correlation thereto; (d) number of present 18-kip single-axle EALAs applied to the roadway; and (e) the average annual rate of traffic growth.

In considering the above possibilities, we conclude that most states are primarily interested in potential changes in truck volumes or truck loadings that are likely to occur in the vicinity of traffic generators and along principal truck routes. The former can be handled quite readily by reassigning vehicles back to the rail and highway networks by (a) identifying the specific links involved in minimum distance (or time), (b) assigning computed traffic vlumes to these links, and (c) summarizing the data on a link basis. Normally, this would be done separately for the base case and each alternative and the final product would be the difference in volumes and the relative change projected to take place.

CONCLUSIONS

The goal of this paper was to present and describe a technique that enables users to prepare freight forecasts in a simple and straightforward manner, deriving insights and related information on changes and impacts brought about by hypothesized or future conditions. In illustrating the use of this technique with examples drawn from two distinctly different problems and applications, it has been demonstrated that the technique is both flexible and adaptable. The framework of the technique, which consists of basic concepts and principles, permits users to organize and structure a process to examine the complex issues involved in freight-related problems. Each of the components of the technique may be expanded on to meet the particular requirements of given situations.

The approach presented encourages the user to incorporate substantive knowledge and understanding in interpreting a problem or situation as well as adapting the technique. Reliance on economic theory and econometric networks is not appropriate in analyzing many freight-related problems, and a balance must be established between what theory tells us and the way the real world behaves. In this sense, the technique is more of a process tailored to a specific situation than a standardized methodology in which only a specified set of data inputs is required to produce results.

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Publication of this paper sponsored by Committee on Statewide Multimodal Transportation Planning.

Development and Application of Statewide, Multimodal Freight Forecasting Procedures for Florida

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The development and application of a goods movement forecasting methodology resulting from the Statewide Multi-Modal Planning Process Project sponsored by the Florida Department of Transportation are described. The methodology involves two steps. First, the generation and distribution of freight are projected through a Fratar model that applies growth factors to current flows of commodities. In the second step, the projected freight flows are distributed among competing modes through modal-split models. The Fratar model was successfully applied to produce reasonable projections of freight traffic to, from, and within Florida in 1985 and 2000. Efforts to develop modal-split models by using the logit formulation were not successful. The Fratar model was based on existing secondary sources of data. Because these sources exist in the same or an analogous form in other states, a similar modeling approach could be developed and applied elsewhere.

State departments of transportation are becoming increasingly involved in multimodal freight planning. The reorganization of railroads in the Northeast and Midwest, state rail plan requirements under the "4-R" Act (Rail Revitalization and Regulatory Reform Act of 1976), railroad mergers, regulatory changes, branch-line abandonments, increasing energy and shipping costs, the availability of all-weather roads, and the importance of financially sound competitive freight service for the overall economy of the states are examples of issues, problems, and developments that are giving rise to increasing state interest and involvement in multimodal freight planning.

In 1977, the Florida Department of Transportation (FDOT) initiated a program to develop a comprehensive statewide transportation plan and to update this plan on a continuing basis. This planning program encompassed all modes of transportation serving the movement of persons and goods throughout the state. Its purpose was to assist FDOT in evaluating and implementing financially sound transportation policies, facilities, and services that would promote the social, economic, environmental, and development goals of the State of Florida.

As part of the statewide transportation planning program, FDOT sponsored the Statewide Multi-Modal Planning Process Project to develop and apply modeling techniques to forecasting future movements of persons and goods by mode to and from as well as within the state. These procedures were intended to assist FDOT in evaluating alternative transportation policies and issues and to facilitate the analysis and evaluation of new or improved intercity transportation facilities and services.

This paper describes the development and application of the goods movement forecasting procedures resulting from the Statewide Multi-Modal Planning Process in Florida. Although the literature on freight forecasting techniques is growing, much of it is theoretical. Relatively little has been written about the development and use of freight forecasting methods in an actual planning situation. Therefore, it is hoped that this paper will give statewide transportation planners not only a better understanding of the problems and issues involved in developing a freight forecasting methodology but also an idea of what can be done with existing secondary sources of data to simulate and forecast the movement of freight.

FLORIDA GOODS MOVEMENT MODELING APPROACH

A large number of freight demand and modal-choice models were reviewed and evaluated early in the Florida Statewide Multi-Modal Planning Process Project. Prior surveys of freight demand estimation and modal-choice techniques were used as sources of information and evaluation for this task (1,2). Among the models that were given special consideration were an adaptation of the abstract mode model developed by Quandt and Baumol, the Herendeen model (3), the inventory theoretic model developed by Townsend (4), and the integrated freight forecasting model developed as part of the 1972 National Network Simulation Program.

