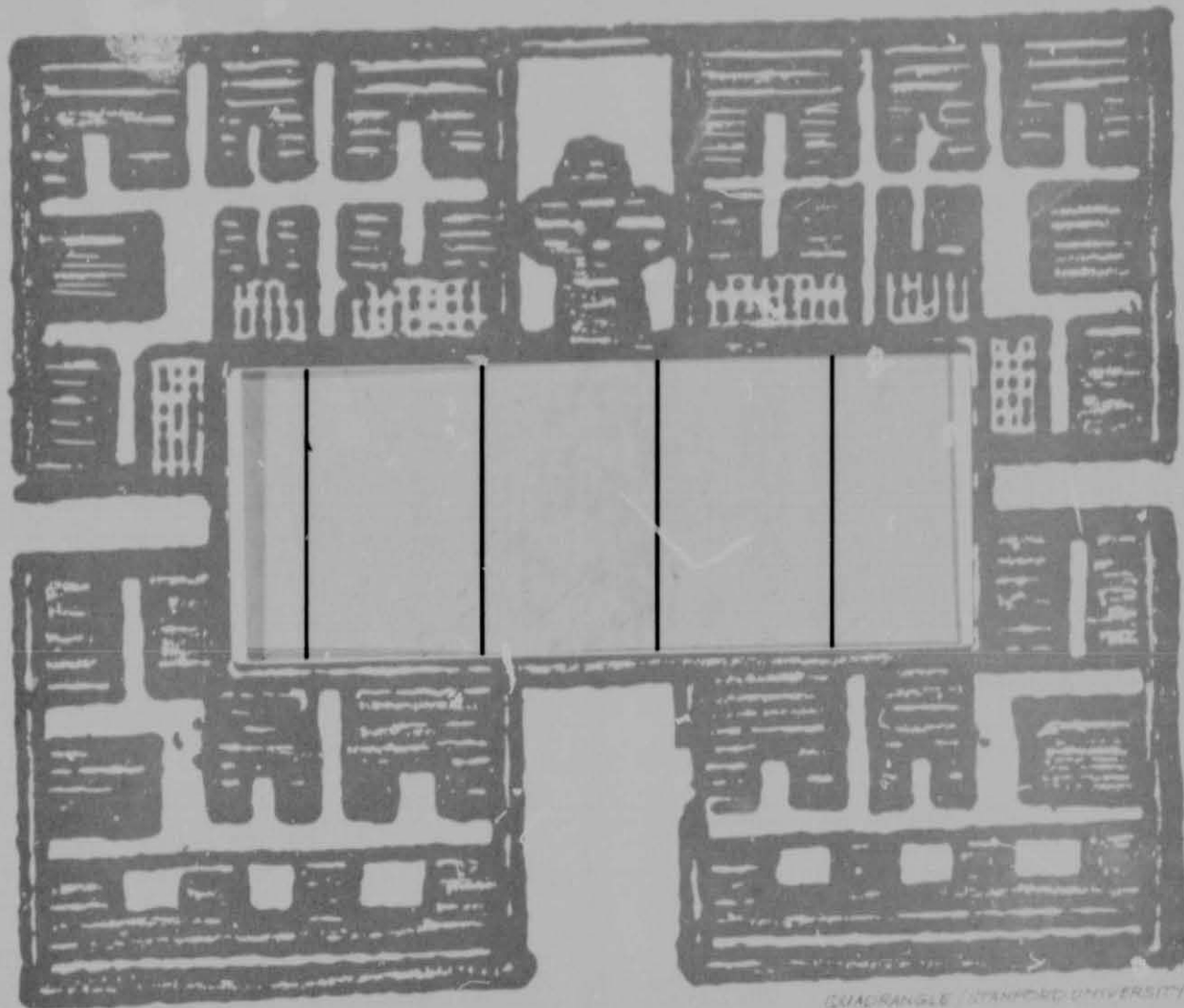


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ASSESSING THE FUTURE OF AIR FREIGHT

by

Jarir S. Dajani*

Working Paper

and

Final Technical Report

(Feb. 1977 - Oct. 1977)

National Aeronautics and Space Administration
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ABSTRACT

This report briefly discusses the role of air cargo in the current transportation system in the United States. It then addresses the question of assessing the future role of this mode of transportation, and recommends the use of continuous-time recursive systems modeling for the simulation of different components of the air freight system, and for the development of alternative future scenarios which may result from different policy actions. A basic conceptual framework for conducting such a dynamic simulation is presented within the context of the air freight industry. Some research needs are identified and recommended for further research. The paper also discusses the benefits, limitations, pitfalls, and problems usually associated with large-scale systems models, and emphasizes the benefits of the exercise as a learning tool which will enable the user to expand his understanding of the freight movement system and the interactions between alternative assumptions and system behavior pattern.

Key words: Air Freight, System & Dynamics, Simulation, Demand, Supply, Technology, Economics.

ASSESSING THE FUTURE OF AIR FREIGHT

1. INTRODUCTION

This progress report is intended to provide an overview of the findings and recommendations of the research team which was involved in the air cargo project at Stanford. An attempt is made to present those findings which are relevant to the direction in which the research is expected to be moving. Some background and additional information are provided to assist the reader in appreciating the total context of the study. The following sections provide a brief description of the air freight system, a discussion of the role of modeling in forecasting and policy analysis and a description of the methodology which was selected for the study. Following those are discussions of the demand for air freight, the level of service concept, and the supply of the service. The latter three sections are presented in a framework which is consistent with the selected methodological approach. This discussion is, by necessity, presented at a conceptual level, since the data collection and validation efforts are both expected to take place during a following phase of the study.

2. THE AIR FREIGHT SYSTEM

Air cargo is one of the smallest, yet fastest growing sectors of the transportation industry. The share of air cargo of the total transportation industry has grown at the rate of 7% per year during the past ten years. When it is considered that the total transportation bill of the nation has doubled during that same period, we are dealing with an industry which is growing at the rate of 15% per year. This percentage is even more phenomenal when considered in terms of revenue ton-miles, since the

cost per ton-mile of air cargo has been reduced appreciably during the same period, relative to its main competitor, the trucking industry.

