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Contents

Freight Transport on the Mississippi: An Analysis of Time Series Data

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The Mississippi River system has enjoyed a unique growth cycle in comparison with other domestic waterways. In the 1959 to 1973 time period freight increased by 140 percent. The problems of water transport have been largely neglected, however, as government transportation planners have focused on the more readily apparent crises in rail transport. This study analyzes the historical patterns of commodity traffic on the Mississippi and presents a set of econometric forecasting equations. Specific projections of commodity freight are estimated and analyzed for the 1977 to 1990 time period; of particular importance is the analysis of coal transport and its impact on the Mississippi system. The study also discusses institutional changes, such as the controversy over Locks and Dam 26 at Alton, Illinois, which may imperil future capacity expansion programs on the Mississippi.

The growth record of freight transport on the Mississippi River during the past 15 years is impressive: from 109.1 million Mg (120.3 million tons) in 1959 to 274.5 million Mg (302.6 million tons) in 1974, a compound growth rate of approximately 5 percent (Table 1) (4). During the same period, ocean-going and inland waterway freight showed compound growth rates of 5.6 percent and 4.6 percent, respectively. All segments of Mississippi River freight demand have thus significantly outpaced the 3.7 percent growth rate of the real gross national product during this time period. Comparing the growth differential of Mississippi water transport with the economy at large strengthens the theory that inroads have been made into the activity of other transport modes, such as rail; the information in Table 1 is too aggregative, however, to enable us to make conclusions about which commodities are propelling growth in freight shipments on the Mississippi.

The purpose of this paper is to analyze the historical factors that generated demand for logistic services on the Mississippi River system and to develop disaggregated projections of future freight on the Mississippi that can shed some light on current policy issues in water transport. Several major reasons can be cited for such a study. First, the United States is slowly moving toward a national freight transportation plan (1). Up to the present time, attention has been focused on transportation crises such as the bankrupt condition of many eastern railroads and the establishment of the Consolidated Rail Corporation (Conrail). Water transport may not be at the crisis stage, but research to determine likely growth parameters is badly needed. Maintaining water transportation as a viable and efficient part of the national transportation system requires time for advance planning. Both motor carriers and the railroad industry have their freight networks, or roadbeds, in existence, and only normal maintenance is required. To augment system capacity motor freight carriers can add additional power units within 2 to 3 months or expand their trailer fleets within 8 to 12 weeks; railroads can add to their rolling stock within 6 to 9 months. Development of a new and bigger set of locks on the Mississippi, however, may take 7 to 10 years (2).

A second major area of concern that strengthens the need for research in water transport is the political one. Congress, the executive branch, and the courts are all involved in the controversy surrounding the U.S. Army Corps of Engineers plan to expand Locks and Dam 26 at Alton, Illinois. This project, which would greatly increase capacity on the upper Mississippi, would directly threaten rail dominance in grain transport. Congress is also considering legislation that would grant the right of eminent domain to coal slurry pipelines. Although the immediate threat is to western railroads, there is also a potential threat to bulk transport on the Mississippi River system. Thus there are both an immediate and a long-run need to provide political decision makers with information about water freight transport.

DISAGGREGATING GROWTH OF MISSISSIPPI FREIGHT TRANSPORT

The Mississippi River system has enjoyed a unique growth cycle in comparison with other domestic waterways (Table 2) (5). From 1959 to 1973, megagrams at point of origin increased by 140 percent on the Mississippi but fell by 8 percent and 61 percent respectively on the Great Lakes and the Atlantic and Gulf Coast. Pacific Coast carriers experienced steady gains during the 1958 to 1969 period, but the level of traffic has fallen since 1969. [Because the purpose of Table 2 is to compare the relative growth rates of domestic water systems, the Mississippi River figures are not directly comparable to data in Tables 1 and 3.] The strong performance of water transport on the Mississippi raises several questions: What commodities have stimulated this surge in Mississippi freight transport? How will future growth estimates compare with the past growth pattern?

Table 3 (4) gives an overview by commodity of the composition of Mississippi River freight (both inland and ocean-going for all carriers) during the 1963 to 1974 period. Comparing the percentage composition of freight in 1963 and 1974 (Table 4) reveals a shift toward a relatively greater concentration in the areas of grain, coal, and chemicals; ores, metal products, and petroleum and petroleum products have made up a declining share of the total traffic. But there has been an across-the-board increase in the absolute freight levels of all major commodity categories (Table 3). Chemicals and fertilizer products exhibited a compound growth rate of 12.1 percent between 1963 and 1974. Coal and lignite also jumped dramatically, climbing by a compound annual rate of 9.5 percent. Grain and soybeans was close behind with a growth rate of 8.7 percent. Although overall growth was moderated by slower growth in some sectors, a dramatic 6.1 percent compound growth rate resulted over the 11-year period from 1963 to 1974.

The data in Table 3 provide a broad picture of the commodity base for total growth in freight transport on the Mississippi; Table 5 (4) further breaks this information down by transport route (upper Mississippi indicates north of St. Louis, above the confluence of the Mississippi and the Missouri) for each commodity category and by megagrams of freight which isolates the divergent growth pattern for each commodity. The corresponding breakdown for aggregate Mississippi freight is also given.

By using the data in Table 4, one can develop a more adequate information base for use in analysis. For example, between 1963 and 1974 the total 92 percent increase in all commodities can be linked to an increase of 89 percent for ocean-going and 94 percent for inland traffic; the latter figure can, in turn, be related to a 100 percent increase in upper inland freight and a 91 percent increase in lower inland freight. Analysis of the 1963 percentage composition reveals that the amount of grain and soybeans carried on the upper Mississippi rose by 185 percent between 1963 and 1974, providing over half the gain in upper Mississippi freight for this time period. As a direct result, grain and soybeans now comprise 40 percent of the freight handled on the upper Mississippi.

1990 FREIGHT FORECAST

Any attempt to develop long-run forecasts is difficult, especially so when one examines individual segments of the total freight transport network. Preparing a freight forecast for the Mississippi means implicitly making an aggregate rail, truck, and barge projection. Thus the task quickly expands into a global forecast. Ideally, an integrated regional forecasting system would be available that was capable of translating macroeconometric scenarios into a commodity-flow grid, but the present state of regional model building is crude compared to the technological capabilities of macroeconometric models. We have been forced, therefore, to rely on a system of equations that directly link macroeconometric output variables (e.g., production indexes for steel, petroleum, and other commodities) to megagrams of Mississippi freight.

The building blocks for this study are the six commodity categories given in Table 4. The major problem in developing freight estimates for the Mississippi is the scarcity of data. We have developed a two-directional forecast approach. First, aggregate (top-down) equations were constructed for upper Mississippi inland, lower Mississippi inland, and lower Mississippi ocean-going traffic. Data were collected for the 1959 to 1974 time period (Table 1). (As expected, 15 data points are insufficient for an elaborate model.) The aggregate equations are listed below.

$$LMI = -106.02 + 182.73JMI + 0.91FPI \qquad R^2 = 0.94$$
$$(-7.15) \quad (10.37) \quad (2.81) \qquad D.W. = 2.11$$
$$S.E. = 5.91 \tag{1}$$

$$LMO = 0.70 + 35.53J33 + 0.65EX72 \qquad R^2 = 0.95$$
$$(0.12) \quad (2.74) \quad (3.64) \qquad D.W. = 1.50$$
$$S.E. = 4.57 \tag{2}$$

$$UMI = -29.9 + 23.95J12 + 49.85JGAS \qquad R^2 = 0.98$$
$$(-5.3) \quad (2.10) \quad (8.20) \qquad D.W. = 2.84$$
$$S.E. = 8.20 \tag{3}$$

where

- LMI = lower Mississippi inland freight (millions of megagrams/year),
- LMO = lower Mississippi ocean-going freight (millions of megagrams/year),
- UMI = upper Mississippi inland freight (millions of megagrams/year),
- JMI = Federal Reserve Board (FRB) production index for mining,
- FPI = farm proprietors income (billions of 1972 dollars),
- J33A = FRB production index for primary metals,
- EX72 = Exports in 1972 dollars,
- J12 = FRB production index for coal, and
- JGAS = FRB production index for gasoline.

These equations were simulated by using the long-term

Table 1. Growth of freight transport on the Mississippi, 1959 to 1974.

	Mississippi[a]				Index (1959 = 100)	
Year	Ocean-Going	Inland Waterway	Total	Upper Mississippi[b]	Total Mississippi	Upper Mississippi
1959	36.3	72.7	109.1	23.5	100	100
1960	41.6	74.8	116.4	24.9	107	106
1961	44.7	79.0	123.7	25.5	113	109
1962	52.5	83.4	136.0	27.7	125	118
1963	54.2	88.9	143.1	28.0	131	119
1964	57.1	92.0	149.4	30.9	137	132
1965	58.1	101.6	159.8	34.3	147	146
1966	67.7	108.3	176.0	37.5	161	160
1967	74.1	119.2	193.3	40.5	177	173
1968	73.1	125.7	198.8	41.8	182	178
1969	74.2	134.0	208.2	45.0	191	192
1970	85.1	142.4	227.5	49.0	209	209
1971	83.8	147.8	231.5	47.9	212	204
1972	84.5	162.2	246.7	55.1	226	234
1973	92.8	157.8	250.6	52.7	230	224
1974	102.3	172.1	274.5	56.0	252	239

Note: Amounts are in millions of megagrams. 1 Mg = 1.1 tons.
[a]2939 km (1837 miles), from Minneapolis to the Head of Passes.
[b]1060 km (663 miles), from Minneapolis to the mouth of the Missouri River. Over 99.5 percent of this freight was inland waterway traffic in 1974.

Table 2. Growth rates of domestic water systems by freight originations of class A carriers.

Year	Mississippi River	Great Lakes	Pacific Coast	Atlantic and Gulf Coast	Total
1959	43.1	18.2	10.5	9.9	81.7
1960	44.8	23.5	11.3	9.5	89.3
1961	47.6	20.4	10.4	8.2	86.6
1962	52.4	17.3	11.3	9.5	92.2
1963	55.7	20.9	11.3	9.4	98.8
1964	55.9	15.1	10.8	9.2	92.6
1965	56.8	15.5	12.2	9.1	95.2
1966	69.4	19.9	17.8	6.3	113.6
1967	73.8	20.5	16.6	6.5	118.9
1968	77.1	20.1	17.9	5.5	121.9
1969	83.4	17.2	18.5	3.2	122.3
1970	94.5	17.6	14.0	3.2	129.4
1971	88.8	16.1	12.6	3.0	120.7
1972	107.3	16.0	14.4	3.0	140.9
1973	103.3	16.8	14.3	3.8	138.4

Note: Amounts are in millions of megagrams. 1 Mg = 1.1 tons.

Table 3. Freight transport on the Mississippi for six commodity categories, 1963 to 1974.

	1963		1966		1968		1969		1970		1971		1972		1973		1974		
Commodity	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	1963 to 1974 Increase (%)
Grain, grain products, and soybeans	26.4	18.4	33.2	18.9	37.8	19.0	38.6	18.6	43.0	18.9	42.5	18.4	57.4	23.3	63.6	25.4	65.9	24.0	150.0
Metallic and nonmetallic ores and metal products	15.5	10.8	16.2	9.2	18.3	9.2	18.2	8.8	21.2	9.3	19.5	8.4	17.3	7.0	17.4	6.9	20.0	7.3	28.7
Petroleum and petroleum products	62.7	43.8	66.5	37.8	78.4	39.3	80.7	37.6	84.1	35.4	85.2	36.3	79.1	34.5	81.8	33.3	90.9	33.1	45.0
Coal and lignite	9.2	6.4	13.2	7.5	17.1	8.6	17.6	8.5	20.0	8.8	19.5	8.4	24.1	9.8	21.4	8.5	24.9	9.1	171.3
Chemicals and fertilizers	9.3	6.5	13.2	7.5	15.7	7.9	17.9	8.6	20.5	9.0	26.5	11.4	31.1	12.6	30.1	12.0	32.6	11.9	252.0
Other	20.1	14.1	33.4	19.0	31.6	15.9	35.1	16.9	38.7	16.5	38.3	16.5	37.6	15.3	36.3	14.5	40.5	14.7	100.9
Total	143.2	100.0	175.7	100.0	198.9	100.0	208.1	100.0	227.5	100.0	231.5	100.0	246.6	100.0	250.6	100.0	274.8	100.0	91.8

Note: Amounts are in millions of megagrams. 1 Mg = 1.1 tons.

Table 4. Changing freight commodity mix on the Mississippi, 1963 to 1974.

Commodity Category	Route	1963 Amount	1963 Percent	1974 Amount	1974 Percent	Increase (percent)
Grains and soybeans	Total	26.4	18	65.9	24	150
	Ocean	14.2	26	33.6	33	136
	Inland	12.2	14	32.4	19	166
	Upper	7.9	28	22.5	40	185
	Lower	4.3	7	9.9	8.5	132
Coal	Total	9.2	6	24.9	9	171
	Ocean	0.7	1	4.0	4	450
	Inland	8.4	9	20.9	12	147
	Upper	4.4	16	6.9	12	58
	Lower	4.1	7	14.0	12	242
Petroleum and petroleum products	Total	62.7	44	90.7	33	45
	Ocean	23.9	44	32.4	32	35
	Inland	38.7	44	58.3	34	51
	Upper	8.7	31	10.6	19	22
	Lower	30.0	49	47.7	41	59
Construction materials and metals	Total	15.5	11	20.0	7	29
	Ocean	6.0	11	8.9	9	48
	Inland	9.5	11	11.1	6	16
	Upper	3.4	12	4.5	8	35
	Lower	6.2	10	6.5	6	6
Chemicals and fertilizers	Total	9.3	6	32.6	12	252
	Ocean	3.0	6	12.2	12	309
	Inland	6.3	7	20.3	12	225
	Upper	1.3	5	5.0	10	321
	Lower	5.0	8	15.3	13	207
Other commodities	Total	20.1	14	40.5	15	101
	Ocean	6.3	12	11.2	11	77
	Inland	13.8	16	29.2	17	112
	Upper	2.4	9	6.1	11	148
	Lower	11.3	19	23.1	20	104
All commodities	Total	143.1	100	274.5	100	92
	Ocean	54.2	100	102.3	100	89
	Inland	88.9	100	172.1	100	94
	Upper	28.0	100	56.0	100	100
	Lower	60.9	100	116.2	100	91

Note: Amounts are in millions of megagrams. 1 Mg = 1.1 tons.

Table 5. Forecast of growth of freight transport on the Mississippi, 1974 to 1990.

