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FINANCIAL BEHAVIOR IN THE AIRLINE INDUSTRY:  
THE MANAGEMENT SYSTEM STRUCTURE

A DISSERTATION

Presented to

The Faculty of the Graduate Division

By

Richard Lee Leatherwood

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## SUMMARY

Research results for an investigation of the long-term financial behavior of a major domestic airline are reported. The research focused on financial control activities, capacity acquisition decisions, and their interaction. The purpose of the research is to demonstrate the manner in which long-term financial dynamics arise from managerial decisions and actions within a feedback control structure and to interpret these results in terms of alternative system designs.

To provide a framework for these decisions, components of the airline decision-maker's environment are examined, and the nature of relationships which these decision-makers strive to maintain between their organization and its environment are documented. Utilizing industrial dynamics methodology managerial decisions, associated information flows and resulting actions designed to control organizational states are incorporated into a system model of feedback relationships. The model consists of a set of first-order difference equations which provides for model validation and system analysis via simulation.

Model variables representing organizational states in the financial and operational sectors of the firm depict the results of previous decisions and actions. Model decision processes utilize information about these states as a basis for generating subsequent actions designed to modify system states and achieve organizational objectives. In particular financial and operational decisions are examined to identify their interrelationships and the impact of these interactions

on the firm's long-term financial performance.

Actual behavior patterns for a major domestic trunkline are examined to identify the impact of various managerial actions. Comparison of simulated system performance with actual system behavior over a fifteen year period accomplished model validation. Response validity of model performance is substantiated by comparable amplitudes, frequency and phasing relationships. Construct validity is supported by the realistic representation of actual system components and relationships.

A related research objective consists of examining the impact of managerial attitudes and judgment on system behavior. This result is accomplished through parametric analysis after the model has been validated. Similarly the effects of inherent system delays and exogenous inputs are identified through experiments in which these parameters and variables are changed from the basic model's conditions.

Drawing upon the model analysis, several conclusions are evident and recommendations for further research and implementation are suggested. The conclusion that all research objectives have been achieved is substantiated by specific research results. Specific conclusions summarize individual research findings concerning the source of various dynamic behavior patterns, the significance of exogenous economic influences, the effect of fare increases and the benefits of promotional programs.

Recommendations for further study involving the capacity acquisition sector, a more detailed level of aggregation and different exogenous inputs are offered. Relative to implementing research findings,

recommendations are made for improved measurement of potential demand, highly focused promotional programs and relatively conservative financial control policies.

## CHAPTER I

### INTRODUCTION

In the last thirty years the airline industry has been characterized by sustained growth and rapid technological change. The industry's desire to accommodate the rising demand for air transportation has magnified capital equipment requirements. Furthermore, the recurring introduction of larger, faster, and more modern aircraft to the industry has brought about greater pressures for capital expenditures. Even with the industry's high growth potential, seven major trunklines have been absorbed via merger since 1945. Other mergers by major trucklines have been considered as individual airlines experience periods of excess capacity and depressed earnings. When demand increases following such periods and the need for additional capacity becomes apparent, funds are not available to finance the desired acquisitions.

These general conditions and the extreme efforts required of some airlines to finance the recent transition to jet aircraft bring the financial difficulties of all the truckline operators into focus. During the period of rapid growth, large quantities of long-term debt were acquired to finance capacity acquisitions. Expanded capacities and an increasing demand provided greater operating revenues. Concurrently, unit operating costs were lowered by the use of larger and more efficient aircraft. Thus, profits increased and the return on capital investments appeared to justify further expenditures requiring

additional debt financing.

Concurrently, demand for air transportation was being stimulated by the influx of new technology, providing greater comfort and shorter travel times. Exogenous factors contributing to the high growth rate in the 1960's included an increased decentralization of business, a healthy economy and continuing increases in population. These combined effects prompted individual airlines to invest in additional equipment at varying rates.

As imbalances develop in the capacity acquisition programs of competing airlines, market shares change. The airline adding new capacity observes the resulting increases in demand. Forecasts of future increases provide a basis for continuing to invest in capital equipment; however, the competitor must react by improving his own capital equipment position. Considering the impact of technological advances and the one to three year delay between ordering an aircraft and incorporating it into the fleet, one can better understand the causes of excess capacity and depressed earnings.

When these conditions exist, the firm suffers financially. Large quantities of debt are generally added to the capital structure during a capacity acquisition program. If a period of reduced profits follows such a program, this debt's presence and the effect of leverage compound the seriousness of the situation. The reduction of internal funds by losses and a rising debt-equity ratio are two symptoms of the financial deterioration of a firm under these circumstances.

### Nature of the Research

Numerous managerial activities are oriented toward maintaining certain desired relationships within their organization. A classic example consists of managerial efforts in a manufacturing firm to equate average production to average sales. A similar managerial activity is concerned with maintaining a desirable relationship between demand and the capacity required to satisfy that demand. Increases in demand resulting from internal actions and/or exogenous factors create a need for additional capacity. Increases in capacity improve service and therefore tend to stimulate additional increases in demand. However, failure to add extra capacity results in limiting future demand to the level which can be serviced adequately by the organization's present capacity. Thus, capacity is increased to accommodate demand or demand is limited by current capacity.

Although this explanation of the relationship is greatly oversimplified, it serves as a basis for many operational decisions in the airline industry. A complicating factor is the high cost of new aircraft to service future demand. Thus, the desire to maintain certain financial relationships in the organization may conflict with the achievement of operational goals. Purchase of new capacity involves depletion of internal funds or the acquisition of new long-term debt. Both actions modify the financial status of a firm as measured by various financial ratios. When new aircraft are integrated into the fleet, costs increase immediately; whereas, revenues increase more slowly as forecasted increases in demand are realized.

This research consists of an analysis of the long-term behavioral

characteristics of a major domestic trunkline. In particular, the research focuses on the above relationships and their interaction. The purpose of the research is to demonstrate the manner in which long-term financial dynamics of an airline arise from managerial decisions and actions within a feedback control structure.

Some of the probable causes of these financial performance patterns may lie outside an airline management's realm of influence. However, much of the dynamic behavior results from the structure of feedback loops containing the important variables and delays within the system of interest. There appears to be a significant area upon which management can act to alter the seemingly uncontrollable and unsuitable patterns of behavior.

An important step toward a better understanding of these difficulties and their causes consists of gaining further insight into management's actions to control the financial states of an airline. By concentrating on the system's structure, one focuses his attention on the causes of the system's problem rather than on its symptoms.

Related to the purpose of this research is a set of specific objectives which serve as a guide in the research effort and the analysis of the results. These objectives are:

(a) To determine the internal variables and structural relationships accounting for the financial performance of a major domestic airline.

(b) To demonstrate that the characteristic behavior of a system's problem existing in many airlines arises from, and is perpetuated by, the feedback control structure.

(c) To examine the impact of managerial attitudes, judgment and decisions on the system's behavior over time. This result can be accomplished by emphasizing the managerial control points within the feedback loop configuration.

(d) To interpret these results and their implications for designing alternative control policies to improve system behavior.

### Research Methodology

A major contribution of the research consists of ascertaining the control system structure producing an individual airline's characteristic patterns of financial behavior. To accomplish this goal, the methods presented in Forrester's Industrial Dynamics<sup>1</sup> are used. Financial records covering extended periods of time aid in isolating the causal mechanisms operating to create the problem and its symptoms. Behavior patterns of interest include the time variations of debt, capital equipment, working capital and earnings. Considering the decision processes and the resulting behavior of the system variables, a model of the system structure is developed. This model contains the information feedback relationships, desired system states and controlling decisions accounting for the system's financial behavior.