One of the conclusions drawn from the assessment of existing freight forecasting methods was that, with few exceptions, the goods movement forecasting methods that have been used with some success have been of the sequential type. The exceptions noted in the literature are all models that have been developed for one or two specific commodities or for a special market situation.

Another important conclusion drawn from the survey of freight demand and modal-split models derives from the intimate connection between freight flows and regional economic development. The difficulty of forecasting regional economic development is one of the inherent problems of freight forecasting. Very few freight forecasts made to date span more than 10 years into the future because technology and the state of the economy are so difficult to predict. In addition, freight forecasts become less stable and reliable as the geographic level of aggregation and the classification of commodities become more detailed or smaller. Thus, national forecasts tend to be more reliable than state forecasts, which in turn are more reliable than county or substate projections. Contributing to the problem is the fact that states are not closed economic systems.

Clearly, the difficulty of forecasting even aggregated goods movements at the state level raises questions about the credibility of models that purport to predict modal freight movements in detail. Thus, the historical emphasis has been on dividing the freight forecasting problem into two parts: demand estimation and modal split. This approach was recommended for the Florida project.

The simulation and forecasting of goods movements to, from, and within the State of Florida were accomplished in two steps. In the first step, the generation and distribution of freight were projected through a technique known as the Fratar method, which applies growth factors to current flows of commodities. Projections were made for each of 13 groups of commodities. In the second step, the projected flows of each group of commodities were distributed among competing modes through modal-split models. A separate modal-split model was necessary for each commodity group.

FREIGHT GENERATION AND DISTRIBUTION GROWTH FACTOR MODEL

Figure 1 is a diagram of the freight generation and distribution growth factor model. The input to the model consists of two sets of growth factors--one for the production of goods and one for the consumption of goods--and a set of base year origin-destination (O-D) volumes of freight for each group of commodities. The growth factors themselves are calculated from forecasts of personal income and earnings and the results of the U.S. Department of Commerce national input-output model. The Fratar technique is then used to apply the growth factors to the base year O-D volumes to obtain tables of O-D freight volumes for a future year. The development of each of the inputs to the growth factor model is discussed below.

Base-Year Freight Flows

The first step in the development of the base-year freight flows was to classify the many thousands of types of commodities into a manageable number of meaningful commodity groups. The definition of the commodity groups depended heavily on how detailed were the available data on the production, consumption, and transportation of various commodities. Almost every source of data examined in this project had its own system for classifying commodities. One of these classification systems, the Standard Transportation Commodity Code (STCC) used in the Interstate Commerce Commission (ICC) annual percent sample of railroad waybills, is very detailed. Most of the classification systems, however, were much broader than the STCC. Fortunately, many of them were related to the STCC and the Standard Industrial Classification (SIC) system, although at a very high level of aggregation.

To determine the principal commodities hauled to, from, and within Florida by each mode, freight volume data from the following sources were analyzed:

1. ICC 1 percent sample of railroad waybills for 1975;
2. The Federal Highway Administration (FHWA) Nationwide Truck Commodity Flow Study, conducted between July 1972 and June 1973; and
3. Waterborne commerce statistics published by the U.S. Army Corps of Engineers in 1975.

Figure 1. Freight generation and distribution growth factor model.

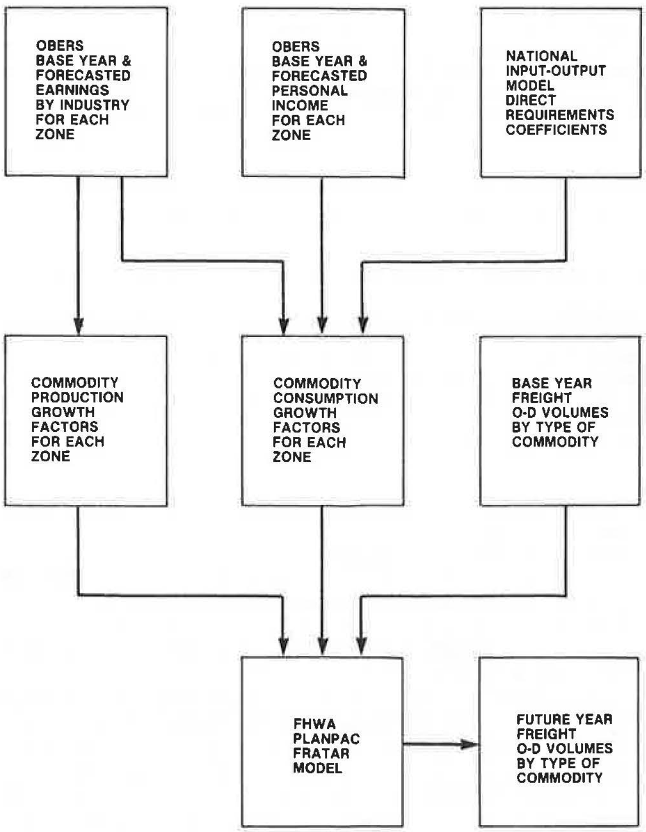

Table 1. Commodity groups selected for freight forecasting in Florida.

