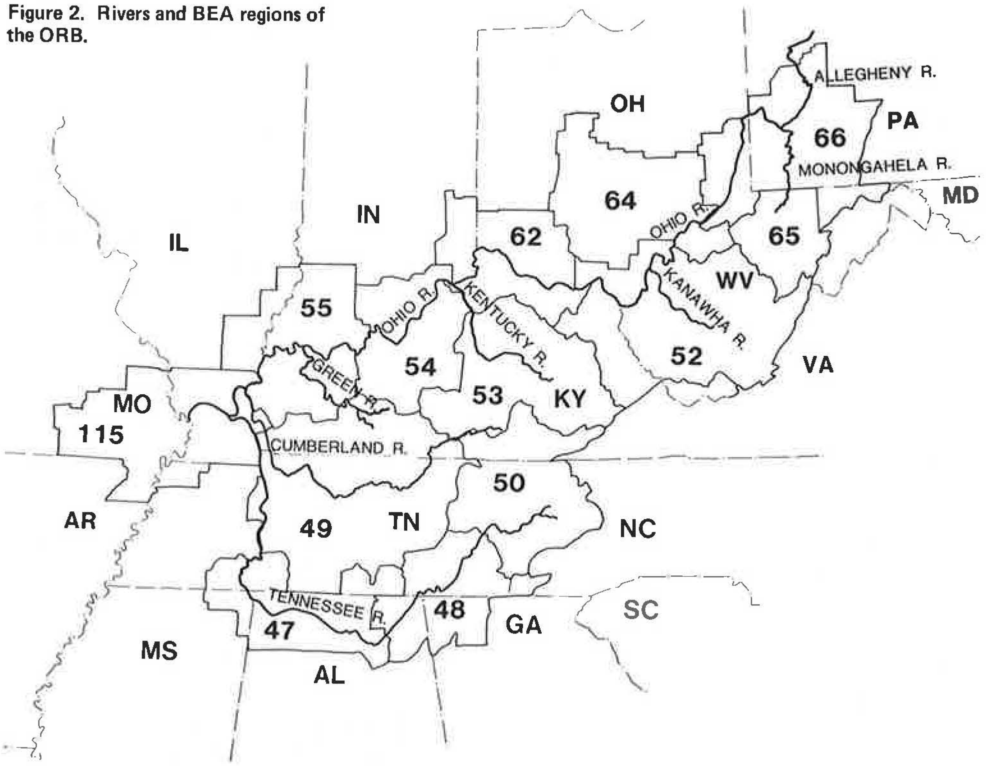
After aggregation, a severe decrease in crude petroleum shipments for the system as a whole was discovered. This decrease was found to correspond with the opening of a pipeline for the transport of crude petroleum. Regression procedures were therefore abandoned for this commodity group in favor of other means of determining future shipments. This is discussed in the final portion of this paper.

The first step in the regression procedure for the other eight commodity groups was to develop a series of regression equations based on the historical data (dependent variable) and the OBERS economic series [independent variable(s)]. The following functional forms were used:

1. Straight line: $Y = a + bX$,
2. Second-degree curve: $Y = a + bX + cX^2$,
3. Geometric curve: $Y = a \times X^b$, and
4. Exponential curve: $Y = a \times b^X$.

For each commodity group, several "specifically targeted" variables were chosen. By specifically targeted is meant those variables that possess some identifiable economic relation to the commodities in a particular commodity group. Then, by using the Statistical Package for the Social Sciences (SPSS) stepwise regression package (4) to choose the variable or variables that had the greatest degree of explanatory power, a series of regression equations was developed. Both national-level economic data and basin-level data

Figure 2. Rivers and BEA regions of the ORB.



[created by aggregating data for the 13 BEA areas that cover the ORB (Figure 2)] were tested. In addition, a regression run was made by using gross national product (GNP) as the independent variable. The equations chosen for projection purposes and the resulting projections appear in the final section of this paper.

At the subsystem level (individual rivers and key lock-and-dam projects), the same independent-dependent variable relations tested at the system level for each commodity group were again tested on the system components. This analysis was undertaken primarily as a means of determining whether traffic on the system components moves in response to the same demand variables and with similar correlations as does traffic at the system level.

In comparing the regression results obtained at the system level with those obtained at the individual river and key lock-and-dam levels of analysis, we find that, when the same independent-dependent variable relations are tested, a fairly strong degree of association exists between the system and its components. Based on this finding, it seems reasonable to use system-level analysis, modified by local trends, to assign future traffic demand to the lock-and-dam projects in the ORB.

Before a decision was made on a technique to be used in forecasting future port-to-port commodity movements, 1969 to 1976 origin-destination (O-D) movements were investigated. A great deal of stability existed in the patterns of O-D movements over the eight-year period. Based on this finding, it was decided that the most appropriate technique for extrapolating the historic O-D movement trends to 1980, 1985, and 1990 O-D flows was to use shift-share analysis (3) in conjunction with the Fratar growth-factor method (4). Both techniques are well suited for extrapolation purposes when no severe changes in historic patterns are anticipated.

Given historic movement patterns and projections of future commodity-group activity, shift-share analysis develops future shipping and receiving (origin and destination) totals for each commodity group and subarea (BEA or PE). These totals correspond to row and column sums of a commodity-specific O-D matrix. The Fratar technique will then construct the future matrix cell entries according to a base-year pattern adjusted by subarea growth factors.

More specifically, the shift-share methodology acts recursively on a series of commodity-group-specific O-D matrices. Each subarea is examined in light of the total originating shipments (row sum of O-D matrix) and total destinations (column sum). Shift-share analysis interprets subarea growth as being dependent on two "parent forces": (a) growth in total shipments and (b) growth in commodity-group shipments between successive time periods. Any growth inconsistent with those parent forces is attributed to unique subarea characteristics.

At this point, the introduction of mathematical notation will aid in the description of the shift-share methodology. The following notation is used:

Q_{ij}^{gt} = total annual tonnage of commodity group g originating from subarea i and terminating at subarea j in year t (O-D matrix cell entry),

$O_i^{gt} \sum_{j=1}^{n} Q_{ij}^{gt}$ = total annual tonnage of commodity group g originating from subarea i in year t (row sum of O-D matrix, the P matrix),

$D_j^{gt} = \sum_{i=1}^{m} Q_{ij}^{gt}$ = total annual tonnage of commodity group g terminating in subarea j in year t (column sum of O-D matrix, the A matrix),

$$Q^{gt} = \sum_{i=1}^{m} O_i^{gt} = \sum_{j=1}^{n} = D_j^{gt} = \sum_{i=1}^{m} \sum_{j=1}^{n} Q_{ij}^{gt}$$

= total annual tonnage for commodity group g, and

$$Q^t = \sum_{g=1}^{9} Q^{gt} = \text{total annual tonnage in year } t.$$

Then, between successive years, the incremental growth in shipments for commodity group g in subarea i (ΔO_i^{gt}) is seen by shift-share as being composed of the following components (a similar analysis is performed for the D_j^{gt}'s):

$$\Delta O_i^{gt} = R_i^{gt} + S_i^{gt} + U_i^{gt} \tag{1}$$

where

R_i^{gt} = raw increment that would occur if commodity group g in subarea i were to behave as the aggregate regional growth rate for all commodity groups,
S_i^{gt} = any growth (or decline) in commodity group g over and above the regionwide aggregate growth, and
U_i^{gt} = the "unique" component: any growth (or decline) in commodity group g within subarea i for which the first two components (R_i^{gt}, S_i^{gt}) take no account.

These components are calculated as follows:

$$R^{gt} = r^t O^{g(t-1)} \tag{2}$$

where $r^t = (Q^t - Q^{t-1})/Q^{t-1}$, the basinwide growth rate for all commodities;

$$S_i^{gt} = (y^{gt} - r^t) O_i^{g(t-1)} \tag{3}$$

where $y^{gt} = [Q^{gt} - Q^{g(t-1)}]/Q^{g(t-1)}$, the basinwide growth rate for commodity group g; and

$$U_i^{gt} = (z_i^{gt} - y^{gt}) O_i^{g(t-1)} \tag{4}$$

where $z_i^{gt} = [O_i^{gt} - O_i^{g(t-1)}]/O_i^{g(t-1)}$, the growth rate for subarea i for commodity group g.

It is the unique growth parameter $z_i^{gt} - y^{gt}$, which we define as u_i^{gt} (excess of commodity-specific subarea growth rate over the regionwide commodity-specific growth factor), that is calculated for each BEA region (origins and destinations), each commodity group, and each of the seven iterations for the years 1969 to 1976. To arrive at the 1980 u_i^{gt} value, a simple time-series regression is performed on the seven historical values. The only other inputs required to obtain the 1980 O-D totals are a projected total tonnage figure for 1980 ($\hat{Q}^t$) and projected tonnages for each commodity group ($\hat{Q}^{gt}$) (^ refers to projected values). These projected tonnages are taken from the systemwide projections, values of which are contained in the final section of this paper.

Procedures for determining the 1985 $\hat{u}_i^{gt}$ growth factors are analogous except the 1980 values are added to the original seven historical values and year (t - 1) now refers to the projected 1980 tonnages. Similarly, the 1990 $\hat{u}_i^{gt}$ values are calculated from nine values (seven observed, two projected), and the year (t - 1) refers to the projected 1985 tonnages.

Once the estimates of subarea growth (ΔO_i^{gt}) have been calculated, they are added to the base-year originating total $O_i^{(t-1)}$ to arrive at a future originating total $\hat{O}_i^{gt}$:

$$O_i^{gt} = O_i^{g(t-1)} + \Delta O_i^{gt} \tag{5}$$

This is done for each of the n subareas so that we now have an n × 1 vector whose entries consist of the raw projected total shipments for each subarea. The sum of these entries should be close to Q^{gt}, the projected total for commodity-group tonnage. In order to obtain a precise match, we calculate a normalizing factor K by comparing the desired value Q^{gt} with the calculated total tonnage $\sum_{i=1}^{n} O_i^{gt}$. This should give us a normalizing factor close to 1.0 by which we multiply each of the O_i^{gt} values, finally arriving at future origination totals for each subarea, the sum of which will equal the projected tonnage for that particular commodity group. The mathematics of the normalizing step is represented as follows:

$$K = Q^{gt} \Big/ \sum_{i=1}^{n} O_i^{gt} \tag{6}$$

$$\hat{O}_i^{gt} = K \times O_i^{gt} \quad \text{for all } i \tag{7}$$

In actually applying the shift-share methodology to the eight years of O-D flow data, it was discovered that extrapolation of the unique growth parameters u_i^{gt} by simple time-series regression was often inappropriate. Since this growth parameter was defined as the difference between two other growth factors ($z_i^{gt} - y^{gt}$), it should not be too surprising that the u_i^{gt} values often did not show any particular trend. As a result, unless the time-series regression yielded an R^2 value greater than 0.5, a simple averaging of the historical u_i^{gt} values was used to obtain the 1980, 1985, and 1990 unique growth parameters.

Furthermore, examination of resulting O-D totals for 1990 showed that time-series regressions of u_i^{gt} sometimes yielded negative u_i^{gt} values and resulted in negative tonnages of shipments. The regression procedure was thus abandoned, and the historical u_i^{gt} values were averaged after the smallest and largest were removed so that inordinately large increases or decreases in shipments did not overly affect future shipments.

After development of the future origin and destination totals, i.e., row and column sums of the future O-D matrices, the next step was to construct the actual matrix cell values that represent commodity flows from a particular origin to a particular destination. The Fratar growth-factor method is ideally suited for this task.

The basic premise of the Fratar method is that the distribution of future shipments from a zone is proportional to the base-year distribution modified by the growth factors of the zones under consideration. This method, as used by the urban transportation computer program package PLANPAC/BACKPAC (7), applies the origin and destination growth factor to each cell of the O-D matrix in such a way that the future origin total (row sum) is preserved. Actual destination totals (column sums) may not agree with those desired, but an iterative procedure designed to achieve a specified degree of accuracy in the destination totals is included. The mathematical representation of this technique is as follows:

$$\hat{Q}_{ij(k+1)}^{gt} = Q_{ijk}^{g(t-1)} F_{jk} F_{ik} \tag{8}$$

where

$Q_{ijk}^{g(t-1)}$ = tons shipped between origin i and destination j for iteration k (represents base-year tonnage when k = 1),
$F_{jk} = \hat{D}_j^{gt} / \sum_{i=1}^{n} Q_{ijk}^{g(t-1)}$

= destination j (column) growth factor,

$F_{ik} = \hat{O}_i^{gt} / \sum_{j=1}^{n} Q_{ijk}^{g(t-1)} F_{jk}$

= origin i (row) growth factor, and

$\hat{D}_j^{gt}, \hat{O}_i^{gt}$ = projected destination (column) and origin (row) totals obtained from the application of shift-share analysis.

After developing the 1980, 1985, and 1990 O-D matrix for each commodity group, the remaining task involves taking these O-D flows and assigning the corresponding tonnages to the navigation projects along the river routes that would have to be traversed in going from an origin to a destination. This task falls under the general category of traffic assignment, which may be broadly defined as the process of allocating a given set of trip interchanges to a specific transportation system.

The traffic assignment program included in the PLANPAC/BACKPAC computer program package previously mentioned, although usually used in modeling an urban transportation system, was easily adapted to our purposes. The river system under study can be thought of as a very simple road network, where PEs take the place of intersections (nodes in traffic assignment) and the navigation projects take the place of the roads that connect intersections (links in traffic assignment). Once the river network has been described to the computer, i.e., the location of all the PEs and navigation projects have been given in relation to each other and the distances involved, the computer constructs a minimum-path tree for all O-D pairs. In the case of the Ohio River system, all paths that involve O-D pairs are unique except for the section where the Barkley Canal provides an alternate path for traffic involved with the Tennessee River or Cumberland River and the Ohio River. In that case, minimum distance was the criterion used for choosing the route. Finally, each commodity-specific O-D matrix is input, the tonnage for each O-D pair is assigned to the navigation projects that would have to be traversed, and assigned tonnage is obtained for each project by commodity group and direction.

Table 1. Equations used in projecting tonnage of commodity groups at the system level.

Commodity Group	Equation
Coal and coke	= -28 506 = 92.7 (earnings in manufacture of chemicals and allied products - 26.1 (earnings in manufacture of fabricated metals)
Petroleum fuels	= -52 619 + 5.22 (earnings in transportation communications and utilities) + 3.06 (basin population)
Aggregates	= -3856 + 7.9 (earnings in contract construction)
Grains	= -14.4 + 7.9 (earnings in wholesale and retail trade) - 2.43 (earnings in agriculture)
Chemicals and chemical fertilizers	= -9544 + 1.35 (earnings in manufacturing) - 1.89 (earnings in agriculture)
Ores and minerals	= -5593 + 5.13 (earnings in manufacture of fabricated metals) + 1.35 (earnings in manufacture of primary metals)
Iron ore and iron and steel	= -247 + 1.62 (earnings in contract construction)
All other commodities	= -10 363 + 1.26 (earnings in manufacturing)

Notes: 1 t = 1.1 tons.
The equations yield projections in thousands of metric tons. All variables represent basin-level data.

Table 2. Projections of demand for ORB traffic by commodity group.

Commodity Group	Observed 1973-1975 Avg Metric Tonnage	Projections (t 000s)			1990 Change Versus Three-Year Avg (%)
		1980	1986	1990	
Coal and coke	84 648	106 392	133 277	165 687	95.7
Petroleum fuels	16 877	22 102	27 786	34 239	102.9
Aggregates	19 512	25 314	30 269	36 115	85.1
Grains	3 172	3 049	3 925	4 960	56.4
Chemicals and chemical fertilizers	9 562	12 121	16 004	20 581	115.2
Ores and minerals	3 111	5 722	7 173	8 854	184.5
Iron ore and iron and steel	4 452	5 676	6 682	7 868	76.7
All other	9 142	11 855	15 536	19 867	117.3
Total	150 476[a]	192 231	240 652	298 171	95.9

Note: 1 t = 1.1 tons.

[a] Includes crude petroleum.

RESULTS

The equations and associated projections given in Tables 1 and 2 represent the results of the regression procedures described earlier. These projections were used in the shift-share procedure to provide a total tonnage figure for each commodity-group-specific O-D matrix in 1980, 1985, and 1990.

Of the nine commodity groups analyzed in this study, coal and coke has historically accounted for the most significant portion of total traffic. Within this group, steam coal, used to generate electricity, is by far the most important commodity (by tonnage). A "good" single indication of steam coal demands was not identified within the OBERS framework, and the industry-specific variables included in the regression procedures represent secondary demand variables since these industries tend to be major energy users.

Because of the significance of steam coal to this projection study, it was felt that some additional sensitivity testing was called for. Under the assumption that earnings in transportation, communication, and utilities provide the best single indication of direct demand for steam coal and that population and earnings in manufacturing provide the best secondary demand indicators for noncommercial and commercial use of electricity, respectively, regression procedures were undertaken in which earnings in transportation, communication, and utilities were forced into the equation and followed by either or both of the other two variables. The projections that resulted from the equation developed in this manner were remarkably close to the projections obtained as a result of the regression procedures described earlier. At both the national and basin levels, population and earnings in manufacturing yielded insignificant F-test values when they were entered into the equation after earnings in transportation, communication, and utilities. By using the single independent variable equations, coal and coke was projected at 158.6 million t (174.5 million tons) (national-level data) and 164.5 million t (181 million tons) (basin-level data) in 1990 versus the slightly more than 165 million t (182 million tons) used in this study.

These results suggest that coal and coke projections are rather insensitive to the choice of OBERS variables used in the regression equation. They also add a degree of confidence to the reliability of the projections.

As noted earlier, crude petroleum experienced a 10-fold decrease in tonnage between 1972 and 1974. This severe decrease corresponded to the opening of a pipeline between Owensboro and Catletsburg, Kentucky. To determine the future of crude petroleum barging, an official of the pipeline division of the Ashland Oil Company—the major shipper of crude petroleum in the ORB area—was contacted and interviewed.

We were informed that within three years all barging of crude petroleum on the rivers of the ORB would cease (the intentions of other shippers will be determined during other projection studies of the ORB planned by the Corps of Engineers). But, until a new pipeline could be constructed or the capacity of an existing one increased, barging of crude petroleum from the Gulf Coast up the Mississippi and eventually to Owensboro would continue at the approximate rate of 5570 m^3/d (35 000 bbl/d). Given that a barrel of oil weighs about 136 kg (300 lb), the annual tonnage of crude petroleum would equal slightly less than 1.8 million t (2 million tons). Therefore, although no further projections of crude petroleum shipments were undertaken, the 1980 upstream tonnages for all lock-and-dam projects on the Ohio River between Cairo and Owensboro reflect this estimated crude petroleum tonnage.

Table 2 compares 1980, 1985, and 1990 projections with the average observed tonnage between 1973 and 1975. Overall, the demand for commodity traffic on the ORB system is expected to increase by 96 percent. Coal and coke, by far the largest commodity group, is projected to increase by a similar amount. Petroleum fuels are expected to more than double by 1990 and aggregates to grow by 85 percent. The commodity group that is expected to show the greatest percentage increase is ores and minerals (185 percent), whereas grains are only expected to show a 56 percent increase, the smallest percentage increase among the eight commodity groups.

CONCLUSIONS

The methodologies used by CONSAD in projecting future demand for waterway commodity flows have all used historic traffic patterns to predict future trends. One should realize that changes in either the physical characteristics of the system (e.g., new or improved navigation projects) or the competitive relationship between water, rail, and pipeline shipping rates could cause significant changes in the tonnages of commodities that move on the waters of the Ohio River Basin. In addition, the projected totals for each commodity group depend on the OBERS Series E projections for population, personal income, and earnings of certain key industries. If these projections turn out to be overly optimistic, the commodity-group demand forecasts derived from them probably will not be reached.

Overall, the CONSAD analysis projects demand for future system traffic at a little less than 298 million t (328 million tons) in 1990. This can be compared with slightly less than 154.5 million t (170 million tons) of traffic moved in 1975. The table below gives total tonnage figures for 5-year periods between 1945 and 1975 and the projected values for 1980, 1985, and 1990 (1 t = 1.1 tons):

Year	Total Metric Tons (000s)	Increase (%)
1945	46 602	
1950	60 084	28.9
1955	92 879	54.6
1960	95 744	3.1
1965	124 178	29.7
1970	149 003	20.0
1975	153 628	3.1
1980	194 049	26.3
1985	240 652	24.0
1990	298 172	23.9

Note that the average 5-year percentage increase between 1945 and 1975 was 23 percent, which is comparable to the predicted 5-year percentage increases between 1975 and 1990. Tonnages for 1985 and 1990 include no crude petroleum.

One might argue that the small increase in total tonnage between 1970 and 1975 represents a slowdown in the growth of waterborne commerce. However, the approximate 4.5 million t (5 million ton) increase between 1970 and 1975 includes a drop of more than 5.4 million t (6 million tons) of crude petroleum shipments attributable to the opening of new pipelines. Thus, this special crude petroleum situation partially accounts for the small increase in total tons between 1970 and 1975.

It may well be that the recent apparent slowdown in the rate of increase in river traffic is the result of the fact that the volume of river traffic is approaching the capacity of the river system; i.e., because of waiting times for lock facilities, the time required to ship by water may have increased to the point where alternate modes of transportation have become more competitive and thus more attractive. It should be noted that capacity constraints were not used by CONSAD in developing its demand projections except to the extent that historic volumes reflected such constraints. If the capacity of current facilities has been responsible for a slowdown in the rate of increase in waterborne commerce and continues to be so, one would not expect river traffic to reach the levels estimated in this study without an improvement of facilities.