While it cannot be expected that the air cargo industry will continue to grow at this phenomenal rate, growth will still occur in years to come. Such growth will be due to general economic growth, an expansion of markets of commodities which are air-eligible, cost reductions, service improvements, and the introduction of new technologies. A recent study by the Federal Aviation Administration foresees that under the most favorable economic growth scenarios, air cargo in the year 2000 will be 20-25 times greater by weight than what it is today. The study also concludes that under any but the worst foreseeable economic conditions, the number of ton-miles transported by air will increase at an annual rate of not less than 6 percent, while the minimum annual growth in tonnage would not be less than 4 percent.⁽¹⁾

Air freight is presently being carried in three submodes: in the bellies of passenger aircraft, on dedicated freighters, or in dual purpose quick conversion aircraft. The first is by far the most common submode and accounts for about 50% of all air freight tonnage moved around the world, and 75% of all freight tonnage moved in the United States. The FAA study has concluded that this proportion will continue at its present level through the year 2000, but that it might drop to 50% under conditions of expansive growth and most favorable economic futures. Most of the rest is being carried by dedicated freighters. It is anticipated that growth in the size and number of these freighters, coupled with increasing land-side and airside congestion, might lead to the development of all cargo

airports in some favorable locations around the country. Such a possibility is presently being considered for serving the San Joaquin Valley at Coalinga, California. Other such proposals include the Pacific International Freeport Center near Ogden, Utah and the International Air Cargo Distribution Project which is being planned for northwestern Nevada. The fact that approximately the same percentages of total air freight are expected to be transported by combined passenger/freight operation may be attributed to the fact that the marginal cost of carrying freight with present aircraft configurations is relatively low, with the result that freight will continue to be carried in this submode, as long as it does not infringe on passenger operations which produce relatively higher revenues to the airlines.

The structure of air freight systems at the present time favors long-haul operations. This is due to the fact that aircraft operating costs are lower for both longer-hauls and larger aircraft. A Boeing 737-200C which has a capacity of 16 tons, for example, will provide transportation at a direct operating cost of about 11 cents per available ton-mile when the stage length is 1200 miles. The cost per available ton-mile rises to 19 cents when the stage length drops to 400 miles. By comparison, the smaller DH-7 which has a capacity of 6 tons only will cost 28 cents per available ton-mile at stage lengths of 400 miles. This cost structure together with the fact that delivery time differences between air and ground transportation diminish as the stage length decreases, result in increased competition between the two modes in the short-haul.

Table 1 shows the distribution of freight by mode in the United States. It also shows the distribution of the National freight bill among those modes. It is clear that air freight remains to be the most expensive mode, and that truck freight is the second most expensive mode. It is clear that some commodities will always go by air, due to a variety of reasons relating to compatibility between commodity characteristics and air service. For other commodities, the competition will be primarily with the truck mode, and the choice will depend on the shipper's perception of the relative time, cost and commodity compatibility of the two competing modes. These relative positions have and will continue to change over time. It is noted, for example, that while truck revenues per ton-miles have kept up with the consumer price index between 1947 and 1973, and have thus risen by 70%, air revenues per ton miles have dropped by 4% during the same period. Such changes in the relative cost will allow some commodities to undergo a shift of mode.

3. FORECASTING THE FUTURE

The future of air freight operations in a given corridor is dependent on a multiplicity of interacting factors, some of which are a function of the social, economic, technological, and institutional/regulatory environment, while others are inherent in the competitive environment affecting particular transportation modes. Not unlike other transportation systems, the amount of air freight which will be shipped between any two locations is dependent on the total demand for shipping certain types of commodities which can be considered to be air eligible, on the relative compatibility of these commodities with available modes, on the level of service provided

Table 1
FREIGHT MODES

	<u>% of TON-MILES</u>	<u>% of REVENUE</u>	<u>REVENUE/ TON-MILE</u>
Airways	0.19	2.32	14.0¢
Motor Carriers	22.78	55.35	5.0¢
Rail	38.80	37.48	1.6¢
Pipelines	22.87	3.59	0.2¢
Waterways	15.36	1.26	0.3¢

by each mode, on available technology and on decisions made by transportation operators vis-à-vis the utilization of these available technologies. Forecasting the future of any mode of transportation must take all these factors into account, and must also consider the complex interactions between these factors.

A typical two-mode transportation system is shown in Figure 1. The three major blocks represent the socio-economic activity system and the supply of transportation services by each of the two modes. The socio-economic activity system is one of the determinants of the demand for the service. This demand is usually not a homogeneous one, but rather one of several market segments, each having its own unique characteristics, expectations, elasticities, and of course, size. In each of the modes, service suppliers are continuously making decisions regarding both the short and long allocation of resources. Their decisions will involve such items as the purchase or sale of particular types of equipment and the