Group No.	Description	STCC
1	Citrus fruit	0121
2	Farm products, except citrus fruit	01[a]
3	Coal	11
4	Crude petroleum	13
5	Phosphate rock	14714
6	Dimension stone	141
	Crushed or broken stone	142
	Gravel and sand	144
7	Food and kindred products	20
8	Lumber and wood products	24
9	Pulp, paper, and allied products	26
10	Chemicals and allied products	28
11	Petroleum and coal products	29
12	Clay, concrete, glass, and stone products	32
13	Miscellaneous manufactured goods	
	Textile mill products	22
	Apparel	23
	Furniture and fixtures	25
	Rubber and miscellaneous plastics products	30
	Leather and leather products	31
	Primary metal products	33
	Fabricated metal products	34
	Nonelectrical machinery	35
	Electrical machinery and equipment	36
	Transportation equipment	37
	Instruments and photographic goods	38
	Miscellaneous products of manufacturing	39

[a]Excluding citrus fruit (STCC 0121).

Two of the principal commodities--nonmetallic minerals and farm products--were further subdivided. A more detailed analysis of the truck and rail data revealed that the motor carriers and the railroads were transporting different kinds of nonmetallic minerals. The motor carriers were primarily hauling stone, sand, and gravel, and the railroads were mostly hauling phosphate rock. Because phosphate mining is an important industry in Florida, phosphate rock was selected as a separate commodity group. For the same reason, citrus fruits were separated from other farm products to form two groups of agricultural commodities.

The commodity groups finally selected and approved by FDOT are given in Table 1 along with the corresponding STCC. The last commodity group given is a conglomeration of 12 manufacturing industries, none of which is extremely large in Florida. Together, however, these industries account for a significant percentage of the freight shipped to, from, and within Florida.

1975 O-D Freight Flow Tables

Once the commodity groups were specified, the next task was to determine the volume of freight transported between each origin zone and destination zone in the base year 1975 by mode of transportation and by commodity group. The results of this task were several sets of freight flow O-D tables similar to the trip tables developed in urban transportation planning.

The O-D freight flow tables indicated the volume of freight in hundreds of tons shipped in 1975 between each origin zone and each destination zone by a particular mode of transportation. Each Florida county and each state outside of Florida constituted a zone. This resulted in a total of 67 internal zones (counties) and 49 external zones (other states). A separate freight flow O-D table was developed for each of the 13 commodity groups and for each of three modes--truck, rail, and water.

Four sets of truck freight O-D tables were produced: true O-D truck freight volumes, truck freight volumes to ports, truck freight volumes from ports, and total truck freight volumes.

The true O-D freight flow tables consisted of the volumes of freight shipped from the zones where the goods were produced (production zones) to the zones where the goods were consumed (consumption zones). These freight flow tables, therefore, did not include truck shipments to and from ports, since ports are places where goods are transferred between modes of transportation.

The volumes of freight shipped by truck to and from ports were determined separately and stored in separate O-D tables. For truck shipments to ports, the origin zone was the zone of production and the destination zone was the Florida county containing the port. Similarly, for truck shipments from ports, the origin zone was the Florida county containing the port and the destination zone was the zone of consumption. The truck-to-port and truck-from-port freight flow O-D tables included only domestic goods. Foreign imports and exports were excluded because the true origin and destination zones of these goods could not be determined from the data that were available.

The total truck freight O-D tables were simply the sum of the true O-D, truck-to-port, and truck-from-port freight flow tables.

The truck freight O-D volumes had to be synthesized from a large number of secondary sources of data. The sources used are given in Table 2. All of

Table 2. Sources of data for development of true O-D truck freight flow tables.