In addition to information feedback, a realistic model of a managerial control system must consider various nonlinear effects, time delays and system parameters. These complicating elements necessitate the use of digital simulation as a means of examining the individual

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<sup>1</sup>Jay W. Forrester, Industrial Dynamics, Cambridge, Massachusetts: The M. I. T. Press, 1961.



loops and their contributions to total system performance. In this way one can realize meaningful results which are unencumbered by invalid or limiting assumptions.

The fundamental assumption underlying the model development, and consequently the research results, pertains to the conceptualization of the decision-making process. Managerial decision-making is modeled as a continuous process taking place within an information feedback configuration. Two aspects of this assumption must be justified; namely, the continuity of decision-making over time and the feedback structure of the system model.

First consider the continuity aspect of the assumption. The observable results of a particular decision, such as an increase in long-term debt or the acquisition of additional capacity, usually become apparent at discrete points in time. However, these results are typically preceded by a period of consideration during which advance actions may have been taken by management in anticipation of the probable outcome. In addition, a decision's output might be such that it cannot be implemented immediately. Therefore, the decision-making process is modeled as a continuous operation with inherent time delays.

With regard to the feedback aspect, the information feedback view of managerial control maintains that a decision-maker monitors the state of the entity he wishes to control. Information concerning the difference between the apparent state of the entity and the desired state serves as a basis, or input, for his decision. The decision's output consists of some action to alter the entity's future state.

Since the new state serves as an input for succeeding decisions, a closed loop is established. This closed-loop system structure will be incorporated into the model in lieu of an open-loop assumption.<sup>2</sup>

Emphasis was placed upon formulating an hypothesized system structure which closely corresponds to the real world system. However, the model need not include all the variables and relationships of the airline - only those contributing significantly to the system's behavioral problem. Attention is focused on an aggregate level of the system which aids in distinguishing true system performance patterns from random and seasonal variations. The study is limited in scope to an analysis of a single airline's behavior; however, the model includes the effects of competition by other members of the industry as well as the airline's impact on its competition.

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<sup>2</sup>An open-loop assumption would imply that the outcomes of present decisions do not affect future decisions.

## CHAPTER II

### LITERATURE SURVEY

An analysis of the firm's past behavior provides a basis for modeling the structural relationships and feedback loop interactions creating the systems problem. These behavior patterns have been studied in the literature with varying degrees of intensity. The investment activity of a firm seems to have received the most attention.

Initial studies of investment behavior used the neoclassical theory of the firm as a foundation. In this theory the firm's objective is to maximize its value. The value of a firm is a function of its future income, and its future income is a function of its investment. With knowledge of these two functions, the value of a firm may be predicted given its investment; and given the value maximization rule, its investment can be determined. Thus, the theory's task consists of obtaining information on these two functions for the purpose of making empirical statements about the value and investment of a firm.

To attain these objectives, the theory's development proceeds under two assumptions: (1) the future is known with certainty; and (2) the firm can freely lend or borrow at a given rate of interest. This drastic simplification of the real world produces decision rules and descriptive statements about the firm which

are of extremely limited value<sup>3</sup>. Attempts have been made to enlarge the theory to recognize the consequences of uncertainty, but these attempts have met with very little success<sup>4</sup>. In view of the theory's limited applicability, a comprehensive review of the neoclassical literature was not attempted. For one of the most complete statements of neoclassical investment theory including modifications to deal with uncertainty, the reader is referred to the work by Frederick and Vera Lutz<sup>5</sup>.

The inadequacy of neoclassical theory as a basis for explaining the investment behavior of real corporations created a need for further research in the area. This research has utilized two approaches:

(1) adaptation of economic theory to provide a normative model of the firm's investment behavior; and (2) collection of empirical results illustrating the firm's behavior under specific conditions. For purposes of discussion, the results of the first approach can be categorized as (i) the accelerator principle and (ii) profit theories of investment.

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<sup>3</sup>By assuming that the future is known, this approach eliminates the problems of financing and valuation of the firm. In neoclassical theory, the firm's value is generally measured by its net worth plus the amount by which the present value of future receipts exceeds the present investment. Financing is based upon the marginal efficiency of capital. Theoretically, the firm will continue to invest borrowed capital until the investment's rate of return equals the cost of capital. However, when uncertainty is introduced, the future receipts are unknown and the theory breaks down.

<sup>4</sup>Myron J. Gordon, The Investment, Financing and Valuation of the Corporation, Homewood, Illinois: Richard D. Irwin, Inc. 1962. p. 1.

<sup>5</sup>Frederick and Vera Lutz, The Theory of Investment of the Firm, Princeton University Press, 1951.

Reduced to its simplest form the accelerator principle states that a firm's capital is a linear function of its output. This statement implies that the investment during a period will be a multiple of the change in output during the period. Many writers have since noted severe theoretical limitations on the principle's validity<sup>6</sup>. Empirical studies have shown that the principle may explain investment behavior when a firm is producing at capacity, but only if production costs increase sharply in response to a rise in output. Under other conditions the principle did not account for the firm's observed behavior<sup>7</sup>.

Profit theories of investment are the major alternatives to the accelerator principle for explaining investment behavior. Tinbergen and Polak<sup>8</sup> argues that investment is motivated by profit expectations and that to a large extent, profit expectations are based upon the magnitude of current profits. They also pointed out that profits are an important source of funds for investment. Kalecki<sup>9</sup> incorporated

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<sup>6</sup>Two of these papers are R. S. Eckaus, "The Acceleration Principle Reconsidered", The Quarterly Journal of Economics, Vol. 67 (May, 1953), pp. 209-30 and Hans Meisser, "Critical Notes on the Acceleration Principle", The Quarterly Journal of Economics, Vol. 68 (May, 1954), pp. 253-74.

<sup>7</sup>J. R. Meyer and Edwin Kuh, The Investment Decision: An Empirical Study, Cambridge, Mass.: Harvard University Press, 1957, pp. 116-30. Also, Robert Eisner, "Expectations, Plans and Capital Expenditures, A Synthesis of Ex Post and Ex Ante Data", in Expectation, Uncertainty and Business Behavior, M. J. Bowman, ed., New York, 1958, pp. 165-88.

<sup>8</sup>J. J. Polak and J. Tinbergen, The Dynamics of Business Cycles. A Study in Economic Fluctuations, Chicago: University of Chicago Press, 1950, p. 166.

<sup>9</sup>M. Kalecki, Theory of Economic Dynamics, London: Allen & Unwin, 1954, pp. 96-108.

these profit effects into a model and was able to explain gross fixed investment in the United States over the period 1930-40. However, efforts to apply this model and its extensions to the individual firm have been unsatisfactory. As a result Meyer and Kuh<sup>10</sup> suggest that profit maximization does not encompass the full scope of modern entrepreneurial motives. They maintain that business firms seek to maximize utility instead of profits, a view which is supported by Simon<sup>11</sup> and other proponents of a satisficing theory of behavior. This concept has been incorporated into models of business behavior by Cyert and March<sup>12</sup> and Gordon<sup>13</sup>.

Although important concepts in the economic theory of investment behavior are being developed<sup>14</sup>, the empirical and theoretical approaches to the subject have little in common. At this point the theory does not satisfactorily explain the observed behavior contained in empirical studies.

The second approach to developing a theory of investment behavior consists of using observed results to define econometric models<sup>15</sup>.

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<sup>10</sup>Meyer and Kuh, op. cit., p. 9.

<sup>11</sup>Herbert Simon, Models of Man, New York: John Wiley & Sons, Inc. 1957.

<sup>12</sup>R. M. Cyert and J. G. March, "Introduction to a Behavioral Theory of Organizational Objectives", in Modern Organization Theory, M. Haire, ed., New York: John Wiley & Sons, Inc., 1959.