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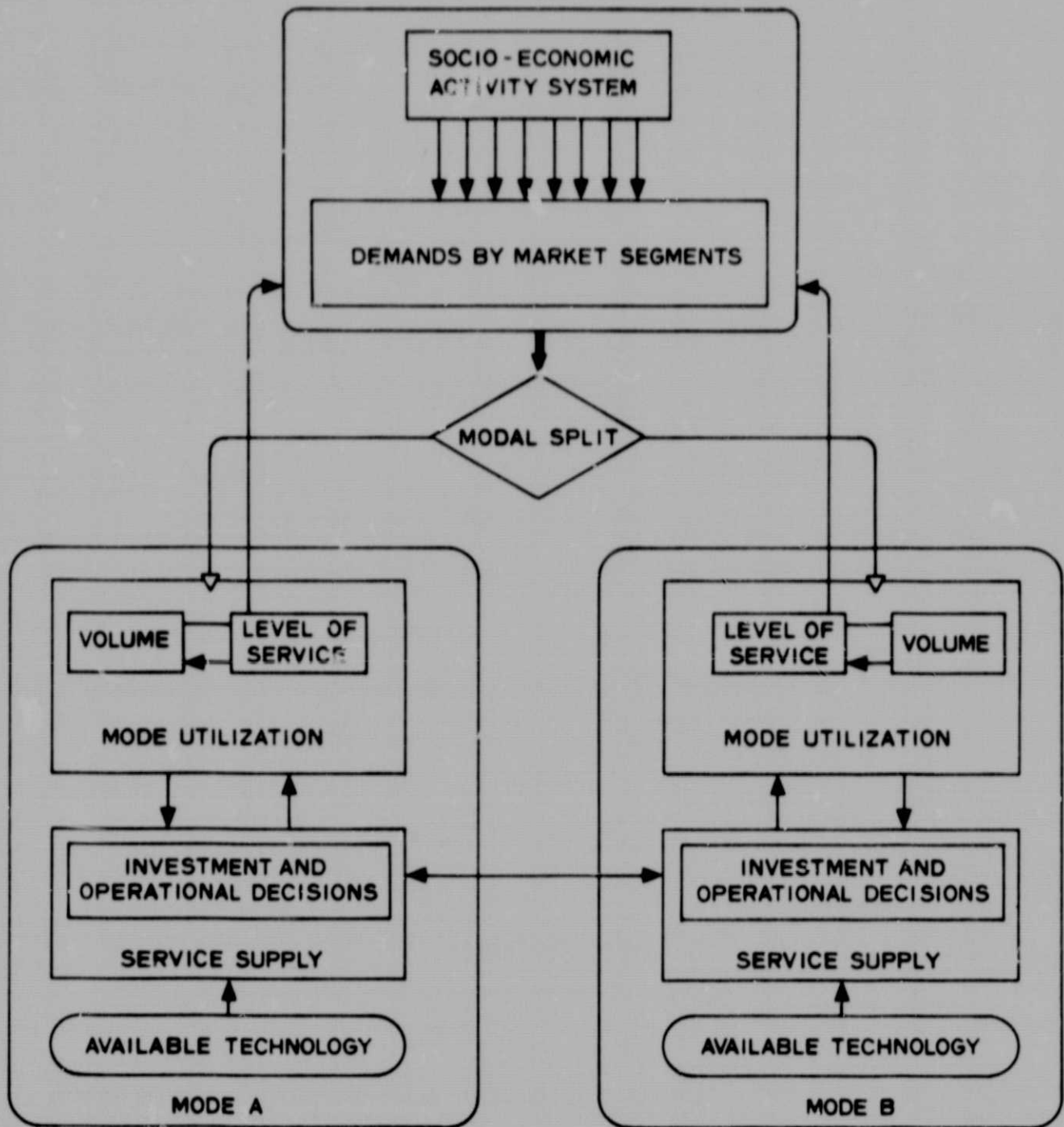


Figure 1: An Analytical Framework for a Bimodal Transportation System

provision of service frequency levels or particular special handling facilities. In making these decisions, the service suppliers will have to consider available technological and managerial options, present and expected future markets, and, of course, the competition. Once these decisions are made, each market segment is then faced with the problem of selecting that mode which is most compatible with its own needs and expectations. The resulting modal split determines the volume of traffic using each mode. Together with the service supply decisions, the volume of traffic determines the level of service provided by a given mode, which in turn influences both future demand levels and future supply decisions, and so on.

Planning, policy analysis and forecasting efforts are often supplemented by the use of analytical models of one kind or another. Transportation is no exception. These models vary in their complexity and their capability of reproducing the real systems which they attempt to simulate. Since those activities are generally future-oriented, they are particularly difficult and hazardous undertakings. They are generally very easy to criticize and very difficult to prove. Since it is generally impossible to prove that a certain forecasting method is providing the "right" answer about a future situation, the best which can be done is to compare such attributes as the method's logical coherence, structure, comprehensiveness, flexibility, and ease of use, with other available methods which are used to achieve the same objectives. Of particular importance is the method's capability of answering the relevant questions about the future which are asked in the present, its capability as a learning tool which will allow the user to better understand and appreciate the subtleties of system

interactions, and a vehicle for better and more informed policy-making.

Three common types of policy planning models in transportation include (i) mental models, (ii) econometric models, and (iii) equilibrium models. The first is the simplest, and perhaps the more common method. It depends on the assimilation capacity of the human mind, and the accumulated experience and judgment of the user. The second is one in which data is processed to provide mathematical relationships between selected sets of variables. These relationships could then be used to predict the future performance of the system. Equilibrium models seek to develop mathematical relationships for the supply of, and the demand for, a particular good or service, and then proceed to find the point at which all the goods demanded are being supplied. It should be noted that these three methods are not necessarily mutually exclusive, and that they can indeed go hand-in-hand in many planning and policy analysis exercises.

Considering the transportation applications of these models, it is clear that many shortcomings plague their use, as can be seen from many existing models. Most of these models are partial, in the sense that they deal with one aspect of the total system described above. They may thus deal with some aspect of the demand or the supply separately. When equilibrium is sought, it is usually done in a static way: finding equilibrium conditions at one point in time. In reality, of course, equilibrium is an elusive concept: a system is never in true equilibrium, although it is usually at some point close to it, and continuously hovering around it as time progresses and as different decisions by different actors are continuously being made. Existing prediction models usually look at the future in relatively large jumps, say 5, 10, or 15 years, while in reality

both actions and reactions are taking place continuously. Ideally, then, a prediction model would simulate the real system in continuously time-dependent fashion.

Many forecasting models presently in use are simplistic in at least two ways: (1) they attempt to forecast the values of particular entities which are end products, or symptoms of a variety of interactions, rather than attempting to obtain these values by modeling their causes, (2) they attempt to produce point projections or forecasts of the value of these entities at some future time, rather than produce alternative forecasts which might be expected to materialize under different conditions. The latter point is an important one, in the light of the expected utility of any forecasting effort. The planning and policy analysis communities are starting to realize that alternative future scenarios can be much more valuable as decision tools than point forecasts and projections. They allow the analyst and the decision-maker to test their policies under varied socio-economic futures and thus, for example, to select those policies which are most robust and least likely to fail under a worst possible future. Two useful types of scenarios are "longitudinal scenarios" which depict the progression through time of a particular system, and "cross-sectional scenarios" which describe the different components of the system at a particular future time.