Item	1974	1980	1985	1990	1974 to 1990 Increase (percent)
Commodity category					
Grain	65.9	86.0	107.0	140.4	112.9
Coal	24.9	37.3	52.2	73.1	194.2
Petroleum	90.7	105.6	125.0	149.4	64.7
Construction	20.0	20.7	22.0	23.7	18.6
Chemicals	32.6	50.0	69.7	95.6	193.6
Other	40.5	54.3	65.8	79.5	96.6
Total	274.5	353.8	441.7	561.7	104.7
Route					
Total	274.5	353.8	441.7	561.7	104.7
Ocean	102.3	129.1	161.2	205.0	100.4
Inland	172.1	224.8	280.5	356.7	107.2
Upper	56.0	74.8	93.3	118.7	112.2
Lower	116.1	149.9	187.2	238.0	104.8

Note: Amounts are in millions of megagrams. 1 Mg = 1.1 tons.

economy model developed by Data Resources, Inc., which provided a top-down set of freight projections. An alternative bottom-up set of estimates was constructed by using the six commodity categories listed in Table 5. Equations constructed for each commodity category linked, for example, megagrams of petroleum on the Mississippi to the FRB production index for petroleum products (FRB 29). These equations were then simulated and aggregated to find total megagrams of freight. As might be expected, the top-down and bottom-up projections differed (by about 10 percent in aggregate). The final figures in Table 6 are, therefore, a hybrid set.

Table 5 represents a business-as-usual projection for the Mississippi: Aggregate freight grows at a compound rate of 4.5 percent over the forecast period from 1974 to 1990, which is lower than the 5 percent rate experienced from 1959 to 1974. Commodities in Table 5 show diverse growth patterns, from an 18 percent increase in construction to a 194 percent increase in both coal and chemicals. A detailed commodity-by-commodity approach is therefore necessary in any intelligent discussion of future Mississippi growth.

Coal projections in Table 5 illustrate the uncertainties that must be considered in developing long-run forecasts. On the one hand, Project Independence has created some optimism in the coal sector. On the other hand, the level of national coal production in 1985 is unpredictable. The following table gives forecasts of national coal production and demand, in millions of megagrams, as developed by various private and government sources (1 Mg = 1.1 tons).

Source	Forecast 1980	Forecast 1985
Temple, Barker and Sloane (6)	669	932
Office of Coal Research (7)		
5 percent growth	797	1017
3.5 percent growth	712	844
Project Independence (8)		
Business as usual	812	998
Intermediate	862	1088
Accelerated	1248	1871
National Petroleum Council (9)	766	908
Task Group on Coal Supply Potential (10)	776	—
Mitre Corporation (11)	775	882
U.S. Bureau of Mines (12)	731	905

Even if there is a rapid increase in coal production, the location of mines and market areas is important to any forecast for the Mississippi. It is dangerous to conclude that, because average barge costs are 1.875 mills/Mg•km (3 mills/ton-mile) compared to 5.6 to 7.5 mills (9 to 12 mills) for railroad, the boom in western coal will automatically cause an increase in megagrams of coal carried on the Mississippi (3).

As pointed out in a recent study by the Hudson Institute (3), the western coal fields are 644 and 966 km (400 and 600 miles) from the nearest navigable river (the Missouri). The Hudson study also mentions that the Burlington Northern is considering a potential intermodal link at St. Louis that would directly affect freight on the lower Mississippi. An alternative means of rail-water access to the East is the Great Lakes.

Table 5 forecasts 1990 coal freight at 73.1 million Mg (80.6 million tons), a level almost triple that of 1974. To put this in historical perspective, however, Mississippi coal freight increased from 9.2 million Mg (10.1 million tons) in 1963 to 24.9 million Mg (27.4 million tons) in 1974—a period of stagnation in national coal production—which indicates that even these coal projections are conservative.

Grain and soybean transport is also unpredictable. As given in Table 4, this category experienced the largest absolute growth—more than 39 million Mg (43 million tons)—in the 1963 to 1974 period. With a forecast increase of 74.5 million Mg (Table 5), it again provides the largest absolute impetus for growth.

As in the case of coal, barge transport of grain offers significant savings to shippers. But, because of the seasonal nature of the commodity, capacity can be a critical problem, particularly in view of the 7 to 10-year lead time required for major water improvement projects. A study recently carried out for the Illinois Department of Transportation estimated that the proposed expansion of capacity at Locks and Dam 26 on the Mississippi River near Alton, Illinois, would divert $70 million/year of traffic (mostly grain) from the Illinois Central Gulf Railroad to the Illinois waterway and that a significant portion of that traffic would make its way to the Mississippi (2). Environmentalists have, for the time being, blocked the dam expansion project through legal action. By itself this controversy may seem unimportant; as a precedent, however, it could bring expansion of capacity on the Mississippi to a halt.

Projected growth in grain transport is lower than that experienced during the 1963 to 1974 period. Most excess agricultural capacity has now disappeared, and it is unlikely that the historical pattern of growth will persist. Strong domestic and world demand for grain, however, will continue to buoy grain shipments on the Mississippi.

Historical shipments of petroleum and petroleum products on the Mississippi have shown steady growth, comprising roughly 40 percent crude oil, 18 percent gasoline, 17 percent residual fuel oil, 11 percent distillate fuel oil, and the remainder in products such as naphtha and tar. Over half of the crude petroleum is ocean going, and about 75 percent of the refined product is inland; the entire range of petroleum products is thus sensitive to shifts in energy policy. We have linked future growth in transport of petroleum on the Mississippi (Table 5) to national output of petroleum and petroleum products, as forecast by the macroeconomic model of Data Resources, Inc.

Construction materials and metals have lagged far behind other commodity sectors (Table 4). Megagrams of sand, gravel, and crushed rock amounted to 5.8 million (6.4 million tons) in both 1963 and 1974. After peaking at 21.2 million Mg (23.4 million tons) in 1970, construction materials and metals have fluctuated around 18 to 21 million Mg (20 to 23 million tons). The slow growth of this sector is reflected in the forecast in Table 5.

Chemicals and fertilizers generated the best track record in percentage growth during the 1963 to 1974 period (Table 4). The major subcategories of this sector include dry and liquid sulfur (14 percent of total), fertilizer and fertilizer materials (40 percent), and chemicals and products (46 percent). Nearly half of the fertilizers, 40 percent of the sulfur, and 25 percent of the chemicals represented ocean-going traffic in 1974. Fertilizer traffic has grown from 2.3 million Mg (2.5 million tons) in 1963 to 12.7 million Mg (14 million tons) in 1974. Phosphate, a critical input to fertilizer production, is the source of a mining boom in Wyoming, which should contribute to future traffic on the Mississippi. Chemicals and fertilizers are projected to reach 95.6 million Mg (105 million tons) in 1990, approximately three times the 1974 traffic level (Table 5).

The commodity category labeled other contains all remaining products, such as molasses, lumber, and automobiles. Historically this category closely paralleled the economy; we have therefore based its future movements on projected values of key economic indicators.

The aggregate outlook, according to the projections contained in Table 5, is for sustained growth propelled by coal, chemicals, and grain. Because of the disproportionate share of coal going inland, ocean-going traffic lags slightly behind. Overall, the picture is for relatively balanced growth between upper and lower Mississippi traffic.

FREIGHT DEMAND AND INSTITUTIONAL CHANGE

It is relatively easy to translate next year's increase in gross national product into freight demand. One can safely assume no radical institutional changes in such a short time. This is obviously not the case in a long-run forecast. It is possible, as mentioned above, that environmental concerns will lead to capacity restrictions on the Mississippi. It is also increasingly likely that the government will start to charge user fees for those governmentally financed projects, such as Locks and Dam 26, that produce direct benefits to users of the Mississippi. Whatever affects the railroads (for example, slurry pipelines) will also have undetermined spillover effects on water transport. It is conceivable that the government will develop subsidies for railroads in the West to match its aid to eastern railroads, and that might have the effect of distorting the rate structure and altering the relative cost advantages of the different transport modes. None of these contingencies has been factored into our analysis. To the extent that significant institutional change does take place we should expect to depart from a business-as-usual forecast.

REFERENCES

1. 1974 National Transportation Report. U.S. Department of Transportation, July 1975.
2. Comments of Illinois State Agencies on Chief of Engineers' Report for Locks and Dam 26. Illinois Department of Transportation, Springfield, June 14, 1976.
3. Research Analysis of Factors Affecting Transportation of Coal by Rail and Slurry Pipeline. Hudson Institute, New York, Vol. 2, April 1976.
4. Inland Waterborne Commerce Statistics. American Waterways Operators, Inc., Washington, D.C.
5. Moody's Transportation Manual. Moody's Investor Service, 1975.
6. Final System Plan. U.S. Railway Assoc., Washington, D.C., Vol. 1, July 1975.
7. Prospective Regional Markets for Coal Conversion Plant Products Projected to 1980 and 1985. Office of Coal Research, U.S. Department of Interior.
8. Report on Project Independence Blueprint. Interagency Coal Task Force; U.S. Department of Interior, Aug. 1974.
9. U.S. Energy Outlook: Coal Availability, National Petroleum Council; U.S. Department of Interior, 1973.
10. Utility Oil Saving Study. Task Group on Coal Supply Potential, Washington, D.C., Jan. 1975.
11. An Analysis of Constraints on Increased Coal Production. Mitre Corp., McLean, Va., Jan. 1975.
12. United States Energy Through the Year 2000. Bureau of Mines, U.S. Department of Interior, Dec. 1975, revised.

Reliability of Commodity Freight Projections for Inland Waterway Ports

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Feasibility studies recommending construction of ports, terminals, or industrial complexes along U.S. inland waterways rely heavily on projections of commodity freight. Tabulated results of projections versus realized results obtained from 12 ports on the inland waterways navigation system indicate that projections of commodity freight made in connection with port development have almost always been too low. Reliable projections of freight by commodity classification are essential in physical port planning, and projections of the amount of freight can be helpful when they indicate a median projection and a stated wide variation above and below that median.

Inland waterway port planning has invariably been based on projections of commodity freight. The use of such projections in benefit-cost justification of inland waterway or canal development dates from the early years of this century, and their use to justify the navigation aspect of a single inland waterway port and waterfront industrial park dates from the end of World War II. At least one case has been examined of actual use versus initial projections for a waterway or canal that had been in use for several years. To our knowledge, however, no such examination has ever been done for individual ports.

This paper investigates the reliability of freight projections for inland waterway ports by examining 12 ports along the Mississippi River system. The objective is to provide answers to the following questions:

1. If projections were made, how reliable have they been?
2. What general range of reliability is required?
3. To what source would the experienced port operator look today for reliable data on which to base projections of commodity freight?
4. Is more detailed investigation justified?

QUESTIONNAIRE

A questionnaire (Figure 1) sent to the directors or managers of 12 inland waterway ports was designed to test the reliability and usefulness of commodity freight projections as a tool in planning waterfront facilities and associated industrial parks. Although the questionnaire was not to be used as a planning and justification tool for navigation improvements, as it frequently is in the case of U.S. Army Corps of Engineers projects for individual ports and related harbors, Corps of Engineers figures proved to be the only ones available for the oldest existing inland waterway ports and were therefore used.

There was a 100 percent response from the 12 port directors contacted. Some responses were detailed, some required further research, and some provided only sketchy information. There was no time to repeat inquiries or to request further information; this, along with other factors, resulted in our decision not to identify the ports involved. Table 1 gives a summary of the responses to the questionnaire.

Diversity of Ports

The 12 ports responding to the questionnaire were all on the Mississippi River system: three on the free-flowing (lower) Mississippi, four on the Ohio River system, three on the Arkansas River system, and two on the upper Mississippi system. All except the three from the lower Mississippi River were in lock and dam river areas. The oldest port had opened its doors to business in 1952, the newest in 1975. (Only projections for substantial improvements were considered for ports in locations that had continuing histories of waterway transportation activity, which in some cases extended back more than a century.) The gross size of port and waterfront industrial areas ranged from 121.4 to 283.3 km^2 (30 000 to 70 000 acres). Systems of organizational control included private, city, county, city-county, and state. Financing methods for landside and waterfront facilities and industrial land sale or lease activities included private, city, and county general obligation bonds, revenue bonds, direct city and county funds, a variety of state taxing and bonding assistance, and various types of federal assistance including recent revenue sharing.

Realized Versus Projected Activity

After establishing the year in which the last projections were made (before the port opened for business or substantial improvement) and requesting information about who made the projections and what method was used, we posed the central question: What is the reliability of river-port commodity freight projections? The responses were reduced to a ratio of actual to projected reliability (Table 1). Information was also requested on actual versus projected sale or lease of industrial lands, and six positive responses were received. There were no useful responses to a request for information on actual versus expected phasing of public terminal expansion.

Utilization of Resources

The surveyed ports were asked to indicate (a) whether, as a result of port projections, resources had been expended for facilities that were never used and (b) whether resources that should have been expended were not because of incorrect projections. Only two respondents completed that section, and both answered in the negative.

Opinions

Statements of opinion were requested. Eight of the 12 respondents gave such statements.

RESULTS

A wide range of responses to the questionnaire had been anticipated. The actual response to critical questions was about 40 percent, with different respondents participating on different questions. Because the subject matter

Figure 1. Inland waterway port questionnaire.

(Please be brief. You may wish to jot the answers on this sheet or reply in letter form. Use the form of response that will be easiest for you.)

I. GENERAL PORT INFORMATION

1. What is the structure of your port organization
   - a. Private ______
   - b. Public
     - (1) Port Authority ____
       - ( ) City
       - ( ) County
       - ( ) Other
     - (2) Other ______
2. Size of port area ______ acres
   - a. ______ acres of waterfront property
   - b. ______ feet of waterfront property
3. How was port financed initially? (Please identify types and combinations - i.e. local government financing; state financing; federal assistance; bank loans; etc.) ______

II. COMMODITY/TONNAGE PREDICTIONS

1. Please provide a copy of the original commodities/tonnage predictions for your port (if more than one was made, send the one which was used for decision making purposes).
2. Year projects were made ______
3. If projections were based on questionnaire, please provide a sample copy and indicate
   - a. Approximate number of returns ______
   - b. Number of solicitations ______
   - c. Supplemented by interviews: Yes ____ No ____
4. Were any methods used to modify the summation of questionnaire/interview results such as use of common sense, independent evaluation of various resources, etc. ______
5. Any other information which is pertinent about the method used. ______
6. Who made the study?
   - a. Consultant ______
   - b. Chamber of Commerce ______
   - c. Port Authority ______
   - d. Other ______

III. RELIABILITY

1. How reliable did those projections prove to be looking back from today's situation
   - a. By commodities. Please show commodities projected and commodities handled. (Suggest you use major commodity groupings rather than details; i.e. fuels and lubricants, agricultural products, building materials, metalic ores, manufactured products, paper, structural steel, plate, etc, and others)

     Projected ______ Actual ______
   - b. Tonnages (gross and by commodities)

     Year ______ Projected ______ Actual ______
   - c. Projections on rate of lease and/or sale of land

     Projected ______ Actual ______
   - d. Projections of type and rate of facility construction

     Projected ______ Actual ______
   - e. Projections regarding private versus public financing and development

     Projected ______ Actual ______

IV. USES

1. Were any resources expended or other action taken as a result of the projections which actions or resources subsequently proved to be unneeded? Yes ___ No ___

   Please explain ______
2. Were any resources or directions subsequently taken which had been initially rejected because of the projections? Yes ___ No ___

   Please explain ______

V. YOUR OPINION

1. What is your present opinion concerning the subject of commodity/tonnage projections including any of the above implied methods and uses? ______
2. What businesses or professions constitute the best source of reliable information for commodity/tonnage projections? ______
3. What method would you use now? ______
4. Any other pertinent comments. ______

VI. BEFORE - AFTER

1. If possible, please supply a slide or picture of the initial facility and one of the present day facility.

Table 1. Responses to the questionnaire.

