tion with the econometric and demographic forecasts. An analysis of the potential impact of other transportation systems on projected commerce flows will reveal the extent to which external factors may constrain projected growth; these may include characteristics of locks and dams, channels, railroads, highways, and vessels. Estimates of cargo-handling capacity by commodity (e.g., bulk and general cargo) for the study areas should be completed. Study area benefits should be estimated based on commodity and econometric projections.

Requirements

The requirements phase includes estimates of cargo-handling requirements; these are translated into terminal types, land areas, waterfront development costs, and hinterland transportation needs. The impact of projected water-port development actions on recreational, conservation, and other adjacent land uses should be assessed. Based on projected needs, and on the assessment of impacts and estimated economic benefits, alternative institutional mechanisms for carrying out waterfront development programs (including the status quo) should be postulated and evaluated.

Formulation

The formulation of the state water-port master plan requires the following elements:

1. A schedule for port development, including equipment acquisition, land development, facility construction, renovation, or abandonment;
2. A definition of the primary hinterland by cargo type for each port in the study area (for example, general cargo handling may be encouraged at a single port to increase frequency of service, or it may be dispersed to serve local markets, and bulk cargo terminals might be encouraged to locate along a particular river reach and at a particular rail line or highway to facilitate efficient use of transportation facilities);
3. An allocation of waters and waterfront lands for port development, fleeting, conservation, recreational, and other uses, to be undertaken in concert with the CZM plan, if appropriate; and
4. A definition of responsibilities of various agencies for implementing the plan and identification of means of implementation (e.g., development rights and zoning laws, eminent domain, permitting requirements, tax incentives, and funding mechanisms).

CONCLUSIONS

An enlarged state role in water-port development is practical and should be undertaken in coordination with local interests. There is ample precedent for this working partnership, a relationship that can effectively address the financial problems facing the nation's ports.

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Statistically Based Methods for Efficient Sampling of Inland Waterway Freight Charges

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Preliminary results of work on the estimation of freight charges for commodity movements in the Ohio River Basin are presented. The U.S. Army Corps of Engineers had rate quotations on 875 of the approximately 12 000 movements in the basin and funds to obtain an additional 325. Consad Research Corporation was engaged to apply statistically based analysis to specify the sample that would give the most accurate estimate of freight rates for the given sample size. The traffic universe and original rate quotations were stratified by commodities and annual tonnage. There were 18 commodity strata, each of which was broken down into 3 volume substrata. The original rate quotations were used to calculate the sample size required for each of the 54 cells at several levels of sampling error and confidence intervals. This indicated the additional points needed. These points were also apportioned among the strata on the basis of freight charges to achieve efficiency in estimating total system charges. Points were also allocated among the three cells of each stratum for purposes of statistical reliability. The resulting sampling plan had a projected error of 5-39 percent for each stratum and an error of 12.9 percent for the system as a whole. Mathematical relations were also derived and applied to estimate freight rates for water and alternative overland movements. The methods used should result in greater reliability in the estimation of freight charges.

One aspect of the evaluation of navigation improvements on the inland waterways system by the U.S. Army Corps of Engineers is benefit-cost analysis. A major component of the benefit side of any such calculation is the difference between the freight charges borne by shippers and receivers who use the waterway mode and freight charges for alternative transportation modes. Such calculations involve estimating freight rates by the waterway mode and by alternative modes of freight transportation. Corps of Engineers planners have developed estimates for many studies, but most of these studies have dealt with a single navigation project. In order to evaluate projects within the context of the systems of which they are a part, there is a need to apply system-analysis methods.

This need has been clearly recognized by the

Table 1. Consad commodity stratification.