<sup>13</sup>Myron J. Gordon, "Security and a Financial Theory of Investment", The Quarterly Journal of Economics, Vol. 74 (August, 1960), pp. 472-92.

<sup>14</sup>A list of recent theoretical papers has been provided by Dale W. Jorgenson, "The Theory of Investment Behavior", p. 130, in Determinants of Investment Behavior, Robert Ferber, ed., New York: Columbia University Press, 1967, pp. 129-55.

<sup>15</sup>A list of recent papers using this approach appears in Jorgenson, op. cit., p. 129.

These models then provide a basis for inductive generalizations about some segment of the business world. The results of this approach have also been inconclusive; however, important considerations have been reported. For instance, Fellner<sup>16</sup> discusses the importance of market structure and relative market shares in determining investment behavior. Other studies indicate that internal liquidity considerations and the availability of internal funds also affect the volume of investment<sup>17</sup>. Empirical research by John Lintner provides insight into policies governing the dividend decision<sup>18</sup>. He found very few cases in which current dividends were based on factors other than the previous rate of payment and current profits.

Although these econometric models are useful in isolating important system variables, they provide little insight into the cause-and-effect relationships of the business firm. In an extensive review of investment behavior studies, Eisner and Strotz offer this comment<sup>19</sup>.

There is, moreover, little understanding of the structural relations by which expectations are formed, and so, even if we succeeded in relating expectations intimately to various

<sup>16</sup>William Fellner, Competition Among the Few; Oligopoly and Similar Market Structures, New York: Alfred A. Knopf, 1949.

<sup>17</sup>The empirical evidence on the preference for internal funds is extensive. Two examples are Joel Dean, Capital Budgeting, New York: Columbia University Press, 1951, pp. 37-43, and George W. Terborgh, Dynamic Equipment Policy, New York: McGraw-Hill Book Co., Inc. 1949, pp. 4-7.

<sup>18</sup>John Lintner, "Distribution of Incomes of Corporations Among Dividends, Retained Earnings, and Taxes", The American Economic Review, Vol. 46 (May, 1956), pp. 97-113.

<sup>19</sup>Robert Eisner and Robert H. Strotz, "Determinants of Business Investment", p. 62, in Impacts of Monetary Policy, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1963, pp. 59-233.

past observables, we should have little understanding as to the effects of policy measures, newly adopted, which might alter the future values of the explanatory variables. Problems of predicting the effects of basic changes, including those that are deliberately produced by public policy measures, are a good deal more difficult than those of forecasting future behavior under conditions involving no important change in the structure of behavior relations.

Due to the incomplete nature of microeconomic investment theory, there exists a large, unresolved gap between this theory and the literature of corporation finance. The latter is concerned with the financial management process including such components as setting financial objectives, controlling ongoing operations, capital budgeting and maintaining an acceptable financial structure. Capital budgeting, which is concerned with evaluating the profitability of alternative investment opportunities, has received the most attention. Papers on this topic usually discuss various methods of computing rates of return, payback periods, net present values and the cost of capital<sup>20</sup>.

The literature of corporation finance usually describes how financial decisions should be made for optimal results under a set of assumed conditions. However some sources report survey results describing how these decisions are actually made in practice. In his book Christy reports on a survey of current capital budgeting practices and discusses their relative advantages<sup>21</sup>. A study of corporate debt

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<sup>20</sup>A number of significant papers illustrating the different approaches are contained in Ezra Solomon, ed., The Management of Corporate Capital, New York: The Free Press, 1959.

<sup>21</sup>George A. Christy, Capital Budgeting: Current Practices and Their Efficiency, Eugene, Oregon: The University of Oregon Press, 1966.



policies has been conducted by Gordon Donaldson<sup>22</sup>. He investigates managerial attitudes concerning the use of long term debt and other external sources of funds. The study also includes an analysis of corporate debt limits imposed by management and the relationship between the debt-equity ratio and other long term policies. Another source reports on a series of interviews concerning the determinants of investment behavior<sup>23</sup>. Eisner discusses a number of factors and their relative importance in different types of firms.

The above information facilitated the research effort in two ways: as an aid in identifying important system variables and by providing insight into system relationships. Valuable assistance was also derived from system studies which have considered various aspects of business behavior. One of these studies, Resource Acquisition in Corporate Growth by David W. Packer<sup>24</sup>, concentrates on the corporate growth process. Using the industrial dynamics methodology, the author examines the impact of managerial actions on growth performance. The study considers "how managerial actions guiding resource acquisition can create problems of growth rate and stability . . ."<sup>25</sup>. Two broad resource types are distinguished: production capacity in the form of

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<sup>22</sup>Gordon Donaldson, Corporate Debt Capacity, Boston: The Harvard University Press, 1961.

<sup>23</sup>Robert Eisner, Determinants of Investment Behavior: An Interview Study, Urbana, Ill.: University of Illinois, 1956.

<sup>24</sup>David W. Packer, Resource Acquisitions in Corporate Growth, Cambridge Mass.: The M. I. T. Press, 1964.

<sup>25</sup>Ibid., p. 5.

labor, machinery or plant space and professional effort derived from managerial and engineering talent.

The primary difference between Packer's study and this research arises from the type of firm considered. The former describes a young, aggressive firm which wishes to grow smoothly and rapidly; whereas, this study deals with mature organizations which have already experienced an extended period of rapid growth. In these firms future growth will be more deliberate and will be geared to future increases in demand. Packer's intentional omission of financial considerations is evidence of this difference since financial difficulties are often recognized as symptoms of problems created by rapid capacity expansion.

Further consideration of the factors affecting corporate growth is contained in a series of papers by Forrester<sup>26</sup>. These studies illustrate the nature of the interaction between manufacturing organizations and their markets via delivery delay. Managerial actions are evaluated with respect to their effect on this delay which affects the firm's future growth rate.

The feasibility of using the industrial dynamics methodology to create a management system model has been demonstrated. The papers

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<sup>26</sup> Jay, W. Forrester, "Market Growth as Influenced by Capital Investment", Industrial Management Review, Vol. 9, no. 2., Winter, 1968.

Jay W. Forrester, "Modeling the Dynamic Processes of Corporate Growth", IBM Scientific Computing Symposium, Yorktown Heights, N. Y., December 7, 1964.

Jay W. Forrester, "Thoughts on Forces Inducing Corporate Growth", D-487-1, an unpublished memo of the industrial dynamics research group at the Massachusetts Institute of Technology, October, 1962.

by Packer and Forrester offer models of hypothetical firms, which are used for purposes similar to those of this study. Modeling the system of interest requires determination of how the present states of variables in the information feedback configuration create subsequent financial behavior. Identification and formulation of these relationships entails collection and analysis of information from various Civil Aeronautics Board reports and company financial records. Since company policies and managerial actions are inherent in the system structure, the above information was supplemented by personal contact with those individuals in the firm concerned with planning and control. Some assistance in this endeavor was provided by studies of individual relationships and surveys of managerial attitudes and policies contained in the literature. However, reports of efforts to aggregate these policies and control activities into a comprehensive model of financial decision-making have not been found.

## CHAPTER III

### THE MANAGEMENT SYSTEM AND ITS ENVIRONMENT

This chapter describes the components and relationships of the management system and its environment pertinent to the research problem. The system structure of airline management reflects characteristics of the industry and other environmental factors. The components of this environment warranting description are:

1. The Civil Aeronautics Board
2. The Market for Air Transportation
3. Competition Within the Industry
4. Aircraft Manufacturers

#### The Civil Aeronautics Board

The eleven major domestic trunklines plus Pan American are regulated by the Civil Aeronautics Board (CAB) which awards route structures and controls the industry fare structure. The CAB, authorized and created by the Civil Aeronautics Act of 1938, is charged with the economic regulation and promotion of commercial interstate air transportation. The Board's economic regulatory activities may be grouped as follows:

1. Awards of operating authority
2. Regulation of rates and fares
3. Regulation of agreements and interlocking relationships among air carriers and between air carriers and other aeronautical enterprises.