In view of the above characteristics of models and needs of policy-makers, it seems clear that some form of simulation would provide the best vehicle for assessing the future of air cargo. The simulation should have the capability of generating useful and internally consistent alternative scenarios. It should be capable of incorporating useful econometric

relationships which have been tested and developed from data. Due to the scarcity of data in the air freight area, the simulation system should also be capable of incorporating qualitative data which may be obtained from expert opinions or Delphi panels. It should, above all, be relatively easy to use and understand, and be relatively flexible to allow quick changes of parameters in order to readily give the analyst a feel for the way in which the system might respond to such changes.

4. THE SYSTEM DYNAMICS METHODOLOGY

An assessment of available techniques for the analysis of such complex systems as those encountered in transportation, had led to the choice of systems dynamics as a theoretical framework, and the computer programs associated with it as practical tools of implementing the simulation exercises. System Dynamics is particularly suited for the analysis of systems which are characterized by both positive and negative feed-back loops, and which require the use of continuous time simulation. The emphasis is on adequately describing the structure of the system in question and the complex interactions among its variables. The computer language DYNAMO provides a readily available and easily usable tool for implementing the analysis. The methodology has the potential of allowing the planner and the analyst to prepare forecasts which accommodate the variety of interrelationships which might influence the future of the system. It also allows them to assess the probable impacts of alternative technological and policy decisions on the future of the industry. The methodology does not preclude the analysis of any length of haul, type of aircraft, or operational strategies. It is of particular interest to note that while this methodology has been widely used in some fields, its transportation

applications are particularly scarce (2,3,4,5). It is also of interest to note that a forecasting model using this methodology for estimating the future general aviation activities on a national scale has been recently developed under the sponsorship of the Federal Aviation Administration. (6)

Two types of variables are sufficient to describe the basic structure of a system in the system dynamics methodology. These are called "level" and "rate" variables. Level variables measure the total accumulated value of an entity, while rate variables describe how level variables change from one time period to the other. Other variables termed "auxiliary variables" are usually used to clarify intermediate causal relationships. A system can thus be fully described using a set of coupled integral equations, in which each equation gives the value of a given level variable at a given point in time, as a function of its value at a previous point in time and the incremental change occurring to it during the time interval. This incremental change, in turn, is a function of both other levels, as well as externally determined (exogenous) variables. The general form of the equations describing the system is thus,

$$L_1(T_2) = L_1(T_1) + \int_{T_1}^{T_2} F_1(L_1, L_2, \dots, L_N; X_1, X_2, \dots, X_M)$$

$$L_2(T_2) = L_2(T_1) + \int_{T_1}^{T_2} F_2(L_1, L_2, \dots, L_N; X_1, X_2, \dots, X_M)$$

.

.

.

$$L_K(T_2) = L_K(T_1) + \int_{T_1}^{T_2} F_K(L_1, L_2, \dots, L_N; X_1, X_2, \dots, X_M)$$

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where

L_1 is a level variable,

X_1 is an exogenous variable,

T_1 denotes a particular time period, and

F denotes any functional relationship

The solution of such a set of equations in closed form, however, is not possible. They could be solved through the use of computer simulation, once they are approximated by difference equations representing incremental changes in the system over small periods of time. The computer algorithm will define a sequence in which levels, rates, and auxiliary variables are updated from one time period to the other. In the computer language DYNAMO, for example, the difference equations are evaluated in the following order:

- (1) Level equations in a given period are evaluated using level, rate, and auxiliary variables values of the previous period.
- (2) The values of auxiliary equations are updated, using values of other auxiliary and level variables in the same period, and rate variable values of the interval between the two periods.
- (3) Rate equations are then evaluated by using level and auxiliary variables in the period in question, and the rate variables value in the interval between the two periods. Rates are assumed to remain constant during a given time interval.
- (4) The process is repeated for the following time period.

One of the major issues confronting a model builder is that of model validation, or of how to build enough confidence in the model to

ensure credible results. It is important that models such as the one proposed in this paper, and which are intended for policy analysis, be validated before they are used as a basis for future policy decisions.⁽⁷⁾ It is, of course, impossible to "prove" that a model is accurately predicting the future, since that future remains to be unknown, and sometimes subject to unpredictable events. It is necessary, however, that a particular model be evaluated in comparison to other available models which are used to produce such predictions, and that it be shown to perform in a superior manner. The difficulty of predicting the future mandates that the model be capable of generating alternative futures from alternative sets of assumptions in such a way as to enable the analyst to assess the possible impacts of alternative actions which he might be considering.

A first step in model validation is to test the model structure for rational behavior. This is usually accomplished by the inspection and analysis of outputs to check for erratic and/or irrational results, to trace such results through the model and to take any necessary corrective actions. Once a model has been tested for rationality, it then becomes possible to introduce empirical and historical information into the model, in an attempt to reproduce historical developments and events. To the extent that this is possible, confidence can be built in the fact that the model is capable of producing forecasts which are at least based on the continuation of past and current trends. The model must also be assessed in terms of the robustness of its policy recommendations, its sensitivity to various system changes, and its behavior under extreme conditions.⁽⁸⁾ Model validation is a significant part of the continuing learning and communication processes which are at the heart of the whole exercise.

5. THE DEMAND FOR AIR FREIGHT

The share of the total freight market which is captured by a particular mode is dependent upon (1) the characteristics of the different commodities in the market, and (2) the relative level of service provided by the different competing modes. In this section, the relationship between demand and commodity characteristics will be addressed. The level of service as a determinant of demand will be discussed in the following section.