Commodity Group[a]	Source
1-2	Florida Department of Agriculture and Consumer Services
	Florida Agricultural Statistics: Citrus Summary, 1975
	Florida Agricultural Statistics: Vegetable Summary, 1975
	Florida Fresh Fruit and Vegetable Shipments: 1974-1975 Season
	Florida Agricultural Statistics: Poultry and Livestock Summary, 1975
	U.S. Department of Agriculture
	Fresh Fruit and Vegetable Unloads by Commodities, States, and Months (4 volumes)
	Fresh Fruit and Vegetable Shipments by States, Commodities, Counties, Stations
	U.S. Bureau of the Census, 1974 Census of Agriculture
3-4	FHWA Nationwide Truck Commodity Flow Study
5	Central Florida Phosphate Industry, Draft Areawide Environmental Impact Statement
6	Bureau of Mines, U.S. Department of the Interior, Minerals Yearbook
7-13	U.S. Bureau of the Census, 1972 Census of Transportation Commodity Transportation Survey public use tapes
11	Florida State Energy Office, Monthly Florida Motor Gasoline Consumption

[a]From Table 1.

Table 3. Sources of data for development of total rail freight O-D tables.

Commodity Group[a]	Source
1	U.S. Department of Agriculture
	Fresh Fruit and Vegetable Shipments by States, Commodities, Counties, Stations
	Fresh Fruit and Vegetable Unloads by Commodities, States, and Months: Southern Cities (Volume 3)
5	U.S. Army Corps of Engineers, Waterborne Commerce of the United States: Parts 1 and 2
1-13	Federal Railroad Administration, magnetic tapes of 1975 ICC rail waybill sample
1-13	Florida Public Service Commission, State Statistics Section from annual report forms R-1 and R-2 submitted by individual Class I and Class II railroads to ICC

[a]From Table 1.

these sources, with two exceptions, are produced periodically by the agencies listed in the table. The two exceptions are the FHWA Nationwide Truck Commodity Flow Study and the environmental impact statement of the Central Florida Phosphate Industry. The Census of Transportation is conducted every five years by the federal government. All of the other sources given in Table 2 are produced annually.

Four sets of freight flow O-D tables were also developed for the rail mode. These O-D tables correspond to those developed for the motor carriers. In the true O-D rail freight flow tables, the zone of origin was the county or state in which the commodities were produced and the zone of destination was the county or state in which the commodities were consumed, either by households or by industries. The rail-to-port and rail-from-port freight flow tables contain O-D volumes for freight shipped by rail to and from a port, respectively. As noted earlier, ports are not considered to be the true origin or the final destination of freight; rather, they are points of transfer among modes. The total rail freight O-D tables were the summation of the above three O-D tables.

In the case of truck freight, the true O-D freight flow tables were developed from the secondary sources of data. The total truck freight O-D tables were then generated by simply adding the truck-to-port and truck-from-port tables. Because of the nature of the data on rail freight, it was easier to develop the total rail freight O-D tables first. The true O-D rail freight tables were then obtained by subtracting the rail-to-port and rail-from-port O-D tables.

Table 3 summarizes the sources of data used to develop the total rail freight flow O-D tables. The principal source was the ICC rail waybill sample tape, which consists of a 1 percent sample of waybills collected each year by the ICC. Each record on this tape represents a sampled waybill. The ICC waybill sample was supplemented by annual reports prepared by the rail carriers for the ICC. The annual reports provided independent estimates of the tons of freight originating and terminating on each carrier's line in Florida.

Additional data were needed to adjust the O-D volumes of citrus fruits and phosphate rock. These data were obtained from reports issued annually by the U.S. Department of Agriculture and the U.S. Army Corps of Engineers.

Two sets of waterborne freight O-D tables were developed. One consisted of tonnages among ports. In these tables, the origin was the zone in which the shipping port was located. The destination was the zone containing the receiving port. In the other set of waterborne freight O-D tables, the origin was the zone in which the commodity was produced and the destination was the zone in which the commodity was consumed. The first set of tables was referred to as the port-to-port freight flow tables; the second set was referred to as the true O-D waterborne freight flow tables.

The most basic source of data on waterborne freight was the information reported to the Corps of Engineers by all operators of vessels on the inland and intracoastal waterways. This information represented a complete enumeration of the movements of all vessels and their cargo at the ports and harbors and on the waterways and canals of the United States, the Commonwealth of Puerto Rico, and the Virgin Islands. The data collected on each shipment included the originating dock, the destination dock, the type of commodity, and the weight in tons. The Corps of Engineers maintains these data on magnetic tapes. Because these tapes contain proprietary data, they are not available to the states. Each year, the Corps of Engineers summarizes the information in a series of five reports entitled Waterborne Commerce of the United States. Although they are useful, these reports do not include data linking origins and destinations.

The U.S. Maritime Administration has aggregated the basic data collected by the Corps of Engineers to avoid disclosing information about individual companies. Computer printouts of the aggregated data were obtained for waterborne freight to, from, and between Florida's ports and waterways in 1975.