4. Support of air service through subsidy payments.
5. Regulation of air carrier accounting and reporting.
6. Enforcement of applicable laws and regulations.

Air carriers may not engage in air transportation over any interstate route within the United States or to and from the United States without a certificate of public convenience and necessity or a permit from the CAB authorizing such air transportation. Certificates of public convenience and necessity are issued after notice is given and interested parties have had an opportunity to be heard. Frequently, the issuance of certificates is opposed by other air carriers who deem that they would be adversely affected. The normal procedure includes a hearing before a hearing examiner and an initial or recommended decision by the examiner, subject to review by the board. Some of these proceedings are long and protracted, involving many parties and lasting several years. Others are relatively simple, and require only a few months. It is not uncommon for an airline to be involved in a number of these hearings simultaneously. Thus management must consider the possibilities of new route awards and increased competition over existing routes when planning future aircraft purchases.

The Civil Aeronautics Board is also authorized to prescribe rates for domestic air transportation. Air carriers are required to file all new tariffs or tariff changes with the CAB. The Board can suspend the new rates for up to 180 days if they feel the proposed rates are unreasonable. During this period the Board can, with due notice and a hearing, determine and prescribe the rate it deems to be lawful. Thus the Civil Aeronautics Board controls the route structure as well as the

rate structure for each airline in the industry. Another method available to the Board for controlling rates is the authorization of more competition over particular routes. This possibility tends to discourage the proposal of increased rates and fares by individual airlines within the industry.

Since the CAB can greatly influence the economic status of an airline, a statement of what constitutes a reasonable financial performance was deemed to be necessary. In 1960 the Board specified that the measure of performance would be the rate of return on investment. They also determined that for domestic trucks a fair and reasonable rate of return on investment was 10.5 percent, taking into account the relative risk and volatility of the industry and the return that would be required for members of the industry to attract needed capital. The Board also determined that this return should be allowed over an extended period of time. It should be noted that this earnings level has been achieved only one year, namely 1965, since that bench mark was adopted by the CAB.

#### The Market for Air Transportation

Another factor to be considered by airline management in programming capacity acquisition is the underlying growth in demand for air transportation. Although automobile traffic is still the dominant form of transportation, air transportation has been developing at an increasing rate. For instance, in 1956 airlines accounted for three percent of all inter-city passenger miles. In 1967 airlines accounted for almost seven percent. During the same period, automobile traffic went from 670 billion passenger miles to 880 billion, an increase of

thirty-one percent<sup>27</sup>. In the past twenty years the airline industry has grown four times faster than the general economy and ten times faster than the population. A number of factors have contributed to this tremendous growth rate: greater decentralization in business, aircraft of greater comfort and safety, a generation which has grown up unafraid of flying, and a period of reasonably high economic activity.

More recently, traffic has increased 196 percent over the six year period from 1961 to 1967<sup>28</sup>. Over the past decade demand for air transportation has increased at a compounded annual rate of approximately fifteen percent. This growth rate and forecasts of future economic activity serve as a basis for traffic projections underlying fleet expansions. However, forecasting traffic growth and future demand is complicated by the seasonality patterns and sensitivity to economic factors exhibited by air transportation demand. Demand patterns for an individual airline depend upon that airline's route structure and the particular markets it serves. Airline management must project the demand in the firm's market and transform these projections into orders for new capacity via the desired ratio between demand and capacity as measured by the passenger load factor.

Based upon forecasts of relevant variables, the airline industry's extraordinary growth is far from over. Our nation's economy is expected

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<sup>27</sup> Richard E. Caves, Air Transport and its Regulators, Harvard University Press, 1962, pp. 48-54, 331-335.

<sup>28</sup> Major U. S. Airlines: Financial Requirements and Projections, 1968-1971, Air Transport Association of America, Report to the Civil Aeronautics Board, June 26, 1968.

to continue to expand at a rapid pace. The gross national product is projected to reach well over one trillion dollars annually by 1975. The population of the United States is expected to increase to over 225 million by 1975. Disposable income will be over 800 billion by 1975, and consumer expenditures will be in excess of 700 billion dollars. All of these projections indicate significant growth in the immediate future and can well be expected to influence similar increases in demand for air transportation. Airline traffic is expected to more than double in the 1970's<sup>29</sup>.

#### Competition Within the Industry

Individual airlines can do little to affect the general economic conditions, population growth and similar exogenous factors influencing their market; however, other basic determinants of demand can be modified. Controllable factors include price, schedule frequency and passenger service.

Regarding the relationship between price and demand, the price elasticity of demand for air transportation has not been established to date. The CAB's belief that the elasticity is slightly above one appears to be the basis for readily approving promotional discounts and rejecting most requests for fare increases. Members of the industry seem convinced the elasticity is less than one. Recently approved increases may provide a basis for further study if the effect of current economic conditions can be removed.

Since increasing market share by reducing price is unlikely,

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<sup>29</sup>Ibid.



airline management traditionally strives to maintain or increase their market share by offering a better product. Product differentiation by competing airlines is very difficult, with two important exceptions - improved flight schedules and the use of faster, newer and more comfortable aircraft. The first of these factors, improved flight schedules, generally requires the use of more aircraft and therefore greater capacity acquisitions. The second factor, more modern aircraft, depends upon technological advances and recent capacity acquisition rates.

Currently, the introduction of new equipment is an action no carrier can afford to completely neglect if it is to remain competitive. As newer and better equipment is introduced on competitive routes, existing equipment is relegated to monopoly situations or less competitive routes. Therefore capacity acquisitions are often motivated by the desire to provide more service to increase the potential demand, and to provide better service for the purpose of retaining or improving the current market position. Obviously competitive airlines over the same routes must react to such an action with similar purchases of their own. Thus a sequence of actions and reactions may be perpetuated in this highly competitive industry which will amplify normal capacity purchases. Another condition resulting from the competitive pressures is the importance management places on fleet revision after every technological advancement. As a result aircraft are replaced by more expensive aircraft which perform the same service.

Historically, the impact of regulation has amplified the conditions underlying high capacity acquisition rates. In the late 1950's, the CAB was faced with a major policy decision. The speed and capacity of

aircraft were increasing but so was the cost. Only airlines with well-integrated route patterns could make efficient use of the new equipment. Airlines with low-density routes were incurring greater operating losses with each addition to their fleet. The CAB's dilemma concerned the question of allowing maximum competition on all the high-intensity routes, which would reduce the rate of return to each airline, or protecting the profit rates on these routes in order that the airlines with greatest access to them could achieve profitable performance. Since the latter alternative would require subsidy of the less profitable airlines, the former course of action was chosen.

Two effects of this decision are still obvious in the industry today. First, a number of airlines have been forced to consider mergers as a result of increased competition. Between the end of the second World War and 1964, seven major domestic trunks have gone out of existence by way of merger. The most significant of these mergers was the combination of Capital Airlines and United Airlines in 1961, which made United the largest airline in America. This merger also brought sharply into focus the financial difficulties of all trunkline operators, aggravated by the increased capacity investment associated with the introduction of turboprop and jet aircraft in the late 1950's, but ultimately due to the overcrowding of the industry's profitable air routes.

The second effect relates to the CAB's authority to grant new route awards and airline management's perception of the importance of capacity levels to future route awards. Airline management maintains that a demonstrated willingness to provide excess capacity for their current system enhances the chances of gaining future route awards.