As in any transportation situation, the market for air freight is not homogeneous: different commodities demand different types of services, and respond differently to alternative service characteristics. The market can generally be segmented into three parts:⁽⁹⁾

- (1) Emergency freight, which is usually shipped on very short notice, frequently in order to avoid the high opportunity cost resulting from plant or equipment breakdowns. Spare parts represent a sizeable amount of this segment of the market.
- (2) Captive freight, which has little choice as far as mode selection is concerned, by virtue of its perishability and its having a limited life. The limited life could either be physical -- as in the case of cut flowers -- or demand-related -- as in the case of newspapers, fashion items or test products. This category includes fresh fruits and vegetables, live animals, and printed matter.
- (3) Choice freight, which will only be shipped by air if a rational analysis of all available modes leads to air being the best among competing modes. Ideally the decision is made on the basis of total distribution costs, which

include handling, packaging, transportation, loss or damage, capital carrying, storage and stockout costs.⁽¹⁰⁾ Commodities in this category include such items as pharmaceuticals, electrical machinery, scientific and optical equipment and office equipment. Choice freight can be further subdivided with respect to the extent of its air eligibility on the basis of its density in lbs/ft³ (Kg/m³) and its value in \$/lb, (\$/Kg). Lighter and more expensive commodities are more likely to be shipped by air than those which are heavier and cheaper. The market share of air transportation is thus strongly influenced by the value and density of the commodity. More than 50% of electronic components shipped between Los Angeles and San Francisco are shipped by air. A recent study shows that 83.3% of all men's clothing and 86.3% of all electronic data processing equipment which are shipped between Los Angeles and New York are shipped by air. In contrast, only 1.2% of all shipments of builder's hardware and 5.9% of all bolts, nuts, and screws moving in the same corridor, are shipped by air.⁽¹¹⁾ Table 2 shows the market size and share of the major commodities which are shipped out of the San Francisco metropolitan area.

Table 2
Commodities Air-Freighted From
San Francisco to all U.S. Destinations
in 1972

<u>Commodity</u>	<u>Tons</u>	<u>Market Share</u>
Machinery, excl. elec.	15,000	10.3%
Electrical Machinery	12,700	18.8%
Food and Kindered Products	6,500	0.1%
Primary Metal Products	6,000	0.5%
Motor Vehicle Parts	500	12.0%
Rubber & Plastics	250	12.8%
Fresh Fruit & Vegetables	17,500	--

It should be noted that a significant proportion of all shipments by air is composed of small shipments. Smith reports that 97% of all consignments and 60% of all air freight weight is made up of shipments of less than 500 lbs. in weight, and that up to half of consignments could consist of items weighing less than 50 lbs.⁽⁹⁾

6. LEVEL OF SERVICE

The volume of freight which selects to use a given mode of transportation is dependent, to a large extent, on the characteristics of that particular mode relative to competing modes. The collective attributes of a given mode are frequently described by the term "Level of Service." This is an elusive concept for which many definitions have been proposed. One such definition is:

"Level of service is a term which, broadly interpreted, denotes any one of an infinite number of differing combinations of operating conditions which may occur on a given (transportation facility) when it is accommodating varying traffic volumes. Level of service is a qualitative measure of the effect of a number of factors, which include speed and travel-time, traffic interruptions, safety..., convenience and operating cost..."⁽¹²⁾

The level of service thus refers to a collective modal attribute as perceived and experienced by the user. Within the context of freight, movement, it is proposed that an attempt be made to construct a measure of the level of service which includes the following three categories of system attributes:

- (1) Cost: This component of the level of service should include the total cost to the shipper, which goes beyond a measurement of the actual freight rate. It also includes differences between modes with respect

to packaging costs, savings in inventory costs, savings in interest on cost of goods in transit, reduction in payment delays resulting from speedier delivery, and reduction in loss or damage resulting from more careful handling.

The determination of freight rates is not a trivial matter. The long history of regulatory actions, negotiations and compromises has resulted in a wide range of rates. Rates in the air freight industry were originally of the postage-stamp type: a fixed amount per unit of weight. As the industry developed, however, rates were differentiated to reflect such criteria as the ability of the shipper of a given commodity to pay, the actual costs of shipping different kinds of commodities and the competitive environment between modes. This resulted in commodity rates which reflect what the market can bear, volume rates which charge a surcharge for low density commodities, minimum charges for handling small shipments, surcharge rates for commodities requiring special handling, quantity rates for large consignments, deferred rates for shipments which can be shipped during off-peak periods, and so on. The complexity of these rate structures has eluded many analysts, and it was not until recently that relatively successful attempts have been made to develop a useful freight tariff estimation model which may hold some promise for analytical studies such as the one described in this paper. (13,14)

(2) Time-in-Transit: Total time-in-transit is dependent on the average inter-city speed of the mode in question, the stage distance, handling facilities at the terminals at both ends of the trip, the number of duration of intermediate stops, and the terminal access time at both ends. It also includes waiting times which may result from queuing situations.

arising as the volume of goods to be shipped approaches the capacity of the carrier.

(3) **Commodity/Service Match:** This includes the general capability of a transportation mode to handle a particular type of commodity. This match may depend on the size of the commodity, the need for special handling and storage facilities, and the perceived significance of such attributes as security and reliability. It is conceivable that some commodities which would naturally select themselves to a given mode, not be able to actually use that mode because of a mismatch which is based on any of the above type of attributes.

Each of the different commodity types described in the previous section will perceive each of these level of service attributes differently. It will also attach different weights to these attributes. Table 3 provides a description of the relative sensitivity of these commodity types to service attributes: For a given commodity, those sensitivities will vary depending on the actual value of cost and time, resulting in functional relationships similar to those given in Figure 2. It should be noted that it is presently not possible to draw these relationships with any confidence. Research into the tradeoffs made by shippers when they select the most appropriate mode of transportation needs to be conducted in order to determine the actual shapes of these curves for different commodity groups. Such research should also identify the relative significance of these modal attributes from the shippers perspective. It then becomes possible to develop a single measure of the level of service provided by a given shipper, and as used by him in order to select his freight shipment mode.