Each listing in the printouts gave the names of the shipping and receiving ports, the commodity, the type of vessel, and the tonnage.

The process of developing the various O-D freight flow tables for the three modes was too long and complicated to be described or summarized adequately in this paper. Numerous secondary sources of data, many assumptions, and a considerable amount of judgment were involved. Each combination of commodity group and mode had to be treated separately. In some cases, different procedures had to be followed for interstate and intrastate freight flows. A full description of the derivation of the O-D freight flow tables can be found in two reports prepared for the Florida Statewide Multi-Modal Planning Process Project (5,6).

Production Growth Factors

Production growth factors were defined as the ratio of the amount of the commodity produced in a zone in a future year to the amount of the commodity produced in the same zone in the base year of 1975. They were calculated for each county in Florida, each state outside of Florida, and each commodity group. The most recent Office of Business Economics/Economic Research Service (OBERS) forecasts of earnings (wages and salaries) by industry were used to calculate these factors. These forecasts were prepared by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The state forecasts were contained on a magnetic tape purchased by FDOT during the study. Forecasts for each Florida county were obtained from BEA projections (7).

It was assumed that the rate of increase in earnings in a particular industry was the same as the rate of increase in production. Thus, the production growth factors were calculated as follows:

$$PGF_{ik} = E^f_{ik}/E^{75}_{ik} \quad (1)$$

where

PGF_{ik} = production growth factor for zone i (either Florida county or another state) and commodity group k;

E^f_{ik} = OBERS forecasted earnings for zone i and industry k (corresponding to commodity group k) in a future year (in 1967 dollars); and

E^{75}_{ik} = OBERS estimated earnings for zone i and industry k in the base year, 1975 (in 1967 dollars).

Note that both the forecast and base-year earnings were expressed in constant dollars. Production growth factors were computed for the years 1980, 1985, and 2000.

Consumption Growth Factors

Consumption growth factors were defined as the ratio of the amount of the commodity consumed in a zone in a future year to the amount consumed in the zone in the base year of 1975. The total consumption of a commodity is composed of two parts--industrial and personal. Industrial consumption is simply the amount purchased by an industry in order to produce its own goods. Personal consumption is the amount purchased by consumers.

To calculate the industrial and personal consumption of goods in each commodity group and zone, the following sources of data were used:

1. OBERS forecasts of earnings by industry, prepared by BEA;
2. OBERS forecasts of personal income, also prepared by BEA;
3. The 1974 Annual Survey of Manufacturers;
4. The 1976 Statistical Abstract of the United States; and
5. The national input-output model developed by BEA.

Industrial Consumption

The first step in the calculation of industrial consumption was to determine the value of the goods produced by each industry. The value of output in the base year and the forecast value of output were determined by the following equations:

$$VO^{75}_{ik} = E^{75}_{ik} \times VER_k \quad (2)$$

$$VO^f_{ik} = E^f_{ik} \times VER_k \quad (3)$$

where

VO^{75}_{ik} = value of goods produced in 1975 by industry k (corresponding to commodity group k) in zone i (in 1967 dollars),

VO^f_{ik} = forecast value of goods produced in a future year by industry k in zone i (in 1967 dollars),

E^{75}_{ik} = OBERS estimated earnings in industry k and zone i in 1975 (in 1967 dollars),

E^f_{ik} = OBERS forecast earnings in industry k and zone i in a future year (in 1967 dollars), and

VER_k = ratio of the value of output to earnings in industry k.

The ratios of value of output to earnings were calculated from data in the 1974 Annual Survey of Manufacturers and the 1976 Statistical Abstract of the United States. The former source was used for manufactured goods and the latter for goods from agriculture and mining. The ratios of value of output to earnings have been quite stable for a number of years. Therefore, it was assumed that they would not change significantly in the future. These ratios are given below:

Commodity Group	Ratio
Farm products (including citrus)	2.58
Phosphate rock	4.74
Stone, sand, and gravel	2.38
Food and kindred products	10.03
Lumber and wood products	4.22
Pulp, paper, and allied products	4.67
Chemicals and allied products	8.08
Petroleum and coal products	11.52
Clay, concrete, glass, and stone products	5.29
Other manufactured goods	3.65

After the value of each industry group's output had been calculated, the amount and types of commodities purchased by each industry group to produce this output were determined. The basis for this computation was the national input-output matrix developed by BEA. This matrix, also known as a transaction tabloid or a direct requirements coefficients table, is given in Table 4. Each column of this table indicates how much of each commodity listed in the first column of the table is needed by the industry group at the top of the column to produce $1 worth of output. For example, to produce $1 worth of food products requires $0.2929 worth of

Table 4. National input-output matrix.