Port	Organizational Control	Size[a]	Year of Projection[b]	Year Port Opened[b]	Reliability Ratio[c]: Commodity Classes	Reliability Ratio[c]: Annual Freight	Land Sale or Lease
A	City-county	2	1966-67	1968	6:4	4:1	All costs recovered, 60 percent unsold
B	Private	2	1975	1975	Unknown	Unknown	5 to 10 years
C	City	3	1962	1969	5:5	1:1	Projected exceeded actual
D	City	Unknown	Unknown	Unknown	Unknown	Unkown	Unkown
E	Private	1	1971-72	1974	4:4	3:1	NA
F	City-county	3	1964	1971	Unknown	<1:1	14:15
G	County	2	Unknown	1959	Unknown	3:1	20:8
H	County	1	1955	1958	Unknown	10:1	5:3
I	City-county	Unknown	Too recent	—	—	—	—
J	City-county	Unknown	Too recent	—	—	—	—
K	City-county	3	1945	1952	Unknown	40:1	Not projected
L	State	Unknown	None				

Note: 1 km^2 = 247.1 acres.

[a] 1 = < 0.4 km^2; 2 = 0.4 to 4 km^2; and 3 = >4 km^2.

[b] Applies in some cases to major port improvement rather than port opening.

[c] Actual divided by projected.

does not lend itself to selective sampling from among a large number of respondents, the usual methods of statistical sampling analysis could not be applied. On the other hand, the approximate 40 percent response (in some cases, much more) to critical questions did have a consistency that offset the small sample size. There is evidence that a more intense investigation might change certain specifics of the responses but would not change their general nature.

Diversity

The greatest number of port organization structures were combined city and county, with most of the remaining ports being city only or county only. Private control and state control were exceptions. [Private control refers in this paper to privately owned public (general-purpose) terminals and associated lands and not to private ownership or privately controlled special-purpose terminals or riverfront industry terminals.] Enough information was supplied in each category to support the conclusion that the reliability of projections is essentially the same regardless of the type of organizational control or the size of the port facility.

In the formulation of projections, the age of a port is a general indicator of its degree of sophistication, the oldest ports being the least sophisticated. At the oldest of the ports we surveyed, local civic leaders used projections principally to justify navigation improvements by the federal government. Projected freight appeared as a single gross item in the federal project report, and there was no indication of the years to which the projection might apply or the types of commodities involved. These responses did not indicate whether freight projections were subsequently used in planning, phasing, layout, or design of landside facilities.

It should be noted that the civic and professional leaders who participated in the initial development of these older ports are probably no longer actively engaged in port operations. The fact that the second port-management generation must now research the projection process to obtain and provide answers creates an urgent need for more detailed research. Repeating surveys every 10 years, for example, could ensure getting accurate data from those actually involved in port management during the period surveyed.

Ports under a governmental control structure now consider detailed projections a normal requirement. Many of the more recently used methods of financing for governmentally controlled ports, such as revenue bonds, general obligation bonds, and state and federal development funds, require detailed projections without regard to whether or not these projections are needed in project planning, phasing, design, and construction. Data obtained from private ports indicate that they tend to be informal concerning projections.

Realized Versus Projected Activity

As previously mentioned, the oldest of the ports used projections of gross freight without indicating classes of commodities. Only three respondents to the questionnaire stated that their port projections included commodity classifications. However, the experience of all three was essentially the same: Reliability for commodity classifications was excellent, ranging from a projected-to-actual ratio of 3:2 to 1:1. Projections of commodity classes are generally quite reliable for the following reasons: (a) They are invariably an easily derived function of local economic conditions, especially concerning commodities that are traditionally susceptible to the economies and benefits of water transportation; and (b) even unexpected increases or decreases in the classification span by one commodity have no major effect on the reliability of a projection stated as a ratio.

All but one respondent indicated that projections of amount of freight had proved to be greatly understated. A federal government feasibility study stated that local decision makers at one of the older ports had projected an annual amount of freight approximately 4 times the amount the government study accepted as accurate. Today the actual annual increase in freight for that port is more than 10 times the federal estimate. Actual versus projected freight ratios on an annual basis ranged from more than 40:1 to 3:1 except in the case of one new port. Freight projections have not generally been reliable. The professional who must make the final projection tends to understate, and properly so. This raises the question, Are detailed freight projections a necessary element of the port planning process?

Most respondents failed to provide useful data on the use of projections in phasing and planning either the original public terminal construction or expansions. Construction of a public terminal is required in most cases where federal assistance has been provided and, once a terminal is constructed, expansions usually follow as a result of successful business activity. Public terminal planning, phasing, design, and construction as well as subsequent expansions appear to derive more from administrative requirements and commodity classifications than from amount of commodity freight. Reliable projections of commodity classifications are therefore important in public terminal planning but accurate, long-term projections of amount of freight are not.

Projections for sale and lease of land are relatively reliable, if we allow for some early years of little activity. The respondents' projections were, naturally, less definitive than those for commodities and amount of freight. Three respondents gave definite figures; their actual projected ratios ranged from 1:1 to $2\frac{1}{2}$:1. Some responses were qualitative, e.g., "all cost recovered with 60 percent of land still unsold."

Utilization of Resources

Responses were inconclusive concerning overutilization or underutilization of resources because of projections.

Opinions

Five of the 12 ports furnished no separately written opinions. Three of the remaining 7 listed experience as the best method to use in projections, implying that quantitative processes are at best built on specifics derived nonspecifically. One respondent said simply that "it is difficult to project." Projections into the distant future can be drastically changed by one unforseeable change.

Personal contact was emphasized. Port users and local producers were mentioned twice in the opinions section as good sources of projection data. Chambers of commerce, business people, economists, and the Corps of Engineers were noted as other sources. The use of a questionnaire was listed once as a specific method, but research was listed twice and that word probably included research by questionnaire as well as by other means.

CONCLUSIONS AND RECOMMENDATIONS

Responses to the questionnaire provided the following answers to the questions originally posed in the study.

1. If projections were made, how reliable have they

been? Projections that included separate commodity classifications proved to be sufficiently reliable for use in planning, initial phasing, design, and construction of facilities. Freight projections were generally much too conservative. Projections on the rate of sale or lease of land have been rare but relatively reliable.

2. What general range of reliability is required? Because the responses offered little useful information on this question, what follows is based on our own personal observations.

Facilities planning usually falls into two distinct categories: (a) public (general-purpose) terminal and (b) associated waterfront industrial park. The public terminal by its nature must be planned for a wide range of commodity classifications and, once the original waterfront facilities are constructed, expansions can rapidly be made to fit unexpected increases in certain commodities. In addition, wharf and mooring capacity usually exceeds other terminal capacity by so much that expansions do not require the per-megagram resources of original design and construction. Projections of amount of freight are more likely to be used to justify financing than to clarify detailed design and planning decisions for the public terminal.

From a planning viewpoint, the related waterfront industrial park resembles ordinary industrial subdividing except that it is also oriented to waterway transport. Both waterfront and nonwaterfront sites are essential. Planning, therefore, is more likely to focus on the sale or lease of the land than on commodity and freight projections, although these projections do constitute a broad indicator. Obviously, then, commodity freight projections need not be very precise from a planning viewpoint. Instead, they should indicate a median projection with a stated wide variation above and below that median, and this should in turn create a demand for physical plans that indicate minimum anticipated development as well as possible expansions.

The question of the general range of reliability required for purposes of physical planning merits additional research, including a larger sampling, more detailed responses, and the construction of a historical base for review at various time intervals.

3. To what source would the experienced port operator look today for reliable data on which to base projections of commodity freight? There appears to be no single reliable source for such data or, if there is one, it has not yet been proved by real-world testing. Port operators did not provide any new answers. Although this is a topic that does not currently merit any additional research, it would be appropriate to ask the question again because port operators are continuously gaining experience and exposure on the front line of the inland waterway transportation industry.

The center of gravity of research in commodity classes and freight projections is invariably national policy and how to influence it. But it is the local decision maker who must use projections because he or she must live within specifically or vaguely stated national policy. Local decision makers need more help than they are getting in this area.

4. Is more detailed investigation justified? We recommend researching a simple system for one federal agency, bureau, commission, association, or business to provide frequently updated box scores on projections. The how, who, what, and where would be part of the research. The initial cost should be low—perhaps $85 000—to encourage simplicity. Funding should be by a nonoperating research organization, one that cannot suggest it assume the updating role following initial research. The project should (a) suggest a format for minimum projection tabulation so that updated box scores can be meaningfully assembled, (b) show singly or in combination the sources of data and opinion that have proved most reliable, and (c) indicate a general range of projection development costs that has proved optimum, perhaps as a percent of project construction costs, to determine whether there is a point at which additional projection costs produce rapidly diminishing returns in the form of useful projections.

Commodity-Flow and Multimodal Transportation Analysis for Inland Waterway Planning

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The inland navigation systems analysis program of the U.S. Army Corps of Engineers is an integrated system of models, data, and planning procedures designed to explain, predict, and plan for U.S. inland waterway transportation. The program forecasts future waterway traffic by means of commodity-flow and multimodal network models. The commodity-flow model is similar to a multiregional input-output model with variable coefficients, in which market behavior and transportation costs determine location, composition, pricing, and level of output and the interregional commodity flows derived from them. The multimodal network model allocates these commodity flows to the several modes, based on transportation cost and performance criteria, and the allocations, as applied to the inland waterway system, constitute the waterway traffic forecast.

The inland navigation systems analysis (INSA) program of the U.S. Army Corps of Engineers (1) is an integrated system of models, data, and planning procedures designed to explain, predict, and plan for U.S. inland waterway transportation and to help planners reach thoroughly examined investment, operation, and maintenance decisions for inland waterways. The models are designed to mimic the national market system and the role of inland waterway transportation within that market system by simulating both inland waterway transportation and transportation markets within the national market system. The purpose of this paper is to describe the models and to explain how they are used to estimate demand for inland waterway transportation.

BACKGROUND

Figure 1 shows a schematic of the INSA structure. Forecasts of demand for commodity transportation are provided by commodity-flow analysis; then these forecast commodity flows are allocated to various modes by means of multimodal analysis, based on transportation cost and performance criteria. Allocations to the inland waterway system are input to the INSA waterway analysis and enable detailed estimates of future fleet requirements for the towing industry and operating characteristics of waterway systems. The cost and performance results of both the multimodal and waterway analyses are then used to evaluate systems and projects. Feedback from the multimodal analysis to the commodity-flow analysis indicates that INSA allows transportation cost and level of service to influence the spatial patterns, mixes, and quantities of commodity flows.

INSA commodity flow and multimodal analysis together constitute a model of transportation demand, which can be viewed at several levels during the analysis. Some of the dependent variables involved are defined as follows:

S_i = quantity shipped from region i,
D_j = quantity shipped to region j,
Q_{ij} = quantity shipped from region i to region j,
Q_{ijm} = quantity shipped from region i to region j by mode m,
Q_{ijmr} = quantity shipped from region i to region j by mode m via route r, and
Q_{ijmrp} = quantity shipped from region i to region j by mode m over network element (node or link) p of route r.

Simultaneous equation models and direct demand models that directly predict any of these variables can be formulated. A more typical approach is to take advantage of the hierarchical structure shown above by developing a chain of sequential models. Demand hierarchy and its implication for model building are discussed by Manheim (2) and Brand (3).

INSA uses the sequential approach. The first three variables, S_i, D_j, and Q_{ij}, are predicted by the commodity-flow model. Predictions of the other three variables are made in the multimodal network model, given interregional commodity flows (Q_{ij}). A discussion of both model systems follows.

COMMODITY-FLOW ANALYSIS

Model

The INSA commodity-flow model, accurately termed a regional economic activity and commodity-flow model, makes use of already well-known theory and empirical evidence but integrates them in a way that has been attempted only once (4). Typical of the overall structure of the model is the multiregional input-output approach (5, 6, 7). The elusive monetary coefficients normally present, however, are not relied on; instead, physical technical coefficients (8) are evaluated from regional production functions (9, 10). Given economic activity by region, flow patterns are analyzed by use of multiregional general equilibrium logic (11). The false security provided by some accepted models, such as physical analogs of mass attraction (12, 13), is avoided.

In the INSA commodity-flow model, the U.S. economy consists of a set of regions, each of which contains a set of economic sectors or industries. Each industry produces a product to satisfy domestic consumer demand, export demand, or demand from other industries. The production process requires that each industry combine raw materials, labor, and capital goods to produce its product; each industry, therefore, seeks the optimum combination of input. The mix and sources of items used in production depend on delivered input prices, including the price of transportation. Commodity flows occur within this system as raw materials travel to the industries demanding them and as what those industries produce travels to locations of domestic consumer demand, export demand, and other industrial demand.

The commodity-flow model is similar to a multiregional input-output model, in which market dynamics determine the location, composition, and pricing of output and the behavior of economic aggregates determines the level of output. Within this system firms and households select commodity suppliers and producers compete for customers on the basis of delivered price, which includes the price of transportation from supplier to consumer and the transportation cost built into free-on-board (FOB) price because of the transportation charge for gathering raw materials. The INSA commodity-flow model, therefore, generates a demand for transportation that depends in part on transportation price.

Brief descriptions of some of the major features of the model follow.

Economic Activity

Commodities are identified as output from an economic activity. Each activity consists of a production function type, a mix of required input commodities, and a unit of measure.

Sector

The basic unit on which the model operates is the regional sector for each activity. Each sector in a region has initial prices for labor, capital, and material and may have unique parameters for production function. Realistic levels of production may be set by placing output constraints on each sector. (Output constraints may reflect depleted mineral reserves or constraints imposed for environmental reasons.)