Table 3

A MARKET SEGMENTATION SCHEME:

	<u>SENSITIVITY TO</u>	
	<u>TIME</u>	<u>COST</u>
EMERGENCY	VERY HIGH	VERY LOW
PERISHABLES	HIGH	MEDIUM
CHOICE DEMAND:		
HIGH VALUE/LOW DENSITY	VERY HIGH	LOW
HIGH VALUE/HIGH DENSITY	HIGH	MEDIUM
LOW VALUE/LOW DENSITY	MEDIUM/LOW	HIGH
LOW VALUE/HIGH DENSITY	MEDIUM-LOW	VERY HIGH

COMMODITY
SENSITIVITY

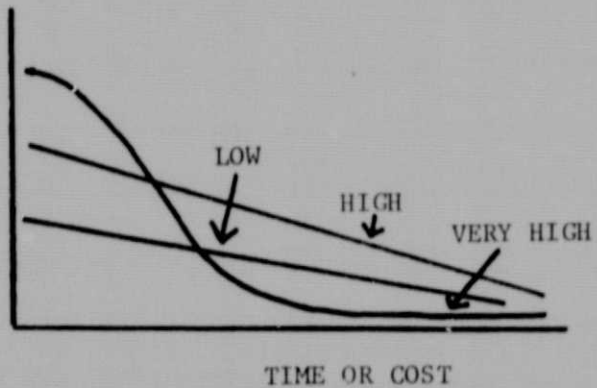


Figure 2

TIME AND COST SENSITIVITY

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Using existing information on the relative levels of service and the relative amounts of goods shipped by the different modes, it becomes possible to calibrate a modal split model which could predict the market share of each mode for each commodity.⁽¹⁵⁾ Conversely, it might be possible to infer perceptions and preferences of the shipper by calibrating a modal split model in such a way that the perceived differences in level of service are obtained, using any one of a variety of functional relationships. One of the simplest and most commonly used relationships has the following general form:

$$\text{Modal share} = \frac{e^{\beta}}{1 + e^{\beta}}$$

Where β is a measure of the difference in the level of service provided by competing modes.⁽¹⁶⁾

7. SUPPLYING THE SERVICE

No analytical model is complete without the inclusion of the decisions of the transportation supplier. The supplier, typically represented by the management of the competing modes being considered, makes decisions regarding both capital investments and operational strategies. His decisions include the acquisition or disposal of equipment, as well as the scheduling of operations and the provision of special services and handling facilities. He can thus determine the level of service to be provided by his particular system. The expansion of such service, however, is constrained by the supplier's fiscal resources and expected return on investment, by market demand and by the actions of competing firms in the industry.

In order to capture the behavior of management with respect to service provision, the simulation model will evaluate a variety of alternative

actions to be taken by management at a specified future time. An analysis of these actions is triggered by two indicators of system performance: (1) the load factor (volume/capacity ratio), and, (2) the market share for a given commodity type. A conceptual sketch of the combination of load factor and market share combinations which will trigger an assessment of the system is shown in Figure 3. The possible values of each of these two indicators are arbitrarily classified as low or high. The dividing line for the volume/capacity ratio might rationally be selected as the load factor, resulting in a break-even operation typically between 50 and 60 percent. The dividing line between the two market share classifications will vary by commodity group, and might thus be 60 percent for electronic devices and 3 percent for fresh fruits and vegetables. The actual value will depend on experiences in similar markets. It thus becomes clear that a mode capturing a large proportion of a given market, and operating at a profitable load factor, needs little change. As the demand expands, however, the system becomes overloaded, waiting times increase, the level of service decreases, the market share drops, and an assessment becomes warranted.

		<u>VOLUME/CAPACITY RATIO</u>	
		LOW	HIGH
<u>MARKET SHARE</u>	LOW	POTENTIAL EXISTS NO CHANGE UNLESS ECONOMICS WARRANT DISINVESTMENT	ROOM FOR EXPANSION OF SERVICE - INVEST
	HIGH	OVERCAPACITY - DISINVEST	GOOD SERVICE SATURATED MARKET NO CHANGE

Figure 3
SYSTEM ASSESSMENT FLAGS

Once it is established that the system needs to be assessed, a number of alternative actions regarding the acquisition or disposal of equipment, and/or the adjustment of operational arrangements are generated. For each alternative, projections of both costs and revenues are made over the planning horizon. These projections are developed on the basis of the values obtained from the simulation over the recent past, with more weight given to the immediate past. In estimating the volume of traffic to be expected during the planning horizon, allowance is made for: (1) the possible growth or decline of economic activity levels in the regions in question, and, (2) the impact of the changed level of service on future traffic volumes. The systems dynamics methodology is particularly adapted to handling such forecasting situations and their inherent feedbacks. The options which are generated will thus include alternative modal technologies; such as vehicles with different payloads, speeds and costs; or terminal facilities and equipment allowing quicker processing of freight or providing services particularly desirable for certain types of commodities. The cost and revenue streams for each alternative over the planning horizon are evaluated, and the one with the highest rate of return on the investment is selected and implemented. It goes into effect after a reasonable delay time which represents the time needed for putting it into effect. The analysis then continues using the new system, until another assessment is called for by the load factor and market-share indicators described above. This process, of course, is followed by each of the competing modes in the system.

8. CONCLUSIONS

The preceding sections have outlined an operational procedure for

the use of a continuous-time recursive model for assessing the future of air freight systems in a given intercity corridor. It is clear that the proposed method is - by necessity at this stage of the research - highly conceptual, and perhaps vague at times. It is also clear that many gaps exist in the present body of knowledge regarding air freight systems. In order for the model which is proposed in this report to become an operational and useful tool for both understanding the system in question and making informed policy decisions which might affect it in what is perceived to be a positive direction, the following activities need to be undertaken:

- (1) Some of the fundamental relationships which are needed to operationalize the model need to be researched. These include the relationships between such variables as (i) regional economic activity and freight generation and distribution, (ii) commodity characteristics and modal splits.
- (2) Research is needed to assess the sensitivity of different commodity types to the basic level of service variables described in Section 6 above. The preferences of shippers with respect to those service attributes and the trade-offs they make between them needs to be investigated.
- (3) The model must be checked, revised, developed, calibrated, tested, and fine-tuned in order to become a useful analytical tool. Actual data for a given corridor must be used to test the model's ability to reproduce historical trends, and thus to enhance its credibility. It should be noted that existing data sources on freight in general, and air freight in particular,

lot to be desired.