Consad Commodity Stratum	Corps of Engineers Commodity Group	Commodity	Rate ($/ton-mile) Amount	Mean	SD
1	1	Coal and lignite	0.021	0.0215	0.0375
2	2	Gasoline	0.008	0.0099	0.0126
	2	Kerosene	0.010		
	2	Distillate fuel oil	0.011		
3	2	Jet fuel	0.006	0.0064	0.0020
	2	Residual fuel oil	0.006		
	2	Liquified gases	0.005		
	9	Lubricating oils and greases	0.006		
	9	Naptha, mineral spirits, solvents	0.006		
	6	Crude products from petroleum	0.007		
	1	Coke, including petroleum coke	0.006		
4	3	Crude petroleum	0.0046	0.0046	0.0008
5	4	Sand, gravel, crushed rocks	0.0137	0.0137	0.0351
6	9	Structural clay products	0.007	0.0082	0.0097
	6	Synthetic rubber	0.010		
	6	Alcohols	0.008		
	6	Benzene and toluene	0.006		
	6	Sulfuric acid	0.009		
	6	Basic chemicals and products	0.008		
	9	Asphalt, tars, and pitches	0.008		
	9	Petroleum and coal products	0.009		
7	6	Gum and wood chemicals	0.005	0.0045	0.0006
	6	Nitrogenous chemical fertilizer	0.005		
	6	Fertilizers and fertilizer material	0.004		
	6	Potassic chemical fertilizers	–		
	6	Phosphatic chemical fertilizers	–		
8	7	Bauxite ore and concentrates	0.004	0.0043	0.0016
	7	Manganese ore and concentrates	0.005		
	7	Nonferrous metal ores and concentrates	0.003		
	8	Iron ore and concentrates	0.003		
	4	Limestone flux and calcareous stone	0.005		
	7	Clay ceramic and refractory materials	0.004		
	7	Salt	0.004		
	7	Liquid sulfur	0.005		
	7	Nonmetallic minerals	0.005		
	9	Lime	0.005		
	9	Slag	0.005		
	7	Copper ore and concentrates	–		
	9	Phosphate rock	–		
9	8	Pig iron	0.007	0.0084	0.0048
	8	Iron and steel ingots	0.008		
	8	Iron and steel pipe and tube	0.009		
	9	Copper and copper alloys	0.008		
9	8	Iron and steel scrap	0.008	0.0084	0.004 8
10	9	Wheat flour and semolina	0.006	0.0051	0.001 2
	9	Tallow, animal fats, and oils	0.004		
	9	Grain mill products	0.007		
	9	Sugar	0.003		
	9	Molasses	0.005		
	9	Prepared animal feeds	–		
	9	Alcoholic beverages	–		
	9	Vegetable oils	–		
11	9	Motor vehicles, parts, and equipment	0.014	0.013	0.001 3
	9	Electrical machinery	0.012		
12	8	Primary iron and steel products	0.013	0.012	0.005 1
	9	Aluminum and aluminum alloys	0.011		
	9	Nonferrous metals	0.010		
13	9	Lead and zinc	0.005	0.0057	0.002 3
	8	Ferro alloys	0.006		
14	9	Pulp	0.005	0.0049	0.000 53
	9	Paper and paper board	0.004		
	9	Basic textile products	–		
	9	Logs	–		
	9	Pulpwood log	–		
	9	Lumber	–		
	9	Standard newsprint paper	–		
15	8	Iron and steel bars	0.024	0.0242	0.071 7
	8	Iron and steel plates and sheets	0.018		
	9	Machinery	0.026		
	9	Fabricated metal products	0.049		
16	9	Building cement	0.016	0.0218	0.031 6
	9	Miscellaneous nonmetallic minerals products	0.017		
	6	Miscellaneous chemical products	0.017		
	6	Sodium hydroxide	0.027		
	9	Rubber and miscellaneous plastic products	–		
	9	Miscellaneous manufacturing products	–		
17	9	Materials used in waterway improvement	0.008	0.0076	0.002 9
	9	Miscellaneous shipments not identified	0.008		
	9	Waste and scrap not elsewhere identified	0.007		
	9	Miscellaneous transportation equipment	0.007		
	9	Ships and boats	–		
	9	Nonferrous metal scrap	–		
18	5	Barley and rye	–	NA	NA
	5	Corn	–		
	5	Oats	–		
	5	Sorghum grains	–		
	5	Wheat	–		
	5	Soybeans	–		
	9	Hay and fodder	–		

Note: SD = standard deviation.

planning staff of the Huntington, West Virginia, District of the Corps of Engineers in its project planning for replacement of the Gallipolis Locks and Dam on the Ohio River. The Huntington District engaged Consad Research Corporation to assist in estimating freight rates for the water mode and alternative modes.