Input Commodity Group[a]	Production Commodity Group[a]										
	1	2	5	6	7	8	9	10	11	12	13
1	0.0317	0.2807	0.0000	0.0000	0.0769	0.0057	0.0000	0.0020	0.0000	0.0000	0.0034
2	0.0975	0.1676	0.0000	0.0000	0.2929	0.0468	0.0000	0.0006	0.0000	0.0000	0.0013
3	0.0000	0.0001	0.0000	0.0025	0.0004	0.0003	0.0016	0.0022	0.0004	0.0039	0.0022
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.4284	0.0000	0.0000
5	0.0004	0.0000	0.0594	0.0008	0.0000	0.0000	0.0006	0.0132	0.0000	0.0031	0.0001
6	0.0042	0.0001	0.0068	0.0268	0.0001	0.0001	0.0013	0.0017	0.0093	0.0566	0.0002
7	0.0000	0.1687	0.0000	0.0000	0.1658	0.0000	0.0030	0.0133	0.0011	0.0004	0.0010
8	0.0038	0.0005	0.0010	0.0000	0.0013	0.1767	0.0268	0.0014	0.0001	0.0059	0.0038
9	0.0005	0.0041	0.0049	0.0089	0.0344	0.0046	0.1280	0.0250	0.0060	0.0333	0.0075
10	0.0805	0.0044	0.0263	0.0204	0.0085	0.0111	0.0226	0.2508	0.0269	0.0261	0.0257
11	0.0317	0.0059	0.0029	0.0314	0.0024	0.0055	0.0038	0.0429	0.0679	0.0075	0.0025
12	0.0009	0.0001	0.0000	0.0000	0.0112	0.0093	0.0008	0.0064	0.0022	0.1039	0.0064
13	0.0231	0.0104	0.0516	0.1019	0.0392	0.1086	0.0366	0.0594	0.0119	0.0627	0.3345

Note: Each entry indicates the fraction of a dollar spent on goods in the commodity group at the left to produce $1 worth of goods in the commodity group at the top of the column.
[a]From Table 1.

citrus fruit, $0.0004 worth of coal, $0.1658 worth of other food products, and so on. The amount of goods in a particular commodity group purchased by an industry is simply the value of the industry group's output multiplied by the appropriate input-output coefficient. The total consumption of goods in a commodity group by all industry groups is then given by the following equations:

$$IC_{ik}^{75} = \sum_j (VO_{ij}^{75} \times C_{jk}) \quad (4)$$

$$IC_{ik}^{f} = \sum_j (VO_{ij}^{f} \times C_{jk}) \quad (5)$$

where

IC_{ik}^{75} = total amount of goods in commodity group k purchased by all industries in zone i in 1975 (in 1967 dollars),

IC_{ik}^{f} = total amount of goods in commodity group k purchased by all industries in zone i in a future year (in 1967 dollars),

VO_{ij}^{75} = value of goods produced by industry group j in zone i in 1975 (in 1967 dollars),

VO_{ij}^{f} = value of goods produced by industry group j in zone i in a future year (in 1967 dollars), and

C_{jk} = input-output coefficient corresponding to industry group j and commodity group k.

Personal Consumption

Coefficients from the national input-output model used to determine personal consumption in each zone are given in the table below. The coefficients indicate how much consumers spend on goods in each commodity group out of each dollar of disposable income.

Commodity Group	Coefficient
Citrus fruit	0.0077
Other farm products	0.0051
Coal	0.0002
Natural gas	0.0091
Stone, sand, and gravel	0.0004
Food and kindred products	0.1255
Lumber and wood products	0.0091
Paper and allied products	0.0143
Chemicals and allied products	0.0169
Petroleum and coal products	0.0227
Clay, concrete, glass, and stone products	0.0015
Other manufactured goods	0.1240

Total personal consumption was computed from the following equations:

$$PC_{ik}^{75} = 0.75 \times I_i^{75} \times C_k \quad (6)$$

$$PC_{ik}^{f} = 0.75 \times I_i^{f} \times C_k \quad (7)$$

where

PC_{ik}^{75} = amount of goods in commodity group k purchased by consumers in zone i in 1975 (in 1967 dollars),

PC_{ik}^{f} = amount of goods in commodity group k purchased by consumers in zone i in a future year (in 1967 dollars),

I_i^{f} = OBERS estimated personal income in zone i in a future year (in 1967 dollars),

I_i^{75} = OBERS estimated personal income in zone i in 1975 (in 1967 dollars), and

C_k = input-output personal consumption coefficient for commodity group k.