In order to achieve the object of this study, use will be made, to the extent possible, of such available sources as the U. S. Census Bureau Commodity Transportation Survey, The Domestic Transportation of U. S. Foreign Trade Surveys, The Civil Aeronautics Board Air Cargo Statistics and the Commodity Attribute File of MIT's Center for Transportation Studies. It should also be noted that attempts are presently being made to improve the data base of freight transportation in the U.S. (17)

Sample model outputs are given in Figures 4 and 5. These are plots over time of the values and parameters of interest. As different technological, economic or regulatory policies are developed, these plots will trace the effects of these policies into the future. Both longitudinal (through time) and cross-sectional (at a particular point in time) scenarios can be readily obtained from these output plots.

It thus becomes possible to evaluate the respective impacts of these policies, and, hopefully, be able to make better informed decisions.

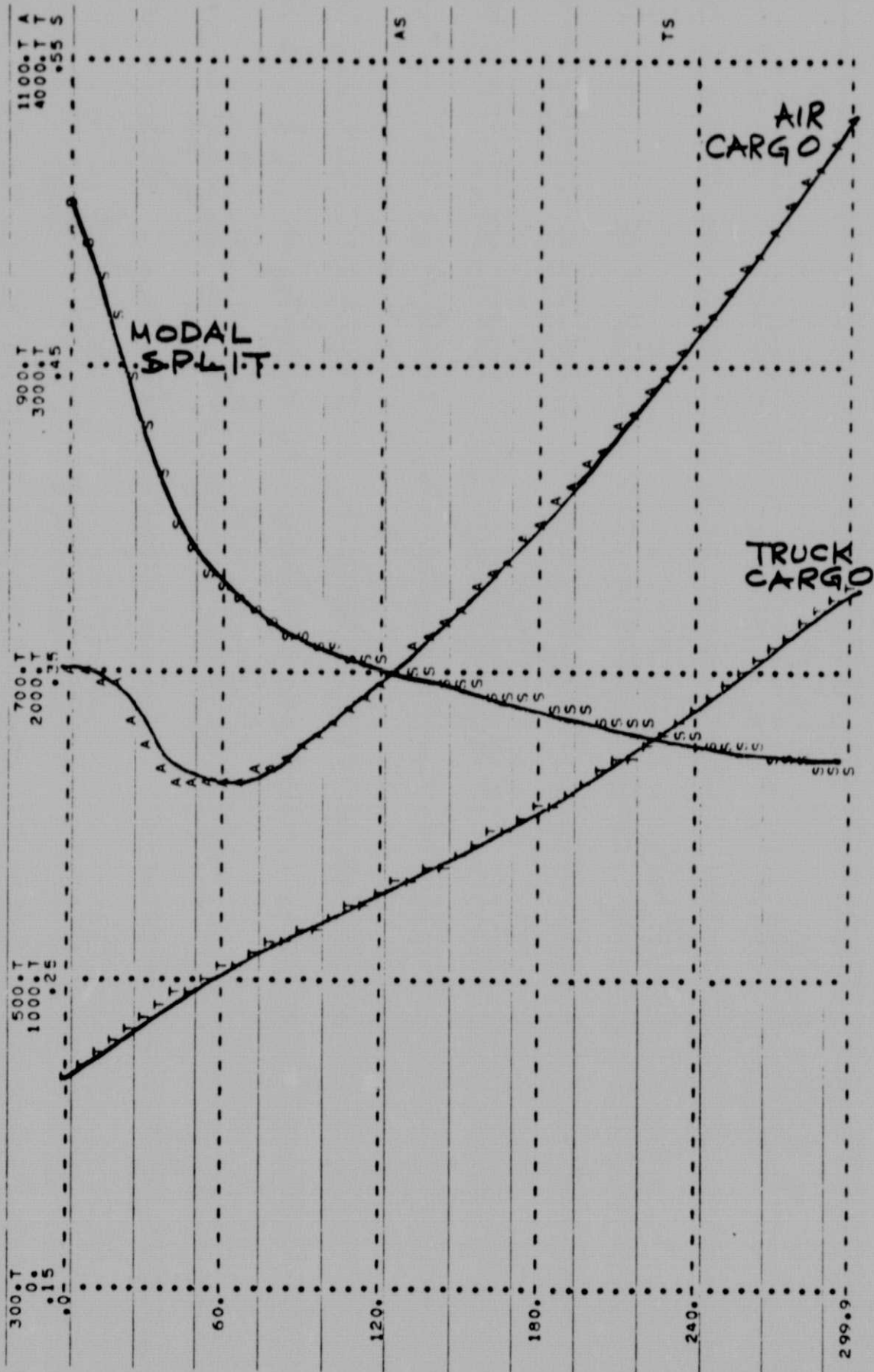


Figure 4
SAMPLE OUTPUT

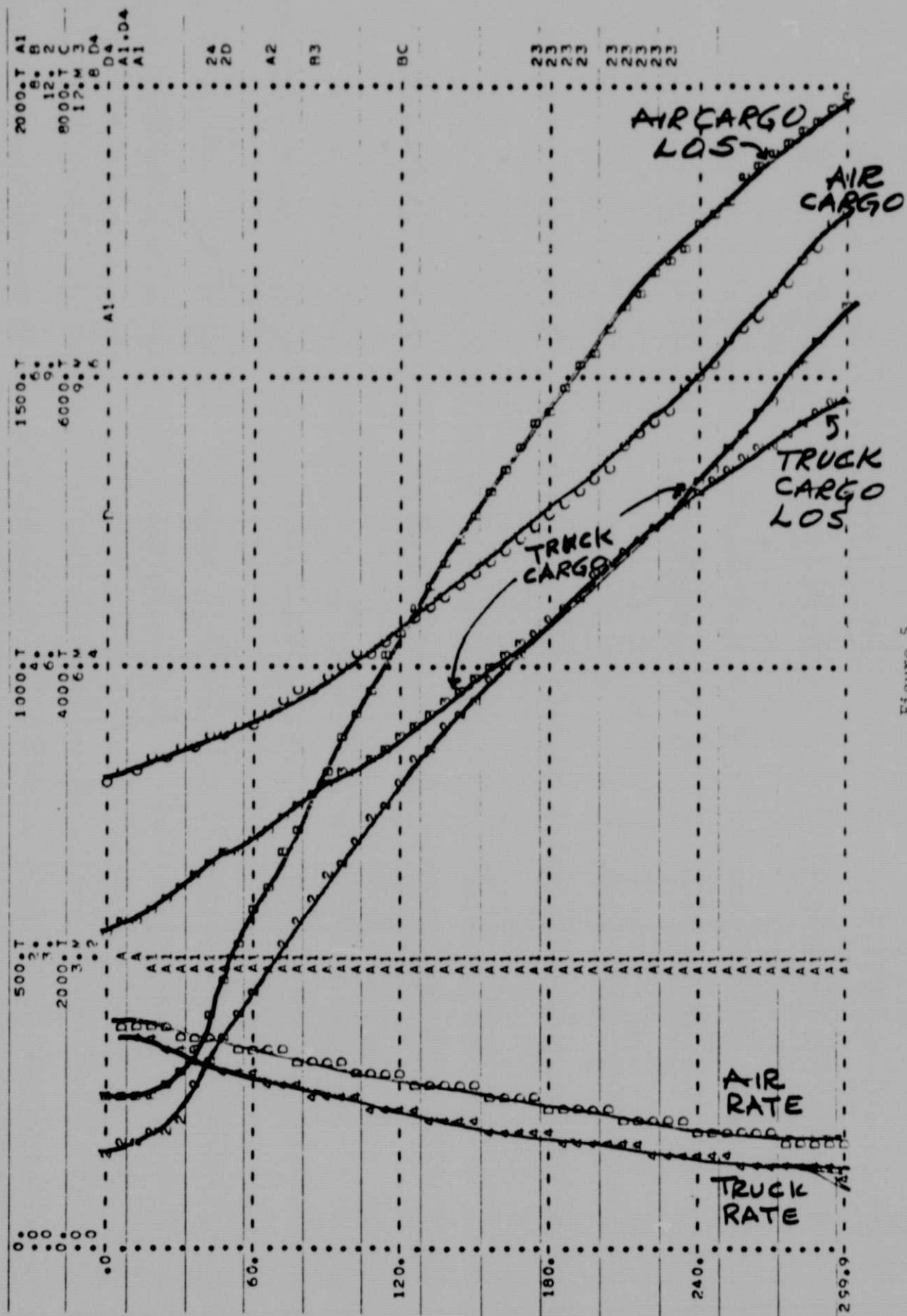


Figure 5
SAMPLE OUTPUT

REFERENCES

- (1) Federal Aviation Administration, Aviation Futures to the Year 2000. Washington, D.C.; U. S. Department of Transportation, 1977.
- (2) Scheller, P., "Possibilities and Limits of Simulation by the Forrester System Dynamics Statement, as a Method for Complex Systems Investigations Exemplified by a Typical Aerospace Transport: Deutsch Lufthansa," Report No. IRL-16-1974 Technische University, Berlin (.G.) Institute für Luft und Raumfahrt, 1974.
- (3) Sussman, J. R., "A Systems Model of the U. S. Railroad Industry," Bulletin O.R.S.A. (USA), Vol. 23, Suppl. 1, 1975.
- (4) Taylor, A. J., "System Dynamics in Shipping," Operator Research Quarterly (G.B.) Vol. 27, No. 1, 1976.
- (5) Vogt, W. G., "Dynamic Simulation of Public Transit with Application to Bangkok Bus Operations," Modeling & Simulation, Vol. 5, 1974.