Specifically, the problem is as follows. In 1976, there were 11 747 specific moves of commodities (according to the four-digit Waterborne Commerce Statistical Center code, a commodity classification scheme for waterborne traffic similar to the Standard Transportation Commodity Classification) that involved the port equivalents in the Ohio River Basin [a "port equivalent" (as defined in the Inland Navigation Systems Analysis program of the Corps of Engineers as an aid in water simulation projects) refers to a stretch of river that has a composite of port characteristics]. The Ohio River Basin consists of the main-stem Ohio River and the Allegheny, Monongahela, Kanawha, Kentucky, Green, Tennessee, Clinch, and Cumberland Rivers. Each move may be represented by a cell in an origin-destination (O-D) matrix. The values in the matrix cells represent the annual tonnage of particular commodities moving between the port equivalents. In 1976, these values ranged from more than 1.35 million tons to as few as 250 tons. O-D matrices of these data were available in computerized form.

The Corps of Engineers obtains rate estimates by engaging knowledgeable traffic-management contractors to provide rate quotations on specific dock-to-dock moves for water transportation, any land leg of a water move, alternative overland means of transportation, and various loading and unloading charges. Several such rate studies have been performed for the Corps of Engineers over the past several years for particular project planning efforts. Those studies provided usable rate quotations for 875 of the 11 747 moves in the Ohio River Basin. Quotations for an additional 274 movements in the upstream portion of the basin were in the process of being developed. The Corps of Engineers planning budget permitted an additional 325 quotations, which would provide an overall coverage of about 12 percent. All of the available rate quotations and those to be obtained were in computerized form, consistent with the traffic data.

The task at hand was to develop a sampling plan for collecting the additional 325 quotations, which would provide the highest degree of statistical reliability in rate estimates.

The study plan then called for the traffic-management contractor to obtain the additional quotations as specified in Consad's sampling plan. Then, by using the total of 1500 rate quotations and the characteristics of the moves rated, Consad developed relations to synthesize the 88 percent of the moves for which rate quotations were not available. Finally, by using both the rate quotations and the synthetic relations, matrices were constructed for waterway rates and rates for alternative modes.

TECHNICAL APPROACH

The system under study lends itself quite well to the application of statistical principles for the selection of additional sample points. Thus, the first step was to stratify the traffic data so as to group moves for sampling. The existing 875 rate samples provided the opportunity to investigate the rate levels and variation in rates that would indicate sampling rates. Therefore, it was important in this first phase of the effort that both the traffic universe and the existing rate sample be stratified by the same factors.

From a knowledge of transportation economic principles and industry practices in rate setting, it was postulated that the factors at work, and thus the stratification of interest, included the following: commodity, distance, annual tonnage, river direction, and number of lockages. However, because both files (existing rate quotations and traffic movements) did not provide usable information on distance, river direction, and number of lockages, these factors were dropped. The files were stratified by commodity and annual tonnage.

The Ohio River Division of the Corps of Engineers uses a commodity stratification that consists of the nine groups given below:

Commodity Group	Rate ($/ton-mile)	
	Mean	SD
Coal and coke	0.021	0.037
Petroleum fuels	0.0087	0.0105
Crude petroleum	0.0046	0.0008
Aggregates	0.0135	0.0346
Grains	-	-
Chemical and chemical fertilizers	0.0094	0.0150
Ores and minerals	0.0043	0.0017
Iron ore and steel	0.0136	0.0461
All other	0.0122	0.0353
Total	0.0127	0.0304

Consad initially grouped the rate sample in this way and analyzed the values for rate per ton-mile for the four-digit commodities within each group. By inspection and statistical analysis, it was found that rate per ton-mile showed considerable variation within the groups. The table above gives the means and standard deviations found for the nine groups. Comparison of within-group variances with between-group variances indicated that there might be a better grouping of the sample. In regrouping the data, we looked for a grouping in which the variance within strata was reduced and the variance between strata was increased. Through inspection and application of analysis of variance, the data were restratified into the 18 commodity strata given in Table 1.