Region

The study area may be divided into regions by a standard approach such as that used by the Bureau of Economic Analysis (BEA), or by a variety of other means. If data needs are simple, states may be appropriate regional units, or counties can be used if greater detail is desired. A mix of definitions, such as BEA regions in the Mississippi and Ohio valleys and whole states on the Atlantic and Pacific coasts, can be used if economic activity near inland waterways is of primary interest.

Demand

All categories of demand for commodity requirements—foreign export, domestic final, and intermediate—are measured in physical units, such as tons or kilowatt-hours, rather than in monetary units. (The INSA model is based on U.S. customary units, and thus no SI equivalents are given.)

Because foreign export demand is given externally to the model throughout simulation, price elasticity of foreign demand must be exogenously estimated. Domestic demand, as estimated by the model, is assumed to be unitarily elastic with respect to price, but the analyst may use values based on alternative assumptions for estimated domestic demand.

Production Function

The aggregate production and consumption behavior of firms in a given sector is described by a production function, the form or type of which is activity specific, although the parameters may vary between regions to reflect technological differences. Firms within a region are treated as a group because (a) the likely behavior of every firm in the nation cannot be computed and (b) data

Figure 1. INSA system.

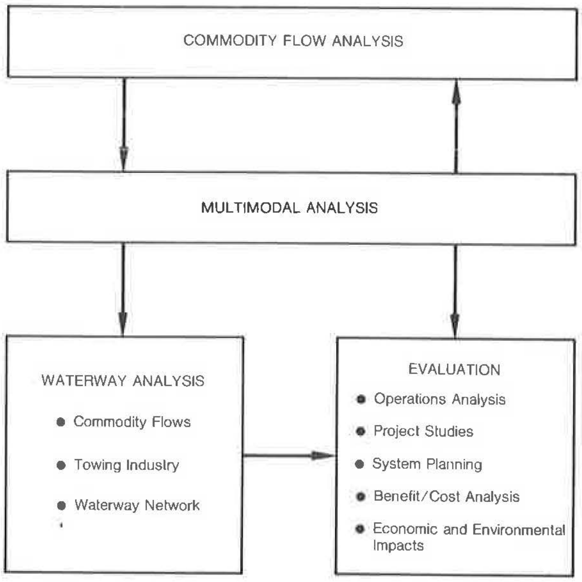
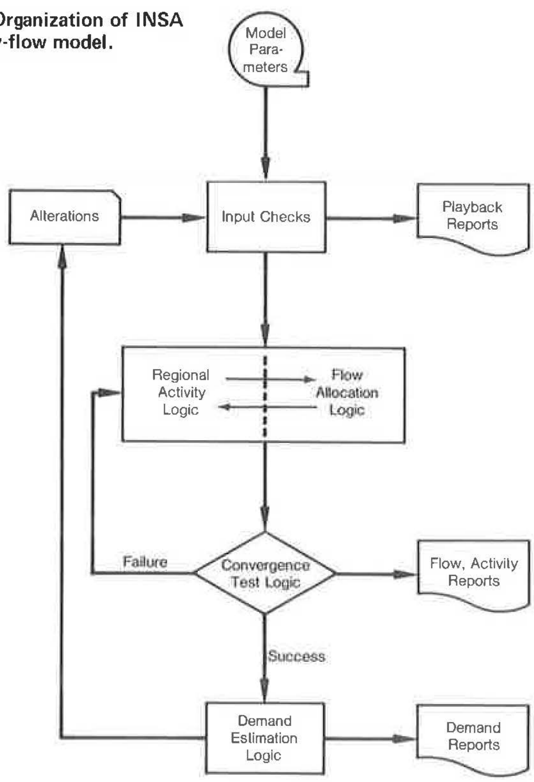


Figure 2. Organization of INSA commodity-flow model.



needed to fit production functions for individual firms are generally not available.

A production function represents the quantity, cost, or price of output in relation to the quantity, price, or mix of input. In the commodity-flow model, it is assumed that the sector will produce the quantity consumers desire. Demand, however, depends on price mechanisms. Two fundamental types of production functions are available to the analyst using the model: fixed input proportion and a wide range of variable substitutions. Fixed proportion is the easiest to estimate because the only data needed are those such as the ratio of labor input to unit of commodity output and units of material input per unit of commodity output. Thus, when demand is given for a commodity in a sector, the factors and individual materials required are solved directly.

Model Organization and Logic

The commodity-flow model iterates through a series of calculations to arrive at predicted annual commodity flows for the current year and demand estimates and new parameters for the following year. Organization of the model is shown in Figure 2.

Because calculations of regional economic activity and flow allocation fluctuate for every sector, the logic for both calculations is shown in the same box. The model uses successive approximations to forecast commodity flows and tests for convergence between the last two approximations; failure to converge leads to additional processing. A successful test computes domestic commodity demand for the coming simulated year.

The main features of model logic are as follows:

1. Calculating minimum cost and location—The model first calculates minimum delivered price of each commodity by consumer region and supply region (delivered price is defined as FOB price plus transportation cost).

2. Allocating demand—Demand or purchasing regions (aggregations of individuals and firms) are treated as rational, economic decision-making units. Domestic or foreign market demand by location is satisfied by production regions offering the lowest delivered price. The allocation of demand to production regions defines a portion of commodity flow as well as the demand for the output of each regional sector. No direct checks are made to determine if new demand exceeds the capacity of a sector; in such a case, the model increments FOB price until demand does not exceed capacity.

3. Estimating transportation cost—Detailed models such as the INSA multimodal network model may be used to estimate transportation cost because cost is entered into the model externally. Any set of costs may be entered to analyze potential policies or unusual events.

4. Forecasting economic activity—Production in any sector is composed of and driven by export demand, domestic final demand, and demand created by other economic activities. Given prevailing production price, a minimum cost mix is used to produce desired demand, which defines, by sector, such production factors as the amounts of commodities the sector requires from other sectors. The price and amount of what is consumed determine the FOB price of that sector's commodity.

5. Allocating commodity flow—Materials required for production by a sector are allocated to other sectors for production. The criterion used is minimum delivered cost—FOB price in the producing sector plus transportation cost between regions.

6. Computing consumption—Wages paid by each sector contribute to the income of consumers in a region. Household income, derived from distributed returns on capital, is allocated to regions on the basis of per capita

earned income. Regional income is then spent or converted to demand for commodities and services by using a function for aggregate household consumption.

The principal output of the model is a set of region-to-region commodity flows that can be used in the planning process, and additional outputs include regional economic activity, national income, and value added.

MULTIMODAL ANALYSIS

Figure 1 shows the pivotal role of multimodal analysis in the INSA model. One of the major purposes of INSA multimodal analysis is to translate interregional estimates produced by the commodity-flow model into estimates of port-to-port waterway traffic. Because inland waterways are only one element of a multimodal transportation network in which waterways compete for freight traffic with other modes, forecasts of waterway transportation demand must be made within this complex framework. Analysis of intermodal competition is necessary if forecasts of waterway commodity flows are to be accurate.

Network Model

The INSA multimodal network model is based on standard techniques of transportation systems analysis (14, 15, 16, 17, 18). The model differs, however, from most freight transport demand models, such as those developed by Silberberg (19), Sasaki (20), Baumol and Quandt (21), Herendeen (22), and the National Bureau of Standards. The difference is that the INSA model does not use a separate modal-split model but combines modal share and network routing analyses. A complete treatment of the theoretical base and logical structure of the model is available elsewhere (1). The main features of the model are described below.

Transportation Network

The multimodal transportation network is a set of connected links and nodes for which the descriptive format is similar to that developed by the U.S. Department of Transportation (24). Links representing line-haul transportation facilities are described by nodes at each end of the link, length, transport mode, capacity, and transit time and cost parameters. The nodes have attributes such as name, number, location (coordinates), mode, capacity, and time and cost parameters. A special class of links called access links represent local transportation and connect commodity origin and destination regions to the network. Another special class of links representing intermodal transfer facilities and operations unite the modal subnetworks into an integrated multimodal network.

Performance Functions

The operating characteristics of links and nodes are represented in abstract form as functions that relate the cost of traversing a link or node to the amount of traffic that uses that link or node. These costs are intended to be fully allocated and may not equal the transportation rates paid by shippers. (Because the formulation of the model is general, rates can be used if desired.) Capacity functions are similar functions that relate transit time to shipment volume. Cost and capacity functions for intermodal transfers and for regional access are also used.

Commodity Movements

Each item for transportation is described by region of origin and destination, commodity type, and tonnage. Optional specifications of historical or estimated modal-split percentages and desired route from origin to destination are also permitted. Commodity types are defined by two-digit classification, value, and inventory factor (sensitivity to shipment time).

Routing Cost

Least cost routes (from the shipper's viewpoint) from origin to destination are found for all shipments. Both perceived and economic costs are allowed to vary with shipment volume on each link, and features that help to achieve equilibrium are included.

Model Organization and Logic

Figure 3 shows the organization of the multimodal network model. The main operations of the model, which consist of algorithmic processes that select paths and assign traffic, are described below.

Path Selection

A principal function of the model is to determine the least cost path for each commodity movement by using data that include definitions of the multimodal network in terms of nodes and links and, for each commodity movement, origin and destination regions, tonnage, commodity type, and route restrictions, if any. The problem is to find the minimum cost path between the origin and destination regions for each commodity movement, a path being defined as a sequence of connecting nodes and links.

Determining routes between two points in a network is a familiar problem in transportation analysis, and the multimodal network model uses standard solution techniques (26, 27, 28) developed for finding the least time, or in this case least cost, route. The cost of traversing a network element is defined as the shipment cost (determined from the element's cost function) plus the cost of delay as perceived by the shipper, which is defined as the product of transit time, commodity value, and commodity inventory factor where transit time is determined from the element's capacity function.

The minimum path algorithm finds the path from origin to destination that minimizes the cost incurred for traversing the nodes and links making up that path. Decentralized shipper decision making is assumed; i.e., paths that minimize cost from the individual shipper's viewpoint are generated rather than paths that minimize total systemwide cost. The aggregate result of individual decisions should converge toward a global optimum if all parts of the modeled market system are truly competitive.

Path Constraints

If commodities are restricted as to transportation mode, nodes and links of the modes not used are not considered in the path selection process (e.g., nonpetroleum products are not shipped by petroleum pipeline). Individual shipments may also be restricted to a specified route from origin to destination. Links and nodes are limited to carrying flows below their capacities.

Circuity Constraint

To lessen computational problems, a constraint is imposed on the number of routes considered in the path-selection process by assuming that the location of each node is given in terms of geographic coordinates. An ellipse of given eccentricity is then constructed about the origin and destination regions for a particular commodity movement; the major axis of the ellipse is the straight line connecting the centers of the two regions. The path-selection algorithm then considers only those routes between the two regions that lie totally within the ellipse. In effect this ellipse constitutes a circuity constraint that greatly shortens the amount of computer processing time required, although the price paid is that circuitous routes that may be less costly than the selected route are ignored.

Figure 3. Organization of INSA multimodal network model.

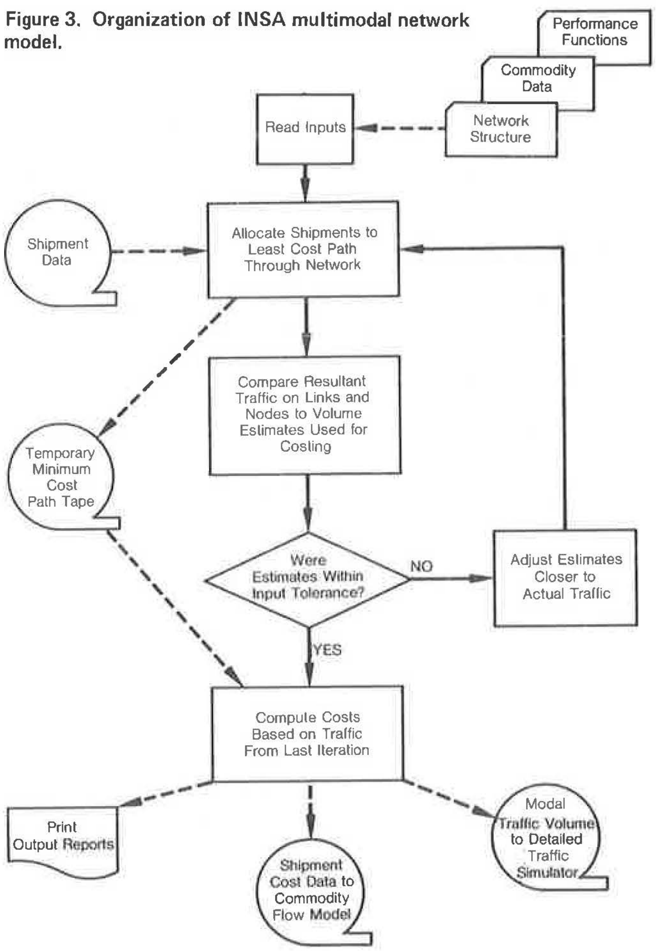
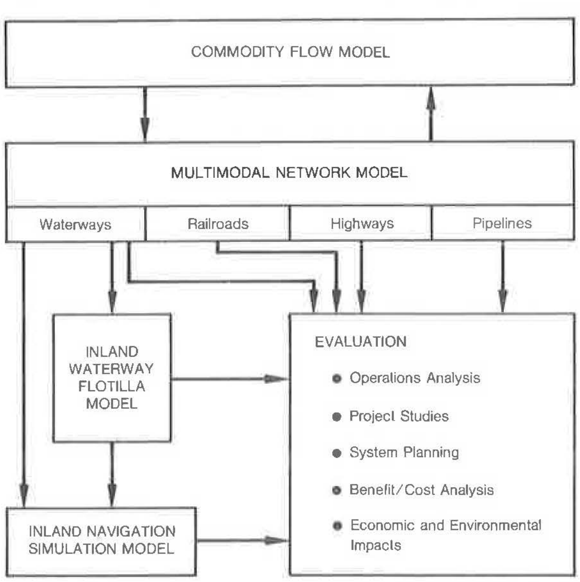


Figure 4. INSA system as a set of interrelated models.



Inertia Effect

An optional inertia effect included in the model may be used to constrain a specified portion of any commodity shipment to observe modal-share percentages input by the user for that shipment. Least cost paths are built for tonnage constrained by mode by using only nodes and links of the specified mode. The remainder of the shipment is free to select the best route. This feature reflects the realities of long-term shipper contracts and other commitments and also prevents the modal results from oscillating in response to small cost differentials among modes.