The assignment of commodity-group tonnages to individual lock and dam projects was the result of the distribution of systemwide projected commodity-group totals among the individual originating and receiving ports according to the base-year distribution modified by historical trends. This "system-to-component" approach seems reasonable in light of the analysis described earlier in which a fairly strong degree of association was discovered between the navigation system and its components. However, this does not belie the fact that certain commodities are moving in response to very different and/or more localized variables than those that were tested in this study. It is expected that such issues will be addressed in other work on traffic projection for the Ohio River Basin.

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Assessment of the Texas Deepwater Terminal

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The results of a study conducted to assess the vitality of a Texas deepwater port are presented. The two major issues in the study were the financial feasibility of such a project and the role of the state of Texas in its development. A deepwater oil terminal at Freeport, Texas, would greatly influence refinery activity along the Texas Gulf Coast. An analysis of many factors indicates that predicted demands for crude oil in the Gulf Coast area would justify a 0.6 million m^3/d (3.75 million bbl/d) facility. A facility of this size would provide an average transportation cost saving of $3.78/$m^3$ ($0.60/bbl) through the use of very large crude carriers instead of smaller tankers. Over a 30-year pay-out period, given operating costs of $3.3 billion and a capital investment of $1.2 billion (1980 dollars), a projected total cost saving of $18.4 billion would be realized. The construction and operation of the offshore terminal facility are expected to bring economic benefits to the local area. The number of jobs that would be created by the offshore terminal and the related expansion of the refinery and petrochemical industry would provide increased opportunities for employment. Use of supertankers instead of conventional small tankers would reduce the number of collisions in the vicinity of ports and harbors. Depending on the average size of the operating fleet, the probability of a collision for supertankers could be one-sixth that for smaller vessels. The results of the analysis indicate that an offshore deepwater terminal on the coast of Texas is practicable.

Crude oil will continue to be the primary source of energy in this country for many years. To meet the projected demand for crude oil, a substantial amount will have to be imported in very large crude carriers (VLCCs) or "supertankers". Such large ships require ports with average depths of 30 m (100 ft) or more; no major U.S. or Gulf Coast port has the required depth.

An alternative to a deepwater port is an offshore deepwater terminal that consists of platforms with flexible pipeline connections that allow a supertanker's crude oil cargo to be pumped to onshore tank storage facilities.

Seadock, Inc., a private consortium, was created by interested parties to develop an offshore terminal off the Texas coast. The Louisiana Offshore Oil Port (LOOP), a similar consortium, is developing a deepwater port off the coast of Louisiana. In February 1978, representatives of Seadock informed the U.S. Department of Transportation (DOT) that they would not pursue any further the development of a deepwater port off the Texas coast. In March, the governor of Texas signed an executive order establishing the Texas Deepwater Port Authority and thereby authorizing the state of Texas to pursue the issue of whether or not a deepwater port for Texas is practicable.

This paper provides an assessment of conditions pertinent to the development of a Texas deepwater terminal. Critical factors are analyzed, and their effects are noted.

ASSESSMENT OF CURRENT CONDITIONS

From the many positions taken on the energy issue, one pervasive fact emerges: The United States continues its dependence on imported crude oil. The increasing development of offshore oil production, the uncertainty of the large Mexican oil reserve, the production and movement of Alaskan oil, and the development of other domestic energy sources all influence levels of imported crude oil. Collectively, these factors influence the locations and methods by which imported crude oil enters the United States.

Status of Seadock

The U.S. Deepwater Port Act of 1974 provided that Congress "authorize and regulate the location, ownership, construction, and operation of deepwater ports in waters beyond the territorial limits of the United States." In December 1975, Seadock submitted to DOT a detailed application that called for a deepwater terminal in the Gulf of Mexico 42 km (26 miles) offshore from Freeport, Texas (1). The facilities proposed included offshore platforms, single-point moorings, and a connecting pipeline to an onshore storage facility. Initial (1980) throughput capacity was projected to be 0.4 million m^3/d (2.5 million bbl/d) and planned expansion (by 1990) to be 0.67 million m^3/d (4.2 million bbl/d). Total project cost at the time of application was estimated to be $658 million for the initial phase and $208 million for the expansion. These cost projections have since escalated drastically.

Partly because of the many federal agencies that are involved in the licensing of deepwater ports, the review of the application took about a year. During that period, testimony was obtained from a variety of sources in a number of public hearings. Finally, in December 1976, the Secretary of Transportation released his decision on Seadock's application. That decision (2) included the following passage:

> For the reasons set forth in this document I have decided to issue a license to Seadock but only subject to certain conditions to preserve and enhance the environment, and to protect and promote competition. In reaching this decision, I have relied heavily—as the Act intends me to do—on the advice and recommendations of other Federal and State agencies and on the views of the public as they have been expressed through the public hearing process.

The Secretary further acknowledged that these certain conditions created special obligations with which Seadock must comply or else not accept the license and abandon the project.

By July 1977, three of the nine member companies—which represented 52 percent ownership interest in Seadock—had withdrawn. Exxon (22 percent), Gulf Oil (15 percent), and Mobil (15 percent) withdrew because of what they considered excessive government interference with the licensing process, overregulation, and the open-endedness required for the permit. The president of Seadock, Hugh L. Scott, stated that government "vendettas against the oil companies" also played a large part in the withdrawals (3). Scott offered little hope that the remaining project members (City's Service Company; Continental Pipe Line Corporation, a unit of Continental Oil Company; Phillips Investment Company, a unit of Phillips Petroleum Company; Crown-Seadock Pipe Line Corporation, a unit of Crown Central Petroleum Corporation; Dow Chemical Company; and Shell Oil Company, controlled by the Royal Dutch-Shell Group) would proceed with the project. He stated that the company did not have the financial resources to complete the project as planned and, since membership had been open for the last four years with no new participants, there was only an outside chance of survival.

The withdrawing oil companies objected to specific actions taken by the U.S. Department of Justice and the Federal Trade Commission (FTC) in the licensing. Both had identified possible antitrust violations concerning discriminatory practices in the area of nonowner use, which prompted inclusion of the following provision in the decision of the Secretary of Transportation (2): "The Secretary can compel expansion of capacity an additional 25 percent in a situation where demand is evidenced by commitments of shippers for throughput...."

In the same context, a provision was included to allow any shareholder to authorize the corporation to expand. Also included were provisions calling for Interstate Commerce Commission (ICC) regulation of not only the deepwater port rates but also the connecting pipelines from shore facility to refinery "to ensure that all shippers through the port have access to common carrier pipelines and that the policies applicable to the port are not frustrated downstream." Another provision called for the dissolution of the corporate subsidiary veil, which, in effect, would make the parent companies totally liable for damages that result from oil spills (2).

Scott has interpreted these provisions as representing the "classic case of government overregulation and regulatory duplication" as well as an attempt "to start down the road of divestiture" (3, p. 13). In a recent article by Burka (4), it is suggested that LOOP resolved the same issues whereas Seadock did not pursue a compromise. LOOP, however, is composed of different companies (Texaco, Shell Oil, Ashland Oil, Murphy Oil, and Marathon Pipeline Company), and half of its imported oil is destined for refineries in the Midwest. Burka further suggests that the "Big Three" were under no pressure to compromise since alternatives to a deepwater terminal—lightering and transshipment—provided the large oil companies with relatively equal economic advantages. In conclusion, Burka offers the prophecy that, "If Seadock survives, it will be Big Oil that saves it; if it dies, it will be Big Oil that kills it" (4).

Position of the State of Texas

When it became apparent that Seadock would not survive, a special session of the 65th Texas Legislature in July 1977 passed Senate Bill (SB) 7, "an act relating to the licensing, acquisition, construction, maintenance, operation, and financing of deepwater port facilities". The enabling legislation authorized the state to seek a federal license similar to that granted to Seadock should that consortium decide not to proceed. The general provisions of SB 7 are as follows:

1. Texas urgently needs an offshore deepwater port that is capable of accommodating supertankers for the importation of crude oil and other fluid commodities that may be carried in ships of that size.
2. It is most desirable for private enterprise to own, construct, and operate such an offshore port.
3. In the absence of any active and workable plan by private enterprise to develop a deepwater offshore port, the state of Texas should construct such a facility, which should be self-supporting and whose design, construction, and operation should be carried out by private companies under contract.
4. Protecting the environment is essential to the proper operation of such a port.
5. The credit of the state of Texas shall not be pledged to finance such a port.
6. The Texas Deepwater Port Authority should be created to implement this policy.

The recent creation of the Texas Deepwater Port Authority was tied to a decision by the governor that "no active and viable plan to develop a deepwater, offshore port by private enterprise exists in Texas" (5). A decision to establish the Texas Deepwater Port Authority was made only when Seadock officially announced a decision to reject the license.

Therefore, the main issue before the authority is to determine whether a deepwater port is workable. Several main elements are (a) the continued role of Texas and its petrochemical industry in a national energy plan, (b) the projected demand for crude oil, (c) financial implications, and (d) other pertinent issues, such as environmental quality.

OCEAN TRANSPORTATION AND MOVEMENT OF CRUDE OIL

In general, any tanker heavier than 145 455 Mg (160 000 tons) is considered a VLCC (tanker weights in this paper are given in deadweight units). The Tatillus, a 500 000-Mg (550 000-ton) tanker, represents the upper boundary of these tankers and is often referred to as an ultralarge crude carrier (ULCC). For example, a 250 000-Mg (275 000-ton) tanker is only twice as long, twice as wide, and twice as deep as a 19 091-Mg (21 000-ton) tanker, but it carries 13 times as much oil. Other benefits of VLCCs are reduced labor requirements and unit operating costs. Figure 1 (6, p. 5) shows the relative size of tankers and their drafts.

Modern techniques have resulted in lower construction and operating costs per deadweight ton for VLCCs than for smaller vessels. For example, in 1975 the cost of constructing a 22 727-Mg (25 000-ton) tanker was about \$550/Mg (\$500/ton) or \$46.25 million. On a voyage from the Middle East to Europe, the ratio in cubic meters of fuel delivered to fuel consumed for a 250 000-Mg (275 000-ton) tanker is 28:1 whereas a 45 455-Mg (50 000-ton) vessel for it is only about 13:1.

There are more than 150 deepwater loading and unloading facilities throughout the world. The United States, however, does not have a major port that is capable of receiving a fully laden VLCC and relies principally on vessels no larger than a fully loaded 45 455 Mg (50 000 tons). In effect, this limits savings in transportation because lightering or transshipment is required before the vessels enter U.S. ports.

Projected Demand for Crude Oil

Of the 2.6 million m^3/d (16.4 million bbl/d) of refinery capacity located throughout the United States, approximately 25 percent is located in the state of Texas. The development pattern of the refineries is rather dispersed since 25 of the 51 Texas refineries are confined to an 81-km (50-mile) deep coastal strip that extends from Mexico to Louisiana and the remaining 26 installations are spread over the rest of the state.

The number of refineries in a specific area, whether it be coastal or inland, is a partial consideration. The capacities of these various units describe the actual dispersion of refining in Texas (7) (1 m^3 = 6.28 bbl):

	Number of Refineries	
Capacity (million m³/d)	Inland Texas	Coastal Texas
0-7.94	21	7
8.09-15.9	4	5
16.0-23.8	0	5
24.0-31.7	0	2
31.8-39.7	0	0
39.8-47.6	0	1
47.7-55.5	0	4
55.5	0	2
Total	25	26

These data indicate that the refineries of the Texas inland district generally tend to have capacities of less than 7.94 million m^3/d (50 million bbl/d). Only 4 of the 25 refineries have capacities greater than 7.94 million m^3/d, and only one approaches 19.9 million m^3/d (100 million bbl/d). Since the inland refineries are generally smaller in capacity, most of the total capacity is found in the coastal district. Of the total state capacity of 0.67 million m^3/d (4.23 million bbl/d), only 0.089 million m^3/d (0.56 million bbl/d), or 13 percent of all Texas refining capacity, is located inland. In addition, all of the crude oil supplied to these refineries is of domestic origin; the majority is supplied by Texas sources.

In the coastal refining district, 19 of the 26 refineries have daily capacities in excess of 7.94 million m^3/d (50 million bbl/d) and 7 have capacities greater than 39.7 million m^3/d (250 million bbl/d). Refineries located inland use only domestic oil. The coastal district refineries use 60 percent domestic crude and 40 percent imported oil.

Figure 1. Relative size of tankers.

Figure 2. Current refining capacity in general marketing area of Seadock in millions of cubic meters per calendar day.

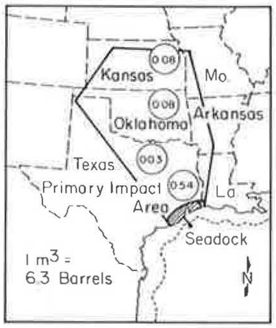
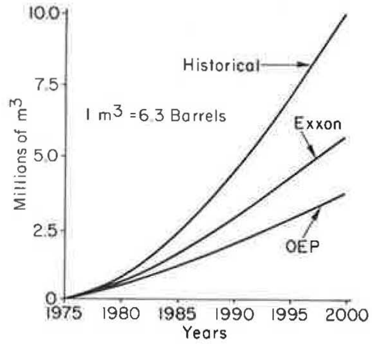


Figure 3. Predicted total cumulative importation of crude oil into Texas by scenario.



The location of the proposed deepwater terminal is in the vicinity of 86 percent of the total capacity of the coastal refineries. As Figure 2 (8, p. 6) shows, approximately 19 percent of total U.S. refining capacity is concentrated in this 242-km (150-mile) long coastal strip, known as the primary impact area.

The recently completed 77-cm (30-in) diameter Seaway pipeline, which starts at Freeport, Texas, and terminates in central Oklahoma, provides an even broader impact area. With the merger of the primary and secondary impact areas, a deepwater port in Freeport could conceivably service 26 percent of total U.S. crude oil refining capacity.

To project future refining capacity and the corresponding demand for crude oil, several existing demand forecasts were evaluated. Each forecast was attached to a possible scenario. The first forecast, referred to as the historical scenario, involves a continuance of current trends whereby demand is maintained at its current rate (9). The second involves an all-out effort to use all measures at hand to conserve energy and create as small a total demand as possible. This is called the Office of Energy Programs (OEP) scenario (9). The third demand forecast represents the most likely future and is referred to as the Exxon scenario (10).

The three scenarios are characterized by different rates of crude oil importation through the Texas coast (see Figure 3). Although over the short run (1 to 10 years) the variance between different trends is slight, over the long run (1 to 25 years) the differences between the scenarios become significant. A review of these rates verified our concern for considering more than one forecast in assessing the demand for a deepwater port.

Historical Scenario

The historical scenario involves the maintenance of current trends with no regard to conserving energy through a lessened demand. The currently available oil supply is assumed to be unconstrained for the foreseeable future. Demand is characterized by dwindling domestic production contrasted with continually rising imports of crude oil.

OEP Scenario

The OEP scenario recognizes the energy shortage and the gradual reduction of the importation of crude oil. Unlike the historical scenario, this scenario emphasizes conservation. It is assumed that demand for crude oil will increase through 1985 and then slowly decrease and that adjustments will be made to the use of alternative energy sources such as coal, solar energy, geothermal, and nuclear power. Additional savings will be obtained by using more efficient machines.

In this scenario, a low deepwater throughput capacity is estimated to be needed. An analysis of the relative demand shows that a throughput capacity of approximately 0.3 million m^3/d (2 million bbl/d) would be required through the year 2000.

Exxon Scenario

In this study, the Exxon scenario is considered the most likely. Although it follows the general pattern of the

OEP scenario, it allows for the attainment of generally higher levels of imported crude oil.

The Exxon scenario is characterized by a higher level of imports than the OEP scenario. The OEP scenario is the result of stringent conservation, whereas the price of oil and the introduction of synthetic fuels are the influencing factors in the Exxon scenario. The Exxon scenario reflects an increase in domestic production through the location of new fields which would allow more stable domestic production through the year 2000.

According to the Exxon demand forecast, a 630 000-m^3/d (4 000 000-m^3/d) capacity deepwater port would be required.

Growth of Refinery Capacity in Texas

The projection of refinery growth in the state of Texas is a function of several factors (1):

1. Declining production of U.S. crude oil,
2. The need for imported crude oil to satisfy U.S. demands,
3. The recent inability of the oil industry to build new refineries on the East Coast because of local and state opposition, and
4. The tendency for any industry to continue to locate where it is already concentrated (agglomeration).

These factors represent the most visible of the influences that affect refinery growth. Based on these four factors, the following assumptions were made with regard to the development of refineries on the Texas coast:

1. There will be growth in refinery capacity.
2. Since recent attempts of the oil industry to build new refineries on the East Coast have met with considerable state and local opposition, Gulf Coast oil could continue to be refined locally and then transported to the East Coast.
3. Since crude oil will continue to be imported, new refining capacity will be expanded in areas that are likely to receive most of the imported oil. The Gulf Coast is considered a likely area for crude oil imports and refinery expansion.

To facilitate this study it was estimated that approximately half of all new refinery construction would occur on the Gulf Coast. The percentage of all Gulf Coast refinery capacity currently located in Texas was found to be 61.2 percent. By multiplying the Gulf Coast growth factor by the Texas percentage of Gulf Coast capacity, the Texas Gulf Coast growth factor was estimated to be 30.6 percent of total U.S. growth. Therefore, of every 1 million m^3/d of refinery capacity added to the U.S. total, 306 000 m^3/d is forecast to be located on the Texas Gulf Coast.

Availability of Domestic Crude

The historical and Exxon scenarios contained forecasts of oil demand that could be satisfied from domestic production, given no new reserves. The difference between the historical and OEP scenarios enabled the development of an estimate of new domestic oil reserves to be discovered.

To determine the total Texas share of the domestic crude to be refined in Texas, an adjustment was made to the different projections. This adjustment was determined through analysis of a data base provided by the Texas Energy Advisory Council. The percentage of Texas and other domestic crude oil processed in Texas refineries amounted to 22.2 percent of the total national demand. It was assumed that Texas would maintain the same share of production of crude oil from fields already in use and that none of the new domestic oil finds would be located in or near Texas. Therefore, U.S. oil field production was multiplied by a factor of 0.222 to provide the domestic crude allotment to the Texas oil refineries.

Texas Import Capacity

The estimated Texas refinery capacity available for imported crude oil equals the state's total refinery capacity less that required for refining domestic crude. In the development stages of this analysis, this relation proved to be a problem in the balancing of domestic and imported oil supplies. It was necessary to review estimates of national demand and determine the amount of fall-off in the demand for crude oil. The amount of fall-off was proportioned to the Texas refineries that use the Texas share of total national refinery capacity.

Mexican Oil

The impact of Mexican crude oil is important and required consideration. A major impact in this study involved the assessment of the change in transportation cost as a result of the close proximity of Mexican oil sources to the Texas coast. The majority of the crude oil being imported into the Texas coastal region currently originates in fields located halfway around the world; the new Mexican fields represent a possible major source of crude oil located approximately 1600 km (1000 miles) from the Texas coast.

Shipping patterns in the world market could change and could create a market for smaller tankers because of (a) the location of the U.S. market and (b) the effect of the large continental shelf near the Yucatan peninsula on the draft of tankers that enter Mexican harbors.

Since it could take 5 to 10 years to develop the Mexican reserves, their effect on a Texas deepwater port is not considered critical. In addition, a deepwater port could still be an important facility if it diverted small tankers from the harbor channels and thereby reduced the possibility of near-shore collisions.

Impact of Alaskan Crude Oil

Another consideration involves shipping Alaskan crude oil to the West Coast of the United States and then transporting it by pipeline to Texas for refining. This could have a major impact on the amount of oil imported to the Texas coast. Two potential alternatives were considered: (a) shipping surplus crude oil to the Gulf Coast by the Panama Canal and (b) extending an existing gas pipeline between Arizona and New Mexico to Long Beach, California, and Midland, Texas, for movement of surplus crude oil to the Texas Gulf Coast refineries for processing.

Currently officials in California argue against the conversion of the existing gas pipeline to a carrier of crude oil. One argument suggests that Mexico may export natural gas to Texas and that the currently existing gas pipeline might be used to transport gas to California. In addition, California environmentalists are opposed to tankers unloading crude oil in California waters, and the use of smaller tankers for long-distance movements and the use of the Panama Canal make the first alternative undesirable.

FEASIBILITY OF STATE FINANCING

Based on an assessment of future demand for crude oil, it can be argued that the financial issues have not been addressed. To facilitate this analysis three levels of capacity were considered. The financial analysis in this paper is based on the information contained in the Seadock 1975 application for license (1).

The initial step was to update Seadock data and capital investment costs. Typical onshore construction, or approximately half of the total project investment, was projected by using an 8 percent compounded rate. The other half of the capital cost was considered offshore construction and was projected by assuming a 13 percent annual growth rate characteristic of offshore experience.

Seadock reported their projected total capital investment and operating and maintenance estimates (in 1975 dollars) over the six- to seven-year construction phase, and that was adjusted to future 1980 dollars, as given in Table 1.