The next step was to substratify by annual volume. In this case, we relied largely on judgment and chose three cells, each of which includes moves that constitute approximately one-third of the tonnage in each stratum. This required that the movements in each stratum be rank ordered by annual tonnage and then accumulated so as to split the tonnage into thirds. The first cell includes the largest moves in the stratum and the third the smallest. The substratification of the traffic universe is indicated in the table below, which gives the number of moves in each cell:

Stratum	Number of Moves by Annual Volume			
	Top Third	Middle Third	Bottom Third	Total
1	25	80	1339	1444
2	34	118	1000	1152
3	26	120	691	837
4	4	9	32	45
5	20	80	1070	1170
6	21	106	973	1100
7	19	83	198	300
8	10	82	706	798
9	57	195	439	691
10	13	71	284	368
11	2	4	36	42
12	2	14	66	82
13	6	50	184	240
14	1	2	37	40
15	103	360	1122	1585
16	8	19	191	218
17	7	27	240	274
18	56	245	1060	1361

It should be noted that, as a whole, small moves (the bottom third of the tonnage in each stratum) make up 82 percent of the movements in the universe of traffic.

The next step was to determine the appropriate sample size for each of the 54 cells. Once again, statistical principles were applied and all available information was used in sample design. This was accomplished by stratifying the existing

Table 2. Required sample size by cell.

Stratum	Cell	Points in Sample	10 Percent Error: Required Number of Samples	10 Percent Error: Additional Points	20 Percent Error: Required Number of Samples	20 Percent Error: Additional Points
1	1	8	25	17	23	15
	2	24	71	47	52	28
	3	143	519	376	183	40
2	1	15	33	18	31	16
	2	33	54	21	21	–
	3	57	101	44	28	–
3	1	15	14	–	6	–
	2	34	22	–	7	–
	3	43	26	–	7	–
4	1	0	3	3	2	2
	2	2	1	–	1	–
	3	3	2	–	1	–
5	1	4	12	8	5	1
	2	22	30	8	11	–
	3	69	719	650	362	293
6	1	12	7	–	2	–
	2	54	90	36	62	8
	3	81	211	130	63	–
7	1	1	5	4	2	1
	2	3	3	–	1	–
	3	1	7	6	2	1
8	1	11	7	–	4	–
	2	27	14	–	4	–
	3	34	47	13	13	–
9	1	12	7	–	2	–
	2	9	8	–	2	–
	3	23	89	66	27	4
10	1	1	6	5	3	2
	2	0	13	13	4	4
	3	5	15	10	4	–
11	1	0	2	2	1	1
	2	0	2	2	1	1
	3	2	3	1	1	–
12	1	0	2	2	2	2
	2	0	11	11	7	7
	3	4	29	25	11	7
13	1	3	1	–	1	–
	2	4	32	28	16	12
	3	12	32	20	10	–
14	1	0	1	1	1	1
	2	0	2	2	1	1
	3	3	3	–	1	–
15	1	14	19	5	6	–
	2	16	20	4	6	–
	3	40	690	650	320	280
16	1	4	8	4	7	3
	2	5	19	14	18	13
	3	11	41	30	12	1
17	1	0	6	6	5	5
	2	0	16	16	8	8
	3	9	33	24	10	1
Total		873	3133	2322	1380	758

rate sample in the same pattern as the traffic universe and calculating variances in rate per ton-mile within each cell. Then, the sample size was determined for each cell, assuming error levels of 10 and 20 percent and 67, 90, and 95 percent confidence intervals by using the following relationship:

$$n_i = N_i(S_i^2 Z^2)/(N_i e_i^2 + S_i^2 Z^2) \quad (1)$$

where

n_i = number of movements to be sampled for cell i,
N_i = number of movements in the universe in cell i,
S_i^2 = estimated variance of rate per ton-mile for cell i,
e_i = acceptable error in the estimate of rate per ton-mile for cell i (the error is a fixed percentage of the rate, such as 10 or 20 percent), and
Z = normal distribution statistic that specifies a specific level of confidence (Z = 1.645 for a 90 percent confidence level).