Assignment Algorithm

An iterative procedure is used to assign shipments to the network. For a base-year case, link and node costs are set by entering the performance functions with flow volumes equal to the practical capacity of each element (volumes for which delays are normal) or some other user-supplied estimate of volume. Shipments with fixed routes are assigned by increasing the loadings on each link and node in the route by the amount of shipment. Shipments with a fixed mode choice are assigned by using the path selection routine. All elements in the path must be of the selected mode. All other shipments are assigned by using normal minimum path logic, and all costs are updated to correspond to the total assigned traffic. This process is repeated in an iterative fashion until assumed and final volumes (and costs) agree within some specified tolerance. For succeeding time periods, volumes and final costs from one period are used as the base volume and cost estimates for the next period.

Output Processing

Standard types of output reports produced by the model are listed below.

1. Optional path traceback for each shipment, which displays nodes along the selected path through the multimodal network;
2. Network flow and cost, for each link and node in the network, including (a) tonnage assigned, (b) transit time, (c) average shipping cost, (d) average inventory cost, and (e) average total cost;
3. Network flow and cost summary, for each mode by node and link class, including (a) average kilotons and kiloton miles (links only), (b) total kiloton days, (c) cost per kiloton mile (links only), and (d) total cost; and
4. Network flow and cost summary by commodity, for each commodity class by mode, including (a) modal share of kilotons, kiloton miles, and kiloton days and (b) modal share of shipping, inventory, and total costs.

In addition, the model provides interface data files for input to other models. Average transportation costs are generated for each commodity and origin-destination pair to be used by the INSA commodity-flow model. For any designated mode, the model keeps track of which nodes were used to enter and leave that modal subnetwork and produces a file of traffic by node of origin and destination and by commodity. This feature may primarily be used to produce port-to-port commodity flows for input to the INSA inland navigation simulation model. It was to determine these prospective waterway traffic flows that the model was originally developed. The additional planning information listed above is generated in the process of obtaining these flows.

INTEGRATED COMMODITY-FLOW, MULTIMODAL, AND WATERWAY ANALYSIS

Figure 4, which is an expanded version of Figure 1, shows the overall structure of the INSA system in the form of a set of interrelated models. In comparing the two figures it may be noted that waterway analysis is expressed in the form of two models, the inland waterway flotilla model and the inland navigation simulation model. In Figure 4 the commodity-flow model serves as the main driving force of the other models, prescribing the kinds and amounts of cargo to be transported. The multimodal network model allocates commodity flows to the four principal modes of intercity cargo transportation and represents these modes at equal levels of abstraction. Waterway freight traffic, as determined by the multimodal network model, is then input to the two waterway models. The inland waterway flotilla model represents the structural aspects of the waterway system in detail but represents waterway traffic flows in the abstract. This model is used primarily to generate fleet forecasts that are consistent with expected commodity flows and characteristics of the waterway network. Forecasts of fleet and waterway traffic are then input to the inland navigation simulation model, which in comparison with the other models contains a detailed representation of the structure and operation of the waterway system. The models collectively provide measures of the cost and performance characteristics of transportation resources used to satisfy the demand for commodity transportation.

The components of the INSA system described above are designed to permit navigation planning to be carried out in a multimodal context by providing four general capabilities:

1. Analysis of the effects of transportation costs on future commodity flows,
2. Estimation of the modal split of freight traffic,
3. Evaluation of the intermodal impacts of waterway improvements, and
4. Comparison of waterway investments with equivalent investments in other modes.

ACKNOWLEDGMENTS

The work described in this paper was carried out under contract with the U.S. Army Corps of Engineers under the direction of the Systems Analysis Applications Branch, Planning Division, Office of the Chief of Engineers. Branch personnel who contributed to this portion of the INSA study included D. Koch, A. Hawnn, and F. Sharp. Assistance and advice were also received from D. Anderson, Transportation Systems Center, U.S. Department of Transportation; R. Schofer, National Bureau of Standards; and A. Eickhorst, consultant. Other CACI contributors were C. Strack, A. Clark, R. Kistler, M. Rahrer, and W. Clark.

REFERENCES

1. Inland Navigation Systems Analysis. CACI, Inc., Arlington, Va.; Office of the Chief of Engineers, U.S. Army Corps of Engineers, Vols. 1-8, July 1976.
2. M. L. Manheim. Practical Implications of Some Fundamental Properties of Travel-Demand Models. HRB, Highway Research Record 422, 1973, pp. 21-38.
3. D. Brand. Travel Demand Forecasting: Some Foundations and a Review. HRB, Special Rept. 143, 1973, pp. 239-282.
4. M. S. Bronzini, J. H. Herendeen, Jr., J. H. Miller, and N. K. Womer. A Transportation-Sensitive Model of a Regional Economy. Transportation Research, Vol. 8, 1974, pp. 45-62.
5. W. Leontief and A. Strout. Multi-Regional Input-Output Analysis. In Structural Interdependence and Economic Development (T. Barna, ed.), Macmillan, London, 1963.
6. B. G. Hutchinson. Forecasting Inter-Regional Commodity Flows. Univ. of Waterloo, Ontario.
7. J. Mortensen. Forecasting Interregional Freight. In Application of Operations Research to Transportation Problems, Western Periodicals, North Hollywood, Calif., 1973.
8. L. N. Moses. Outputs and Prices in Interindustry Models. Papers, Regional Science Association, Vol. 32, 1974, pp. 7-20.
9. R. J. Moroney. The Structure of Production in American Manufacturing. Univ. of North Carolina Press, Chapel Hill, 1972.
10. N. Shakashita. Production Function, Demand Function and Location Theory of the Firm. Papers, Regional Science Association, Vol. 20, 1968, pp. 109-122.
11. L. Cooper. Solutions of Generalized Locational Equilibrium Models. Journal of Regional Science, Vol. 7, 1967, pp. 1-8.
12. P. O'Sullivan and B. Ralston. Forecasting Intercity Commodity Transport in the U.S.A. Regional Studies, Vol. 8, 1974, pp. 191-195.
13. A. G. Wilson. Entropy in Urban and Regional Planning. Pion Limited, London, 1970.
14. M. L. Manheim. Search and Choice in Transport Systems Analysis. HRB, Highway Research Record 293, 1969, pp. 54-82.
15. E. N. Thomas and J. L. Schofer. Strategies for the Evaluation of Alternative Transportation Plans. NCHRP, Rept. 96, 1970.
16. Methodological Framework for Comprehensive Transportation Planning. Transportation Research Institute, Carnegie-Mellon Univ., Pittsburgh; Pennsylvania Transportation and Traffic Safety Center, Pennsylvania State Univ., University Park, 1968.
17. R. J. Paquette, N. A. Ashford, and P. H. Wright. Transportation Engineering. Ronald Press, New York, 1972.
18. M. Beckmann, C. B. McGuire, and C. B. Winsten. Studies in the Economics of Transportation. Yale Univ. Press, New Haven, Conn., 1956.
19. E. Silberberg. The Demand for Inland Waterway Transportation. Water Resources Research, Vol. 2, No. 1, 1966, pp. 13-29.
20. B. R. Sasaki. Predicting Transporter's Choice of Mode. TRB, Transportation Research Record 577, 1975, pp. 13-18.
21. R. E. Quandt and W. J. Baumol. The Demand for Abstract Transport Modes: Theory and Measurement. Journal of Regional Science, Vol. 6, 1966, pp. 13-26.
22. J. H. Herendeen, Jr. Theoretical Development and Preliminary Testing of a Mathematical Model for Predicting Freight Modal Split. Pennsylvania Transportation and Traffic Safety Center, Penn-

sylvania State Univ., University Park, Rept. TTSC 69D8, April 1969.
23. J. R. Meyer, ed. Techniques of Transport Planning. Brookings Institution, Washington, D.C., 2 vols, 1971.
24. Urban Transportation Planning: General Information and Introduction to System 360. Federal Highway Administration, U.S. Department of Transportation, March 1972.
25. E. F. Moore. The Shortest Path Through a Maze, Proc., International Symposium on the Theory of Switching, Harvard Univ., April 1957, Harvard Univ. Computation Laboratory Annals, Vol. 30, 1959, pp. 285-292.
26. G. B. Dantzig. On the Shortest Route Through a Network. Management Science, Vol. 6, 1960, pp. 187-190.
27. S. E. Dreyfus. An Appraisal of Some Shortest-Path Algorithms. Operations Research, Vol. 17, 1969, pp. 395-412.

Inland Navigation Systems Analysis

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The objectives of the inland navigation systems analysis program are to develop within the U.S. Army Corps of Engineers the capability to optimize the design and schedule for implementation of future improvements to U.S. inland waterways and improve the operating efficiency of inland navigation. The program is an integrated system of four computer models, data, and planning procedures to (a) forecast commodity flows, (b) predict modal shares of traffic, (c) simulate and monitor inland waterway transportation, (d) predict economic impacts of inland waterway improvements, and (e) select the best size, location, and timing of inland waterway improvements.

The inland navigation systems analysis (INSA) program of the U.S. Army Corps of Engineers is designed to help Corps planners make the best possible decisions concerning the development of the inland waterway system and specifically to help them achieve two goals: to operate and maintain the inland waterway system as efficiently as possible and to select the best size, location, and timing of inland waterway improvements.

INSA essentially provides a planning capability and comprises an integrated system of four models, data, and planning procedures. Because the program recognizes that waterway transportation is a dynamic physical system embedded in an equally dynamic multimodal transportation market and national economic system, the system of models is designed to mimic the national market system and the role of inland waterway transportation within that market system. INSA simulates the market forces by use of a commodity-flow model and a multimodal model. The commodity-flow model is a multiregional input-output model designed to reproduce the market conditions of the U.S. economy, and the multimodal model gives modal transportation supply conditions. When these models operate together, they simulate the interplay of the national economy and the modal transportation system in bulk commodity movement.

Another pair of models simulates inland waterway transportation. Interaction among commodity traffic, the towing industry, and the waterway are simulated by a flotilla model and a navigation simulation model. The flotilla model represents the towing industry's response to commodity traffic, physical waterway characteristics, and operating delays caused by congestion. Given the waterway network, commodity traffic patterns, and expected operating delays, the flotilla model generates a least cost fleet or mix of towboats and barges required for the movement of commodities. The inland navigation simulation model is intended to represent inland waterway navigation as a large interacting system and to test by simulation the local and systemwide performance impact of a replacement structure, a new channel configuration, or an entirely new waterway. The navigation simulation model can also test new lock operating policies, variations in lock design, changes in channel depth, and many other controllable factors. Together the two models can estimate waterway network cost and capacity for providing freight transportation, and those estimates in turn can be used to estimate economic impacts, costs, and benefits.

The four INSA models are shown schematically in Figure 1 and described below. These four models can be operated together as a unit or as individual models by using any means or models other than those of INSA as input.

This paper summarizes the results of several years of intensive research. Because of the extent and complexity of the study, it is not possible to present more than the general concept of the models.

COMMODITY-FLOW MODEL

The purpose of the INSA commodity-flow model is to forecast the demand for interregional bulk commodity transportation. The commodity-flow model is largely concerned with predicting the size and shape of particular sectors of an economic system. In the model, an economy consists of a set of regions, each of which contains a set of economic sectors or industries. These economic sectors produce an output product to satisfy perceived domestic and export demand. The production process in each sector requires using a combination of inputs (raw materials, labor, and capital goods) to produce the output product. The mix and sources of inputs to the production process depend primarily on delivered input prices, including the price of transportation, as each sector seeks efficient input combinations. Commodity flows occur in this system as raw materials travel to production sites and commodities move to satisfy domestic and export demand.

The commodity-flow model is a multiregional input-output model in which market dynamics determine the location, composition, and pricing of output and the behavior of economic aggregates determines the level of output. In this system consumers select commodity suppliers and producers compete for customers on the basis of delivered commodity price, which includes the price of transportation for inputs and the price of transportation from suppliers to consumers. The commodity-flow model then generates a demand for commodities that depends on transportation price.

The commodity-flow model functions as the interacting components of production and consumption, which generate the demand for transportation based on economic transactions across geographic space. The result is commodity flow. The information flow for the commodity-flow model is shown in Figure 2. Figure 3 shows the elements of the model based on input requirements, processing procedures, and output reports.

Input

The following types of economic data and information are represented in the model:

1. Economic activities—Commodities are identified as output from an economic activity. Each activity has a specified type of production function—either Cobb-Douglas or constant elasticity of substitution—and speci-

Figure 1. INSA system.

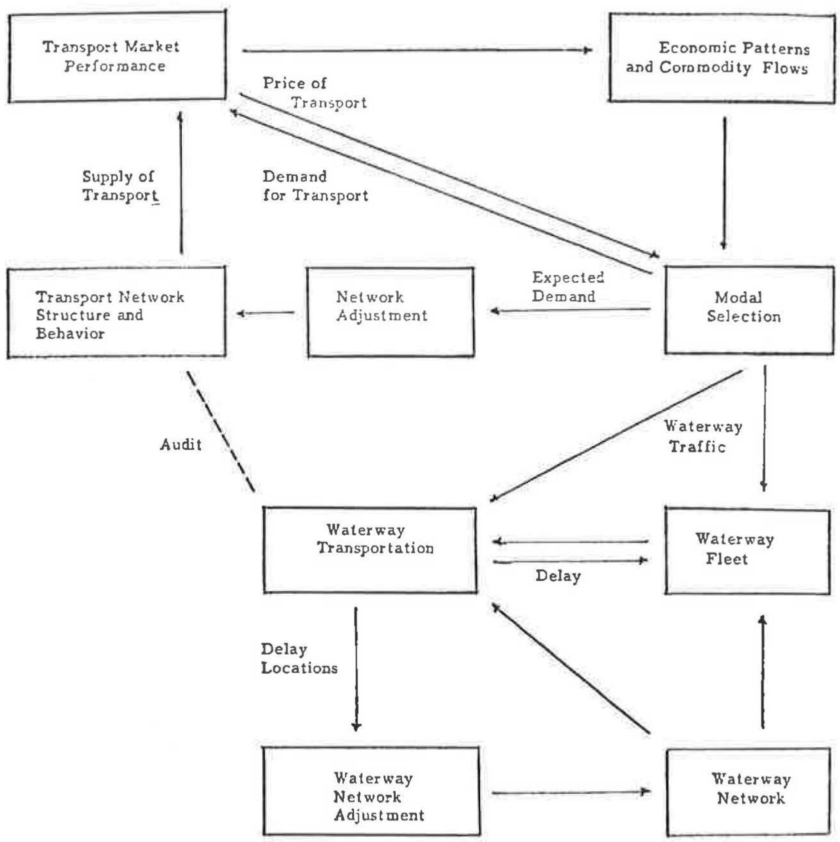
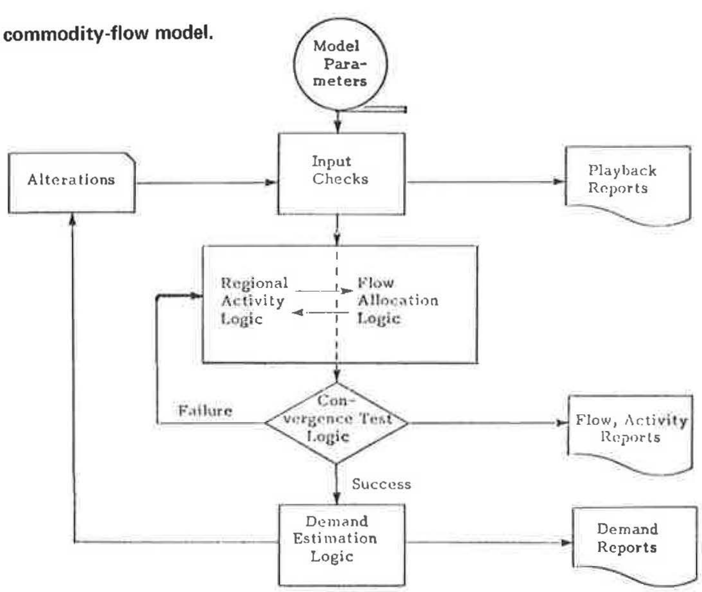


Figure 2. Structure of INSA commodity-flow model.



fies its production requirements for raw materials, labor, and capital goods as well as prices of those requirements. The value of output is given, but output level is generated by the model.