The factor 0.75 was used to convert personal income to disposable income. It was assumed that the overall effective tax rate on personal income is 25 percent.

Total Consumption

The total consumption of goods in a particular commodity group was the sum of the industrial consumption and personal consumption. The consumption growth factors were simply the ratio of total consumption in the future year to total consumption in the base year, 1975. Consumption growth factors were computed for each zone for the years 1980, 1985, and 2000.

Fratar Model

As Figure 1 shows, the production and consumption growth factors as well as the 1975 true O-D freight flow tables became the input to a distribution model known as the Fratar model. The Fratar model was one of the earliest trip distribution techniques used in urban transportation planning. A discussion of the theory behind this model and its mathematical formulation can be found in the FHWA publication describing the FHWA PLANPAC battery of computer programs for transportation planning (8).

The output of the model was a set of O-D freight flow tables for a future year. The FHWA PLANPAC battery of computer programs contains a program for

Table 5. Total tons of domestic freight by type of commodity by all modes combined.

Commodity Group	Tons (000s) 1975	1985	2000	%Δ 1975-2000
Citrus fruits[a]	9 578	10 544	12 872	34
Other farm products[a,b]	4 664	5 178	6 146	32
Coal	5 967	8 567	13 048	119
Crude petroleum	1 102	1 066	1 621	47
Phosphate rock	36 695	NA	NA	NA
Stone, sand, and gravel	67 401	92 773	145 562	116
Food and kindred products	14 054	17 803	23 922	70
Lumber and wood products	7 674	9 879	14 518	89
Pulp, paper, and allied products	5 151	7 191	11 074	89
Petroleum and coal products[c]	25 002	30 727	38 319	53
Chemical and allied products	14 084	20 097	32 667	132
Clay, concrete, glass, and stone products	9 118	18 031	35 573	290
Other manufactured goods[d]	6 875	8 824	12 190	77

Note: Tonnages given represent tonnages between the origins (the zones of production) and true destinations (the zones of consumption) and were obtained by adding the true O-D freight flow tables for truck, rail, and water. Therefore, they do not include truck and rail shipments to and from Florida's ports. Only domestic shipments were used; international shipments are not included.
[a]Excludes truck shipments into Florida except those to Miami.
[b]Excludes truck shipments of all farm products except principal fruits and vegetables and feeder calves.
[c]Excludes intrastate truck shipments and interstate truck shipments from Florida.
[d]Excludes truck shipments of textiles and apparel, furniture and fixtures, rubber and plastics products, leather products, primary metal products, nonelectrical machinery, instruments, and photographic goods originating in Florida.

distributing freight by the Fratar method.

MODAL-SPLIT ANALYSIS

The analysis of the base-year freight flow O-D tables revealed very little apparent competition between the motor, rail, and water carriers. For most of the commodity groups, one mode was predominant, hauling at least three times as much tonnage as the other modes. The analysis, however, also indicated that a more detailed examination of the modal split between truck and rail might be warranted for four of the commodity groups: (a) food products, (b) lumber and wood products, (c) chemicals and allied products, and (d) clay, concrete, glass, and stone products.

Consequently, an attempt was made to develop mathematical models of the modal split between truck and rail for each of these commodity groups. These models were to be sensitive to changes in shipping times and shipping costs by truck and by rail. The logit equation was selected as the formulation of the modal-split models.

Many separate formulations of the logit model were attempted. In each case the pseudo R-square statistic, a measure of how well the logit model accounts for the variation in the modal split, was extremely low. Although the signs of the coefficients for shipping time and shipping cost should have been positive, in many cases one or both of the signs were negative because of the high correlation between the two explanatory variables.

The fact that a mathematical relation between modal choice and shipping costs and times could not be found for the four commodity groups was most likely due to the high level of aggregation of the commodities. The four commodity groups chosen for the modal-split analysis were very heterogeneous. They included bulk commodities as well as packaged goods and commodities with a low unit value as well as commodities with a high unit value. It is possible that a more detailed breakdown of the commodities in each of the four groups would have revealed that the motor carriers and the railroads were hauling different kinds of food products, wood products, chemicals, and clay, concrete, glass, and stone products. Shipping costs could also be determined more accurately if a more detailed breakdown of these commodities could be made. Unfortunately, the existing secondary sources of truck data did not permit a more disaggregate approach to modeling the modal split of freight.