Table 2 gives the sample size required for a 90 percent confidence level. To achieve a 10 percent error in all cells would require a total of 3133 rate samples, which amounts to 2322 additional sample points. Even a 20 percent error level would require 758 additional points (planning funds were available for 325 points).

The next step was to search for a decision rule by which to allocate the 325 new sample points to the 54 cells. It is important to note that there is wide variation among the strata in the amount of traffic included within each cell. Data given in

Table 3. Tonnage and freight charges by stratum.

Stratum	Annual Volume (millions of tons)	Percentage of Tonnage	Annual Freight Charges: Millions of Dollars	Annual Freight Charges: Percent
1	102.990	57.8	199.799	40.7
2	14.832	8.3	72.888	14.8
3	6.836	3.8	46.590	9.5
4	0.883	0.5	4.213	0.8
5	19.899	11.2	32.436	6.6
6	8.587	4.8	37.355	7.6
7	1.058	0.6	9.798	2.0
8	6.203	3.5	33.592	6.8
9	1.197	0.7	9.216	1.9
10	1.222	0.7	7.811	1.6
11	0.028	0.01	0.422	0.09
12	0.159	0.09	1.470	0.3
13	0.627	0.3	4.919	1.0
14	0.512	0.3	3.497	0.7
15	1.949	1.1	15.266	3.1
16	1.817	1.0	5.256	1.1
17	3.907	2.2	6.133	1.2
18	5.384	3.0	–[a]	–[a]
Total	178.090		490.661	

[a]Not included in total.

Table 4. Points indicated and justified by stratum.

Stratum	Points Required for 90 Percent Confidence and Error of 10 Percent	Points Required for 90 Percent Confidence and Error of 20 Percent	Points in Existing Sample	Additional Points Indicated: 10 Percent	Additional Points Indicated: 20 Percent	Additional Points Justified
1	615	258	175	440	83	128
2	188	80	105	83	–	47
3	62	20	92	–	–	30
4	6	4	5	1	–	3
5	761	378	95	666	283	21
6	308	127	147	161	–	24
7	15	5	5	10	–	6
8	68	21	72	–	–	22
9	104	31	44	60	–	6
10	34	11	6	28	5	5
11	7	3	2	5	1	0
12	42	20	4	38	16	1
13	65	27	19	46	8	3
14	6	3	3	3	–	2
15	729	332	70	659	262	10
16	68	37	20	48	17	3
17	55	23	9	46	14	4
18	–	–	0	–	–	10
Total	3133	1380	873	2294	689	325

Table 3 show that stratum 1 (coal and lignite) includes 103 million tons (58 percent of the total tonnage) whereas the smallest stratum, stratum 11 (motor vehicles, parts, and equipment and electrical machinery) contains only 28 000 tons. Thus, a 10 percent error in stratum 1 is much more critical to the overall effort than such an error in stratum 11. Further consideration of the objectives of the study focused on the factor of concern in the benefit-cost analysis, which is not tonnage but freight charges. The transportation benefits used in the benefit-cost analysis are actually the difference in system total freight charges for transportation by waterway and transportation by alternative overland modes.

By using the mean rates from the rate sample and the total system tonnages from the traffic file, the estimated freight charges attributed to each stratum were calculated. As the data in Table 3 show, although the first stratum (coal and lignite) represents 58 percent of the tonnage, it accounts for only 41 percent of the system freight charges. Conversely, stratum 2 (gasoline, kerosene, and distillate fuel oil) represents only 8.3 percent of the tonnage but, mostly because of length of haul, accounts for 14.8 percent of the system freight charges.