2. Regional attributes—This model uses the U.S. Department of Commerce delineation of 173 Bureau of Economic Analysis (BEA) areas to give commerce flows from area to area. Other regional approaches may also be used. BEA data are collected on the characteristics of an area, including earned income, work force, wages, population, return on capital, and consumption expenditures.

3. Demand—Demand is based on domestic and export conditions. Export demand is treated as an exogenous factor and must be specified by the analyst. Domestic demand is estimated by the model and is assumed to be of unitary elasticity with respect to price. All demand is measured in physical rather than monetary units. Domestic conditions must be estimated for first-year forecasts; the model then estimates demand for subsequent years.

4. Transportation costs—Data on the cost of shipping between all regions by commodity must be specified and may be obtained from the INSA multimodal model or an alternative source. Transportation cost is needed to determine delivered commodity price.

Operations

The following operations are performed by the model:

1. Determination of minimum cost and location—Initial calculations are made to determine the minimum delivered price of each commodity for each supply region and for each consuming region.

2. Computation of consumption—Regional income is derived from earned income by area, wages paid by each sector, and distributed returns to capital, allocated on the basis of per capita earned income. Regional income is then spent or converted to demand for commodities and services by using a consumer expenditure function.

3. Determination of demand—The demand for commodities is based on regional historical evidence and augmented by regional consumption patterns.

4. Organization of transportation costs—Transportation costs, which consist of transport cost of input and delivery cost of product, are organized by the model and used to determine transportation demand.

5. Forecast of economic activity—Supply region activities are generated based on given inputs and prices and regional production functions.

6. Allocation of commodity flow—The selection of input materials, based on minimum delivered cost, allows the model to determine free-on-board (FOB) prices and, eventually, transportation cost.

Output

The following information is output by the model.

1. Commodity flow report—A list of flow volumes between origin (supply region) and destination (consumption region) is compiled for each commodity. Commodities destined for export are noted.

2. Domestic demand report—Data on wages, work force, income, and demand generated as a result of income and expenditures are given for each region.

3. Origin flow report—Each region's market for all outputs is displayed.

MULTIMODAL MODEL

The basic purpose of the INSA multimodal network model is to provide a device for evaluating within a market concept the economic benefits obtainable from specified capital investments in any one or combination of the following transportation modes: inland waterways, railroads, highways, and pipelines. In such an evaluation the model simultaneously considers all modes and thus reflects important interactions among them. Because of system complexity, the scope and purpose of the model are confined to evaluating particular facility and network improvements. In accomplishing this function, however, the model indicates which portions of transportation modal networks will benefit most from improvement. This information is useful in determining gross allocation of transport investment across modes and suballocations within modes.

The chief distinguishing characteristic of the INSA approach to multimodal analysis is its emphasis on transportation markets and their interplay with commodity markets. In a market context, the transportation system is viewed as a connected set of links and nodes, each offering transportation according to a supply schedule that relates cost to shipment volume. Demand schedules for links and nodes are derived by finding for each shipment the least cost path through the network. Transportation supply and demand interact to determine jointly the equilibrium values of transportation market prices and service levels. Predicted changes in market equilibrium caused by changes in commodity-flow patterns and by adjustments to the transportation network are the principal product of the analysis and can be used to compare and evaluate alternative transportation investments.

A principal function of the model is determining the least cost path for each commodity movement. Each commodity movement is defined by origin and destination regions, tonnage, commodity type, and route restriction, if any. (Because the INSA model uses U.S. customary units, SI equivalents are not given.) The problem is to find, for each movement, the minimum cost path between the origin and destination regions, where a path is defined as a sequence of connecting nodes and links. Figure 4 shows the structure of the multimodal network model, and Figure 5 shows the model elements.

The Modal Network

Determining routes between two points in a network is a familiar problem in transportation analysis, and the multimodal network model uses standard solution techniques that have been developed for finding the least time and least cost route. The cost of traversing a network element is defined as shipment cost (determined from the element's cost function) plus shipper-perceived cost of delay. The latter cost is defined as the product of transit time as determined from the element's capacity function.

The operations of the path-selection algorithm yield the following results:

1. Identification, for each commodity shipment, of the route to which the shipment was assigned;

2. For each link and node of the network, the number of tons assigned;

3. For each commodity shipment, shipping costs incurred for the assigned route; and

4. For each network link and node, shipping costs and transit time of assigned traffic.

To alleviate computational problems, a constraint is imposed on the number of routes considered in the path-

Figure 3. Elements of INSA commodity-flow model.

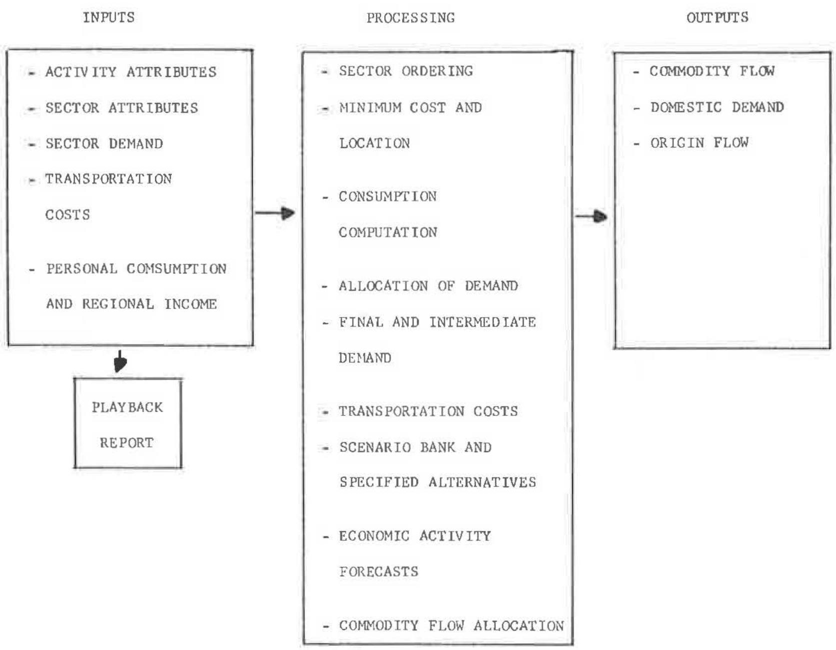
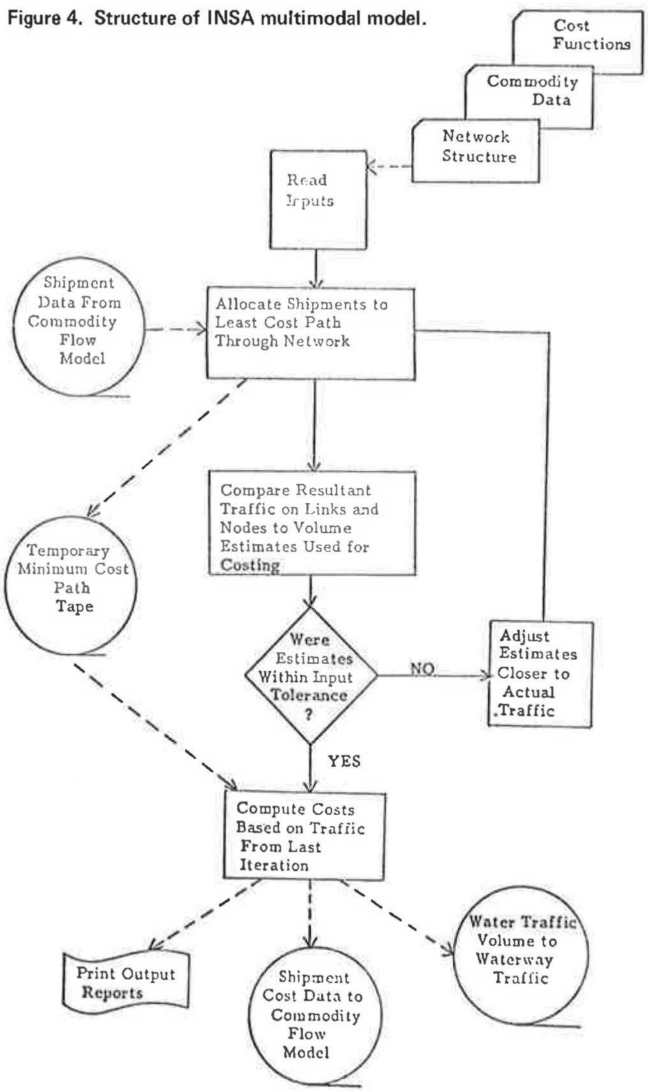


Figure 4. Structure of INSA multimodal model.



selection process by a simple method that assumes that the location of each node is given in terms of geographic coordinates. An ellipse of given eccentricity is then constructed about the origin and destination regions for a particular commodity movement; the major axis of the ellipse is the straight line connecting the centers of the two regions. The path-selection algorithm considers only those routes between the two regions that lie within the ellipse. The algorithm permits the ellipse to automatically increase in size, according to specified criteria, to ensure that at least one route is included. This inclusion ellipse constitutes a circuity constraint that greatly shortens the amount of computer processing time required; the price paid is that circuitous routes that may be less costly than the selected route are ignored.

Commodities may also be restricted as to which modes of transportation they may use. In this case, nodes and links of the disallowed modes are not considered in the path-selection process. For instance, nonpetroleum products are not shipped by petroleum pipeline. Individual shipments may be restricted to following a specified route from origin to destination. Links and nodes are limited to carrying flows below their capacities.

An optional inertia effect is also included in the model, whereby a specified portion of any commodity shipment may be constrained to observe modal-share percentages input by the user for that shipment. Least cost paths for the mode-constrained tonnage are built by using only nodes and links of the specified mode. The balance of the shipment is free to select the best route. This process reflects the realities of long-term shipper contracts and other commitments and prevents oscillation in the model results in response to small cost differences among modes.

An iterative procedure is used to assign shipments to the network. For a base-year case, link and node costs are initially set by entering the performance functions with flow volumes equal to the practical capacity of each element (that flow volume for which delays are normal) or some other user-supplied volume estimate. Shipments with fixed routes are assigned by increasing the loading on each link and node in the route by the amount of shipment. Shipments with a fixed mode choice are assigned by using the path-selection routine and updating all costs to correspond to the total assigned traffic. This process is repeated in an iterative fashion until assumed and final volumes, and thus costs, agree within some specified tolerance. Then volumes and final costs from one period are used as the initial volume estimates for the next period.

The output routine organizes the results of the processing procedure and presents them in several types of reports, including reports giving the allocations of movement requirements to the elements of the network and the cost associated with such allocations. Because the multimodal network model is designed to interact with other INSA models, the output routines also provide data interface files. Interregional transportation cost is generated for use by the commodity-flow model, and commodity traffic flows from origin node to destination node for a given mode (e.g., port-to-port waterway traffic) are output for use by a modal simulation model.

Features

The following is a brief description of the features of the multimodal model.

Problem Size

The size of problem the model can handle is subject only to computer limitations. There are no inherent restrictions on the number of network elements or commodity shipments.

Transportation Networks

The multimodal transportation network is represented as a set of connected links and nodes. The network description format is very similar to that developed by the U.S. Department of Transportation. Links represent line-haul transportation facilities and are described by the nodes at each end of the link, length, transport mode, capacity, and transit time and cost parameters. Nodes have attributes such as name, number, location (coordinates), mode, capacity, and time and cost parameters. A special class of links, called access links, represent local transportation and connect commodity origin and destination regions to the network. Another special link class represents intermodal transfer facilities and operations and unites the modal subnetwork into an integrated multimodal network.

Figure 5. Elements of INSA multimodal model.

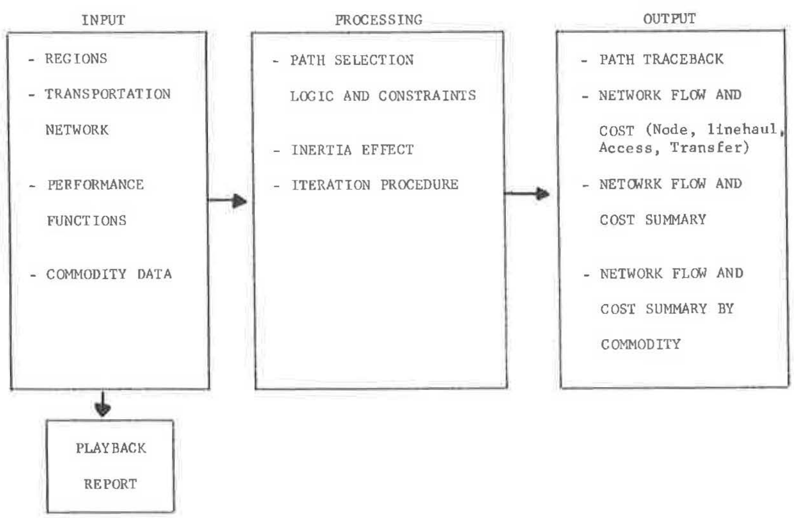


Figure 6. Structure of inland navigation simulation model.