GOODS MOVEMENT FORECASTS FOR FLORIDA

As mentioned earlier, the Fratar model was used to project the generation and distribution of freight to, from, and within the State of Florida. Table 5 presents the projected tonnages of domestic freight for all modes combined in 1985 and 2000. The commodity groups that showed the largest percentage increases were (a) clay, concrete, glass, and stone products; (b) coal; (c) chemical and allied products; and (d) stone, sand, and gravel. Projections of phosphate rock tonnages were not developed because of uncertainties associated with environmental impacts of future mining operations in central Florida. The draft areawide environmental impact statement for the central Florida phosphate industry was considered to be a better source of phosphate production estimates.

Although projected increases in citrus fruit and other farm products were relatively modest, the growth in tonnages of food and kindred products (i.e., processed products that use sizable quantities of citrus fruit and other farm products) was estimated to be on the order of 70 percent between 1975 and 2000. The projected 67 percent increase in the state's population between 1975 and 2000 appears to be promoting major increases in the use of construction-related commodities such as stone, sand, and gravel and clay, concrete, glass, and stone products.

Intrastate movements of virtually all commodities were projected to increase more significantly then interstate movements to and from Florida. This appears to be attributable to the large growth in population and economic development projected for the state through the year 2000. The percentage increases in interstate commodity movements to and from Florida were similar to the intrastate projections. The state is likely to continue to "import" more goods than it "exports" to other states.

Projections of freight tonnages by mode were made under the assumption that the current modal choice of freight shipments in Florida will continue in the future. For many commodity groupings, truck tonnages were estimated to increase more significantly than rail and water tonnages. Both rail and water were estimated to experience large increases in tonnages of bulk commodities and products, including lumber and wood products, chemical and allied products, and clay, concrete, glass, and stone products.

Intrastate shipments of virtually all commodity groups by both truck and rail were estimated to increase dramatically over the 25-year forecast period. These intrastate movements are generally increasing by several hundred percent as a result of projected economic development in the state.

Interstate shipments by truck, rail, and water were projected to increase but at a more modest rate than intrastate shipments. The percentage increases in truck movements into Florida were larger than those for movements out of the state. This finding also applied to rail and water movements.

ASSESSMENT OF FLORIDA FREIGHT FORECASTING PROCEDURES

The Fratar model for forecasting future goods movement flows by commodity group, mode, and geographic area (i.e., county in Florida and state outside of Florida) produced reasonable projections based on the demographic and economic forecasts formulated by FDOT. The goods movement model can be used to identify the potential demands for freight services by mode and geographic area. The methodology is sensitive to important state economic factors, such as personal income and earnings by type of industry.

It should be recognized that external governmental policies may have a significant impact on future freight flows. For example, national energy policy with regard to the fuels used in power plants may have a significant impact on coal movements. Environmental policy may have a significant impact on the mining and transportation of phosphate rock.

The Florida model was built for long-range planning purposes. Because the model was built on secondary data sources, it is both feasible and advisable to update its base-year freight flows. For instance, the 1977 Census of Transportation could be used, with other sources, to construct a 1977 data base. The 1967 input-output coefficients could be replaced with 1972 coefficients. Finally, by updating the base year, the "old" model can be run on the "old" base-year data set to forecast the new base year. Any major discrepancies can be used as a check on the soundness of the model.

The FDOT model does not contain capacity constraints and does not assign freight flows over particular routes. However, the model can be used to indicate potential congestion points in the state's transportation infrastructure. In particular, the model can be used to determine (a) which ports will experience substantial increases in waterborne activity, (b) which county pairs will experience significant growth in truck traffic between them (and thus possible congestion on the highway system linking the pairs), and (c) which city pairs will experience significant increases in rail traffic.

In this manner, state DOT officials can ascertain where transportation bottlenecks may occur, where increased road construction and maintenance may be expected, and, based on the economic forecasts used, when in the future these problems will probably occur. Such information gleaned from the model's results can then be used for long-range local and state capital budgeting plans.

One aspect of statewide goods movement that was not addressed in the development of the Florida freight forecasting methodology and data base was the movement of goods that neither originate nor terminate within the state. Through traffic is relatively minor in a peninsular state like Florida. However, in most states, particularly those in the Midwest, through traffic is quite significant. A national network analysis is needed to analyze this portion of freight traffic.

The Florida model and data base also did not cover international traffic. In Florida, international goods movements are either waterborne or airborne. In states bordering Canada, international truck and rail traffic could also be significant. More research is needed on the generation and distribution of international freight.

The FDOT model was built on existing secondary data sources. Most of those sources exist in the same or analogous form in other states. Thus, the same set of exercises could be repeated to construct a freight transport model in another state.

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Publication of this paper sponsored by Committee on Statewide Multimodal Transportation Planning.