Freight charges provide the rule for apportioning the additional sample points. That is, the 325 points should be selected from among the strata in proportion to each stratum's percentage of freight charges in the traffic universe.

Since there were no rate quotations available for stratum 18 (grain), its points were selected on the basis of tonnage (3 percent), and 10 points were chosen for that stratum. The remaining 315 points were allocated in proportion to freight charges.

Table 4 gives the indicated sample points for each stratum. It shows large discrepancies in some strata (e.g., 1, 5, and 15) between the number of points required to attain 10 percent error and the number of points that can be justified on the basis of planning efficiency. It should be noted that many of the points indicated actually fall within the third cell of each stratum, in which there are very large numbers of movements.

The justified points must also be allocated to the three cells in each stratum. It was reasoned that, because of the smaller number of moves in the first cell of each stratum, a rate quotation from that cell will always be more valuable in the sense of added statistical reliability than one from the second or third cell. In the same way, it will be more effective to select a point from the second than from the third cell of any stratum. Therefore, it was decided that in each stratum the allocated points will be assigned to cells 1, 2, and 3, respectively, to the level justified by a 10 percent error and a 90 percent confidence level.

The 325 additional points were thus assigned to each cell. For the 18 strata, the first cell was always assigned sufficient points to yield a projected 10 percent error.

PERFORMANCE OF THE SAMPLING PLAN

The performance of the sampling plan can be projected by assuming that the means and standard deviations of the ultimate rate sample are the same as those of the initial rate sample. The table below gives the projected percentage and dollar-valued error in freight charges by stratum:

Stratum	Projected Error at 90 Percent Confidence: Percentage of Rate	Projected Error at 90 Percent Confidence: Freight Charges ($000 000s)
1	12.8	25.587
2	10.9	7.967
3	7.9	3.680
4	5.3	0.223
5	24.1	7.841
6	12.9	4.815
7	10.4	1.018
8	5.0	1.707
9	11.6	1.068
10	15.4	1.214
11	10.5	0.044
12	39.0	0.574
13	17.2	0.847
14	10.7	0.375
15	29.1	4.437
16	14.2	0.745
17	18.7	1.147
18	-	-
Total	12.9	63.289

These data indicate that there is substantial variation in error among the strata. Yet this is a near-optimal situation for allocation of the 325 sample points from the viewpoint of minimizing error in estimates of freight charges for the system as a whole.

Based on these data, it can be projected that, with an additional 325 sample points, system total freight charges can be estimated with 90 percent confidence to within 12.9 percent of the actual value.

SAMPLE SELECTION

The final step in the sampling plan was to select the actual commodity-origin-destination movements to receive rate quotations. This involved random ordering of the movements in each of the 54 cells and selection from that list. Sufficient moves were selected in each cell to allow replacement of any moves on which quotations could not be obtained. The Corps of Engineers then requested that the traffic-management contractor develop rate quotations specified by origin-destination-commodity in the Consad sampling plan.

SYNTHESIS OF RATE ESTIMATES

In addition to selecting the supplemental rate sample, Consad was charged with developing estimates of rates for the 90 percent of the movements for which rate quotations were not available. Although this work is still being done and has not received Corps of Engineers review, preliminary results can be presented here as work in progress.

The Consad approach to this task has been to apply multiple regression analysis to movements in the rate sample in order to develop relations between unit barge rates as dependent variables and a series of independent variables. A total of 1502 rate samples were available for use. These included the 875 previously analyzed during supplemental sample selection, 274 additional samples subsequently obtained from upper-basin studies, the 325 samples selected by Consad, and additional grain samples drawn by the Corps of Engineers. The unit barge rates were expressed as both rate per ton and rate per ton-mile. The independent variables considered were mileage (rate per ton only), annual tonnage, and three variables that reflect the effort involved in moving traffic between two points on the inland waterway system (changes of elevation between the two pools, river direction in terms of

Table 5. Results of regression analysis by stratum for waterway rate per ton.