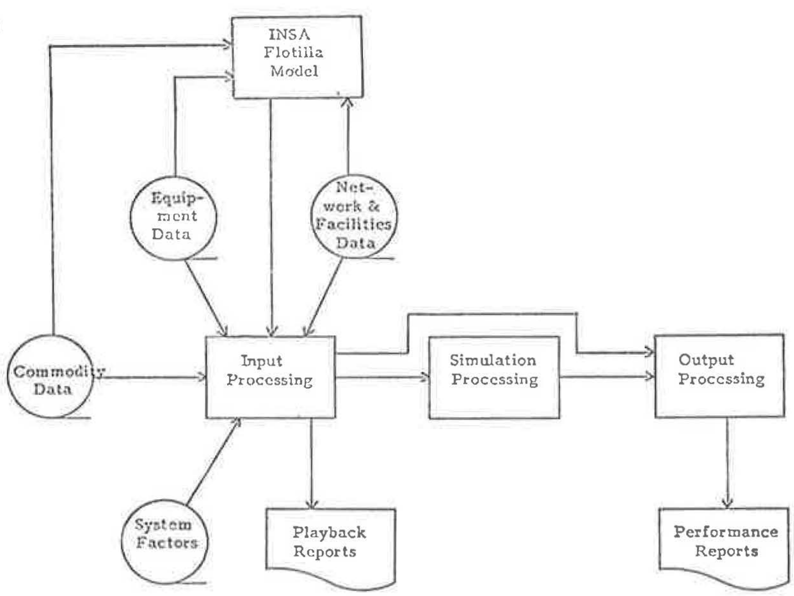


Figure 7. Elements of inland navigation simulation model.

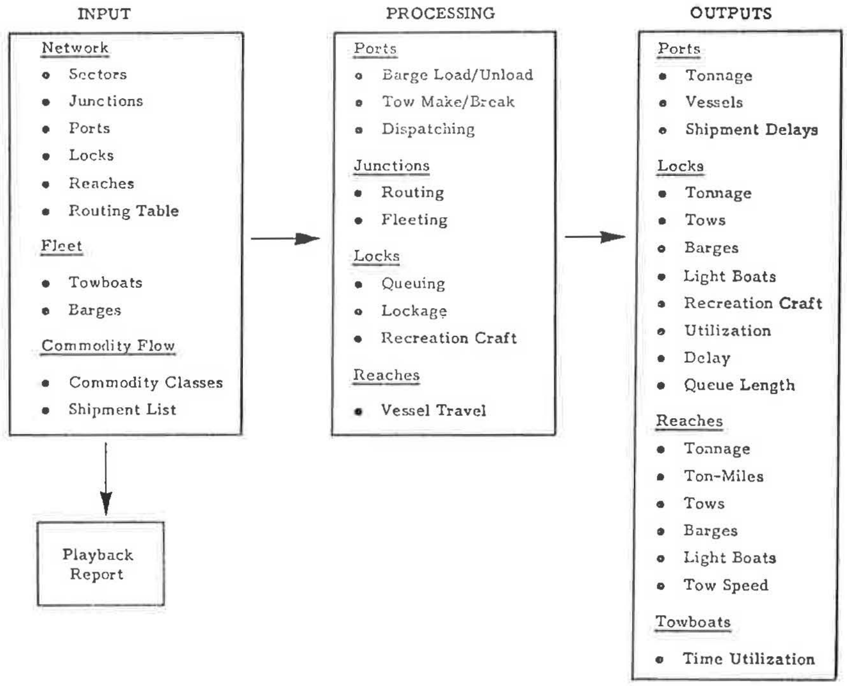
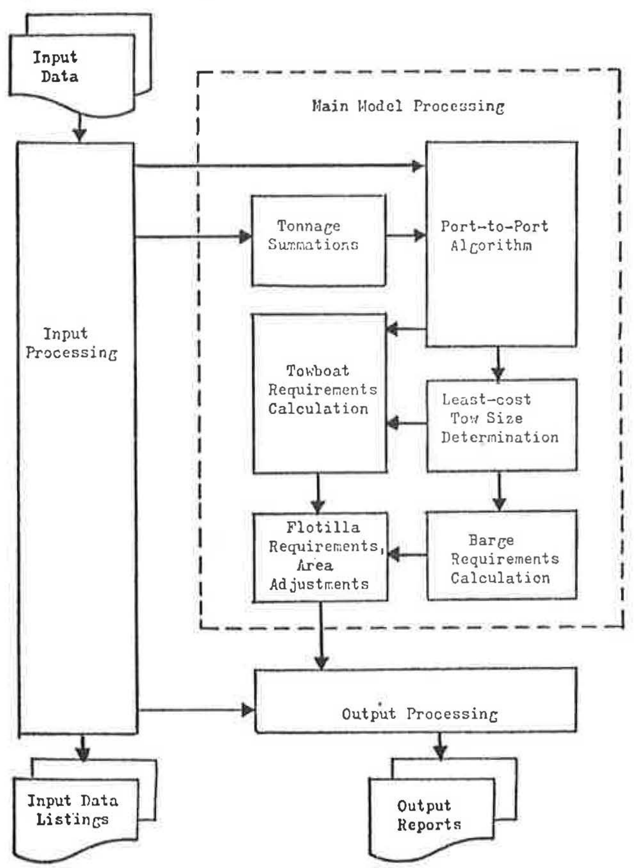


Figure 8. Structure of INSA flotilla model.



Performance Functions

The operating characteristics of links and nodes are represented in abstract form as functions relating the cost of traversing a link or node to the amount of traffic that uses that link or node. These costs are intended to be fully allocated; they may therefore not equal the transportation rates paid by shippers. (The model formulation is general; rates can be used if desired.) Similar functions, called capacity functions, relate transit time to shipment volume. Cost and capacity functions for intermodal transfers and for regional access are also used.

Commodity Movements

Each requirement for transportation is described by origin region, destination region, commodity type, and tonnage. Optional specifications of historical or estimated modal-split percentages and desired route from origin to destination are also permitted. Commodity types are defined by two-digit classification, value, and inventory factor (sensitivity to shipment time).

Transportation Equipment

Individual power units, cargo vehicles, and other transportation equipment are implicitly included in the link and node performance functions. No separate vehicle representation is used.

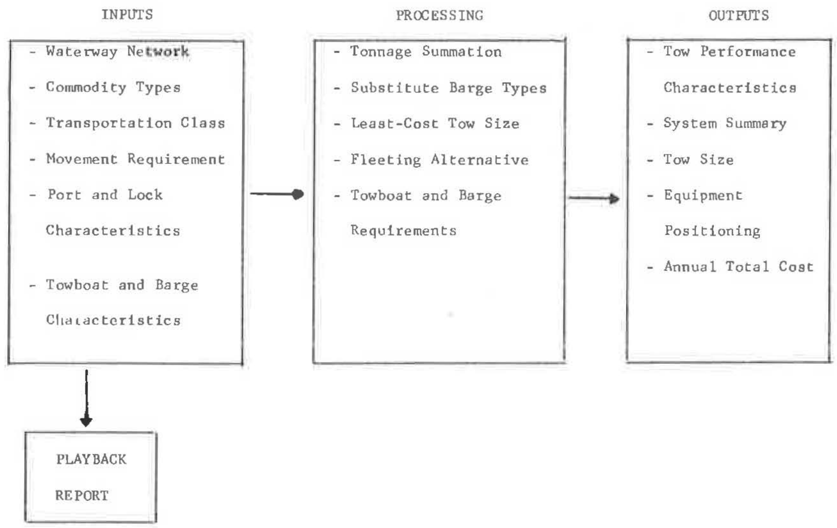
Shipment Routing

Least cost routes (from the shipper's viewpoint) from origin to destination are found for all shipments. Both perceived and economic costs are allowed to vary with shipment volume on each link. Equilibrium-seeking features are included.

WATERWAY SIMULATION MODEL

The purpose of the INSA waterway simulation model is to represent on a computer the movement of commodity flows on the U.S. inland waterway system. Simulation of the system enables observing and predicting its performance under a variety of economic and technical assumptions. These performance predictions are used to assess the adequacy of the existing system and to estimate the economic benefits and environmental impacts

Figure 9. Elements of INSA flotilla model.



of waterway improvements.

The navigation simulator was designed to represent inland navigation as a large interacting system. The model was developed to test by simulation the local and regional performance impact of a replacement structure, a new channel configuration, or an entirely new waterway system. The simulator is also capable of testing such controllable factors as new lock operating policies, variations in lock design, and changes in channel depth.

The inland navigation simulation model assumes a set of waterway traffic shipments determined by transportation markets outside the model, combines these shipments, a fleet, and a waterway network, and then simulates inland waterway transportation as a large, dynamic, interacting system. Figure 6 shows the structure of the simulation model: The commodity-flow model provides inputs on cargo flow and demand, and the flotilla model provides inputs on tow performance and size, towboat and barge positioning, and cost data. Figure 7 shows the primary elements of the simulation model operation—the input requirements, processing procedures, and output reports.

The INSA simulation model is a generalized model that provides explicit representations of individual waterway facilities, cargo consignments, and vessels. The following is a brief description of the model's principal features.

Problem Size

The size of the problem 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, number and type of towboats and barges, or commodities. The model is specifically designed to accommodate systems as large as the entire Mississippi River-Gulf Coast waterway system.

Waterway Network

Ports, locks (and their chambers), and reaches represent the physical features of the inland waterway system. In the inland waterway network the locations of ports, locks (and their chambers), junction points, and sector boundaries are represented as nodes; links represent reaches and are thus segments between nodes. Contiguous link-node groups are organized into sectors. Sectors and river systems identify and organize the elements of the network for processing and analysis. The effects of specific channel conditions, such as bends and shoals, are normally represented implicitly by their constraining effects on navigation.

River Systems

River systems are groups of sectors that facilitate the collection of statistics and the sorting of output. The simulation model thus enables analysis of waterway sections or regions with common characteristics and can accommodate potential projects involving the evaluation of specific ports, locks, and regions.

Sectors

A sector represents an unbranched section of the network on which limitations on tow operations are uniform. Although a sector typically extends from one river junction to another or to a system end point, it can be divided into two or more sectors if significant differences in characteristics exist along its length. Because sectors always begin and end at ports, a port must be located at each junction and end point of the network.

Ports

Each INSA port is called a port equivalent to avoid confusion between ports and major ports. Because of number and variety of ports and docks and the resultant data base requirements, linear stretches are combined and abstracted as a single point at which cargo originates and terminates. Port processing is thus represented by loading and unloading times and by barge pick-up and drop-off times.

Locks

Each lock facility is explicitly represented in the form of tow processing time for each chamber. Processing time is broken down into approach, entry, chambering, and exit times (in accordance with performance monitoring system data). An optimal simplified lock representation scheme is included; single, setover, multiple-cut, multiple-vessel, and open-pass locks are accommodated; and both "first come-first served" and "N up-N down" queuing disciplines are available. A relatively large number of data are required to describe lock systems. The central abstraction used is random processing time distributions to represent lock operations. The model considers the following factors in calculating lock operation time:

1. Type of lock—straight single, setover (the model classes as setover all single locks that require reconfiguration), multiple-cut, or multiple-vessel;
2. Direction of travel—upstream or downstream;
3. Type of entry to and exit from the chamber—fly, turnback, or exchange; and
4. Load category of barges in the tow—loaded or empty.

Reaches

A reach is a section of waterway between two ports or locks. Reaches influence tow traffic in two principal ways: (a) The physical characteristics of a reach limit the size and draft and thus the cargo capacity of tows and (b) tow traffic is constrained by the time it takes to travel a reach, which is a function of the length of the reach and the attainable tow speed.

Cargo

Commodity movements enter the model in the form of a list of individual shipments characterized by commodity type, ports of origin and destination, tows, and earliest possible departure time. This list is compiled by a separate interface program that operates on a port-to-port, origin-destination tonnage matrix. The data for the interface program are output from the INSA commodity-flow model.

Dispatching

Tow make-up (allocating shipments to barges and barge groups to towboats) and tow movement (along the waterway network between origins and destinations) are internal to the model. En route drop-off and pick-up of barges as well as fleet operations are represented. Empty barge movements needed to accommodate trade imbalances are scheduled internally by means of decision rules built into the program.

Vessels

Individual towboats and barges are explicitly represented and denoted by identification number, horsepower (towboat only), size, maximum permissible flotilla size, and sectors of operation. Barges in tow are represented as barge groups—one or more barges of common characteristics. Recreational craft are individually represented by arrival at a lock for lock processing, but trip connectivity is not represented for these vessels. Different weekend and weekday arrival rates may be specified.

FLOTILLA MODEL

The INSA flotilla model determines a cost-effective fleet of towboats and barges required to satisfy a given mix of commodity movement requirements while operating in a waterway network of existing or assumed characteristics. Outputs include the required fleet or tow mix, the corresponding total, and ton-mile costs. Results may be used in independent studies of towing industry projections and as inputs to other methods of waterway analysis developed by INSA, particularly the inland navigation simulation model. The flotilla model may be characterized as an expected value simulation of the inland waterway network with an embedded algorithm for calculating least cost tow sizes over a predefined waterway route. The model can consider the entire waterway network, or any portion of it, and provide a level of detail concerning the number of ports, locks, and reaches that is limited only by the study objectives and the computer size.

Data requirements for commodity flows are provided to the model as origin-destination tonnage by season and by commodity class; origin and destination ports are given by the network definition. Any number of towboat and barge types, and their distinguishing operational or cost characteristics, can be accommodated.

Figure 8 shows the overall structure of the flotilla model. The program elements of the model are specified in Figure 9 according to input requirements, processing procedures, and output reports. As shown in Figures 7 and 8, the model formulates flotilla requirements, adjustments, and use.

Basic inputs to the flotilla model include descriptions of the ports, locks, and channels of the waterway system as parts of a connected network. Operating characteristics of ports and locks, as well as descriptions and performance measures of assumed types of towboats and barges, are given. Seasonal commodity flows are input in terms of commodity type, tonnage, and origin and destination ports. After input data are processed, (a) requirements for origin-destination movements are analyzed and (b) various tonnage sums for each season are calculated, including inbound and outbound tonnages for each port, upstream and downstream tonnages for each lock and link (or reach) of the network, and aggregations of tonnage by commodity type into a smaller number of classes having common transportation characteristics.

After initial processing of the input data, a port-to-port algorithm is used to calculate productivity and cost measures for possible tow sizes operating between two ports for a particular class of cargo. An appropriate tow size is selected for each towboat class, and total round-trip operating and delay times and costs are calculated based on port, lock, and waterway operating characteristics and types of utilization coefficients. Towboat type and tow size with least cost per ton mile are determined for tows containing dry and liquid cargo respectively. The types and amounts of equipment required are then adjusted for seasonal effect, and the resulting equipment requirements and costs are aggregated for output purposes.