One major factor that affects the profitability or even usefulness of Seadock is the difference in cost between conventional tankers and VLCCs. "World scale 100" shipping rates are used as a basis for negotiating the cost of contracts between fleet owners and shippers. VLCCs in a normal market could be expected to receive contracts at 60 percent of world-scale rates, whereas conventional 36 363- to 45 455-Mg (40 000- to 50 000-ton) tankers would pay around 125 percent of scale rates (1). This is the result of many factors, from reduced crew size to drastically reduced fuel consumption per cubic meter of oil shipped (11, 12).

For purposes of estimation, it was assumed that 70 percent of the imported crude oil would come from the Persian Gulf, 28 percent from West Africa, and 2 percent from North Africa (1). In terms of a VLCC carrying crude oil from the Persian Gulf to Houston, Texas, shipment of oil would cost approximately $\$13.64/m^3$ (\$2.17/bbl) in 1980 dollars. The cost for the same crude oil transshipped by VLCC to Freeport, Bahamas, and then shipped to Houston by conventional tankers would be $\$17.28/m^3$ (\$2.75/bbl) in 1980 dollars. The current oversupply of VLCCs makes lightering about $\$0.32/m^3$ (\$0.05/bbl) cheaper than the projected Seadock fees, which are discussed later (4).

To calculate the actual saving, several other items must be considered. The following charges were based on the original estimates in Seadock's license application and were updated to 1980 dollars. Offloading charges are computed by dividing estimated annual revenue by annual throughput level for each of three cases. The transshipment cost was estimated by Seadock at $\$1.25/m^3$ (\$0.20/bbl) and converted into 1980 dollars at $\$1.82/m^3$ (\$0.29/bbl). Likewise, the Seadock estimate of $\$0.94/m^3$ (\$0.15/bbl) for onshore private docks along the Texas Gulf Coast is increased to $\$1.39/m^3$ (\$0.22/bbl).

To compare estimated costs of a deepwater port with costs of transshipment to a refinery dock, the cost of new pipelines to connect the offshore port with users of the facility must be considered (see Table 2). In addition, consideration should be given to using underground salt domes rather than aboveground tank farms as storage reservoirs for the imported oil. The U.S. Department of Energy plans to spend \$7.6 billion to store 79.4 million m^3 (500 million bbl) of oil in salt domes in Texas and Louisiana. Of this \$7.6 billion, \$6.2 billion is for the purchase of oil and \$767 million for construction [or approximately \$7300/L (\$27 891/gal) of oil, excluding the purchase price] (13, p. 11). At this level, it can be assumed that the salt dome in Louisiana was preferred by LOOP partly because of the overall cost advantage. Environmental problems such as disposal of brine may be very difficult to resolve. Because of these risks, this analysis assumes the use of a conventional tank farm, as envisioned by Seadock.

Table 3 gives the projected transportation cost savings for a 0.6 million m^3/d (3.75 million bbl/d) facility based on the original estimates by Seadock (5). Table 4 gives a comparison of projected transportation cost savings for a facility at three levels of capacity. Each savings estimate was computed in a fashion similar to that used in Table 3. These unit savings are the basis for the following transportation cost savings (1), which are given in 1980 dollars ($1\ m^3 = 6.28$ bbl):

Total Throughput Capacity (million m^3/d)	Projected 30-Year Transportation Cost Savings (\$000s)	Average Transportation Cost Savings (\$000s)
0.397	11 821 479	394 049
0.595	18 375 858	612 528
0.83	25 894 410	863 147

The construction of the 0.6 million m^3/d facility, which has a projected 30-year transportation cost savings of \$18.4 billion at an operating cost of \$3.26 billion and capital investment of \$1.2 billion, offers apparent inducements for private investment.

Bond Financing

The financing requires the issuance of tax-exempt revenue bonds, which may be secured either by a pledge of revenues of the authority, by the revenues associated with leases or contracts, or by other revenues specified by board resolution or indenture. Alternatives are available to the Texas Deepwater Port Authority with respect to how the bonds will be secured. One method would be to attempt to issue the bonds backed solely on the projected revenues. The acceptance of such security would most likely require a higher interest rate. Alternatively, the state could seek to have the major oil company users guarantee the debt through the operating lease agreement, "take or pay" contracts, or simply an inclusion in the indenture to the effect that the oil companies guarantee the issue. This third method was recently used effectively in a tax-exempt issue of marine terminal revenue bonds by the city of Valdez, Alaska. The principal and interest payments on the bonds are payable from pipeline lease revenues and guaranteed by the Standard Oil Company and the British Petroleum Company, Ltd. The state of Texas could set up a similar arrangement for financing its deepwater terminal, offering interested parties depreciation and investment-tax-credit incentives along with the associated less expensive financing.

Data given in Table 5 are based on Seadock projected volumes, capital investment, and operating and maintenance costs adjusted for inflation to 1979 dollars (1). The figures are for a facility with a 0.6 million m^3/d (3.75 million bbl/d) capacity attained in the third year of operation. Note that projected throughput is depicted in the volume column of the tables and is a critical factor in the calculation of the tariff. The tariff figures have been calculated by dividing total yearly costs by yearly volume. No provision has been made for any additional return in these tariff figures. It is important to note that the table is intended to present relative numbers regarding the construction and operation of a deepwater terminal.

Four tariff schedule plans were generated, and their

Table 1. Capacity of Seadock terminal.

Total Throughput Capacity (million m³/d)	Total Capital Investment		Thirty-Year Average Annual Cost	
	1975 Dollars	1980 Dollars	1975 Dollars	1980 Dollars
0.397	517 010 000	856 107 000	52 881 667	77 700 000
0.595	728 310 000	1 205 995 000	74 097 337	108 873 000
0.667	812 480 000	1 345 370 000	86 904 333	127 691 000

Note: 1 m³ = 6.28 bbl.

Table 2. Estimated cost of pipeline distribution system from Seadock to refineries along Texas Gulf Coast.

Item	Diameter (cm)	Estimated Length (km)	Estimated Cost ($000s/km)	Total Cost ($000s)
Distribution				
Freeport, the Bahamas, to Houston, Baytown, Texas City, Beaumont, and Port Arthur, Texas	103-123	363	1185	164 565
Beaumont to Lake Charles, Texas, and others	62-77	129	829	41 141
Freeport, the Bahamas, to Sweeney, Texas, and others	41-51	40	474	7 347
Total				213 053
Pumping station, delivery facilities, etc.				66 120
Total				279 173

Note: 1 cm = 0.39 in; 1 km = 0.62 mile.

Table 3. Comparative shipping costs: Seadock versus transshipment for facility with capacity of 0.6 million m³/d.

Crude Oil Source	Cost Item	To Seadock, to Refineries	To Freeport, Bahamas; to Houston, Texas; to Refineries	Cost Savings for Crude Shipped Through Seadock ($/m³)	Percentage Shipped From Source[a]	Total Cost Savings ($/m³)
Persian Gulf	VLCC[b]	11.38	10.63			
	Handling charge	-	1.82			
	Transshipment[c]	-	3.33			
	Offloading	1.57	1.38			
	Pipeline transport[d]	0.57	0.13			
	Total	13.52	17.29	3.77	70	2.64
West Africa	VLCC[b]	6.29	5.35			
	Handling charge	-	1.82			
	Transshipment[c]	-	3.33			
	Offloading	1.57	1.38			
	Pipeline transport[d]	0.57	0.13			
	Total	8.43	12.01	3.59	28	1.01
North Africa	VLCC[b]	6.29	5.66			
	Handling charge	-	1.82			
	Transshipment[c]	-	3.33			
	Offloading	1.57	1.38			
	Pipeline transport[d]	0.57	0.13			
	Total	8.43	12.32	3.90	2	0.13
	Total cost savings for all crude transported through Seadock					3.78

Notes: 1 m³ = 6.28 bbl.
All dollar amounts are given in 1980 dollars.

[a] Seadock estimate.
[b] Estimated cost of transport by 227 273-Mg tankers at 60 percent of world scale 100.
[c] Estimated cost of transport by 36 360-45 450-Mg tankers at 125 percent of world scale 100.
[d] From Seadock on ship tanker to Gulf Coast refineries or from private oil dock to refineries.

Table 4. Cost savings for offshore terminal (at various facility capacities) versus transshipment.

Facility (million m³/d)	Cost Savings ($/m³)			
	From Persian Gulf	From West Africa	From North Africa	Total
0.40	0.065	0.024	0.0016	0.090
0.60	0.067	0.025	0.0032	0.095
0.67	0.073	0.027	0.0032	0.103

Notes: 1 m³ = 6.28 bbl.
All dollar amounts are given in 1980 dollars.

relative merits were compared. The four schedules were as follows:

1. Assuming uniform principal payments beginning year 1 for 20 years [average tariff = $1.27/m³ ($0.2022/bbl) over 20 years or a present worth value of 0.0899],
2. Assuming uniform principal payments beginning year 3 for 17 years [average tariff = $1.31/m³ ($0.2072/bbl) over 20 years or a present worth value of 0.0884],
3. Assuming tariff held constant after first three years [average tariff = $1.36/m³ ($0.2154/bbl) over 20 years or present worth value of 0.0868], and
4. Assuming constant tariff for years 1 to 10 and 11 to 20 [average tariff = $1.35/m³ ($0.2151/bbl) or a present worth value of 0.0867].

Figure 4 shows the comparison of resultant tariff schedules.

Plan 1 showed a tariff that would result if debt principal payments were begun immediately on operation, whereas plan 2 delayed the initial principal payment for three years. Plan 3 delayed any principal payment for four years and made the tariff approximately constant after the third year of operation. Plan 4 held one constant tariff through the 10th year and another constant tariff from the 10th to the 20th year (Table 5).

In each of the first three plans, the low volumes associated with startup produced relatively high tariffs

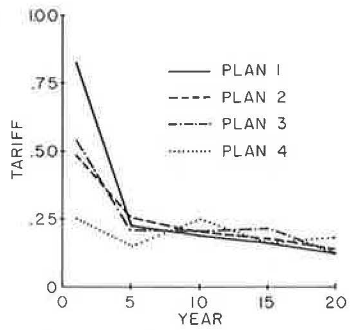
Table 5. Constant tariffs for years 1 to 10 and 11 to 20 of operation of deepwater terminal.

Calendar Year	Year of Opera-tion	Volume (000s m^3/d)	Total Capital Investment ($000s)		Annual Operating and Maintenance Costs ($000s)	Principal ($000s)	Long-Term Debt (Short-Term Debt) Interest[b]	Total Cost ($000s)		Tariff[c] ($/$m^3$)	Present Value[a] ($/$m^3$)	Cumulative Short-Term Debt[d] ($000s)
			Annual	Present Value[a]				Annual	Present Value[a]			
1979	-2		44 864	49 350								
1980	-1		438 924	438 924								
1981	1	79.4	345 741	314 310	68 310	-	30 237	98 457	89 506	1.58	1.43	52 832
1982	2	159	238 873	197 415	101 016	-	51 645 + (4 227)	157 088	129 825	1.58	1.30	118 670
1983	3	317.5			131 586	-	66 775 + (9 494)	207 855	156 165	1.58	1.18	144 025
1984	4	429			135 831	-	66 775 + (11 522)	214 128	146 252	1.58	1.07	111 778
1985	5	444			133 994	-	66 775 + (8 942)	209 711	130 214	1.58	0.98	65 989
1986	6	460			132 158	-	66 775 + (5 279)	204 212	115 272	1.58	0.89	5 576
1987	7	476			130 294	76 235	66 775 + (446)	273 750	140 477	1.58	0.81	-
1988	8	476			127 369	84 371	62 010	273 520	127 706	1.58	0.73	-
1989	9	476			124 444	92 569	56 737	273 750	116 097	1.58	0.67	-
1990	10	476			121 519	101 279	50 952	273 750	105 542	1.58	0.61	-
1991	11	476			181 580	41 563	44 622	204 765	71 768	1.18	0.41	-
1992	12	476			115 655	47 086	42 024	204 765	65 244	1.18	0.37	-
1993	13	476			112 730	52 954	39 081	204 765	59 313	1.18	0.34	-
1994	14	476			109 791	59 202	35 772	204 765	53 921	1.18	0.31	-
1995	15	476			106 866	65 828	32 071	204 765	49 019	1.18	0.28	-
1996	16	476			103 941	72 867	27 957	204 765	44 563	1.18	0.26	-
1997	17	476			101 016	80 346	23 403	204 765	40 512	1.18	0.23	-
1998	18	476			98 077	88 307	18 381	204 765	36 829	1.18	0.21	-
1999	19	476			95 152	96 751	12 862	204 765	33 481	1.18	0.19	-
2000	20	476			92 227	109 044	6 815	208 086	30 931	1.2	0.18	-
Total		8552.9	1 068 402	1 000 000	2 260 556			4 030 287	1 742 637	1.36	0.55	

Notes: 1 m^3 = 6.28 bbl.
All dollar amounts are given in 1979 dollars.

[a] Ten percent end-of-year discounting. [b] Interest rate of 6.25 percent. [c] Total cost ÷ volume for year. [d] Short-term interest rate of 8 percent.

Figure 4. Tariff schedule plans.



for the first three years of operations in comparison with later years. Plan 1 resulted in the lowest average tariff over the 20-year life of the facility; however, when the present values of total annual costs and tariffs were compared, plan 3 showed the lowest average tariff. Plan 3 also offered the advantage of a tariff that was constant except in the first three years.

Constant tariffs throughout the life of the facility would offer advantages, and plan 4 was formulated to attempt to provide such. To meet fixed expenses with the first year's low throughput volumes, without charging a high tariff, additional capital must be employed. The additional funds could be obtained as part of the original long-term debt, or they could be obtained on a short-term basis. Plan 4 assumes the short-term funds requirement is satisfied by short-term debt financing. No principal payments are made until the seventh year, and the short-term debt accumulated in the first three years is paid off in the fourth through the seventh year. This financing alternative produces tariffs that closely approximate the average tariff figures in plan 3, and the constant tariffs provide obvious planning advantages to the customers of the terminal. The constant tariff would also prevent companies from delaying participation until after the first years of higher tariffs.

Each of the plans shows average tariffs that indicate potential savings in shipping costs utilizing a deepwater terminal. Since these tariffs are based on a break-even operation, it may be argued that the oil companies would receive no return for the risk they would incur by guaranteeing the required debt financing. The Texas Offshore Terminal Commission answered this argument in the following way (14, p. 2):

> It is still to the primary interest of the oil companies that the product of their industry be marketable at the lowest cost at the retail level. There would be no profit or loss to the oil companies in this segment of the production chain if (the terminal were) publicly financed. Thus, this segment should be of no consequence to the companies so long as they can still sell and make a profit at retail. Public financing will aid in providing the lowest cost at the final destination of the product.

Oil companies may feel, however, that the demand for their product is sufficiently inelastic to discount such a rebuttal. It should also be noted that different crude oil customers incur different transportation costs and that any comparison is necessarily made on an average at best. This preliminary analysis, however, does show that it may be in the best interest of consumers to construct the deepwater terminal, and a more detailed financial analysis is justifiable.

CONCLUSIONS AND RECOMMENDATIONS

Based on the information currently available, the projections and analysis performed in this study indicate that there is justification for a Texas deepwater port. The projected demand for crude oil and the financial feasibility of a deepwater terminal as well as the associated favorable economic and environmental impacts indicate the desirability of the facility.

As the only high-volume supplier of crude oil in the area, a deepwater port off Freeport, Texas, will greatly influence refinery activity along the Texas Gulf Coast. The predicted demands for crude oil in this area indicate that a facility with a capacity of 0.6 million m^3/d (3.75 million bbl/d) could be justified.

The financial analysis indicates that the transportation cost savings are attractive. A 0.6 million m^3/d facility could provide a transportation cost savings of \$3.78/m^3 (\$0.60/bbl). Over a 30-year payout period, it was projected that a total cost savings (in 1980 dollars) of $18.4 billion, operating costs of $3.3 billion, and a $1.2 billion capital investment could be realized.

Bond financing alternatives were explored with an investigation of tariffs required to offset the port costs. Table 5 establishes constant tariffs for the first and second decades of the terminal's operations. Tariffs of $0.2500 and $0.1870, respectively, are assessed. Investigations showed average tariffs of $1.26-$1.39/m^3 ($0.20-$0.22/bbl).

The impact on the Texas Gulf Coast if a deepwater terminal is not built is difficult to evaluate. Among a number of considerations are the following:

1. The projected demand for crude oil could be satisfied by transshipment or lightering. The projected Seadock cost savings associated with a deepwater port would become an added economic burden on the petrochemical industry that would undoubtedly be passed on to the consumer.
2. LOOP might be drastically expanded and tied into the projected Seadock area by new pipelines, which would create a shift in economic activities in the Gulf Coast region.
3. Crude oil demand in the Seadock import area might not be met, and this would adversely affect one-third to half of the petrochemical plants in the United States.

In view of the findings provided in this assessment, it is recommended that the Texas Deepwater Port Authority expedite the establishment of the offshore port. The initial study should be a detailed financial and operational analysis. The net benefit of the port would be nationwide and should promote a return to marine transportation for the United States.

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An investigation of this nature obviously requires timely and accurate information as well as access to data and pertinent reports. I wish to express my appreciation to Joe Moseley, formerly with the Texas Coastal and Marine Council and now with the Texas Deepwater Port Authority, for his participation in this study. A very special thanks is extended to Danny Burger of the Municipal Advisory Council of Texas for his review of the bond financing schemes.

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Time-Based Multicriteria Evaluation Model of User Charges

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The results of a study conducted to develop a model of waterway user charge impacts and test the model on a case study region are summarized. The model developed is a Markov decision theory model with an implied transition period of five years. The transition probabilities were estimated subjectively based on a state space defined by change in freight traffic movement. Reward estimates were based on multiple criteria such as change in shipping costs and change in equity. The rewards were developed from a variation on the rank-based expected-value method of

evaluation. These were also produced subjectively based on the results of previous studies. The input on the upper Mississippi River case study site was processed by a Markov decision theory computer program. Considerable sensitivity analysis on rewards and transition probabilities was done. In the majority of cases, the alternative of no user charge was favored. In certain periods of high growth in freight traffic, a low-level fuel tax was favored. The case study results themselves are not as significant as the problem structuring that was accomplished and the introduction of time and nonmonetary criteria into the evaluation process.

A review of the history of transportation in the United States reveals that one of the distinguishing features crossing nearly all modes has been the need for government assistance in establishing and maintaining the transportation network. There has not been sufficient incentive in the private sector to build and maintain transportation facilities on a national scale. Reasons for this include the economies of scale necessary to make transportation facilities attractive to the private firm, the jointly reinforcing nature of the provision of transportation facilities and economic growth, and the usual lag between investment and profitability. These factors have joined to make transportation systems investments undesirable to the private firm, at least in the infancy of a mode.

A controversy that has existed in the freight transportation area for nearly 40 years is that of user charges for users of the inland waterway system. The controversy has been particularly strong in the past five years; legislation has been introduced in Congress to enable the recovery, by various means, of the federal investment in facilities as well as federal expenditures on operations and maintenance. Many studies have been done by various agencies and organizations on different aspects of user charges. This paper addresses the need for evaluation of longer-term and noneconomic impacts of inland waterway user charges. It focuses primarily on the development of a planning model that can be used to investigate various forms of user charges as they affect a transportation system and a national economy that demonstrate considerable uncertainty.

PROBLEM PARAMETERS

The development of a model of the effects on freight transportation caused by the imposition of various forms of waterway user charges requires model parameters that are broader than the inland waterway system itself. To model the public perspective adequately, the model must include the effects of policies on water, rail, truck, and pipeline transport. The geographic range of the model could be either the entire country or a major river basin. For planning purposes, the time horizon should be 10 or 20 years.

MARKOV DECISION THEORY

The case study model is the Markov decision theory model. It is similar in some respects to the dynamic programming model. The states are parametric descriptions of the system under study. There also exists the concept of a transition. The probability of going from state i to state j in one stage is called a transition probability. A matrix of transition probabilities exists for each alternative solution for the system proposed by the analyst. The transition period may be 1 s or 10 years, depending on the system being modeled.

In a similar way, the reward to the decision maker for each possible transition is described in a matrix. For each alternative there exists a reward matrix. The Markov model solution is known as a policy vector. It arrays the optimal alternative to pursue contingent on the present state of the system. There are several excellent sources on Markov decision theory and its applications (1-4).

CASE STUDY ANALYSIS

Study Area

The area selected for case study analysis is the upper Mississippi River, which runs for 1375 km (852 miles) from Minneapolis to Cairo, Illinois (at the mouth of the Ohio River). Most of the 26 locks and dams on the reach between Minneapolis and St. Louis (see Figure 1) have a single lock chamber. Minimum channel depth is 2.7 m (9 ft), and channel width is 91-106 m (300-350 ft).

The following data on freight transport on the upper Mississippi are taken from statistics of the American Waterways Operators, Inc. (5). The section of the upper Mississippi between Minneapolis and St. Louis carried more than 57 million t (63 million tons) of cargo in 1975. Net tonnage on that same section of the upper Mississippi grew from nearly 23.6 million t (26 million tons) in 1968 to more than 57 million t in 1975. The principal commodities carried in 1975 were grains and petroleum products, which constituted almost 62 percent of the tonnage. Towing industry costs on the upper Mississippi are estimated to be 1.85 mills/t•km (2.7 mills/ton-mile). This is 0.3 mills more than costs on the lower Mississippi, principally because of delays caused by locking and the need to limit tows to 10 to 12 barges.