Non-essential capacity acquisitions may be scheduled in anticipation of receiving additional routes in the future. Whether the CAB actually considers this factor is not obvious. However, the Board does award new routes to airlines in financial trouble because of excess capacity. Therefore, the effect is the same; purchasing unnecessary capacity will lead to new route awards in the future. However, severe financial problems may result in the interim. The long delays and uncertainty associated with the Board's route decisions also complicate this relationship.

Thus, airline management must make decisions regarding additional capacity under uncertainty about future route awards and competition over existing route structures. Capacity acquisition programs for individual airlines tend to be periodic and uneven. Major purchases generally reflect technological advances and the airline's current competitive position. Since the acquisition programs are relatively insensitive to underlying demand growth, severe financial losses are incurred due to excess capacity. These losses continue until an increase in demand is achieved from an increased market share, gaining new routes, or waiting for the market to grow from exogenous causes.

#### Aircraft Manufacturers

In consummating an order for new aircraft, the individual airline must interact with the aircraft manufacturing industry. This industry is characterized by a small number of highly competitive manufacturers who have well-defined but limited markets for their product. The dominant aircraft technology generally has been quite evident to

both the aircraft manufacturer and the airline industry. Military aircraft research, as an important source of commercial aircraft technology, has been a substantial force in creating homogeneity in capital equipment. Product differentiation is limited in the industry since individual firms draw on an essentially common pool of technical information in which new ideas are quickly disseminated.

Due to the magnitude and infrequent nature of aircraft purchases by an individual carrier and the limited number of sellers, the new aircraft market is characterized by individual bargaining sessions. The intense competition among aircraft manufacturers and the absence of technological product differentiation create a marketing situation in which special concessions are granted to the customer to assure a particular sale. Typical considerations might include earlier delivery times or higher trade-in allowances on older equipment. An important promotional device offered by aircraft manufacturers involves special financial assistance for financing the new aircraft acquisition. This financial assistance may take the form of a reduced deposit upon order or special terms for delaying payments prior to aircraft delivery. Such considerations have constituted an important source of funds during past acquisition programs.

A number of factors have combined to practically eliminate this source of financing for the airlines. The rapidly increasing costs of modern aircraft have reduced the funds available to the manufacturers. To illustrate the magnitude of these cost increases, the DC-4, introduced in 1945, cost about \$480,000; the Lockheed Super Constellation, entering service in 1948, cost 2.3 million dollars; and the Boeing 707

in 1958 cost about five million dollars. The Boeing 747, which recently entered service, costs approximately twenty-five million dollars each.

Since more capital is committed to aircraft under development and construction, less is available to fund trade credit for the airlines. Recent government reductions in expenditures for defense and space activities have also greatly reduced the funds available to the aircraft manufacturers. Thus, an important source of short-term financing for the airline industry has been virtually eliminated.

#### The Capital Market

Another environmental component directly related to financial decision-making is the capital market. Financial institutions, such as banks and insurance companies, provide the funds for financing a great portion of the new capacity. The primary influence of these institutions is upon the financial structure of the airline. Certain requirements must be met with respect to the proportion of debt in the capital structure before additional funds can be acquired. This consideration results in financial managers striving to achieve a desirable financial performance for their firm as measured by certain financial ratios and relationships. Since the airlines are operating under a certificate of convenience and necessity issued by the Civil Aeronautics Board, they feel obliged to incur debt whenever necessary to provide the capacity required to service their market. Such actions may enhance their chances of gaining future route awards and a greater share of their current market. Counteracting these forces is the hesitancy to finance these acquisitions with additional long-term debt because of the debt's

influence on the firm's capital structure. Certain key financial indicators, such as the debt-equity ratio and investment turnover, become significant control variables in financial decision-making because of their importance in acquiring future external funds from financial institutions.

Airline management generally prefers to avoid the dilution of earnings which would result from a common stock issue. Typical forms of financing include long-term notes and bonds with convertible debentures being used when other forms cannot be obtained under attractive terms. Interest rates were four and five percent in the 1950's, about six percent in the early 1960's, and approximately eight percent in recent years. In general, interest is charged at the prime rate or at prime plus one-fourth percent; however, it appears that the cost of capital is not a consideration when deciding to acquire additional debt. Another form of financing widely used in the airline industry is equipment leasing. The investment tax credit made this form of financing popular with firms having excess internal funds who could use the tax credit to reduce taxes on their own profits. Removal of the investment tax credit has greatly reduced the availability of this form of financing.

#### The Labor Market

Although capital equipment costs have increased by a factor of one hundred over a thirty year period, technological advances and increases in aircraft capacity have resulted in lower operating costs. However, increases in labor costs have offset gains in operating efficiency resulting in a constant or slowly decreasing passenger mile

yield. Strong unions in the airline industry have relentlessly pressed for continuing wage and salary increases which negate the benefits of operational improvements. Uncertain labor relations and the potential financial impact of a prolonged strike further complicate the conditions of managerial planning and control in the airline industry.

Hence, management must function in an environment of uncertainty regarding technological advances, regulatory actions and labor relations. The decision-maker must plan capacity acquisitions to meet forecasted increases in demand, remain technologically abreast of the competition, and satisfy standards imposed by the Civil Aeronautics Board. These plans must be tempered by the external funds requirement, the impact of such funds on the firm's capital structure and the requirements for future financing. The airline must maintain an acceptable position with respect to environmental factors while attempting to achieve a reasonable financial performance. The efforts to achieve these goals and the results of these efforts are the focal points of this research.

## CHAPTER IV

### THE MANAGEMENT SYSTEM - STRUCTURE AND BEHAVIOR

An organization's managerial control system cannot be examined apart from management's planning activities. The planning elements are charged with specifying the firm's goals and the general procedure for achieving these goals. A clearly defined organizational goal can then be used as a basis for establishing objectives at various levels in the firm. A related output from planning efforts consists of basic rules and principles which should be observed in attaining these objectives. These operational policies and strategies serve as guidelines and constraints for the decision-maker as he specifies actions to achieve the stated objectives. Further definition of the planning outputs results in specific programs, schedules and budgets which serve as a basis for control.

Control, therefore, is introduced to assure that these programs, schedules, and budgets are really being met, and to provide a continuous means of highlighting any tendency to depart from the basic elements of plans. Control must involve the process of receiving pertinent information on the activities related to attaining the firm's objectives. Hence, the control process requires monitoring key variables and comparing their values with the desired magnitudes of these variables which relate to the firm's specified goals and objectives. To close the control loop, the decision-maker takes action based on a discrepancy between



desired and actual variable magnitudes to resolve this discrepancy.

Of course the preceding description is a vast simplification of the control procedures in an operating organization. One complication results from the existence of multiple operating areas, each monitoring different variables and affecting different outputs which contribute to the firm's overall objectives. Different sub-organizational goals, utilization of different information flows with varying amounts of error and bias, and location within the organizational structure all contribute to decisions and outputs which are contradictory rather than reinforcing. Thus, the firm may be subjected to conflicting forces which produce fluctuating behavior patterns and deter the achievement of stated objectives. The purpose of this chapter is to describe two major components of an airline management system: the capacity control sector and the financial control sector. Policies and objectives are examined; key variables are described; and the performance patterns which result from the joint functioning of these two components are presented. A schematic representation of the two components and their interrelationship is presented in Figure 1.