Commodity Stratum	Number of Sample Points	Percentage of Total Tonnage	Significant Variables at 95 Percent Confidence	R^2
1	389	58.1	Mileage	0.93
2	87	2.9	Mileage	0.73
3	239	9.0	Mileage, annual tonnage	0.96
4	6	0.5	Annual tonnage, mileage	0.96
5	161	12.5	Mileage	0.90
6	100	2.3	Mileage, number of lockages	0.97
7	103	3.0	Mileage	0.84
8	24	0.6	Mileage	0.74
9	95	2.7	Mileage, annual tonnage	0.54
10	33	0.4	Mileage	0.75
11	50	0.6	Mileage	0.59
12	99	1.1	Mileage, river direction	0.17
13	6	0.02	Mileage, number of lockages	0.98
14	18	0.1	River direction	0.32
15	6	0.3	Mileage	0.75
16	26	0.7	Mileage	0.68
17	9	2.1	Mileage, elevation	0.68
18	51	3.0	Mileage	0.72

percentage of the move that is upriver, and the number of lockages between origin and destination).

It can be postulated that there are other factors that affect barge rates or reflect variation in such rates. However, a necessary condition in this analysis was that the independent variables be available in both the rate analysis and the traffic universe. After some data development and coding, all five variables mentioned above met that condition.

Regression analysis was applied to the points in the rate sample as broken down into the 18 strata. In most cases, the results for rate per ton were quite good. As the data given in Table 5 indicate, the R^2 values for the major commodity strata are high. In fact, the 8 strata with R^2 values in excess of 90 percent account for more than 87 percent of the tonnage and more than 70 percent of freight charges. More than 94 percent of the tonnage (which accounts for more than 90 percent of the freight charges) is in strata with R^2 values greater than 75 percent.

An analysis in which rate per ton-mile was used as the dependent variable was much less successful and was not carried further.

The chosen regression relations for rate per ton-mile for the top five commodity strata (1, 3, 5, 7, and 18) are as follows for stratum 1,

$$RPT = 0.722 + 0.004\,41 \cdot \text{mileage} \quad (R^2 = 0.93) \tag{2}$$

for stratum 3,

$$RPT = 1.629 + 0.0052 \cdot \text{mileage} - 3.156 \cdot \text{annual tonnage} \quad (R^2 = 0.96) \tag{3}$$

for stratum 5,

$$RPT = 0.731 + 0.005\,05 \cdot \text{mileage} \quad (R^2 = 0.90) \tag{4}$$

for stratum 7,

$$RPT = 0.933 + 0.0055 \cdot \text{mileage} \quad (R^2 = 0.84) \tag{5}$$

and for stratum 18,

$$\ln(RPT) = -3.392 + 0.749 \cdot \ln(\text{mileage}) \quad (R^2 = 0.72) \tag{6}$$

where RPT = rate per ton.

These preliminary findings indicate that the effort to reliably synthesize rates for the 90 percent of the movements for which quotations are not available should be successful. This result also shows the consistency in barge rates.

Consad's efforts for the Corps of Engineers also involved similar analysis of overland rates. Those results are too preliminary to present at this time, but it can be reported that the results in terms of the ability to fit a regression equation to the rates were much less successful. The structure of overland rates for commodities that currently move by waterway appears to be much more complex than that of waterway rates and to involve factors that could not be captured by using the data available for this study.

CONCLUSION

The effort described in this paper represents application of well-established statistical analytic methods and transportation planning principles in the development of a sampling plan for estimating freight rates for movement of traffic in the Ohio River Basin. These methods should result in a higher level of reliability in estimates of freight charges than could be expected with the same investment of planning resources in the absence of such methods.

Preliminary findings on the synthesis of rates for nonsampled movements indicate that high levels of reliability can be expected in relationships developed for waterway rates. Less reliability can be expected for rates developed for alternative overland movements.

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