The upper Mississippi represents one link in the 40 300-km (25 000-mile) inland waterway system in the United States. It was selected as a basis for case study analysis of user charge policies for several reasons:

1. It has two major sections that have characteristics similar to those of most other inland waterways. The section above St. Louis has many locks and suffers from capacity problems at Locks and Dam 26. The section below St. Louis is free flowing and operates at relatively low cost.
2. The upper Mississippi handles a spectrum of commodities. The grain and petroleum commodities that are important on the upper Mississippi form a large percentage of all traffic on the inland waterways.
3. In terms of modal competition, there exists considerable parallel rail trackage with excess capacity (6).
4. Preliminary impact data for various user charge schemes were available from the U.S. Department of Transportation (DOT) (7-9) and others (10, 11).

Alternatives for Case Study

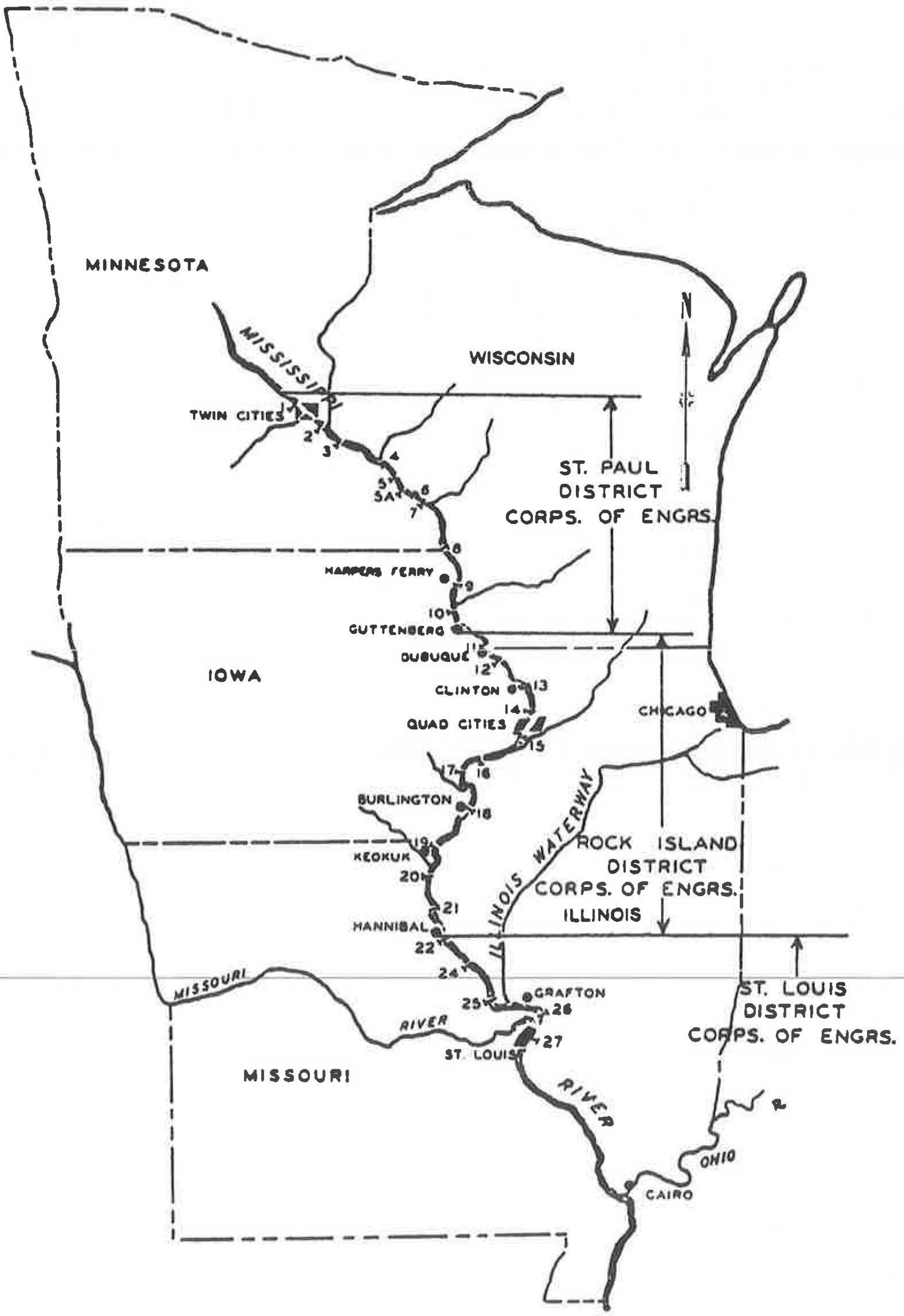
This section presents the alternatives that were selected for analysis by the case study model. The two most commonly mentioned and studied forms of waterway user charges are the fuel tax and the segment toll. The lockage fee is commonly considered in conjunction with either of these. Studies by both DOT and CACI, Inc. (7, 12), consider systemwide fuel taxes and segment-specific ton-kilometer tolls in their analyses. The study by the Iowa DOT (10) deals with a combination fuel tax and lockage fee. The Tennessee study (11) considers a full range of lockage fees with and without congestion tolls, license fees, segment tolls, and fuel taxes.

Since the studies by the U.S. DOT and CACI develop preliminary levels of some impacts on the upper Mississippi case study area, it was decided to use both fuel taxes and segment tolls as alternatives. Further, to provide a range for each type of alternative, recovery levels of 50 and 100 percent of waterway operation, maintenance, and rehabilitation costs were chosen. To provide a baseline of comparison, the alternative of no user charges is also included. These alternatives are given below:

Alternative	Type	Recovery Level (%)
1	Segment toll	100
2	Segment toll	50
3	Fuel tax	100
4	Fuel tax	50
5	None	0

For the upper Mississippi, the 50 and 100 percent recovery levels by segment toll result in fees of 0.000 66 and 0.000 33 cents/t·km (0.000 964 and 0.000 484 cents/ton-mile), respectively (7). Fuel taxes at 50 and 100 percent recovery levels would result in fuel taxes of approximately 3.3 and 6.7 cents/L (12.5 and 25.5 cents/gal), respectively (12). The next section develops the state space and state transition probabilities for the case study area.

Figure 1. Upper Mississippi River case study area.



State-Space Formulation

As discussed earlier, one of the central concepts of the Markov model is that of the states of the system. For the purposes of this case study, the states need to be able to reflect the behavior of the freight transportation system in response to various alternative user charge policies. The states should also portray realistic levels of change in the system over the transition period chosen. On this basis, the transition period was set at five years, and a single state parameter of change in freight traffic tonnage carried was chosen. This parameter is a good measure of the health of the freight system and the economic health of the nation as a whole. Freight traffic moves in response to manufacturing activity. Currently about half of the nation's gross national product (GNP) consists of goods (as opposed to services). GNP itself is perhaps the best known measure of national economic health. In this context, freight traffic is an excellent state parameter.

The definition of freight traffic is restricted here to rail and water. The various growth and decline rates were chosen to be reasonable for a five-year period. Between 1968 and 1973, waterway tonnage grew by roughly 5 percent (5). The five-year transition period represents a reasonable period for the perturbations caused by policy changes to settle out of the system. The states are given below:

State	Change in Freight Tonnage (%)
1	0
2	+5
3	+10
4	-5
5	-10

The 5 and 10 percent rates of growth and decline provide a reasonable balance of possible freight system activity over a five-year period.

Estimation of Transition Probability

Given the system states defined above, the next task was to develop a logical and consistent process whereby the state transition probabilities p_{ij} could be estimated for each alternative. To provide some sensitivity analysis, two sets of transition probabilities were estimated for each alternative. The first set reflects general low economic growth for both the nation and the study area, and the second set assumes relatively high economic growth conditions. If they were related to the GNP, these statements would represent a 5 percent decline in real GNP for the low economic growth set and a 5 percent rise in real GNP for the second set of transition probabilities. The actual process of estimating the transition probabilities was subjective; quantitative and qualitative guidelines were applied that were consistent with underlying economic assumptions.

Transition Probabilities for Low Economic Growth

The basic assumption that underlay the estimation of the transition probabilities for conditions of low economic growth was that the system would tend to move toward a decline in freight traffic carried and that probabilities of moving toward an increase in freight traffic would be low. Another assumption relevant to the system is that the system tends to have an "inertia" that results in smaller probabilities for transitions that imply large changes in traffic carried. A practical rule of implementation was that the combined probabilities of ending up in a state of no growth, low growth, or high growth (state 1, 2, or 3) did not exceed 0.45. The table below gives an example of this for low economic growth transition probabilities for alternative 1:

	State				
State	1	2	3	4	5
1	0.20	0.10	0.05	0.4	0.25
2	0.5	0.10	0.10	0.15	0.15
3	0.5	0.10	0.10	0.15	0.15
4	0.2	0.05	0.05	0.45	0.25
5	0.1	0.05	0.05	0.35	0.45

By summing the first three elements in each row, we obtain the probability of going to a period of equilibrium, low growth, or high growth. These sums range from 0.2 for starting in state 5 to 0.35 for starting in state 1. In moving from one alternative to the next, the assumption was that, the higher the effective user charge was, the higher shipping costs would become. Based on this, higher recovery rates resulted in less freight traffic and probabilities that increasingly leaned toward low decline and high decline (states 4 and 5) in cargo carried.

Transition Probabilities for High Economic Growth

Transition probabilities for high economic growth were estimated by using assumptions similar in concept but opposite in effect to those for the low economic growth transition probabilities. The combined probabilities of ending a transition in a state of no growth, low decline, or high decline (state 3, 4, or 5) were limited to 0.45. This works in a fashion similar to that of the example given earlier for transition probabilities of low growth. Again, since alternatives implied higher shipping costs, the probabilities of ending in a state of no growth, low decline, or high decline increased. The system inertia previously discussed was also assumed. These transition probabilities and the system rewards for the alternatives (developed below) are used to develop the case study results.

REWARD ESTIMATION

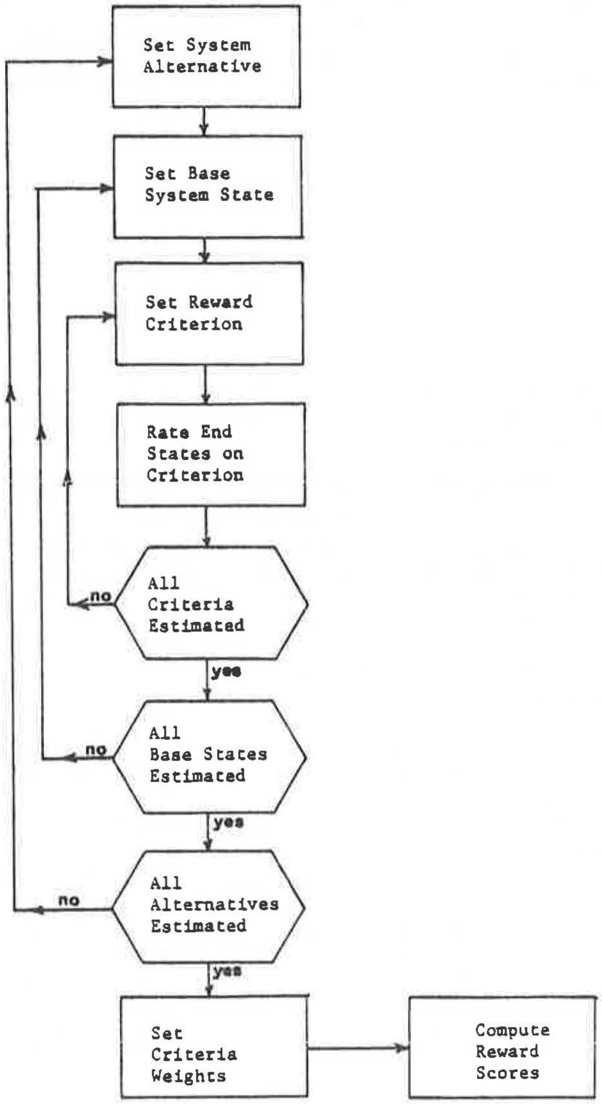
Overview

The general method of reward estimation is the technique of the rank-based expected value. It is particularly useful in evaluation situations in which multiple criteria are appropriate. It provides a way to combine criteria for different types, units, and levels of precision and thus produce relative scores for the alternatives evaluated. The application used here uses as alternatives the possible ending states given a particular starting state. These alternative ending states are rated on a fixed scale with regard to the specific criteria being considered. The relation to the other user charge alternatives is also considered.

Criteria

The criteria selected for the estimation of system rewards represent a broad range of national policy issues and attempt to capture the major potential impacts of alternative user charge policies. They have all been identified in other reports on user charges.

Figure 2. Reward estimation process.



Change in Freight Shipping Costs

Change in freight shipping costs attempts to capture the change that results from different user charge policies. Based on impact estimates for the upper Mississippi study area in the DOT study (9), segment tolls raise shipping costs more than fuel taxes at the same recovery level. Obviously, higher recovery levels would cause sharper increases than lower recovery levels. In addition, declining freight traffic, seen through state transition, results in higher shipping costs because of the high fixed investment characteristic of both waterway and rail.

Change in Energy Use

The key factor in energy use is the energy efficiency advantage of waterways over rail (10, 13). In using this concept, those alternatives and state pairs that imply more traffic being carried receive relatively lower ratings. These results are supported in the CACI study (12).

Change in Cargo Carriage Safety

Safety in the transportation of hazardous commodities relates to the amount of such types of cargo carried and the safety characteristics of the mode by which they are carried. In general, accident studies and reports (14, 15) find that ratings for safety decline with increasing traffic and with diversion of traffic to rail, which historically has higher accident rates and rates of population exposure (14).

Jobs

One possible impact of various user charge policies is the impact on jobs in industries whose cost structures are changed by higher shipping costs. The Tennessee study (11) estimated job losses attributable to various recovery levels and methods. In general, higher recovery levels and segment tolls receive lower ratings with respect to jobs. In the context of state change, lower freight traffic levels also imply fewer jobs in manufacturing and distribution.

Equity

Some of the key rationales that support the imposition of user charges are based on economic principles. Foremost among those highlighted by Johnson and Berger (16) is equity. The equity argument is that any cost recovery treats waterway users on a more equitable basis with the railroads, which provide their own rights-of-way.

Environmental Factors

Several types of environmental factors may be considered. Problems with dredge spoils are somewhat independent of the user charge policy (10). Production of air pollutants and noise in urban areas are somewhat sensitive to water-rail modal split.(17). Damage to wildlife habitats can be caused by disposal of dredge spoils, and herbicides used on rail rights-of-way may do damage (17). The ratings on the environmental factor decline with situations that imply increasing freight traffic. Since waterways have a slight advantage in environmental effects, situations that dictate increasing rail modal shares receive lower ratings. The ratings could be set by using these two rules.

Technique

The process of estimating rewards is shown in flow-chart form in Figure 2. When the general specifications given in the previous section were used, the ending states were relative to the beginning state, the other possible ending states, and themselves under different alternatives. The ratings were made on a scale of 10 to allow more precise ordering of the relative values than a simple ranking would allow. In the case in which one alternative was twice as desirable as the next best alternative, its rating could be twice the rating of the next best alternative. This allows more use of the analyst's knowledge of the systems involved. Simple ranking would mask these differentiations. The criteria weights reflect the relative importance of the criteria from various perspectives. The score for each ending state is computed as follows:

$$\text{Score } ijk = \sum_{m=1}^{6} r_{jmik} W_m \qquad (1)$$

where

score ijk = reward for alternative k of going from state i to state j,
r_{jmik} = rating of the j th ending state for the m

criterion beginning in state i for alternative k, and

W_m = criterion weight for the m th criterion.

The weight is multiplied by the rating for each ending state and for each criterion. The scores are summed for each ending state. The score for ending state j associated with base state i and alternative k can be seen to be the r_{ij} element of the reward matrix for the k th alternative.

Results

The reward-estimation process described above was used to produce four sets of reward estimates. The difference was in the criteria weights used. In the first set of rewards, all criteria received equal weights. This functions as a baseline. The weights for alternative 1 are given in the table below:

	State				
State	1	2	3	4	5
1	4.17	3.83	3.83	4.0	4.0
2	3.83	3.83	3.67	3.33	3.67
3	4.0	3.5	3.5	2.83	3.17
4	4.67	3.5	3.17	3.5	3.5
5	4.83	3.17	3.0	4.0	2.83

The second set of reward estimates assumes a hierarchy of criteria weights. At the top, energy and safety each receive a weight of 0.25, which reflects their prominance as national issues. At the next tier, shipping costs, jobs, and environmental criteria receive weights of 0.15. Finally, equity receives a weight of 0.05.

The third set of reward estimates stresses a national economic policy emphasis on reducing inflationary pressures and unemployment. Shipping cost and jobs criteria receive weights of 0.25, equity receives a weight of 0.05, and all other criteria receive weights of 0.15.

The final set of reward estimates reflects a policy emphasis on equity and environmental concerns which get weights of 0.25 each. These have at times been dominant national policies. Shipping cost receives a weight of 0.05. All other criteria receive weights of 0.15.

Results of Application of Markov Model

The alternatives, transition probabilities, and rewards are now brought together in the Markov model analysis of user charge policies for the upper Mississippi case study area. The various analysis runs, their results, and the significance of the results are discussed.

Analysis of Problem Combinations

Earlier, two sets of transition probabilities were developed to represent scenarios for low and high economic growth for the study area. In addition, four sets of rewards were estimated under different weighting schemes for the reward criteria. Bringing these together results in eight possible combinations of transition probabilities and reward estimates. A summary of these combinations is given below:

Transition Probability	Reward Estimate
Low economic growth	Uniform criteria weights
Low economic growth	Emphasis on energy and safety
High economic growth	Uniform criteria weights
High economic growth	Emphasis on energy and safety
Low economic growth	Emphasis on equity and environment
Low economic growth	Emphasis on shipping cost and jobs
High economic growth	Emphasis on equity and environment
High economic growth	Emphasis on shipping cost and jobs

Computational Results

The Markov solution maximizes the test quantity $q_i^k + \Sigma p_{ij}^k v_j^k$ for each state of the system over all alternatives. In all eight of the cases cited in the table above, the process closed on three or fewer iterations. The result of each iteration is a policy improvement summary in which, for each state, the maximized test quantity and the associated optimal alternative are shown. The resuts tell the analyst, in effect, if the system is in state 1, implement alternative K_1; if the system is in state 2, implement alternative K_2; and so on for all states.

The iteration summaries and results for the first scenario—low economic growth transition probabilities and uniformly weighted rewards—are given below:

Iteration	State	Best Alternative	Test Quantity
1	1	5	6.067
	2	5	5.999
	3	5	6.103
	4	5	6.484
	5	5	6.109
2	1	5	6.169
	2	5	6.080
	3	5	6.137
	4	5	6.567
	5	5	6.171

Clearly, alternative 5—the no user charge policy—dominates throughout. The policy vector solution values show the relative value of starting in various states. These values, which are given below, relate to the original rating scale of 10 used for the reward process:

State	Optimal Alternative	Value
1	5	6.169
2	5	6.080
3	5	6.137
4	5	6.567
5	5	6.177

The second scenario analyzed included low economic growth transition probabilities, but the rewards emphasized safety and energy use. Again, alternative 5 was selected as the optimal alternative for each of the five states. Results indicate that the associated value in the policy vector solution is highest for states 4 and 5, the states of 5 and 10 percent decline in tonnage. This is reasonable since alternative 5 is the only one that does not increase the costs of freight haulage. The value of not imposing the user charge would logically seem to be higher in a period of decline than in a growth period. Since waterway transportation generally performs better than rail in the cargo safety and energy efficiency areas and since these criteria are emphasized, the choice of a no user charge alternative is reasonable.

The third scenario included the high economic growth transition probabilities and uniform criteria weights for rewards. Alternative 5, the no user charge policy, was chosen across all five possible starting states. Results show that the state values are lower than those for scenario 1 except for states 4 and 5. This indicates that, when there have been previous period declines in freight traffic, it is more important not to have user charges under conditions of high economic growth than under conditions of low economic growth.

The fourth case study analyzed was that of high economic growth transition probabilities with an emphasis on energy and safety reward criteria. The results follow the others in that alternative 5 is unanimously chosen. The state values are higher than they are for scenario 3 partly because of the tendency toward higher growth in the transition probabilities and because of the criteria emphasized.

The fifth scenario analyzed used low economic growth transition probabilities and emphasized equity and environmental criteria. Results indicate that the no user charge alternative (alternative 5) dominates except when the system is in state 3—high growth in freight traffic. In this circumstance, the moderate recovery level fuel tax is indicated. This can be interpreted to mean that the harmful effects of a fuel tax will be relatively insignificant in a period of high freight traffic growth.

The sixth scenario again used low economic growth transition probabilities but emphasized considerations of shipping cost and jobs. As might be expected from the discussions of reward estimation, the no user charge alternative was selected for each state of the system.

The seventh scenario analyzed used high economic growth transition probabilities and emphasized concerns of equity and the environment. As in scenario 6, when equity and environmental factors are emphasized, user charge alternatives are more likely to be favored. As is seen in the table above, the moderate recovery level fuel tax (alternative 4) is chosen when the system is in state 1, a no-growth condition. An interpretation of this is that, since freight traffic levels typically rise with high economic growth transition probabilities, the moderate fuel tax would not be a great burden to that growth.