#### The Capacity Control Sector

The need for control in an organization originates from management's desire to maintain certain relationships within the firm and between the firm and its environment. A manufacturing firm's efforts to equate production with sales over the long run is a common example of this phenomenon. Similarly, the decision-makers in the operating segment of an airline strive to provide adequate capacity to service the

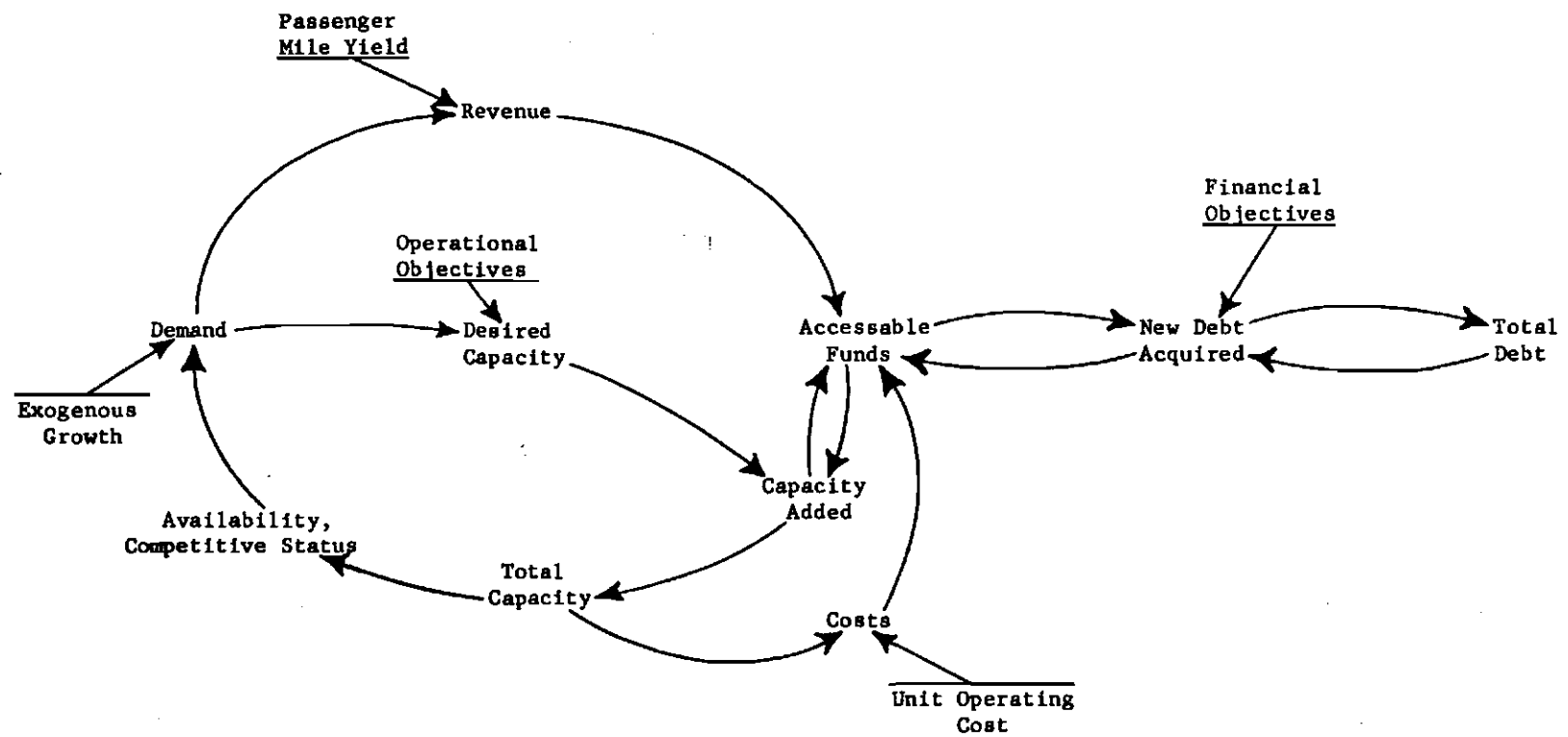


Figure 1. Financial and Operational Component Interactions

demand for air transportation over their particular routes. As this demand increases due to exogenous market factors and the firm's own actions, additional capacity must be acquired to maintain the desired relationship between demand and capacity. Failure to take such an action would eventually result in a capacity-limited operation in which continued growth is unlikely. This outcome is even more likely due to CAB policies on route awards and the aggressiveness of competing airlines.

A key variable, the passenger load factor (PLF) which is the ratio of revenue passenger miles to available seat miles, reflects the relationship between the CAB and an airline management system. An available seat mile (ASM) is generated by flying one seat one air mile regardless of whether or not it is occupied. Thus, the available seat miles produced by an airline over some period of time is a direct measure of capacity. A revenue passenger mile (RPM) is generated by transporting a paying customer one air mile; therefore, RPM's measure the quantity of goods sold.

Since the passenger load factor is a measure of the utilization of capacity to generate revenue, airline management would like to see the passenger load factor approach one, implying a one hundred percent utilization of capacity. However, the CAB has historically maintained that an airline consistently achieving a high load factor is not providing enough capacity to satisfy the industry's best customer, the businessman, in periods of peak demand. In general, the CAB maintains that a load factor exceeding sixty percent over an extended period of time indicates inadequate capacity for the present route structure. In addition, the passenger load factor for a particular airline may be

considered in awarding new routes or in increasing the competition on an airline's present routes<sup>30</sup>. Thus airline management must strive for an efficient and economical operation while limiting the average utilization of capacity to sixty percent.

In addition to the desired passenger load factor, capacity acquisition decisions require a forecast of future demand levels. Fundamentally, all forecasting starts with an evaluation of past performances at the industry and company level. From this base an attempt is made to establish trends and to project these trends for prediction of future occurrences. The airline industry is no different. Although past demand patterns may be analyzed on an individual route or city-pair basis and sophisticated statistical methods may be used, the resulting forecasts of future demand represent an extrapolation of past demand based on current information.

Traffic growth represents a major uncertainty in this process. For instance, demand for air transportation is clearly sensitive to general economic conditions. It is relatively certain that the tremendous increases seen in the mid-1969's will not be repeated. These were caused by several unique events: the acceleration of the Republic of Vietnam military effort, the proliferation of promotional discount fares, and the concurrent upswing in economic activity. The equipment purchases during this period were triggered by misreading these abnormally high growth rates and anticipating their continuation.

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<sup>30</sup> Although the CAB's policies in these areas have never been clearly defined and documented, the airlines' perception of these policies and their implications greatly influence airline decisions. The above interpretation is attributed to Mr. Robert Oppenlander, Senior Vice-President of Finance, Delta Air Lines, Inc.

Another complication associated with the capacity acquisition decision arises from the delay between placing an order and adding the new aircraft to the fleet. This delay may range from twelve months up to thirty-six months depending upon the size of the order and the length of time since the aircraft's introduction. Even promised delivery dates are subject to uncertainty due to labor strikes in the aircraft manufacturing industry and priority Government orders.

To place forecasting activities and corporate operational objectives in perspective, consider the operational segment of Figure 1 shown in Figure 2. Demand increases due to exogenous market growth, new route awards, and an improved market position create a need for additional capacity. This need may result from a desire to maintain the traditional passenger load factor, the goal of establishing an aggressive market position with regard to seat availability and technology, or the desire to enhance future route awards by demonstrating a willingness to provide extra capacity. Assuming the availability of funds, this need for additional capacity is converted to an order for additional aircraft based upon forecasts of future demand and the desired passenger load factor. Following a delivery delay, the new aircraft are added, increasing the fleet capacity and technological level. If other factors including competition have remained constant, the new aircraft will stimulate additional increases in demand and perpetuate the loop's movement in the same direction. Thus, a perfectly regulated operational control loop of this nature would maintain capacity at a level which satisfied the desired passenger load factor. In reality, deviations from the ideal occur because:

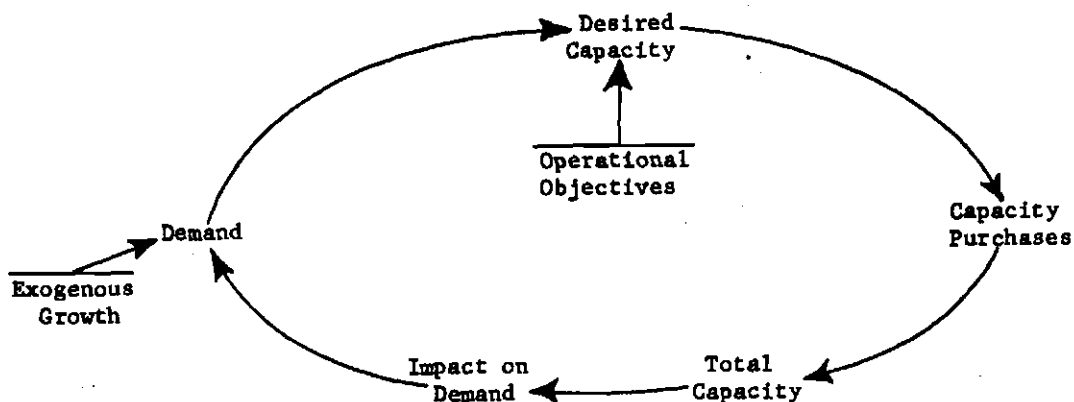


Figure 2. Operational Component

(a) The market does not grow at a constant rate which is perfectly predictable.

(b) Orders are placed in discrete lots and are subject to uncertain delivery times.

(c) Competitive actions triggered by the firm may alter the market share from the expected level.

Certain operational characteristics of the capacity control sector should be noted. As discussed earlier, an increase in demand and capacity will set forces in motion which perpetuate additional increases if other factors remain constant. Conversely, a decrease or smaller increase in demand creates a desire to reduce capacity. However, aircraft on order continue to arrive creating excess capacity. Since the sale of aircraft by airlines is costly and infrequent, the firm must operate with excess capacity until demand increases to a suitable level. However, failure to add capacity when appropriate suppresses future increases in demand to a level consistent with the capacity currently available. Thus, the control loop provides for a long term

relationship between demand and capacity. Management's goal consists of ensuring that this relationship will also permit a reasonable growth pattern and a profitable performance over time. The growth rate and resulting profit performance greatly depend upon the firm's objectives and aggressiveness as translated into capacity acquisition decisions.

### The Financial Control Sector

Just as the operations manager seeks to balance capacity with demand, the financial decision-maker strives to maintain certain relationships between his firm and sources of external capital. In addition, he is concerned with allocating the firm's monetary resources to activities which will contribute to future profits. Financial information may serve more than one purpose in an organization. First, it measures the firm's past success in a summarized report of performance. Such financial indicators as profit, return on investment and profit on sales yield valuable information on the quality of past decisions. In industries requiring large capital investments of a recurring basis, financial variables are also used for control purposes. Such is the case in the airline industry.

In the capacity control sector previously discussed, managerial decisions result in new aircraft orders which augment the airline's current capacity. Total capacity, measured in available seat miles, produces a flow of funds in the form of operating revenue, primarily passenger revenue. Offsetting this revenue is a concurrent outflow of cash resulting from operating expenses. The status of the firm's internal funds or working capital is primarily the net result of these

two cash flows. Internal funds available must be considered in programming capacity acquisitions, for these funds, compared with the cost of new capacity, dictate the amount of external capital required.

This external capital in the form of long-term debt or additional equity alters the firm's capital structure and ability to attract additional external funds in the future. Financial managers monitor these flows of funds and the relationship between internal and external funds to maintain a desirable position with respect to external supplier of capital. Again referring to Figure 1, the operational control sector and financial control sector are coupled via the availability of funds to acquire additional capacity. Although traffic forecasts may indicate a need to order additional aircraft, the funds required and the impact of additional external funding on the capital structure may preclude placement of the order.

Conversely, a successful performance over an extended period of time generates additional funds which enhance the airline's financial status and provide for future capacity purchases. Inherent in the problem of matching increased revenues with increases in costs is the delay associated with the production of additional revenues from new capacity. Since approximately ninety percent of the expenses associated with operating an aircraft are fixed, costs increase immediately when capacity is increased. Although the addition of new, advanced aircraft to the fleet will stimulate increases in demand, a significant delay occurs prior to the realization of forecasted traffic growth. Consequently, capacity acquisitions generally result in a period of excess capacity with increased costs prior to producing a long-term increase



in demand and revenue. If losses are incurred during this period, internal funds are depleted further.

This impact on internal funds and the magnitude of capacity acquisition programs require a substantial use of external capital. Common sources of outside funds in order of preference are: (1) long-term debt in the form of bonds and notes, (2) convertible debentures and (3) common and preferred stock issues. Equity financing becomes increasingly difficult as profits and earnings per share decline. This factor in conjunction with the potential dilution represented by past convertible issues make airline stocks or additional senior debt unattractive from a potential investor's point of view.

Although a major capacity acquisition program may be initiated during a period of high earnings and rapid growth, the financial impact is severe. Large amounts of debt are added to the capital structure, costs increase rapidly and profits decline. Although the situation will be resolved when sufficient demand increases are realized, various circumstances may delay the occurrence of this event.

(1) The orders may have resulted from overly optimistic forecasts of future demand. The large deliveries of extended-fuselage jets in 1968 and 1969 reflected the industry's anticipation of a continued growth rate comparable to the mid-1960's and extensive route awards in the Pacific and Caribbean areas.

(2) The purchases may be reactions to technological advances in the aircraft manufacturing industry. This factor prompted excessive capacity acquisitions and subsequent financial problems in the early 1960's when the jet was introduced and appears to be amplifying current

purchases of the wide-body jet.

(3) Capacity acquisition may be a reaction to the introduction of new aircraft by the competition. Capacity purchases resulting from such circumstances and not from an underlying growth in demand produce a more severe financial crisis since corresponding revenue increases are delayed even longer.

Airline management is thus faced with maintaining relationships with three components of their environment. They must maintain a relationship between capacity and demand as measured by the passenger load factor. This relationship directly affects company earnings and supposedly alters the company's status as perceived by the CAB. Secondly, the company must provide adequate capacity to satisfy market demand. Failure to do so results in a loss in market share resulting from customer reactions and/or CAB actions to increase competition. Thirdly, airline management must maintain an acceptable financial status to acquire future financing for capacity acquisitions.

Capacity purchases which appear necessary to achieve operating goals may directly conflict with the firm's financial objectives. Various financial indicators are used to measure a firm's financial performance and status over time. A key variable used by airline management as well as potential investors is the debt-equity ratio. This ratio simply measures the proportion of assets financed by long-term debt as opposed to equity capital.

Industry debt-equity ratios have varied considerably, with the highest ratios occurring during periods of major re-equipment. From

the early 1960's through 1966 airlines were able to rely largely on internal sources of funds including retained earnings and depreciation. Profitable operations during the first half of the decade allowed them to reduce debt-equity ratios from a peak of two-to-one in 1961 to about 1.2 to one in 1966. With the major equipment purchases in 1968 and 1969, the industry's debt load has increased rapidly to its current level of approximately 1.8<sup>31</sup>.

The highly levered capital structures combined with depressed economic conditions in the early 1970's have resulted in a poor financial performance by the industry. In addition capital financing for the generation of wide-bodies aircraft is in progress. The initial absence of a competitor for the B-747 and the current condition of the aircraft manufacturing industry has resulted in demands for greater deposits by the airlines in financing these aircraft. For example, fifty percent must be paid six months before delivery; whereas, only thirty percent up to delivery time has been more conventional terms for aircraft. One result has been a postponement of orders by the airlines resulting in lower wide-body jet production than originally anticipated. However the increased cash requirements for financing the jumbo jet acquisition programs conflict with the drain of internal funds by operating losses. Consequently external sources of funds must be used at a time when the debt load is already great and earnings have been poor.

