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.

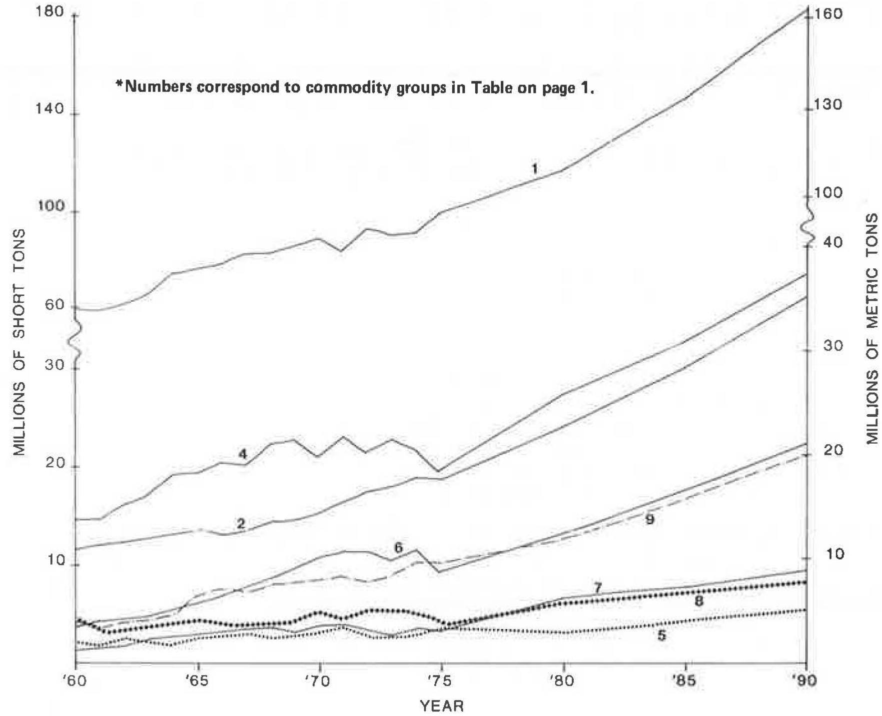
3. Independent projections of waterway traffic by commodity group and direction of movement (upbound-downbound) were also generated for the main stem of the Ohio River and each navigable tributary in an attempt to identify the degree of association between the behavior of the total system and its components. 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.



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).

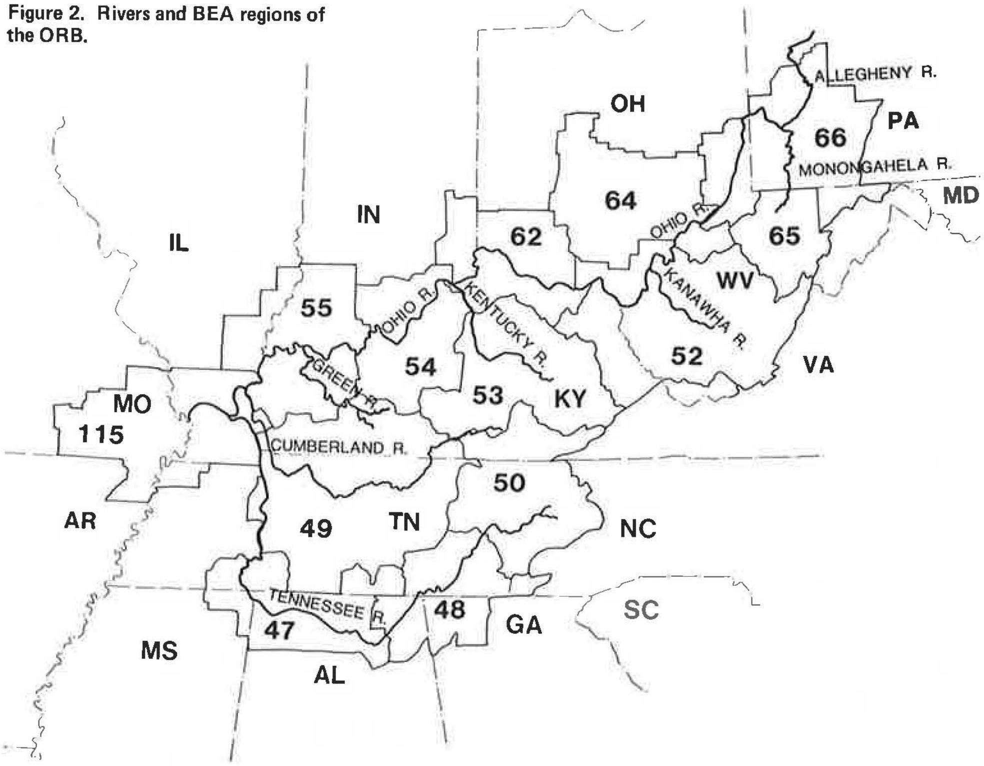
After aggregation, a severe decrease in crude petroleum shipments for the system as a whole was discovered. This decrease was found to correspond with the opening of a pipeline for the transport of crude petroleum. Regression procedures were therefore abandoned for this commodity group in favor of other 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):

$$\Delta O_i^{gt} = R_i^{gt} + S_i^{gt} + U_i^{gt} \quad (1)$$

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:

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

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

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

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

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

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 ($\hat{Q}^{gt}$) ($\hat{}$ 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 $O_i^{g(t-1)}$ to arrive at a future originating total $\hat{O}_i^{gt}$:

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

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:

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

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

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:

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

where

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

$$= \text{destination j (column) growth factor,}$$

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

$$= \text{origin i (row) growth factor, and}$$

$\hat{D}_j^{gt}, \hat{O}_i^{gt}$ = 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) 1980	1986	1990	1990 Change Versus Three-Year Avg (%)
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.

REFERENCES

1. Waterborne Commerce of the United States: Part 2—Waterways and Harbors, Gulf Coast, Mississippi River System and Antilles. U.S. Army Corps of Engineers, 1976.
2. Projecting the Demand for Ohio River Basin Waterway Traffic Using Correlation and Regression. Huntington District, U.S. Army Corps of Engineers, Huntington, WV, 1979.
3. Series E OBERS Projections. Bureau of Economic Analysis, U.S. Department of Commerce, 1972.
4. N. H. Nie, C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. Statistical Package for the Social Sciences. McGraw-Hill, New York, 2nd Ed., 1975.
5. E. S. Dunn, Jr. A Statistical and Analytical Technique for Regional Analysis. Papers, Regional Science Assn., Vol. 6, 1960, pp. 97-112.
6. B. G. Hutchinson. Principles of Urban Transport Systems Planning. Scripta Book Co., Washington, DC, 1974, pp. 84-85.
7. Computer Programs for Urban Transportation Planning: PLANPAC/BACKPAC—General Information. Federal Highway Administration, U.S. Department of Transportation, April 1977.

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