- (6) Federal Aviation Administration, "General Aviation Dynamics," Report No. FAA-AVP-77-20, 1977.
- (7) Barney, Gerald, "System Dynamics and the Analysis of Social Policy," Professional Paper No. 89, Center for Naval Analysis, Washington, D.C. 1972.
- (8) Senge, Peter M., "Tests for Building Confidence in System Dynamics Model," System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Mass., 1977.
- (9) Smith, Peter S., Air Freight: Operations, Marketing and Economics, London: Faber, 1974.
- (10) Roberts, Paul O., "Forecasting Freight Flows Using a Disaggregate Freight Demand Model." Center for Transportation Studies Report 76-1, Massachusetts Institute of Technology, Cambridge, Mass., 1976.
- (11) Douglas Aircraft Company, Cargo/Logistics Airlift Systems Study (Class), Midterm Oral Review, NASA Langley Research Center, October 1977.
- (12) Transportation Research Board, Highway Capacity Manual. (Special Report 87), Washington, D.C.: Transportation Research Board, 1965.
- (13) Samuelson, Ralph D., Lerman, Steven R., Roberts, Paul O., and Kneafsey, J., "Freight Tariff Estimation Models," paper submitted to the Transportation Research Forum. March 1976.
- (14) Samuelson, Ralph D., and Lerman, Steven, "Modeling the Freight Rate Structure," Proceedings of the Transportation Research Forum, Vol. 18, No. 1, 1977, pp. 387-396.

REFERENCES (cont'd)

- (15) Christenberry, William S., "The Relationship of Freight Modal Split to Shipper Perceptions of Transportation Service Characteristics," Proceedings of the Transportation Research Forum, Vol. 18, No. 1, 1977, pp. 515-522.
- (16) Stopher, Peter and Meyburg, Arnim, Urban Transportation Modeling and Planning. Lexington, Mass. Lexington Books, 1975.
- (17) Wright, Donald, "Commodity Movement Data: An Assessment of Sources and Coverage with Emphasis on the Commodity Transportation Survey," Proceedings of the Transportation Research Forum, Vol. 18, No. 1, 1977, pp. 183-191.