The last scenario examined used high economic growth transition probabilities and emphasized shipping costs and jobs. The no user charge alternative dominated here as it did in scenario 6. The results seem to be insensitive to the type of transition probabilities used.

Summary of Computational Results

The computational results above clearly show the dominance of the no user charge alternative under the prescribed conditions and assumptions. However, alternative 4, the fuel tax at a 50 percent recovery level, came reasonably close to being chosen throughout the analysis. When equity and environmental factors were emphasized, alternative 4 was chosen but usually under conditions that favored growth in freight traffic. These conditions would also tend to ameliorate some of the detrimental job-related consequences of a tax scheme. Even when not optimal, alternative 4 was close enough that it could have been chosen over the no user charge alternative for reasons external to the analysis. The other alternatives were much less desirable under all conditions.

To some extent, the results achieved are determined by the definition of states, reward criteria, transition probability assumptions, and criteria weights. The object here is to demonstrate the utility of using this structured approach to evaluating user charge policies that account for monetary and nonmonetary criteria, a reasonable time frame, and uncertainty. The application to the upper Mississippi data demonstrates that this type of analysis can be used for a particular river segment. In addition, it can be expanded to examine policy options at the national level.

CONCLUSIONS

The principal objective of this work was to analyze a current and somewhat controversial issue in transportation policy by developing a pragmatic and sound modeling format and applying this modeling format to a case study area. At the outset, this model was designed to respond to the need for a planning model that encompassed an adequate time frame, was capable of handling various types of decision criteria, and was able to deal adequately with uncertainty. The model developed here accomplishes these three results. In addition, it synthesizes the variety of impacts of potential user charge mechanisms and other related issues in a logical and structured manner. In this sense, it allows the decision maker more power in reducing the weight of rhetoric and increasing the weight of objectivity.

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Inland Navigation Simulation Model: Verification and Evaluation

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The inland navigation simulation model is part of the methods and models developed by the Office of the Chief of Engineers to assist the U.S. Army Corps of Engineers in efficiently and effectively managing the inland waterway system. The model is used to evaluate system performance under current or proposed conditions. Verification and evaluation were critical tasks in establishing a basis for confidence in the model results. The testing effort focused on four areas: (a) determination of steady-state conditions, (b) minimization of the effects of randomness, (c) sensitivity analysis of key input parameters, and (d) historical comparison. Three versions of the model were tested. Each subsequent version incorporated more explicit representation of various navigation lockage activities and corrected deficiencies found in earlier versions. The preliminary findings of the Corps of Engineers evaluation study indicate that the model performs satisfactorily. However, the degree of accuracy in applying the model to specific navigation studies will depend heavily on the quality of data, the input specifications, and the computer and human resources assigned to the task.

The inland navigation simulation model is part of the methods and models developed by the Task Group for Inland Waterways Systems Analysis of the Office of the Chief of Engineers, U.S. Army Corps of Engineers. These tools assist the Corps of Engineers to achieve their goals in the area of navigation, which are (a) to operate the current inland waterway system as efficiently as possible and (b) to select the best size, location, and timing of inland waterway improvements.

The inland navigation simulation model fits within the waterway network analysis phase of the comprehensive methodology of waterway systems analysis. As part of the interrelated activities of demand and modal-split analysis, it quantitatively assists in the evaluation of system performance for planning, project studies, and operations analysis.

Although simulation techniques for the analysis of navigation facilities have been developing over the past 15 years, most of the earlier models were developed for special studies. The inland navigation simulation model was developed to handle analysis of a large-scale navigation network, including the entire inland waterway system of the United States.

Incorporating the necessary flexibility in the model was a complex task. The verification and evaluation efforts, which have involved extensive data collection and the development of support programs to organize input and analyze output, have also been formidable. Verification established a basis for confidence in the results that the model will generate under future conditions. Evaluation determined the situations to which the model can best be applied and also revealed its limitations. This paper deals primarily with the verification and evaluation efforts of the Navigation Studies Staff of the Pittsburgh District, U.S. Army Corps of Engineers, for the Office of the Chief of Engineers.

DESCRIPTION OF THE MODEL

The inland navigation simulation model is a generalized model that provides explicit representations of individual waterway facilities, cargo consignments, and vessels. Figure 1 shows the major elements of model input and output. The size of problem that the model can handle is limited only by the computer resources available. There are no inherent restrictions on the number of ports, locks, river segments and tributaries, towboats, barges, types of towboats and barges, or commodities. The model was specifically designed to accommodate systems at least as large as the entire Mississippi River-Gulf Coast waterway system.

Inland waterways are represented in the model as a network of interconnected links and nodes. Contiguous link-node groups are organized into sectors. Nodes represent the locations of ports, locks, junction points, and sector boundaries, and links represent river segments between nodes. Figures 2 and 3 show the general network and sector components. The effects of specific channel conditions, such as bends or shoals, are normally represented implicitly by their constraining effects on navigation. Special channel conditions can, however, be explicitly represented. Each lock facility is explicitly represented in the form of tow-processing time distributions for each chamber. Processing time is broken down into approach, entry, chambering, and exit times in a manner compatible with historical data. Single, setover, multiple-cut, multiple-vessel, and open-pass lockages are all accommodated. Other waterway facilities such as bridges, piers, and navigation aids are represented implicitly through their effects on tow size and speed. Linear stretches of docks are combined and abstracted as a single point at which cargo originates and terminates. Port processing is represented by loading and unloading times and by pickup and drop-off times.

Commodity movements enter the model in the form of a list of individual shipments characterized by commodity type, origin port, destination port, tonnage, and earliest possible departure time. This list is created either by a separate interface program that operates on a port-to-port, origin-destination tonnage matrix or through specific waterway demand analysis studies.

Individual towboats are explicitly represented and described by identification number, power, size, maximum permissible flotilla size, and sectors where they may operate. Barges in tow are represented as barge groups that consist of one or more barges with common characteristics. All types of towboats and barges are permitted, including dedicated equipment. Origin-destination movements through the waterway network are explicitly represented. Tow makeup (allocation of shipments to barges and barge groups to towboats) is internal to the model. En route drop-off and pickup of barges are permitted, and fleeting operations are represented. Empty-barge movements needed to accommodate trade imbalances are scheduled internally by means of decision rules built into the program. Recreation vessels are individually represented in terms of arrival at a lock for lock processing, but trip connectivity is not represented. Weekend and weekday arrival rates are specified by the user.

MODEL VERIFICATION

Data collection and model testing, modification, and evaluation were all required to determine the validity of the model. Various existing data sources were used, including (a) physical characteristics of inland waterways, navigation charts, and performance monitoring system (PSM) data of the Corps of Engineers; (b) historical commodity flow data of the Waterborne Commerce Statistics Center (WCSC); and (c) vessel data and regulations of the U.S. Coast Guard. These sources provided sufficient information for model testing; however, in application of the model, field studies were recommended for the forecasting of future demand, fleet composition, and port operations.

Four series of tests were performed to evaluate the capability and accuracy of the model. The purpose of the first test was to determine the amount of simulation time required to reach stable, or steady-state, conditions. The simulation model randomly allocates towboat and barge equipment to ports in the system by a preliminary scan of the shipment file. At the point at which equipment utilization became stable and all originating tonnage was shipped during the desired time interval, the system was defined as having reached a steady state.

Tests were then made to ensure that the effects of randomness caused by the use of probability distributions in various system operations were minimal. Several model runs were made by using different initial random number seeds (within the conditions specified for the pseudorandom number generator used in SIMSCRIPT II.5) to analyze this effect.

The third set of model tests performed a sensitivity analysis of several key input parameters. The tests included altering the amount and types of towing equipment, the timing of shipments, shipment sizes, physical lock characteristics and components of lockage time, port handling operations, and waterway channel characteristics such as channel depths and velocities. The sensitivity analysis checked model logic against known or intuitive system responses. It also revealed the importance of various input parameters and provided insight into where the greatest effort should be made in future data collection studies.

Figure 1. Primary input and output for inland navigation simulation model.

Inputs

WATERWAY NETWORK
NAVIGATION LOCKS
FLEET
COMMODITY FLOW

⇨

Outputs

UTILIZATION - Locks and fleet
TONNAGE - Thru locks, at ports, on reaches
TOWS - Thru locks, on reaches
DELAY - At locks and ports
QUEUE - At locks

Figure 2. Typical network representation.

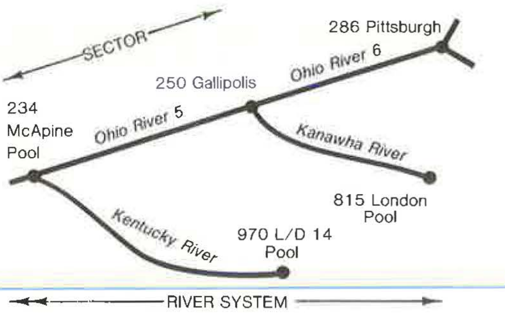
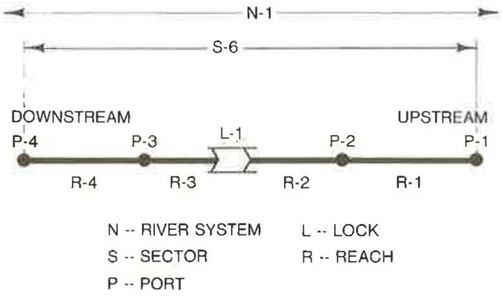


Figure 3. Typical sector representation.



Finally, and most important, model output was statistically compared with known system conditions for a selected historical time period. The desired response was to reproduce historical lock operations at a 95 percent level of confidence. The time period selected was September 1976. Variables analyzed during these tests included lock utilization; average tonnage per tow, barges per tow, delay per tow, service time, queue length, and lockages by type and chamber; and total tonnage and tows and barges by chamber and direction for the entire simulated time period.

The model tests described generated a large volume of output for analysis. Several support programs were developed to expedite the process of verification. The most important of these programs statistically compared simulation model output with historical data. The program, named ANALYS, was developed by the North Central Division of the Corps of Engineers. The method of batch means is used by the program to eliminate autocorrelation in simulation and historical time-series data. An analysis of variance is performed with the classical t- and f-tests. The output of ANALYS provides for each variable and batch count and mean and standard deviation values for each data series in the two input files (historical and simulation), the calculated t-statistic and f-statistic, and level-of-significance factors. This information was used to determine which test was applicable and to construct the confidence level achieved by the model output. The ANALYS processor was also used to compare model output from sequential time periods. This comparison checked the significance level of the randomness effect and assisted in determining stable system conditions achieved during any model run.

EVALUATION OF MODEL TESTS

During the first phase of the development of the Corps of Engineers inland navigation systems analysis (INSA) model, system and shipment data files were prepared to include all of the U.S. inland waterway system. This scale represented the maximum network size the model would be required to handle. Model verification and evaluation with the maximum size of system would have been impractical from both a time and cost standpoint. The network scale was reduced to approximately one-fifth the size of the original model. The test network included the Ohio River main stem and the Monongahela, Allegheny, and Kanawha tributaries in detail; the remaining system was abstracted to a few major shipping and receiving areas. Elements of the network included eight river systems, 29 river sectors, 125 ports, 42 locks, nine commodity classes and groups, 27 towboat classes with 482 towboats, and seven barge classes with 12 860 barges. The reduced network scale adequately served the needs of model verification and saved considerable staff and computer time over the number of model runs required for each iteration of the testing effort.

Three versions of the model have been tested to date. They are identified as SIMGO, SIMGO2, and SIMGO3. Based on the inadequate results of tests with SIMGO, logic changes were made to the handling of the movements of empty towboats (lightboats). The modification ensured that only one towboat would be flagged to pick up a shipment and that a towboat would not travel light for

Figure 4. Lock utilization versus simulation time.

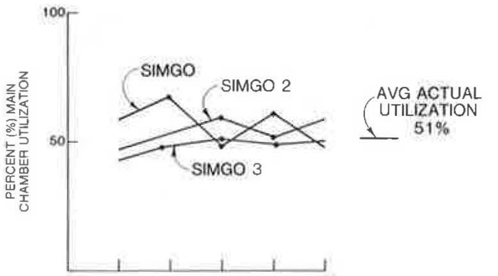


Figure 5. Average lock tonnage versus simulation time.

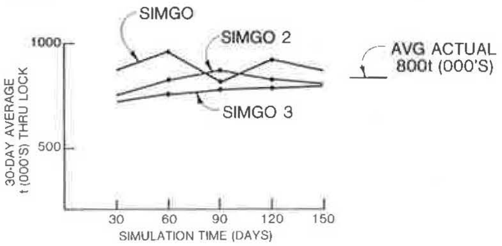
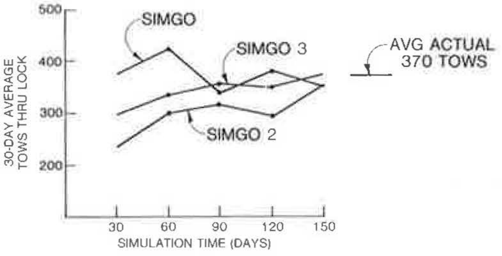


Figure 6. Average number of tows versus simulation time.



an unreasonable distance to pick up a shipment. In addition, if a shipment was picked up by a passing tow earlier, the assigned lightboat would be released to pick up another shipment. Along with this modification, the input was reviewed and updated with the results of recent detailed studies of the current Corps of Engineers PMS and WCSC data.

SIMGO2 performed substantially better in the model test but was not adequate in the historical comparison. At this point, several additional capabilities were recognized as desirable. As a result, SIMGO3 was developed. SIMGO3 incorporates a modified logic for determination of lockage type. The procedure used by SIMGO and SIMGO2 versions is based on the relative surface areas of tow and chamber. Basically, the ratio R of the total deck area of the tow to the area of the lock chamber was computed, and the corresponding type of lockage was looked up in a user input table. Over a specified range of R, a choice between straight single and setover was made randomly according to given probabilities. The principal drawback of using areas was that the chamber capacity could be overestimated in cases in which barges do not pack efficiently into a chamber. The resulting problem was particularly dominant at smaller or odd-sized older locks in the system. However, the method was originally chosen to save the extensive computer time and storage requirements that would be necessary to handle a direct packing algorithm. A revised computational method was developed. In most cases, this modification improved the accuracy of the determination of type of lockage.

There was also a desire for a more flexible policy of chamber selection in the model. The logic originally incorporated in the model for selection of a chamber at a multichamber lock facility was strongly biased toward the use of a main chamber. This policy appeared to reflect actual operations at many locks but, at highly congested locks and locks where both chambers were of the same size, it was less realistic.

In adapting the model for specific project studies, SIMGO3 modifications included additional lockage operating policies, particularly for the analysis of nonstructural alternatives. Originally, the model permitted priority policies of "first come, first served" and "up and down" to be specified. Among the other policies that are now available are (a) ready to serve, (b) queue balance (i.e., the first tow in the longer queue would be chosen), (c) hours up, hours down (upbound tows served for a fixed period of time and then downbound tows served for another, possibly unequal, period), and (d) commodity priority, which takes into account the value of the commodities being shipped. SIMGO3 provided the most successful results for the historical comparison tests.

All test results could not be covered in this paper. The most important results are summarized in Figures 4-6 for a typical lock in the system. Figure 4 compares use of a main-chamber lock for various lengths of continuous simulation time for the three model versions with average actual utilization for the September 1976 period. The results of SIMGO indicated that the system did not attain a steady-state condition. SIMGO2 improved the run condition, and SIMGO3 indicated that the system stabilizes after 60 days of simulation warm-up time. The stabilized period fell below average actual utilization for September 1976. However, examination of the total tonnage, tows, and types of lockages that occurred similarly varied between actual and simulated. The variance was not determined to be significant in this case.

The variation in results is shown in Figures 5 and 6. The fluctuations in utilization, tonnage, and tows were a result of long waits for towboats and barges at ports. This problem was reduced by modifying the model logic and restructuring the towboat and barge input data to more realistically represent existing operating areas. This prevented concentrations of equipment in areas that were distant from shipment demands.

A typical set of results for the historical comparison test is given below (1 t = 1.1 tons):

Variable	Actual (September 1976)	Simulation (SIMGO3)
Utilization (%)	61	66
Tonnage	2 025 450	1 602 700
Total tows	808	797
Total barges	2185	2291
Average tow size (barges per tow)	2.7	2.9
Average delay per hour (%)	0.5	0.8
Total lockages	859	919

Because SIMGO and SIMGO2 did not stabilize, SIMGO3 provided the only valid simulation model results for comparison with the historical data. Average tow size, number of lockages, and distribution of lockage types are comparable. Average delay and queue vary, but these variables are highly dependent on an arrival pattern. The historical arrival pattern was not explicitly represented in the model but was implicitly represented in the timing of commodity movements within the shipment file.

Although the model has essentially been verified, its limitations must be recognized. The modifications made to develop SIMGO3 are relatively minor in view of the overall task of developing the initial simulation model. They have increased the flexibility of the model to handle a wider range of navigation project studies at various depths of detail. However, this increased flexibility has added significantly to the cost of operating the model. The most direct cost is computer resources. Simulation programs are notoriously heavy users of computer time, and representational inefficiencies are magnified by the commonly specified requirement that series of runs be made under varying conditions, often by replicating individual runs to obtain statistical validity. Increased computer costs are not the only burden of increased detail. Frequently, the level of detail has been and is limited by the availability of data or simply by a lack of detailed knowledge of how the system actually works. The latter factor was particularly prominent where human decisions were involved. The dispatching of towboats in the waterway system was a prime example.

Selecting the optimum level of detail was and will be largely a matter of judgment based on the particular navigation study being undertaken. Recent validation tests have given only a general idea of the adequacy of the representation and analytical complexity of the model for the Ohio River system scale.

CONCLUSIONS

The inland navigation simulation model represents a key part of the systems analysis required for the navigation planning efforts of the Corps of Engineers. In conjunction with commodity flow and modal-split analysis, the simulation model provides, through network analysis, insight into system reactions to proposed changes. The verification and evaluation phase was most important in developing confidence in model results under new conditions.

Data collection and model testing and calibration for this large-scale simulation were extensive. There cannot be enough emphasis put on the importance of good input data. As with all types of computer modeling efforts, the "garbage in, garbage out" principle holds true here. The success of the historical comparison tests was largely dependent on the extensive data collection and analysis efforts. For each potential application of the model, the amount of detail desired will have to be balanced with the economic feasibility of data collection and computer resource limitations. In addition, in this context the degree of confidence desired is directly related to the effort required in specific model formulation. Trade-offs may be necessary to meet budgetary and time constraints in the application of the inland navigation simulation model to ongoing and future navigation program and project planning studies.

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Method for Estimating Nonphysical, Transportation-Related Business Losses Caused by Flooding on the Inland River System

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Research undertaken to develop and document a methodology for the estimation of secondary transportation-related flood losses to commercial and industrial firms is reported. The categories of loss estimated exclude physical damage, which is already included in current methodologies. The methodology categorizes transportation-related flood losses into three broad areas. The first area is losses in travel time and travel cost—estimated costs of additional route circuity and travel time, primarily for the movement of freight. The second area is that of business interruption losses, which relate to transportation in the sense that access is essential to the functioning of businesses. The third area of loss is consequences of flood conditions that are not measured solely in dollars. Typical of this category might be increases in energy consumption or air pollution as a result of flood conditions.

The objective of the research reported in this paper on the development of a methodology for the estimation of transportation-related flood losses is to describe the estimation problem, present alternative methodological approaches, and select an approach for further development. Before this work was undertaken, the estimation process for assessing transportation-related flood losses was restricted to direct physical losses. These include rehabilitation or replacement of roadways and bridges as well as property-damage losses for commercial and industrial establishments. These estimates have been based on postflood surveys of many sites.

The research described here develops an estimation methodology for other types of transportation-related flood losses, which can be categorized into three broad areas. The first of these is losses in travel time and travel cost. These are estimable costs of additional route circuity and travel time, primarily for the movement of freight. The second area is that of business interruption costs, which relate to transportation because access is essential to the functioning of businesses. The third area is consequences of flood conditions that are not measured solely in dollars. Typical of this category might be increases in energy consumption or air pollution as a result of flood conditions. It should be noted that these three categories specifically exclude physical damage, which is already included in current methodologies.

ALTERNATIVE METHODOLOGIES

The first candidate methodological approach, shown conceptually in Figure 1, uses monetary impacts only. Given substantive input on flood magnitude and duration and a business and shipment inventory, the various travel time and travel cost components can be estimated. Business interruption costs can be calculated for basic and nonbasic sectors and standard industrial classification (SIC) categories that are directly affected by flood conditions.

There are several private, corporate, and institutional fiscal impacts. The following impacts are worthy of record for both basic and nonbasic industry:

1. Income loss on ledger sheet, by day, attributable to loss of sales and/or cessation of deliverable production output of product;
2. Tax impacts, including those on personal income, corporate income, sales tax, and appraised value of business;

Figure 1. Conceptual methodology using monetary impacts only and regional multiplier effect.