When the process is completed, towboat and barge requirements, as well as associated ton-mile costs and other results, are accumulated over all movement requirements by output processing routines, and the results are displayed in several types of output reports. The output reports of the flotilla model consist of the projected numbers of towboats and barges by type that are needed to satisfy commodity-flow requirements. These projections are input to the INSA inland navigation simulation model, which investigates the operation of the waterway system as a whole. The simulation model in turn provides refined estimates of lock delay factors and other parameters used by the flotilla model. Both models may share input data describing the network, base-year equipment, commodity flows, and other system features.

Since calculated fleet requirements and associated transportation costs are sensitive to the structural aspects of the inland waterway system, the model may also assist in evaluating alternative capital investment programs and performing benefit-cost analyses. Specialized studies such as fleet distribution requirements in response to seasonal demand or commodity mix, changes in fleet composition indicated by long-term trends in the economy, and studies of other exogenous influences may also benefit from use of the INSA flotilla model.

SUMMARY

The inland navigation systems analysis program was intended to provide the Corps of Engineers with tools to diagnose inland waterway transportation problems. The program attempts to investigate waterway problems for their transportation and economic impacts and also to evaluate actions proposed for coping with these problems. In identifying the problems, reviewing potential solutions, and testing proposed actions, the INSA program has always been operated from the perspective that problems and solutions should be considered in light of their effects on transportation cost and capacity. INSA can thus predict the probable course of problems and the probable impact of proposed actions on inland waterway navigation.

REFERENCE

1. Inland Navigation Systems Analysis. CACI, Inc., Arlington, Va.; Office of the Chief of Engineers, U.S. Army Corps of Engineers, Vols. 1-8, July 1976.

Port-Funding Dilemmas in a Regional Planning Context

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The purpose of this paper is to explore the funding problems that confront those who prepare comprehensive development plans for inland ports. Using as an example the study of the Port of Metropolitan St. Louis conducted by the East-West Gateway Coordinating Council, the paper discusses traditional and innovative funding sources and their applications, advantages, and weaknesses, with reference to the ongoing regional port study. It is concluded that, although the survival of the inland waterway industry as a healthy mode of transportation depends on improved port operations, the existing port authorities and related planning agencies often lack adequate financing for planning port development. It is therefore vital that some type of sole-source funding program be developed to provide the funds necessary for efficient port planning and development.

Although the amount of freight carried on the inland waterways of the United States has grown annually since the 1920s, growth of freight traffic at the Metropolitan Port of St. Louis has not kept pace. Between 1961 and 1970, for example, freight carried on the Mississippi River as a whole grew by 87 percent, but freight at the metropolitan port [based on the 30-km (19-mile) definition] grew by only 10 percent.

The Port of Metropolitan St. Louis, like many other U.S. ports, has been faced with a bewildering dilemma in recent years: an overwhelming need for some kind of development plan that would serve not only to identify areas suitable for industrial and port-related development but also as a rallying point for those who make their living in the waterway industry. The need for such a plan for the port became apparent in 1973. There was general agreement among the business and labor leaders of the community that something had to be done, but that something was not yet defined. To add to the confusion, there was no single port authority to whom they could turn.

THE PROBLEM

In an effort to better understand the current position and problems of the port, community leaders turned to the East-West Gateway Coordinating Council, the regional planning agency, for an investigative analysis of the port. The general objective was to enhance the economy of the St. Louis area by capitalizing on the strategic location of the port of St. Louis on the inland waterways of the United States.

Although an agency had been identified to conduct the study, community leaders were faced with another dilemma: How were they to pay for the study effort? The council was authorized to survey all existing funding sources to determine the best method. Careful analysis revealed that there were no existing programs at the local, state, or federal level to provide funds for the type of effort needed. There was only one ray of hope: Community leaders had been advised by officials in a federal agency that if the local community provided funds for the preliminary investigation as a gesture of its good faith and to indicate how serious it felt the problem to be, the federal government might provide funds to complete the effort. Based on this premise, the study was divided into a series of phases. The first phase was designed to be an investigative effort, with a funding requirement between $50 000 and $60 000. Ultimately, a 35-member task force, organized to provide advice and guidance to the council, raised nearly $57 000 through private sources.

The first phase of the study of the Port of Metropolitan St. Louis was completed in 1973. Its principal recommendation called for the St. Louis region to develop an efficient inland port to serve the industries that are major users of inland waterway transport. However, the task force and the council were again faced with the problem of obtaining the funds needed to prepare a port development plan. Again, the council was charged with the responsibility of surveying all available sources of funds. Now that the first phase of the study had been completed, the staff went to the federal official who had implied that he could provide the funds for completion of the study. No funds were available.

METHODS OF FUNDING

In examining various traditional methods of funding port development, the staff of the East-West Gateway Coordinating Council surveyed the following sources:

1. General obligation bonds,
2. Revenue bonds,

3. Consolidated bonds,
4. Industrial development bonds,
5. State and local subsidies,
6. Federal aid, and
7. Other.

General Obligation Bonds

General obligation bonds have traditionally been used for capital financing for the acquisition, construction, maintenance, or operation of a facility. This type of bond is generally tax supported and is usually issued by a state, county, or municipality acting as the legislative parent of the port authority. On issue of a general obligation bond, the state, county, or municipality is required to provide collateral security by pledging its full faith and credit. The payment of these bonds is the responsibility of the issuer and payment is made from, and primarily secured by, ad valorem property taxes. The issuance of a general obligation bond is normally preceded by a voter referendum in which the community accepts or rejects each bond issue. Should such a bond be issued, the principal and interest are usually repaid by the issuing body either from general revenues or through a special tax assessment or levy on the taxpayers.

Although this type of financing is used by many port authorities and districts throughout the United States, it could not be used by the Metropolitan Port of St. Louis primarily because there is no single port entity to sponsor such a bond issue (the metropolitan port encompasses two states and seven counties, and none of the states or counties would be able to issue the bonds necessary to finance a regionwide effort).

Revenue Bonds

Revenue bonds are normally issued by a port based on lease and operation of facilities that can generate sufficient funds to repay both principal and interest. Many U.S. ports prefer revenue bonds to general obligation bonds as a means of capital financing because the revenues accruing from the facility itself are pledged as security for the outstanding bonds. However, despite the fact that interest rates on revenue bonds are generally higher than on general obligation bonds, revenue bonds are not normally attractive to investors because all financial risks are borne by the port rather than by the state or local government.

Because of the regionwide nature of the port of St. Louis this method of financing was not suitable either. There was simply no equitable formula by which the counties and the two states could issue revenue bonds to provide the necessary funds to complete the planning effort.

Consolidated Bonds

Consolidated bonds are normally used by ports that have broadly based sources of revenue. For example, a port that operates not only waterway terminals but also bridges or tunnels, owns real estate, and has a good reputation with investors can issue revenue bonds backed not only by the potential revenue of one project but by the revenue obtained from all of the facilities within the organization. Proceeds from such a bond could then be used for the acquisition of new facilities or the renovation of older facilities at the discretion of the port without being subject to the more confined terms of the single-facility revenue bond.

This source of financing was not available to the port of St. Louis because of the multiplicity of agencies within the port boundaries. Had the port districts and authorities been legally linked in some way, this source might have been available, but that was not the case. As port agencies begin to work more closely together in the future, this will probably become a viable method of financing.

Industrial Development Bonds

Industrial development bonds are normally issued by local governmental bodies and used to buy or build docks, terminals, or manufacturing plants and to obtain equipment that could in turn be leased to private enterprise. Normally, industrial development bonds are issued as revenue bonds, which are then repaid with the rents or fees derived specifically from the benefiting facility. It is possible, however, to issue an industrial development bond under terms similar to those for a general obligation bond. This method of financing was not available to the port because, although the ultimate outcome of the effort would be industrial development, the funds were needed primarily for planning purposes and not facility development.

State and Local Subsidies

Almost every public port in the United States receives some kind of public aid or subsidy from some level of government. These funds range from direct appropriations, direct taxes levied by the port district, and taxes levied by local government on behalf of the port authority to exemptions from taxation or indirect subsidies incorporated in public community services provided to the port authority by the local, city, or county government.

This source of funding appeared to hold promise for the St. Louis effort because the port had two states from which it could petition funds and six operating, autonomous port authorities that could act as intermediaries in obtaining funds from the states. Unfortunately, the Missouri port authorities, with the exception of the port commission of the city of St. Louis, had only been established under a law passed in 1974 and were operating out of the Missouri Department of Transportation, which was not yet 5 years old. The amount of funds available to these relatively new organizations was extremely limited. In fact, two of the Missouri port authorities were operating on budgets of less than $10 000/year. The Illinois port districts were in comparatively better condition, but only one of those districts had a full-time staff and the other two did not own or operate a single dock.

Federal Aid

There are more than 40 federal agencies whose activities affect the operation, administration, or development of U.S. ports. Only three of these agencies—the U.S. Coast Guard, the U.S. Maritime Administration, and the U.S. Army Corps of Engineers—have either direct or indirect responsibility for port operation and development. The activity of even these agencies is very limited in the area of port development; none has any statutory authority to provide funds to public or private port authorities for development projects involving terminals or other port structures.

The port program of the Maritime Administration stresses the promotion and development of U.S. ports and related transportation facilities, but its participation is limited to rendering advice and technical assistance. The Corps of Engineers is responsible for constructing, improving and maintaining navigable waterways, channels, and harbors—not for port-development planning. The Coast Guard is responsible for the protection and security of vessels, harbors, and riverfront facilities and for enforcement of environmental regulations.

The federal government does provide funds for port improvement through the Economic Development Administration (EDA) of the U.S. Department of Commerce, which has a public works and development program of grants and loans. Before an area can qualify for these funds, however, it must be declared an economically depressed area by EDA. Some counties within the Port of Metropolitan St. Louis did not qualify.

Other Sources

The only other apparent source of funding was revenue derived from the port's daily operations, i.e., rent, leases, and service charges. However, as noted above, only two of the six port authorities were actually operating, and neither had any surplus funds for a region-wide port planning effort.

FURTHER ANALYSIS AND SOLUTIONS

Nearly $60 000 had been expended in the unfinished study of the Port of Metropolitan St. Louis, and no solution to the problem of funding had been found. Nevertheless, it was apparent that, if the port was going to continue to benefit the people and the economy of the region, it would have to become an efficient inland port to serve the industries that would be its major users for the next 25 years.

The Maritime Administration determined in 1973, in conducting a comprehensive market analysis of all domestic waterborne shipping, that there would probably not be future advances in the efficiency of line-haul waterborne movements comparable to the major advances of the last 40 years. There did appear, however, to be an opportunity for significant improvement in inland port operations. Consequently, a domestic waterborne shipping market analysis recommended that the Maritime Administration promote development and widespread use of improved cargo-handling technology for inland waterway ports. In this area the council finally found a common interest between a federal agency and the port of St. Louis. The port had operational problems peculiar to an inland river port that would have to be alleviated or solved before it could develop to its full potential; the Maritime Administration, through its research and development program, had funds available to investigate those problems.

The combined interest of the U.S. Maritime Administration and the East-West Gateway Coordinating Council ultimately led to the study of inland waterway port operations at St. Louis. The study had two main objectives: (a) to determine the impact of water flow, including fluctuations of river level, on the operation of inland ports and (b) to devise strategies to minimize the adverse effects of these and other operational problems. This was called the phase 2 study, and, because of its research and development nature, the Maritime Administration provided 80 percent of the funds needed. The council staff was able to obtain local matching funds from the Illinois Department of Transportation and the Ozarks Regional Commission in Missouri.

Phase 2 was completed in a little more than 12 months and resulted in the development of information on present port operations, an analysis of these operations to identify opportunities for improvement, an analysis of specific applications of new waterway concepts (such as LASH-SEABEE), and a set of recommendations for consideration by the Maritime Administration and the waterway industry. Freight forecasts through the year 2000, by commodity, were also developed based on historic and economic trends.

Two additional tasks that could not be included in the study funded by the Maritime Administration because of its unique application to the St. Louis region were necessary to complete the port development plan and to institute development activities to attract water-related industries. These tasks were

1. To conduct detailed market research interviews to identify the specific requirements for attracting port and waterway development to the region (this was originally called for in the study recommendations of phase 1 and would provide the information needed to attract major target industries) and
2. To package the recommendations for regional port development in a form suitable for effective communication and for use in promoting both the port and the region to prospective new industries (this would take the form of a document and a slide presentation explaining the recommendations for regional port development in terms appropriate for a variety of audiences).

The council was once more faced with the problem of obtaining funds to complete the effort. Because private industry had provided money for the first phase of the study, the staff hesitated to go back to them for additional funds. The remaining work could not be considered as research and development; because of its regional nature, the federal government would not provide the funds needed; and the local port districts and authorities had not yet developed any funding sources for such purposes.

The only sources left were the two state governments. Because the Port of Metropolitan St. Louis is about evenly divided between Missouri and Illinois, neither state was willing to provide more than half the funds needed for fear its money would be used to the other state's advantage. For several months the council staff and various agencies of the two state governments explored alternative methods of financing. Ultimately, the Ozarks Regional Commission provided some of the funds because of the economic development that would occur as a result of the effort, and the Illinois Department of Transportation provided some because of the impact that this effort would have on regional transportation patterns.

CONCLUSION

The problems encountered by the East-West Gateway Coordinating Council are not unique to the Port of Metropolitan St. Louis but are faced by all planners of inland river ports. The ever-increasing necessity of making the best possible use of the land available within port areas makes the problem critical. Until recently there has been a decided lack of planning for inland waterway ports. Random development is the single most important cause of the current inefficiency of port operations. There is an urgent need for carefully designed river docks associated with industrial parks and for new materials-handling procedures specifically designed for use in the river environment. Present commodity-handling technology is based on equipment designed for situations that no longer exist. Design criteria for new equipment must be related specifically to loading and unloading river barges.

Survival of the inland waterway industry depends on improved port operations. Opportunities for improving the efficiency of inland waterway port operations are greater than are the productivity increases presently foreseen for barge line-haul transportation. Potential productivity increases in the railroad industry (especially as a result of federal aid) make port improvements mandatory if river transportation is going to remain competitive.

Port authorities and related planning agencies, however, often lack adequate financing for planning port development. Some type of sole-source funding program must be developed to provide the funds for efficient port planning and development. Because critical decisions relating to the successful functioning of an inland port are made before any construction or development takes place, funds invested in this area may largely determine the future viability of inland waterway transportation.

REFERENCES

1. Port of Metropolitan St. Louis Appendix A: Profile of the Port, 1975. A. T. Kearney, Inc., and East-West Gateway Coordinating Council, St. Louis, 1976.
2. E. Schenken and H. Brachel, eds. Port Planning and Development as Related to Problems of U.S. Ports and the U.S. Coastal Environment. Cornell Maritime Press, Inc., Cambridge, Md., 1974.
3. R. E. Takel. Industrial Port Development. Scientechnica, Bristol, England, 1974.