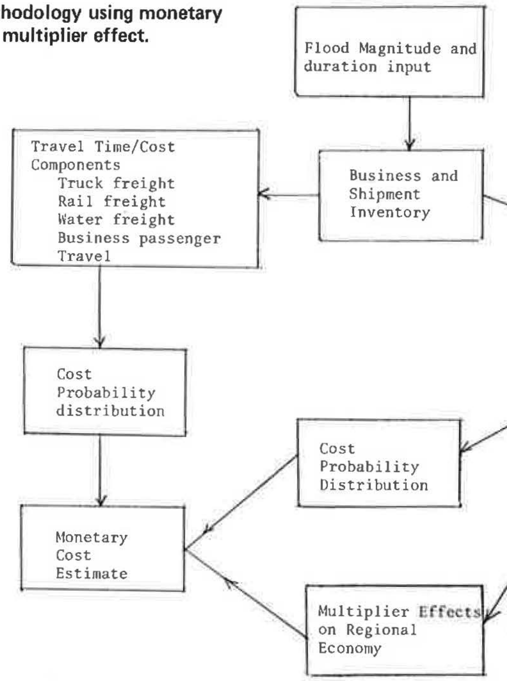


Figure 2. Conceptual methodology using monetary and nonmonetary impacts.

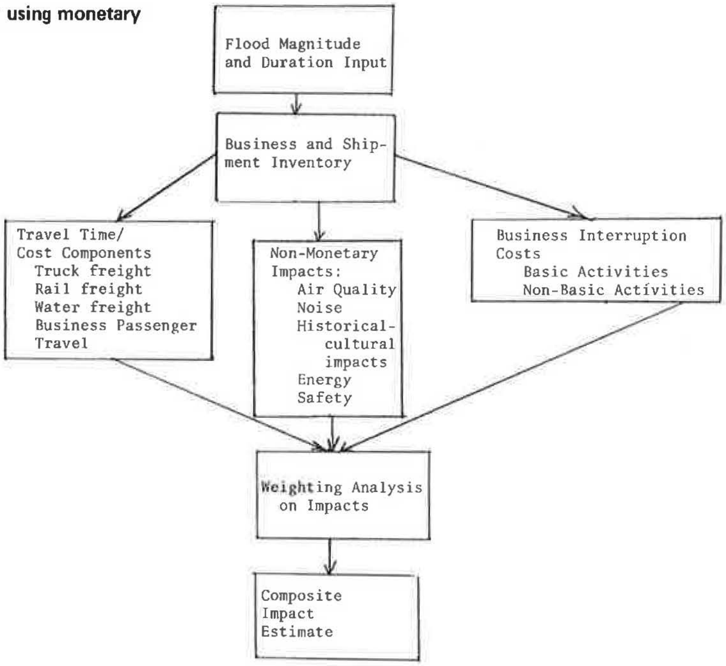
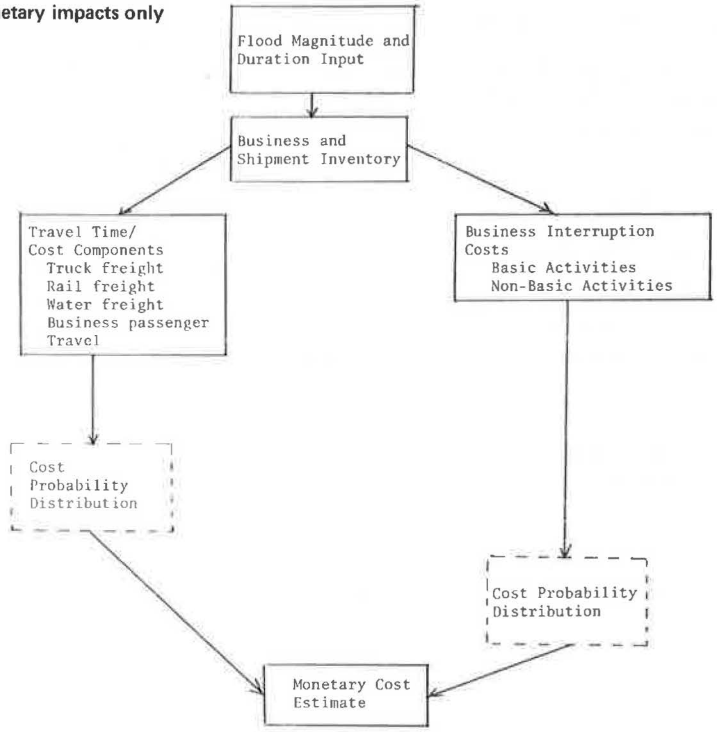


Figure 3. Conceptual methodology using monetary impacts only and optional cost probability distribution.



3. Loss in market value of real estate, attributable to loss of net income, in conjunction with an appraisal of income-producing real estate and use of specified capitalization rates (this yields resultant loss in assessed valuation and real estate taxing level); and
4. Loss in raw land value, as related to market comparables approach of appraisal.

Knowledge of such loss of basic or nonbasic income can be coupled with a regional multiplier to yield an estimate of total regional income or surrogate alteration of "regional value added" caused by a flood of particular magnitude and duration. The duration and magnitude of the flood could be given as probability distributions so that expected monetary costs would result. In addition, probability distributions could also be used on the component travel time and business interruption cost levels.

The second proposed methodological approach, which is shown schematically in Figure 2, is a broader derivation of the first one. Again, distributions on flood magnitude and duration and business inventories are used as input. Monetary impacts related to travel time and costs and business interruption are handled as before. In addition, however, calculable nonmonetary impacts, such as altered noise levels, energy differentials, changes in air quality levels, predicted changes in historical-cultural landmarks, and changes in hazardous incidents that involve personal injury, are also estimated. The monetary and nonmonetary impacts are weighted on a subjective weighting scale to yield a composite impact score for a flood of particular magnitude and duration.

The final approach (see Figure 3) is a variant of the first two. It uses first-round income stream losses only, deals only with monetary impacts, and ignores the multiplier effects included in the first method. As previously indicated, cost probability distributions can be used as an option to account for uncertainty in impact estimates for a particular flood magnitude and duration.

These three methodological approaches were reviewed with respect to the data and the complexity of information required, conceptual simplicity, and versatility for both pure cost estimation and consideration of nonmonetary consequences. The third methodology appears to be the most reasonable candidate for development and case study testing. It requires only readily visible and recorded first-round income stream changes and does not require the analyst to derive or be capable of manipulating regional multipliers. Further, the second approach, although esoteric in its conceptual analysis of multidimensional nonmonetary impacts, requires reasonably refined analyses of environmental impacts such as air and noise pollution and subjective estimation of the importance of these impacts to the region. Accurate calculation of such impacts is a state-of-the-art problem in constant flux, and conflicting viewpoints of important regional attributes may not render subjective weighting of impacts meaningful. Thus, on balance, the third candidate approach is pragmatic and capable of calculation and will be developed in full algorithmic form.

DISCUSSION OF LOSS-ESTIMATION METHODOLOGY

The detailed flow chart for the methodology of loss estimation is shown in Figure 4. As each component of the flow chart is discussed, data sources are mentioned as appropriate. The methodology tasks are referenced by letter and number: A-tasks refer to items related to first- and second-round business interruption costs, and B-tasks refer to transportation costs.

In task A.1, commercial and industrial land uses within the bounds of the floodplains are surveyed by using aerial photographs and business directories. By using this inventory, company reports, and interviews, daily salary and wage losses caused by business interruption can be estimated in task A.2. From this estimate of salary and wage loss, direct tax losses on personal income can be determined in task A.3 for the municipal, state, and federal levels on the basis of average tax rates. In addition, in task A.4, the survey and interviews will yield computation of the industrial and commercial income losses from foregone sales and lost production. This task, along with task A.2, can be used to estimate the secondary losses to other businesses attributable to the multiplier effect of lost wages and lost production on other businesses inside and outside the region, which is shown as task A.13. This information can be estimated on the basis of available ratios of basic industry wages paid to nonbasic wages generated.

From the estimates of task A.4, production and retail sales tax losses can be computed in task A.5. Based on the effects of lost production, in task A.4, on the firm's cash flow, the change in the firm's net worth can be estimated in task A.6. This loss results in commercial and industrial income tax losses in task A.9, which can be based on the net worth of the business. Discussions were held with a private certified public accountant versed in corporate income tax accounting, corporate net worth auditing, and business value appraisals to ascertain realistic treatment of tasks A.6 and A.9. By using the income stream losses determined in A.4 in conjunction with typical capitalization rates for commercial and industrial property in task A.10 and comparisons with other comparable properties in task A.8, the loss of property value can be determined through the income-producing property appraisal process in task A.7. Conclusions on these results in task A.11 also contribute to the net worth losses computed in task A.6. In addition, they also result in lost real estate taxes based on assessed valuation, computed as task A.12. The various sources of income losses, property and business value losses, and tax losses are synthesized in task A.14 as the total economic loss caused by business interruptions and the regional decrement in value added.

In dealing with the transportation cost aspects of the methodology of loss estimation, the focus is on additional transportation costs imposed by flood conditions. In task B.1, the probability information on flood duration and magnitude is reviewed. The contours and land-use maps of the area are reviewed in task B.2. As Figure 4 shows, these also serve as inputs to the business interruption estimates that begin in task A.1. In task B.3, the business inventory is reviewed for purposes of estimating business travel patterns and related trip generation in conjunction with task B.4, a review of regional origin-destination (O-D) travel patterns. From these and other historical travel studies, vehicle volumes of business passenger travel can be computed in task B.5, and commercial vehicle volumes related to the flood area can be estimated in task B.6. In task B.7, the location and number of kilometers of inundated highway routes are estimated by using the information from tasks B.1 and B.2. Realistic detour kilometers are estimated in task B.8 for highway travel, and cost factors are applied in task B.9 for additional (business) passenger and freight vehicle kilometers.

In task B.10, inundated rail routes are estimated from tasks B.1 and B.2. Typical detour kilometers are estimated in task B.11. Interregional commodity flows are estimated for rail for the flood area in question in task B.12. In task B.13, this information is converted to railcar volumes affected. That information, in addition to the detour kilometers in B.11, allows application of cost factors and the estimation of additional costs attributable to rail detours in task B.14.

Similarly, information from tasks B.1 and B.2 allows an estimation, in task B.15, of water routes that would become impassable. Typical interregional commodity flows by water are estimated in task B.12, and this yields, in task B.16, the estimated number of tows delayed. On the basis of information on flood duration and magnitude, the number of hours of delay is estimated in task B.17. Finally, in task B.18, cost factors are applied to find delay costs for the water mode. The highway, rail, and water costs are summed in task B.19 to yield transportation losses caused by flood conditions. In task A.15, these are then aggregated with business interruption costs over all SICs to yield total losses caused by flood conditions.

CASE STUDY APPLICATION

Because of some data limitations, the quantitative results reported here represent a fraction of the total economic loss brought about by flood-related business interruption. These limitations do not, however, reduce the validity of the computational approach used or its general applicability to the problem of economic loss in any study area.

Study Area

The study area consists of the Meramec River bottoms and adjacent areas that extend from the MO-141 bridge at Valley Park, Missouri, to the confluence of the Meramec and Mississippi Rivers. Seven major highway bridge crossings and three rail bridge crossings affect surface transportation patterns in the study area. There are many industrial and commercial facilities at the upper end of the study area, including the Chrysler automobile and truck assembly plants, the Treecourt Industrial Park, and a variety of wholesale, retail, and manufacturing facilities. Farther downstream, gravel pits, wholesale and retail facilities, and the Union Electric Meramec generating plant are found. Extensive ground surveys were used to identify businesses for further contact in the study area. Altogether, 71 businesses were identified for further contact.

Transportation Interruption

Since delay time and detour kilometers are major components of costs incurred as a result of transportation interruptions, operating and delay costs are given for truck, rail, and towing operations in Tables 1, 2, and 3 (4), respectively. For purposes of illustration, assume that the MO-30 bridge approaches were inundated. Missouri State Highway Department traffic counts for 1973 indicate that 1030 commercial vehicles, including 270 trailer combinations, used this bridge. Total detour kilometers depend on origins and destinations, but a reasonable distance by the I-44 crossing would be 32 km (20 miles). We assume that the length of haul is 80.47 km (50 miles) (longer hauls would likely use the Interstate system).

Estimated delay costs for trailer combinations = 270 vehicles × \$4.18/vehicle-km (\$6.74/vehicle mile) × 32.3 vehicle-km (20 vehicle miles) = \$36 396/day.
For the remaining single-unit trucks the cost = 760 vehicles × \$2.49/vehicle-km (\$4.01/vehicle mile) × 32.3 vehicle-km (20 vehicle miles) = \$60 952/day.

These calculations assume that no deliveries would be canceled and include driver wages, operating costs, maintenance, capital recovery, and terminal labor costs.

Similarly, for travel by individuals for business reasons, we can estimate the losses caused by closure of the MO-30 crossing. The average daily traffic crossing is 20 000 vehicles, and it will be assumed that 10 percent of all traffic is business related. Origin-destination patterns will dictate that 60 percent of the traffic will detour via I-44 and 40 percent via I-55. Estimated detour distances are 16 and 24 km (10 and 15 miles), respectively, for I-44 and I-55. Out-of-pocket operating costs for intermediate-sized automobiles are 0.2 cents/km

Figure 4. Methodology for estimating secondary transportation-related flood losses to commercial and industrial firms.

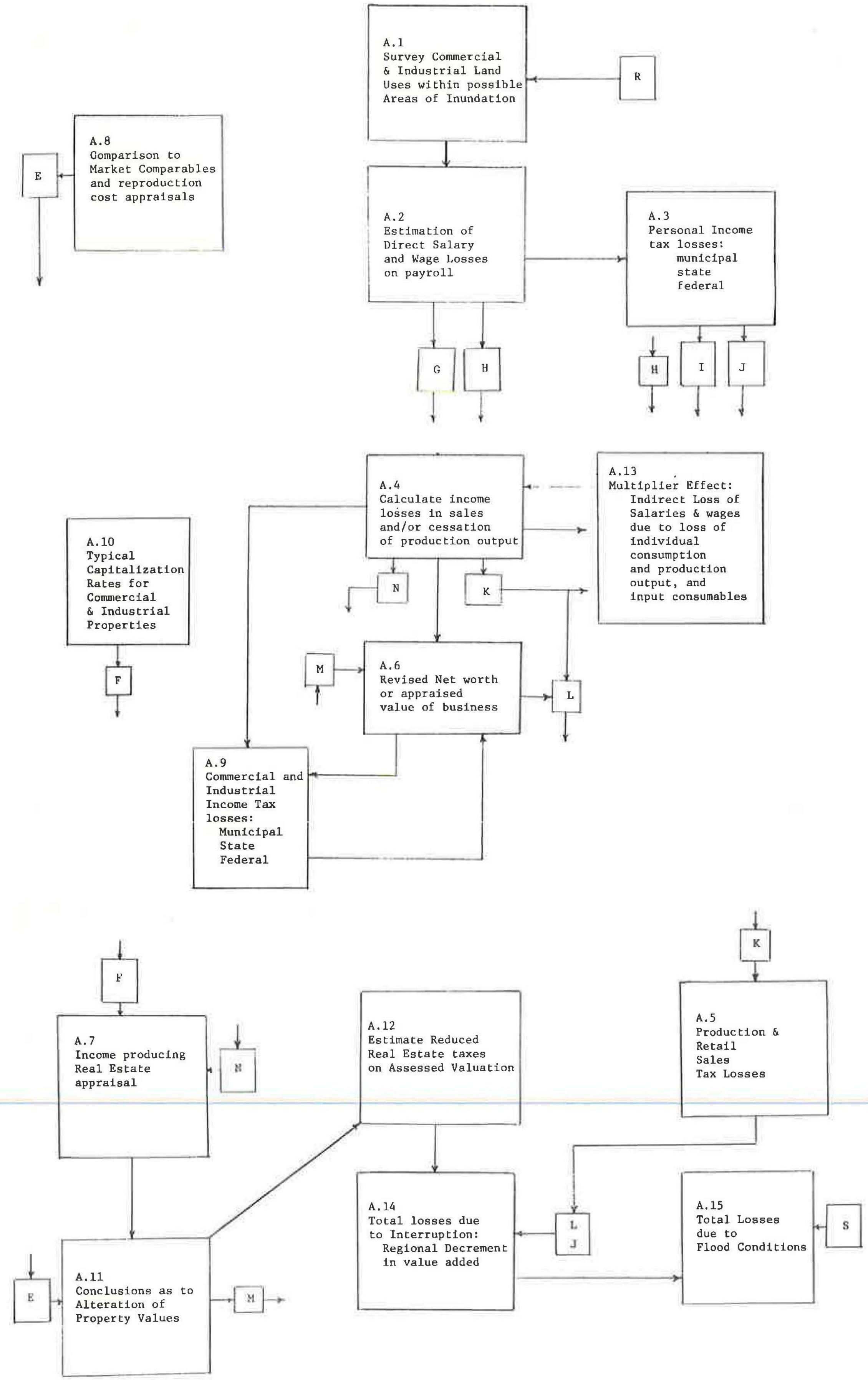


Figure 4. Continued.

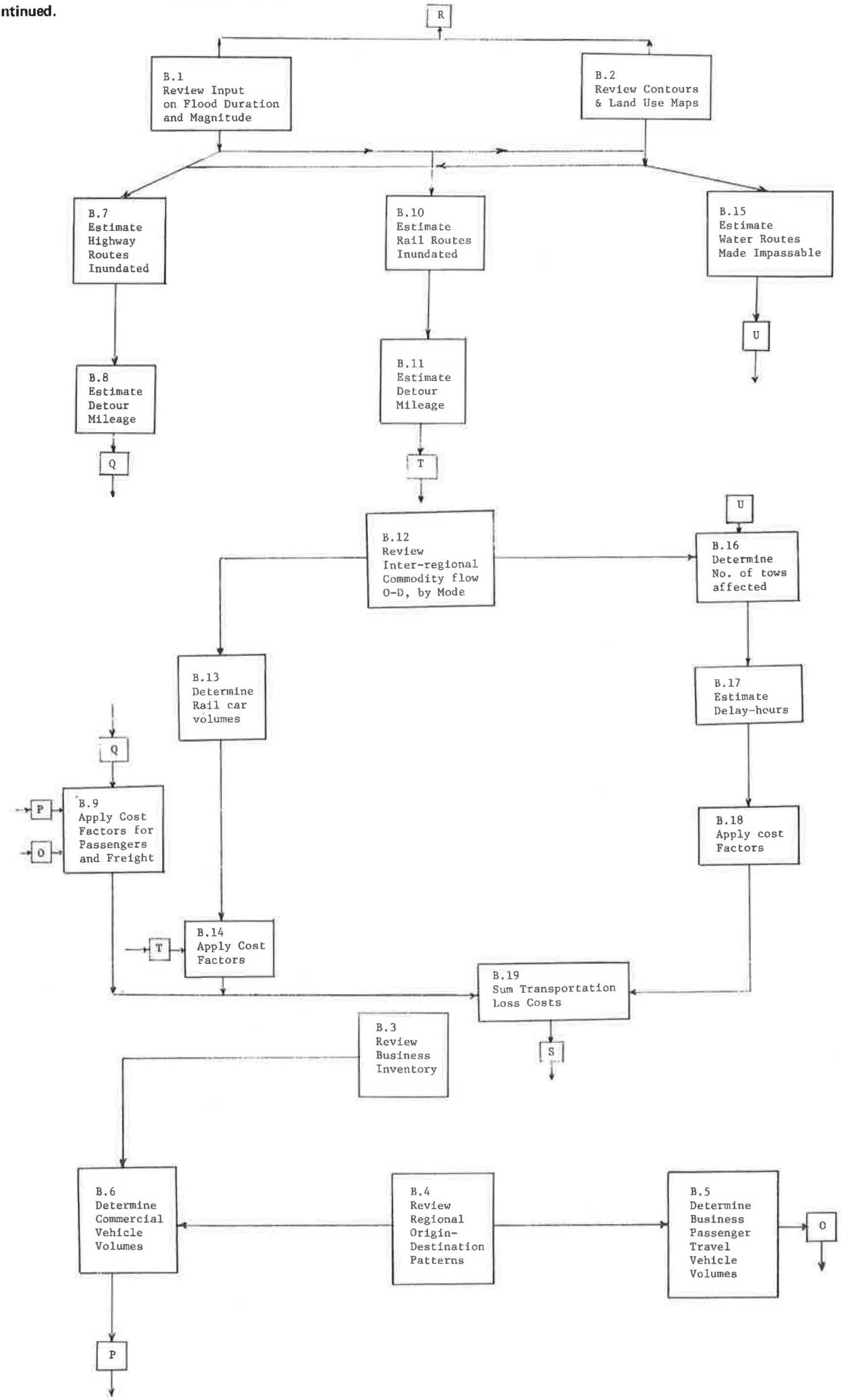


Table 1. Truck costs—1977.

Length of Haul (km)	Cost	Tractor-Semitrailer[a] Dollars per Vehicle Kilometer	Tractor-Semitrailer[a] Cents per Ton-Kilometer	Single-Unit Truck[b] Dollars per Vehicle Kilometer	Single-Unit Truck[b] Cents per Ton-Kilometer
81	Wages	0.17	1.64	0.14	2.40
	Operating	0.19	1.78	0.16	2.53
	Maintenance	0.08	0.75	0.07	1.16
	Capital[c]	0.07	0.69	0.06	0.96
	Load and unload	3.67	34.52	2.06	34.59
	Total	4.18	39.39	2.49	41.65
161	Wages	0.17	1.64	0.14	2.40
	Operating	0.19	1.78	0.16	2.53
	Maintenance	0.08	0.75	0.07	1.16
	Capital[c]	0.07	0.69	0.06	0.96
	Load and unload	1.84	17.26	1.03	17.26
	Total	2.35	22.13	1.46	24.32
323	Wages	0.17	1.64	0.14	2.40
	Operating	0.19	1.78	0.16	2.53
	Maintenance	0.08	0.75	0.07	1.16
	Capital[c]	0.07	0.69	0.06	0.96
	Load and unload	0.92	8.63	0.51	8.63
	Total	1.43	13.49	0.94	15.69
645	Wages	0.17	1.64	0.14	2.40
	Operating	0.19	1.78	0.16	2.53
	Maintenance	0.08	0.75	0.07	1.16
	Capital[c]	0.07	0.69	0.06	0.96
	Load and unload	0.46	4.32	0.26	4.38
	Total	0.97	9.18	0.69	11.44
1290	Wages	0.17	1.64	0.14	2.40
	Operating	0.19	1.78	0.16	2.53
	Maintenance	0.08	0.75	0.07	1.16
	Capital[c]	0.07	0.69	0.06	0.96
	Load and unload	0.23	2.12	0.82	2.19
	Total	0.74	6.99	1.25	9.25
1613	Wages	0.17	1.64	0.14	2.40
	Operating	0.19	1.78	0.16	2.53
	Maintenance	0.08	0.75	0.07	1.16
	Capital[c]	0.07	0.69	0.06	0.96
	Load and unload	0.19	1.78	0.10	1.78
	Total	0.70	6.64	0.53	8.84

Notes: 1 km = 0.62 mile; 1 t·km = 0.685 ton-mile; 1 kg = 2.204 lb.
Computations are based on data from a 1975 cost study by the Transportation Regulatory Board of the Iowa Department of Transportation and 1975 data of the University of Minnesota (1).

[a] 17 242-kg payload.

[b] 12 250-kg payload.

[c] Capital costs reflect equipment depreciation and interest costs based on annual equivalent costs at 11 percent interest and a seven-year life expectancy.

Table 2. Rail costs—1974.

Length of Haul (km)	Conventional Train[a,b] Dollars per Train Kilometer	Conventional Train[a,b] Cents per Ton-Kilometer	Unit Train[c,d] Dollars per Train Kilometer	Unit Train[c,d] Cents per Ton-Kilometer
161	106.64	4.62	23.81	1.03
322	64.48	2.76	18.25	0.79
806	39.06	1.49	14.76	0.65
1613	30.38	1.23	14.28	0.62
3226	26.04	1.10	13.81	0.57

Note: 1 km = 0.62 mile; 1 t·km = 0.685 ton-mile; 1 t = 1.1 tons; 1 kW = 1.34 hp.

[a] Data from the Interstate Commerce Commission (2).

[b] Assumes 64-car train made up of a mixture of cars that average 36 t of cargo per car, average conditions, and three 1493-kW locomotives.

[c] Data from the U.S. Railway Association (3).

[d] Assumes 50-car train with four 1493-kW locomotives.

(2.8 cents/mile) (4). Therefore, detour costs are as follows:

20 000 vehicles × 10 percent × business travel = 2000 vehicles.
0.6 (for I-44) × 2000 vehicles × 16 km (10 miles) × 0.0174 cents/km (0.028 cents/mile) = $336/day for diversions to I-44.
0.4 (for I-55) × 2000 vehicles × 24 km (15 miles) × 0.0174 cents/km (0.028 cents/mile) = $358/day for diversions to I-55.
$336 ÷ $358 = $694/day diversion cost.

For the rail mode, we adopt assumptions similar to those for the truck example. Assume an 805-km (500-mile) length of haul and conventional train operations. If the Missouri-Pacific (MOPAC) rail crossing at the confluence of the Meramec and Mississippi Rivers were inundated and four daily MOPAC trains were detoured only 16 km (10 miles) in southern Missouri to cross over the MOPAC trackage on the Illinois side, then the costs are $39.15/train-km ($63/train-mile) × 16 km (10 miles) × 4 trains = $2520/day.

Business Interruption

In the application of the business interruption portion of the methodology, some multiplier effects in task A.13 are excluded. The data collected were used in conjunction with other financial data sources to develop estimates of loss related to business interruption by SIC codes. The tabulations of loss presented here represent an approximate 20 percent response to the survey form and to follow-up phone calls.

To illustrate the working methodology shown in Figure 4, data and related computations from an electrical

Table 3. Estimated operating costs of towboats on the Mississippi River system—1976.

Item	Operating Cost by Power Range ($)				
	1343-1642 kW	2090-2537 kW	2985-3284 kW	3731-4478 kW	4552-5224 kW
Investment (average new cost)	1 000 000	1 700 000	2 200 000	2 600 000	3 100 000
Fixed costs					
Return on investment	177 500	199 700	258 400	305 400	364 100
Administration and supervision	55 700	80 500	94 500	117 200	130 000
Subtotal	173 200	280 200	352 900	422 600	494 100
Operating costs					
Wages and fringe benefits	250 000	325 000	325 000	350 000	350 000
Fuel	180 000	300 000	400 000	564 000	666 000
Maintenance and repairs	45 000	60 000	80 000	95 000	105 000
Supplies	25 000	34 000	38 000	42 000	44 000
Subsistence	20 000	28 000	28 000	31 000	31 000
Insurance	30 000	50 000	65 000	80 000	93 000
Other	7 000	8 000	9 000	10 000	11 000
Subtotal	557 000	805 000	945 000	1 172 000	1 300 000
Total annual costs	730 000	1 085 200	1 297 900	1 594 600	1 809 200
Hourly operating costs	88	131	157	193	217

Note: 1 kW = 1.34 hp.

Table 4. Business interruption losses for one-week period.

SIC Code	Wage Loss ($)	Income Tax Loss ($)				Decrement in Property Value ($)
		Personal		Corporate		
		State	Federal	State	Federal	
3079	32 307	1938	8 075	624	5 736	96 000
3811	59 340	3560	14 835	572	23 896	135 000
4214	15 384	923	3 845	25	100	3 980
5085(2)	10 500	630	2 620	125	855	19 450
5111	5 000	300	1 250	50	215	7 925
5139	6 615	395	1 650	995	7 910	23 400
5943	15 380	923	3 845	148	1 160	22 800
Total	144 526	8669	36 120	2539	39 872	308 555

instrument company (SIC 3811) are used. A summary of these data is given in Table 4. If it is assumed that business is interrupted for a period of one week, the approximately 230 hourly employees would lose almost $258 each, excluding social security taxes. State income tax loss on these wages would be $3560 at an assumed marginal tax rate of 6 percent. Federal income tax loss would be $14 835 at an assumed marginal rate of 25 percent.

Losses to the employer can be estimated as follows. Again, assume a one-week shutdown and further assume that production and sales are not recovered for the week. The losses in Missouri state and federal corporate income tax would be $572 and $23 896, respectively. Based on statement studies for SIC 3811 businesses (5), salaries and wages typically account for 26 percent of net sales revenue. By using this and information on salaries and wages, the net sales of the company can be estimated to be approximately $16 million. Further research from the above sources indicates that net profits are approximately 5.7 percent of net sales; thus, annual net profits are $900 000, and a one-week loss in profits would amount to $17 500.

In a related impact, it is possible to appraise the loss in property value for this business location that results from interruption by flooding. Using a realistic overall market capitalization rate of 13 percent for the area and the income-appraisal approach of the National Association of Independent Fee Appraisers (6) gives

$$V = I/R \tag{1}$$

where

V = value of the property,
R = overall market capitalization rate, and
I = net annual income.

The one-week loss in net income can be substituted into the equation, and the reduction in appraised property value can be derived as $135 000. The alteration in property value should be compared with actual sales prices of like or comparable land uses in the study area to yield an effective check on the effect of loss of income on property values. Further, such reduction in property value presumes the interruption would occur annually. Given the infrequent reassessment of real estate value in Missouri, it is unlikely that there would be a loss of real estate taxes related to sporadic or annual increments in property value.

If annual reassessment were to occur, the loss in property taxes based on the above example could be calculated as follows. The property tax rate on the example property is $7.36 per $100 assessed valuation. By law in Missouri, property is assessed at one-third of market value. The loss would then be $135 000 × 0.33 × $0.0781 = $3479 for the one-week interruption. If the assessed valuation percentage were one-fifth or one-half, the corresponding losses would be $2109 and $5272, respectively. In addition, in a related computational aspect of Figure 4, interviews with an experienced corporate tax accountant indicate that the altered net worth of a business attributable to interruption cannot be predicted except on a detailed case-by-case basis.

The losses shown in Figure 4 can be estimated for all businesses in a flood area by SIC code by using the assumptions and calculations carried out above for the one company. This was done for the businesses that responded to the field survey (Table 4). In these calculations, tax items that were available directly from the firm, such as federal income tax, were used; otherwise, such inputs were estimated on the basis of net profits (as previously illustrated) by using annual statement studies. Retail sales tax losses, as described in the original methodology in Figure 4, are not applicable to most of these firms because of their status as wholesalers. (Note that these figures do not include any of the large industrial plants, such as Chrysler, because of the lack of timely response. It is likely that the figures for Chrysler alone might exceed the total for all others in the study area.)

The results of application of the methodology reveal several appropriate conclusions. First, the amount of new data required of the businesses surveyed is not great or time consuming to assemble. The amount of additional financial information necessary for computing losses caused by business interruption is not large. The calculations involved in an application are quite simple and cheap to use and make use of specific software developed for this study. Finally, the use of the SIC code allows a reasonably refined and classified set of secondary losses to be estimated.

CONCLUSIONS

The results of the development and case study application of the methodology that were carried out in this research support several relevant conclusions and define further research needs. Estimation of nonphysical damage losses caused by flood conditions is a multifaceted and complex problem. It requires knowledge of the transportation function of commercial and industrial firms as well as the composition of the transportation network itself. In addition, knowledge of public- and private-sector accounting and real estate appraisal is required. The methodology developed here synthesizes these various components into a technique that requires some collection of field data and the use of previously compiled financial relations and network travel data. With some additional refinement, the technique could also take into account the effect of the documented losses on the rest of the economy of a region. This could be accomplished by using basic-nonbasic multipliers or typical regional input-output types of economic linkages. This is an appropriate subject for further research and expansion of computational capability.

The results provide the means for developing reasonably quick estimates of the losses that result from flood conditions. Application of the approach to other sites can be carried out by using the existing technique and existing financial and accounting information inputs. The computer software and user-related materials provide a capability for generalization and ease of use at other sites.

ACKNOWLEDGMENT

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Waterway User Charges: Some Likely Impacts in the Tennessee Area

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Research whose purpose was to assess potential waterway user charges and their impacts and to provide the basis for the establishment of a state position is reported. The research was intended to serve the function of an informational report and not to provide hard recommendations either for or against a user charge. Most of the information was gathered through secondary sources published by water carrier associations and various federal agencies. Data were also collected, by means of survey and sampling techniques, from such primary sources as waterway carriers and industrial shippers. An analysis of the financial profile of the towing industry suggests that any user charge levied on towing firms will ultimately be passed on to the consumer. Smaller firms will probably suffer most since they operate with smaller margins and high turnover. Reduction in overall industry market share of national commodity transports will remove some of the economies associated with large-volume movements and eventually affect the profitability of larger towing firms. A segment toll represents the greater impact in terms of towing industry operating costs, shipping rates, state waterway traffic volume, employment, and electrical consumer utility costs. A $0.01/L ($0.04/gal) fuel tax represents the smallest impact. In light of the lack of complete empirical evidence, any cost-recovery scheme should be phased in on a gradual basis so as to allow for a cautious monitoring of both positive and negative impacts.

The state of Tennessee, with its access to three of the nation's major navigable waterways, has found its river systems to be a great asset in attracting basic industries Recently, developments in government policy have focused attention on the "free use" of U.S. inland waterways, and this has culuminated in various proposals for imposing a user charge on the nation's towing industry. The immediate concern of the state of Tennessee is that such a development may reduce the inherent advantages of a river transport system and thus destroy some of the economic vitality and job opportunities provided by the state's river system.

USER CHARGE OPTIONS

The four likely forms of user charge are (a) fuel taxes, (b) lockage fees, (c) segment tolls, and (d) licensing of floating equipment. Fuel tax cost-recovery schemes are analyzed at various levels that range approximately from $0.01 to $0.11/L ($0.04 to $0.40/gal). The magnitude of the lockage-fee method of collection was derived for each specific lock-and-dam facility based on the determination of an "imputed" value that commercial operators place on lockages by taking into consideration costs of delays and congestion. Segment-toll analysis is based on fees levied per commercial ton kilometer, and the toll is set for each river segment to recover the costs of that segment. The license-fee cost-recovery alternative is approached on the basis of power for towboats and tonnage capacity for barges.

Certain aspects of the waterway user charge issue are relevant to any of the alternatives under consideration. The first of these aspects deals with an assessment of congressional intent in relation to the distinction between commercial and recreational use of waterways. If legislative action results in the exemption of recreational vessels, the benefits that could be gained from any form of user charge would be substantially reduced.

Another aspect of importance relevant to all methods of collection deals primarily with the proper definition of the U.S. inland waterway system. Much discussion by policy makers and researchers has centered on the cross subsidization of various river segments in an attempt to establish a user charge program that would be equitable for all sections of the nation. The interdependence of the various subsystems and the commercial intercourse between the various segments are such that each subsystem becomes an integral and economically justifiable component of the entire national river system. The implication of this idea for the analyst is that no one subsystem can be completely separated from the total system without distorting the true values of potential impacts. Any loss of traffic on the Tennessee river system would ultimately be felt on other river segments and vice versa. The impact measures in this paper deal only with potential initial-round adjustments that can be directly associated with a specific river system. They do not take into consideration any loss of traffic that occurs as a result of secondary influences ultimately felt in the long chain of economic adjustments. The immediate question becomes, How will industry in general, and the towing industry in particular, respond to a waterway user tax?

OPERATING AND PERFORMANCE CHARACTERISTICS OF THE TOWING INDUSTRY

Any likely economic impacts of a waterway user charge on the economy of Tennessee will probably be conditioned by how the towing industry responds to the tax. This response in turn may be expected to be related to the operating and performance characteristics of the industry, which will in turn have economic implications for industry in general and its use of river transportation.

Some general guidelines on the financial status of waterway towing firms are published by Robert Morris Associates (1). These data represent good approximations to the financial nature of the industry.

The asset structure of towing firms is dominated by fixed assets where about 66 percent of total investment is accounted for. Smaller firms ($1 to 10 million in revenue) tend to be characterized by slightly more investment in current assets than do larger firms—about 26 percent compared with about 24 percent of total assets. A category of other noncurrent assets, which is not readily definable, balances out the asset structure for these firms. Thus, in terms of asset structure, the firms appear to be quite similar; there appear to be only small differences in current assets between large firms and small firms.

Table 1. Analysis of return on assets and equity.

Size of Firm	Turnover[a]	Margin[b] (%)	Return on Assets[c] (%)	Return on Equity[d] (%)
Small	1.0	8.0	8.0	19.1
Large	0.64	12.8	8.2	23.0
All	0.74	11.2	8.3	21.3

[a] Sales/total assets. [b] Income/sales. [c] Income/assets. [d] Equation 1.

The towing industry depends on a great deal of debt financing in its total financial structure. Short-term financing constitutes 20.7 percent of the total. In general, the average towing firm uses 43.5 percent long-term debt. In terms of total debt, firms in the industry could be considered highly leveraged: Total debt represents 57.9 percent of the financial structure for smaller firms and 65.0 percent for larger firms. Thus, net worth or owner financing represents about 42 percent of total financing for smaller firms and 35.0 percent for larger firms. The major significance of these debt ratios is that, if income were to fall significantly for some reason, the return to the owners in this industry would be subject to an abrupt decline.

Expenses or operating costs, when compared with the revenue dollar, differ significantly between small firms and large firms. For small firms, profit before tax represents 8 percent of the revenue dollar; for larger firms, it represents 12.8 percent. For whatever reasons, the smaller firms display less efficiency in converting the revenue dollar into income.

The observations on the industry's financial structure have already indicated the highly leveraged position of the industry. The median ratio for smaller firms is 1.3 times whereas that for larger firms is 2.2 times. This high proportion of debt relative to net worth indicates a good deal of potential debt pressure in the industry. As the high ratios suggest, firms in the industry tend to owe more to creditors than their ownership can cover.

The ultimate value of interest for the owners is the amount of total return generated by all assets. For all firms in the sample, the before-tax return on equity was 20.6 percent. It should be emphasized at this point that the return on equity is related to the turnover of all assets and the profit margin on revenue given the amount of debt used in the financial structure. Return on investment expresses income before taxes as a percentage of the total assets of the firm, whether financed by owners or creditors. The relation of return on assets (investment) to returns on equity may be stated as

$$\text{Return on equity} = \text{return on assets}/[1 - (\text{debt}/\text{total assets})] \tag{1}$$

It is obvious that the amount of debt influences the size of the denominator in the equation and high amounts of debt will translate into higher percentage returns on equity, other things being equal. However, if the return on investment declines because of poor use of assets or poor profit margin and if the debt ratio remains constant, the return to the owner will decrease. The relation between turnover of assets, profit margin, return on assets (investment), debt ratio, and return on equity is given in Table 1.

Although the preceding comments relate to the general operating and financing profile of waterway towing firms, there are major differences that are related to type and volume of specific kinds of shipping by the towing firm. Thus, conclusions that are reached with respect to likely impact must be viewed as being based on industry averages and allow for considerable differences from these averages on an individual basis.

One of the proposed user charge alternatives is the fuel tax. Given current fuel costs, it is imperative to know what portion of a towing firm's total operating expenses is represented by fuel. Among the Tennessee firms surveyed for this study, fuel averaged 31.2 percent of operating costs.

Other studies have shown that tow-related costs are dominated by fuel and depreciation whereas most of the remaining costs in the crew category are dominated by wages and fringe benefits (2). In these studies, it was found that fuel costs currently represent about one-third of total operating costs.

Another important aspect is the towing industry's cost of hauling compared with alternative modes (2). The cost of barge line-haul service to shippers is about 2.1 mills/t·km (3 mills/ton-mile) compared with about 9.6 and 14.4 mills/t·km (14 and 21 mills/ton-mile) for rail and truck, respectively. It is important to note that these rates apply only to line-haul and not to the total cost of moving an item from one point to the ultimate point of use.

When handling costs are included with line-haul costs, the barge advantage declines and in some cases may be eliminated (2). Another important consideration for shippers is the value of the commodity being shipped. Since the water mode lags behind both rail and truck in terms of flexibility and speed, long transit times for high-value commodities result in larger inventory investment for the shipper. Clearly, the waterway industry will be less capable of passing user charges on to the shipper when the cost differential between water and other modes, particularly rail, is not as great as it appears at first glance to be.

An overall profile emerges in which the most important factor in modal choice is the distance between origin and destination: The longer the distance is, the more likely is the movement by water. The cost and time of barge loading and unloading require a reasonably long haul to make the water mode attractive. Increasing value per ton has a depressing effect over long hauls because of the slower speed of the water mode and its effect on inventory costs. The bulk versus nonbulk nature of commodities also has its effect since bulk commodities are more likely to move by water. The economies associated with long hauls and the costs of handling for certain commodities suggest that the basic traffic patterns in terms of distance and handling will have to be maintained in the industry. It would be difficult to avoid the effects of segment tolls or lockage fees without losing the economies of long haul and handling advantages.

TENNESSEE TOWING INDUSTRY

In terms of annual gross revenues, the majority of Tennessee's towing firms are in the $1 million-$10 million category. About 52 percent of total traffic is accounted for by activity on the Mississippi River, about 20 percent by activity on the Tennessee River, about 5 percent by activity on the Cumberland River, and the remainder by activity on other river systems. The revenue profile given below is based on a sample of 13 firms that represent about 48 percent of Tennessee-based towing firms in class 1 (regulated carriers) and class 2 (exempt, for-hire carriers):

Size of Firm ($000 000s)	Number of Firms
<1	1
1-10	10
11-50	2

Data on the assets of the surveyed firms, taken from a Memphis State University survey of Tennessee industrial waterway users, are given below:

Size of Firm ($000 000s)	Number of Firms
<1	2
1-10	7
11-50	3
≥51	1

It can be seen that total assets exceed total revenues, which suggests an asset turnover of something less than one.

If midpoints for both revenues and assets are used for estimating purposes, and if the ≥$51 million category is treated as near $50 million, revenue can be estimated to be near $100 million and assets near $175 million. This combination of figures produces a sample asset turnover of slightly less than 0.60, which appears to be somewhat low compared with the estimates provided by the Robert Morris Associates survey (1).

Other evidence from the sample suggests that the asset estimate is too high. Since total assets for the sample can be estimated from a review of the value of towboats and equipment submitted by the respondents, an alternative estimate of assets is available for purposes of comparison. By using these estimates and allowing for depreciation, a book value for tows in the sample can be determined at approximately $23 million. A barge value of approximately $64 million can be determined by using estimated purchase prices of equipment and allowing for depreciation.

Since it was previously shown that fixed assets represent 66 percent of total assets for the industry, $131 million of total assets can be estimated for the sample. By comparing the $131 million in total assets with the revenue estimate of $100 million, an asset turnover ratio of 0.76 is generated. The ratio for all firms generated by Robert Morris Associates (1) was 0.74, which shows that assets for the sample are reasonably representative of suggested norms and are of average size.

Another important consideration at this point is whether the industry is capable of raising its asset turnover to offset any possible decline in profit margin that could result from the industry's need to absorb part of any waterway user charge that might be levied. The largest-powered tow in the sample was 2610 kW (3500 hp); the most common size was 1342 kW (1800 hp). In all likelihood, the industry has already determined the most efficient power for their tows given the characteristics of the river systems on which they must operate. It is unlikely that the efficiencies that relate to larger tow sizes and speeds are available to the system. Thus, on the surface it appears that the industry will have difficulty improving utilization of assets or enhancing profit margins to offet user charges. This suggests that user charges levied on the industry will ultimately be passed on to the river-using firm. The extent to which they will be passed on to the consumer will depend on competitive conditions under which these firms sell in the national markets.

User Charge Effects

The obvious question at this stage is, What effect will all this have on the volume of commerce hauled on the Tennessee waterway system? If the towing industry does have difficulty finding new efficiencies to offset the user charge, the charge will be passed on to the waterway shipper. To the extent that cheaper transportation alternatives are available, the amount of traffic on the system will likely decline. Smaller firms will probably suffer most since they already operate with smaller margins and higher turnovers. Any reduction in traffic will reduce both turnover and margin and result in the increased possibility of early failure for these firms. Larger firms are probably in a better position to absorb the user charge because of the higher margins they currently enjoy.

Furthermore, reductions in market share could possibly remove some of the economies of scale associated with large-volume traffic movements. This will eventually affect larger firms in terms of profitability but, more important, it will have an adverse effect on their ability to service the large outstanding debt.

Industry Reaction

How will the waterway shippers react to any attempt by the towing industry to pass along user charges? Of course, conclusions here must be related to the proposed level of the user charge and the relative size of the current barge cost advantage compared with alternative shipping modes.

The operating characteristics of the towing industry are such that fuel represents about one-third of its operating costs. This means that about a 100 percent increase in fuel cost would result in approximately a 33 percent increase in waterway freight rates. These figures need to be viewed in the context of how the respondent reacted to the survey question about specified rate changes: If the implementation of a waterway user charge results in higher water freight rates, at what cost increase would you abandon waterway shipping entirely? Responses to this question are given in the table below (3):

Rate Increase (%)	Number Who Would Abandon Waterway Shipping
10	5
11-24	8
25-49	4
50-99	3
100-199	3
≥200	0
None of the above	9

It is apparent from these responses that the advantage of shipping by barge is not overwhelming for at least 13 of the respondents. Reasonably modest rate increases would result in their abandoning waterways altogether. The effect on the towing industry is obvious: It would suffer a loss in traffic volume. But it should be emphasized that a 10 percent rate increase is associated with a 30 percent increase in fuel prices. Chances are that a \$0.01/L (\$0.04/gal) tax would result in no firms abandoning the water mode since the rate increase would be in the neighborhood of 3.5 percent. As the tax rate was raised, the effects would be more pronounced. It is important that about one-third of the sample would abandon waterways when the tax on fuel reaches about \$0.066-\$0.069/L (\$0.25-\$0.26/gal). The latter amount would be associated with about a 75 percent increase in fuel prices.

In addition, a user charge may have a significant moderating influence on the cost of shipping some commodities. Because handling costs for some commodities are quite high, the line-haul cost to which the user charge would be applied represents only a portion of the costs that face the shipper. If the line-haul on a commodity costs approximately \$5.51/t (\$5/ton) and handling costs \$5.51/t, the total cost to the shipper is \$11.02/t (\$10/ton). However, when line-haul costs increase by 50 percent to \$8.27/t (\$7.50/ton), the total cost to the shipper increases to \$13.78/t (\$12.50/ton) or by 25 percent. To the extent that some efficiencies in handling can be realized in the future, part of the impact of a user charge may be offset. As previously noted, the towing industry already operates at a disadvantage in handling certain types of commodities whereas in the handling of others the marine mode is found to be cheaper. For those commodity groups for which shipping by water involves a handling disadvantage, handling costs considerably offset the line-haul cost advantage enjoyed by the towing industry, and this makes it more difficult for waterways to remain competitive in certain commodity areas. It thus appears that the impact of a user charge will not be felt evenly over all commodity areas in the industry.

The extent to which industrial firms currently depend on water for their incoming and outgoing shipments is another important consideration. In a survey sample of 32 firms that operate in Tennessee with access to water, 20 firms responded that water accounts for 56 percent of their incoming shipments and 15 firms responded that water accounts for about 40 percent of their outgoing shipments. As expected, water is more important for incoming shipments.

Firms in the sample were asked to estimate what percentage of incoming and outgoing freight they would ship by water given specified rate increases. Their responses are indicated in the table below:

Incoming Freight (%)	Rate Increase (%)	Outgoing Freight (%)
34	1-10	17
17	11-24	15
14	25-49	11
9	50-99	9
7	100-199	3
7	200+	2

At a 1 to 10 percent rate increase, the firms in the sample indicated that they would continue to ship about 34 percent of their incoming freight by water. The percentage abruptly drops, however, to 17 percent as the rates rise to the 11-24 percent category. Because of the nature of their operations, some firms would remain with the water mode even at very high rate increases. Although outgoing shipments do not lend themselves so readily to the water mode, rate increases appear to have a significant impact on the volume of shipments. These data suggest that the impact of a user tax on the water mode may be more severe than that indicated when one simply looks at the number of firms that would abandon the mode as a result of rate increases.

The locational characteristics of the firms surveyed also have some bearing on their willingness to change modes. Rail access is available to about 91 percent of the firms, whereas highway access is available to all. One other consideration is likely to result in more long-term consequences for industry in Tennessee. About 97 percent of the firms surveyed indicated that water transportation was an important factor in their decision to locate at their present site of operation. The apparent readiness of firms to change modes as a result of rate increases suggests that any advantages the water mode might have offered to some of these firms in the past will no longer exist. In time, some of these firms may relocate, but it is more important that the region will be less attractive to firms that are considering relocating in the Tennessee area for the first time.

One other important factor is the effect that transportation mode has on a firm's investment in inventory. The long shipping times involved in water transportation will tend to discourage the shipment of high-value items on the river systems. Twenty-three of the firms in the sample indicated that the method of transportation did influence their inventory investment; 15 of these firms indicated that water transportation results in higher average inventories. To the extent that this is a cost implicit in shipping by water, the line-haul cost advantage associated with large shipments is reduced to a degree that is related to the value of the cargo hauled and the time involved in shipping. Thus, for shipments of high-value commodities that are costly to handle, the line-haul cost advantage may be offset by higher handling cost and implicit inventory costs.

Cost-Recovery Alternatives

Although current legislation ensures a fuel tax as a means of collecting tax revenues, all likely forms of user charge alternatives were examined and are briefly reviewed here.

Fuel Tax

The consequences for Tennessee waterway operators of a fuel tax cost-recovery collection program can be seen in the data given below (1 L = 0.264 gal):

Measure	Mean	Standard Deviation
Price of fuel (¢/L)	9.67	0.54
Fuel cost ÷ operating cost (%)	31.2	13
Percentage increase in price of fuel resulting from tax of		
2.11 cents/L	21.9	1.3
6.34 cents/L	65.8	4.04
10.57 cents/L	109.5	6.37
Percentage increase in operating costs resulting from tax of		
2.11 cents/L	7.3	2.88
6.34 cents/L	22.3	8.7
10.57 cents/L	36.4	14.83

Based on the responses from towing firms, extrapolations were made to determine the effect of three fuel tax rates—2.11, 6.34, and 10.57 cents/L (8, 25, and 40 cents/gal)—on both fuel and operating costs. The estimates reflect no adjustment for possible fuel conservation measures. These data show that a 10.57 cents/L (40 cents/gal) fuel tax, or a 109.5 percent increase in fuel prices, would increase operating costs by an average of 36.4 percent, and a 2.11 cents/L (8 cents/gal) tax rate would increase operating costs by 7.3 percent. The significant point to note is that operating costs increase by about one-third the increase in fuel costs; the result is that towing firms are likely to increase shipping rates by the same amount if they can be passed on to the users of water transportation.

The relation between fuel costs and operating costs provides a meaningful basis on which to analyze how shippers are likely to react to any attempt by the towing industry to pass along these cost increases. In an attempt to measure the elasticity of demand by Tennessee industrial shippers, the survey responses of 32 shipping firms were analyzed:

Increase in Shipping Rate (%)	Number Who Would Abandon Waterway Shipping	Percentage of Sample	Elasticity of Demand
1-10	5	15.63	-10.00
11-24	8	25.00	-4.00
25-49	4	12.50	-2.00
50-99	3	9.38	-1.00
100-199	3	9.38	-0.50
≥ 200	0	0.00	-0.25

Nine shippers, or 28 percent of the sample, indicated that they would never abandon the water mode. Thirteen shippers, or 41 percent of the respondents, reported that they would shift from water transportation if waterway rates increased by 25 percent. Since a 10.57 cents/L (40 cents/gal) fuel tax is estimated to result in a 36 percent increase in operating costs, increases of this amount in shipping rates would result in sharp reductions in Tennessee's total waterway traffic. Shippers who can shift to other modes with relative ease will do so. The cost increases that will be borne by these firms will vary according to the current rate differential between the rail and truck modes and the towing industry, assuming that the rail and truck modes do not increase their present rate structure.

Segment-Specific Fuel Tax

Another possible form of user charge would be a fuel tax levied on a segment-specific basis although the necessary record-keeping and administrative costs would tend to discourage it. Cost recovery could be achieved with a segment-specific fuel tax of approximately 1 cent/L (4 cents/gal) on the lower Mississippi River, 6.9 cents/L (26 cents/gal) on the Tennessee River, and 21.1 cents/L (80 cents/gal) on the Cumberland River. Given recent fuel costs of 9.67 cents/L (36.6 cents/gal), this cost-recovery scheme on the Cumberland would result in more than a 200 percent increase in fuel costs and prohibitive increases in freight rates on that river. River transportation could not survive on the Cumberland.

Lockage Fees and Congestion Tolls

The philosophy behind the imposition of lockage fees is that the expenditure of federal funds for lock-and-dam maintenance and operations should be financed through the collection of fees from commercial tows and possibly recreational vessels. The major advantage of lockage fees is that the tax would be imposed on vessels at the moment of lockage, which would make possible service-specific user charges. It is argued that, if waterway users are not willing to pay the price necessary to cover the cost of waterway services, then the particular lock or dam, or perhaps the entire river segment, does not "meet the market test" and the facility should be closed.

In situations where dams and locks are constructed in advance of regional economic development, a dilemma arises for policy makers. Such development requires, at least in the beginning, freedom from any user charge program that would restrict the development and generation of river traffic.

From an economist's point of view, a lockage fee depends on determination of some market price for lockages, or an "optimal congestion toll". The calculation of such tolls for the Tennessee river systems can be demonstrated by using computerized data from the Corp of Engineers performance monitoring system. A series of 12 regression equations were estimated for nine locks on the Tennessee River and three locks on the Cumberland River. Delay time—the dependent variable—was regressed against seven independent variables. The results of these 12 regression equations provide insight into the present operations of locks and dams on the Tennessee and Cumberland Rivers. As expected, average delay time was found to vary greatly between the various locks:

River System	Lock	Average Delay Time (min)
Cumberland	Barkley	87.2
	Cheatham	8.4
	Old Hickory	6.8
Tennessee	Kentucky	316.6
	Pickwick	43.6
	Wilson	17.7
	Wheeler	8.4
	Guntersville	10.8
	Nickajack	10.8
	Chickamauga	11.9
	Watts Bar	9.1
	Fort Loudoun	17.3

It was possible to calculate the cost of delay per unit of congestion for each of the locks tested by extracting the coefficient for congestion from each fitted regression equation. This coefficient represents the delay time, in minutes, that is created for the last vessel in a queue by each preceding vessel. By using a figure of $200/h as the average cost of delay (3), the implicit cost of delay or the cost of congestion can then be determined for each unit of congestion.

Calculation of the congestion toll, based on the observed behavior of commercial vessels, produces a fee that represents the transformation of the implicit cost commercial tows are already experiencing under the present rationing mechanism into an explicit charge for priority lockage. Based on observed behavior, the basic congestion cost represents the "imputed value" that commercial operators place on lockages since such costs are currently incurred each time a vessel must wait to receive lockage services. These lockage tolls range from a high of $948.52 for an average toll for the Kentucky Lock to a low of $28.13 for the Old Hickory Lock (3). These average tolls for priority lockages on each dam would become the minimum lockage fee for all vessels. The revenue that could be generated from imposition of such a lockage fee depends on the mix of vessels that pay the basic fee and the priority-lockage surcharge.

To the extent that queuing represents the "revealed value" of lockages to commercial tows, the Tennessee River data imply that a large portion of federal costs for maintaining that river system could be recovered from a system of lockage fees, provided commercial tow operators were willing to pay such fees. This, of course, depends on the recognition by waterway operators that the cost of a lockage fee is, in fact, equal to the average cost of delay that they experience under current conditions. Recovery of operating and maintenance costs for the Cumberland River is more doubtful under such a revenue-raising scheme. Congestion costs on the Cumberland are low because total river traffic, both commercial and recreational, is relatively light.

Segment Toll

The segment toll calls for a fee per ton kilometer of commercial traffic, the toll being set for each river segment to recover the cost of that segment. Proposed segment tolls for the three river systems of interest to Tennessee (4) are given below (1 t·km = 0.685 ton-mile):

River System	Estimated Segment Toll (mills/t·km)	Resulting Increase in Operating Costs (%)
Lower Mississippi	3.7	4.0
Tennessee	17.4	28.5
Cumberland	38.3	81.0

A segment toll would be similar in cost impact to a differential fuel tax of 1.6 cents/L (6 cents/gal) on the lower Mississippi, 6.9 cents/L (26 cents/gal) on the Tennessee, and 21.1 cents/L (80 cents/gal) on the Cumberland. Administration of the segment toll, which would require constant monitoring of all traffic movements over specific segments of a given waterway, may be complicated and expensive. Specific problems are related to the disposition of empty tows, congestion problems, high-bulk items of low value and heavy weight, and lightly used waterways. Such tolls would likely be resisted as inefficient, inequitable, and potentially fatal to some commerce on Tennessee rivers, especially the Cumberland.

License Fee

The license-fee proposal calls for license fees to be levied on the basis of power capability for towboats and tonnage capacity for barges. One proposal calls for a tax rate of $24.67/rated kW ($18.41/hp) for towboats and $3.45/t ($3.13/ton) of capacity for barges. If levied in such a manner, the fee actually amounts to a capital tax of quite high proportion on capital equipment over its productive life. As a result, producers or shippers may attempt to substitute less expensive and lower-cost tows or barges, which may result in a loss of some economies of scale and increases in shipping costs, terminal costs, and shipping times.

It is quite possible that license fees could be levied for specific river systems. Based on a figure of 385 commercial vessels operating on the Tennessee River in 1976, a license fee of $9960/vessel would have been necessary to fully fund the Tennessee River segment. Based on a figure of only 194 vessels operating on the Cumberland River, a license fee of $19 766 would be necessary for commercial operators on that system. Because of an overlap of 105 vessels on the two rivers, a decision might be made to treat the two rivers as one system and set a license fee of $15 413/vessel to apply to both systems based on system costs. In general, the inefficiencies and delays encouraged by such a program would tend to make the licensing option an unattractive method for financing waterway costs and improvements.

OTHER ECONOMIC CONSIDERATIONS

Summary of Impact of User Charge Alternatives

Prediction of the ultimate impact of waterway user charges on the Tennessee economy depends on which form and what level of user charge are imposed.

The fuel tax appears to be the more popular alternative, but it is likely to face some difficulties if levied at a level high enough to recover all costs for monitoring and operating the river systems. For example, when taxes reach a level at which operating costs increase by about 25 percent, a substantial number of shippers will abandon the waterway system in the short run and may eventually relocate in the long run. This carries obvious implications for employment and ex-

Table 2. Likely economic impact of selected waterway user charges on the Tennessee river system.

User Charge Alternative	Increase in Operating Costs (%)	Increase in Shipping Rates (%)	Decrease in Waterway Tonnage (%)
Systemwide fuel tax			
1 cent/L	3.70	3.30	5.16
2.11 cents/L	7.30	6.60	10.32
6.34 cents/L	22.30	20.10	32.46
26 cents/L	36.40	32.80	44.53
Segment-specific fuel tax			
Tennessee River (6.9 cents/L)	23.70	21.33	34.51
Cumberland River (21.1 cents/L)	72.90	65.60	56.06
Mississippi River (1.6 cents/L)	5.50	5.00	7.82
Lockage fee (all vessels paying)			
Tennessee River	6.80	6.10	9.53
Cumberland River	28.00	25.20	40.73
Lockage fee (recreational vessels exempt)			
Tennessee River	28.00	25.20	40.73
Cumberland River	63.00	56.70	54.39
Segment toll			
Tennessee River	28.50	25.70	40.98
Cumberland River	81.00	72.90	57.43
Mississippi River	4.00	3.60	5.63

Note: 1 L = 0.264 gal.

penditures on new plant and equipment.

Although a lockage fee may reduce congestion on the Tennessee River and thus reduce commercial delay times, it would fall far short of collecting most operation and maintenance costs on the Cumberland River. Because these toll levels must be so high on some river systems to recover costs, not much confidence can be placed in the effectiveness of a lockage toll.

Under the segment-toll option, a user charge would increase operating costs on the Cumberland River by 81 percent and require about a 72.9 percent increase in shipping rates. Alternatively, a segment-specific fuel tax set at a level necessary to recover operation and maintenance costs would increase operating costs by 72.9 percent and increase shipping rates by about 65.5 percent. Setting the fee at a level necessary to recover all federal expenditures would probably result in the large-scale abandonment of the Cumberland River by commercial operators.

Table 2 (4) gives the best estimate (in light of the problems of adequate data accessibility) of the likely impact of each user charge option on waterway shipping on Tennessee rivers. The smallest impact occurs with a 1 cent/L (4 cents/gal) fuel tax; the segment toll represents the greater impact in terms of towing-industry operating costs, increases in shipping rates, and potential loss in the volume of state waterway traffic.

Impact on Employment

The severity of the impact of a user charge for the various waterway systems in Tennessee depends on both the method of collection that is ultimately selected and the ultimate level of cost revovery. In 1973, it was estimated that 65 273 jobs were associated with river-related industry (5). This figure may be converted into approximately 6019 direct and indirect jobs on the Mississippi River, 45 242 jobs on the Tennessee, and 14 013 jobs on the Cumberland.

If economic feasibility is considered and it is assumed that percentage decreases in direct employment have some relation to percentage reductions in waterway shipping, the worst impact on employment would result from the implementation of a segment toll. In contrast, the imposition of the least-impact alternative—the 1 cent/L (4 cents/gal) fuel tax—would result in the smallest decreases in employment.

Indirect employment, or the employment provided by industrial firms that have located in Tennessee as a result of the state's river systems, must also be considered. Loss of employment in these industries will, however, be mitigated by the ability of industrial shippers to switch to other modes of transport. Although the effects of user charges may influence the future expansion or relocation decisions of these firms, it is unlikely that the disappearance of these jobs will occur over the short run given the sunken capital investments of river-related industry. Job losses will likely be a longer-term proposition. It is difficult to measure accurately the potential long-term loss of industry plant locations completely new to the state, given the many uncertainties of industry relocation decisions.

Information is available from Tennessee Valley Authority sources regarding the amount of capital investment in industrial plants along the Tennessee River over the past 20 years or so. The data suggest that these outlays have been growing at approximately a 9 percent compound rate annually. Given these past trends, estimates for future expenditures can be arrived at, assuming no waterway user charge. It is significant, however, that 96.9 percent of the survey respondents indicated that the waterways were important to their decision to locate in the Tennessee area. The estimated loss of such capital investments could be determined for each possible level of a fuel tax by using the amount of decrease in waterway traffic volume as a proxy for the possible loss in new plant expenditures and expansions. The expenditure losses could then be converted to employment losses based on ratios of capital to labor. Depending on the rate levels imposed, employment-related consequences for the state can be described as ranging from moderate to devastating, especially when one considers that these estimates do not include the possible job losses on the other two river systems or the secondary effects that would ultimately be felt throughout the state's economy. When the possible loss of existing jobs is considered, the implications for Tennessee become even more critical.

SOCIAL IMPLICATIONS

The ultimate objective of a waterway user charge is to shift the burden of navigational improvements from general tax revenues, or the taxpayer in general, to the direct users of navigable rivers. The implicit consequence for the public would be a change of roles in the financial support for waterway projects; that is, the citizen would benefit as a taxpayer by getting some relief from the pressures of an expanding tax liability but would ultimately face higher prices for certain consumer goods.

The user charge program will probably distribute the costs of navigational improvements among a larger number of citizens, thereby reducing the relative cost share of some individuals, particularly middle-income persons. But identifying the specific individuals who are to be added to the rolls of those who financially support navigational improvements may cause some uneasiness, especially among policy makers.

Only Congress can decide on the desirability of such a redistribution of the financial burden. However, because not enough is known about the complex interactions that could be initiated by implementation of a user charge program or about the final outcome, it would be sensible to phase in any cost-recovery scheme gradually and thus allow for cautious monitoring and analysis of both positive and negative impacts.

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