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<sup>31</sup>Air Carrier Financial Statistics, Civil Aeronautics Board, Washington, D. C.

This situation is symptomatic of the recurring conflict between operational and financial objectives in the airline industry. Decision-makers in both segments of the organization must be concerned with the capacity level which produces the most desirable financial performance over an extended period of time. Three system parameters which directly affect this performance are:

- (1) the capital cost associated with acquiring an additional unit of capacity (available seat mile),
- (2) the yield associated with each unit of sales (revenue passenger mile), and
- (3) the cost of operating an additional unit of capacity.

Whereas there have been huge rises in the capital investment per employee, the capital cost per available seat mile has been almost constant for fifteen years, and promises to remain so. Although the cost per aircraft has soared, the larger, faster jets produce proportionately more seat miles in operation. In fact the stretched versions of the DC-8 and Boeing 727 have slightly lower capital-to-output ratios<sup>32</sup>; whereas, the Boeing 747 jet may have a slightly higher ratio than existing jets in spite of its size, because of the high unit cost and low density seating arrangements.

Based on the increased seat-mile production of today's advanced aircraft, one would expect concomitant increases in the passenger-mile yield. However, fare increases have not kept pace with inflation's

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<sup>32</sup>Aircraft Operating Cost and Performance Report, Civil Aeronautics Board, Washington, D. C.

impact on the dollar. While the Consumer Price Index increased eighty-eight percent between 1946 and 1969, over-all airline fares rose only twenty-seven percent<sup>33</sup>. Therefore, the two effects have offset each other in the past producing a relatively constant passenger-mile yield<sup>34</sup>.

The third parameter to be considered is the direct operating cost associated with producing an available seat-mile. Unit operating costs will be related to capacity (ASM) as opposed to sales (RPM) since most (approximately ninety percent) of the operating costs are incurred whether a passenger occupies the seat or not<sup>35</sup>. Direct operating costs include direct flying expenses, such as flight crew salaries and related expenses, fuel and oil, insurance, rental of flight equipment, maintenance and overhead, and depreciation. Such costs are also dependent upon the efficiency of scheduling; that is, utilization, and the nature of the route system. Over the last two decades, seat-mile costs have steadily declined as plane size and speed have increased. The bigger, faster planes have lower operating costs per passenger, and the ratio of pay load to aircraft weight has increased as plane size has increased<sup>36</sup>.

Jet technology, largely because of the turbine engine, has

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<sup>33</sup>"Stormy Weather for CAB's Secor Browne", Nation's Business, March 1971, p. 74.

<sup>34</sup>Major U. S. Airlines: Financial Requirements and Projections 1968-1971, op. cit.

<sup>35</sup>Sample data which support this statement are presented for each domestic trunkline in both Moody's Transportation Manual, Moody's Investors Service, Inc. New York, New York, and Air Carrier Financial Statistics, Civil Aeronautics Board, Washington, D. C.

<sup>36</sup>Aircraft Operating Cost and Performance Report, op. cit.

produced a sharp discontinuity in the gradual reduction of aircraft operating costs. The turbine engine produces greater thrust, greater speed, and hence much lower cost for fuel and maintenance per ton-mile of pay load. Fewer overhauls and higher daily utilization rates have also resulted from the introduction of this engine<sup>37</sup>. As a result, jets can achieve utilization rates on the order of ten hours a day as contrasted with a figure of about seven hours per day for piston aircraft<sup>38</sup>. Similarly, crew costs have been sharply reduced because the bigger, faster planes use crews of the same size.

Again these economies have been offset by increases in operating costs not directly associated with the aircraft. The primary source of these increases is labor. The airline industry is labor intensive and characterized by strong, active unions. These factors combined with the financial impact of strikes have provided for wage increases which offset the operational economies of the advanced aircraft<sup>39</sup>.

In subsequent chapters the relationships involving these parameters is discussed. Hypothesized system behavior for an individual airline based upon these relationships is presented, and a realization of these behavior patterns produced by a major domestic trunk line is offered.

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<sup>37</sup>Ibid.

<sup>38</sup>Air Carrier Analytical Charts and Supplemental Carrier Statistics, Civil Aeronautics Board, Washington, D. C.

<sup>39</sup>Major U. S. Airlines: Financial Requirements and Projections 1968-1971, op. cit.

## CHAPTER V

### RESEARCH HYPOTHESIS AND MODEL CONSTRUCTION

A qualitative description of an airline management system and its environment has been presented in previous chapters. Components of this system have been examined and potential results of their goal-seeking activities have been suggested. The purpose of this chapter is to incorporate these objectives and the component interrelationships into a system model of feedback relationships. The fundamental hypothesis of this study is that this system of feedback relationships underlies the dynamic behavior of members of the airline industry.

#### Observed Behavior Patterns

The following presents a graphical representation of general behavior patterns associated with a member of the airline industry. The first set of curves depicts the hypothesized relationship between an airline's actual demand measured in revenue passenger miles and the average demand it would realize by maintaining a constant market share. All effects of seasonality have been removed since capacity acquisition decisions are based on underlying trends, and seasonality is offset by rescheduling aircraft. For an airline with a fixed route structure shared by at least one competing airline, the average market potential would increase over time due to the exogenous growth factors discussed earlier. This growth is depicted as a straight line discounting the impact of economic conditions which are not subject to managerial

control. Ideally the airline would add sufficient capacity to accommodate this market growth thereby maintaining their market share and avoiding excess capacity. A discrepancy between this average market potential and the airline's actual sales may be created by several factors: a competitor's actions, a delay in receiving new aircraft, inadequate aircraft purchases due to financial constraints and others.

When the effects of such factors have been reduced or removed, demand increases rapidly. Since these increases include the underlying market growth as well as market share recoveries, the perceived growth in demand exceeds the true increase in average market potential. Demand forecasts based upon perceived traffic growth result in new capacity orders because:

(1) the demand for air transportation appears to be increasing more rapidly than in previous periods.

(2) few aircraft were purchased during the previous periods when the airline was operating below the average market potential, and

(3) the recent increases in demand have provided for a more profitable operation and more funds for capacity acquisitions.

Since the addition of new aircraft may assist in regaining a previous market position, demand increases may be temporarily reinforced by capacity acquisitions. In fact the airline may even succeed in capturing a portion of the competitor's market. Thus the forecasts are self-fulfilling over a short period of time.

However, the rapid growth in demand is ultimately limited when the airline reaches or exceeds the market share equilibrium point.



Competitive reactions to regain lost markets and CAB awards to increase competition suppress further gains at the expense of competing airlines. Ideally, the airlines would then continue operations at the equilibrium point with appropriate capacity levels.

Unfortunately, orders for additional aircraft have already been placed on the basis of earlier demand projections. Because of the long delays (one to three years) between ordering and receiving new aircraft, substantial increases in capacity occur after the market equilibrium point has been reached. Since additional market share gains have been suppressed, excess capacity occurs. The new capacity order rate and subsequent delayed receipt of new aircraft is reflected in the second set of curves in Figure 3.

During the market share recovery phase, demand increases exceed capacity additions due to the inherent delay in ordering and receiving additional capacity. As a result the passenger load factor increases and operations are more profitable. After demand growth is slowed by the market and competition, subsequent capacity arrivals reduce the passenger load factor. The resulting excess capacity increases costs, and profits decline. Internal funds which were augmented during profitable operations are now depleted by capital expenditures and operating losses.

After internal funds are exhausted, subsequent capacity additions must be funded by long-term debt. Since demand and profits are not increasing at the projected rate, the required debt generally exceeds anticipated levels. Hence, debt control policies are violated and the capital structure is weakened. High debt-equity ratios and low

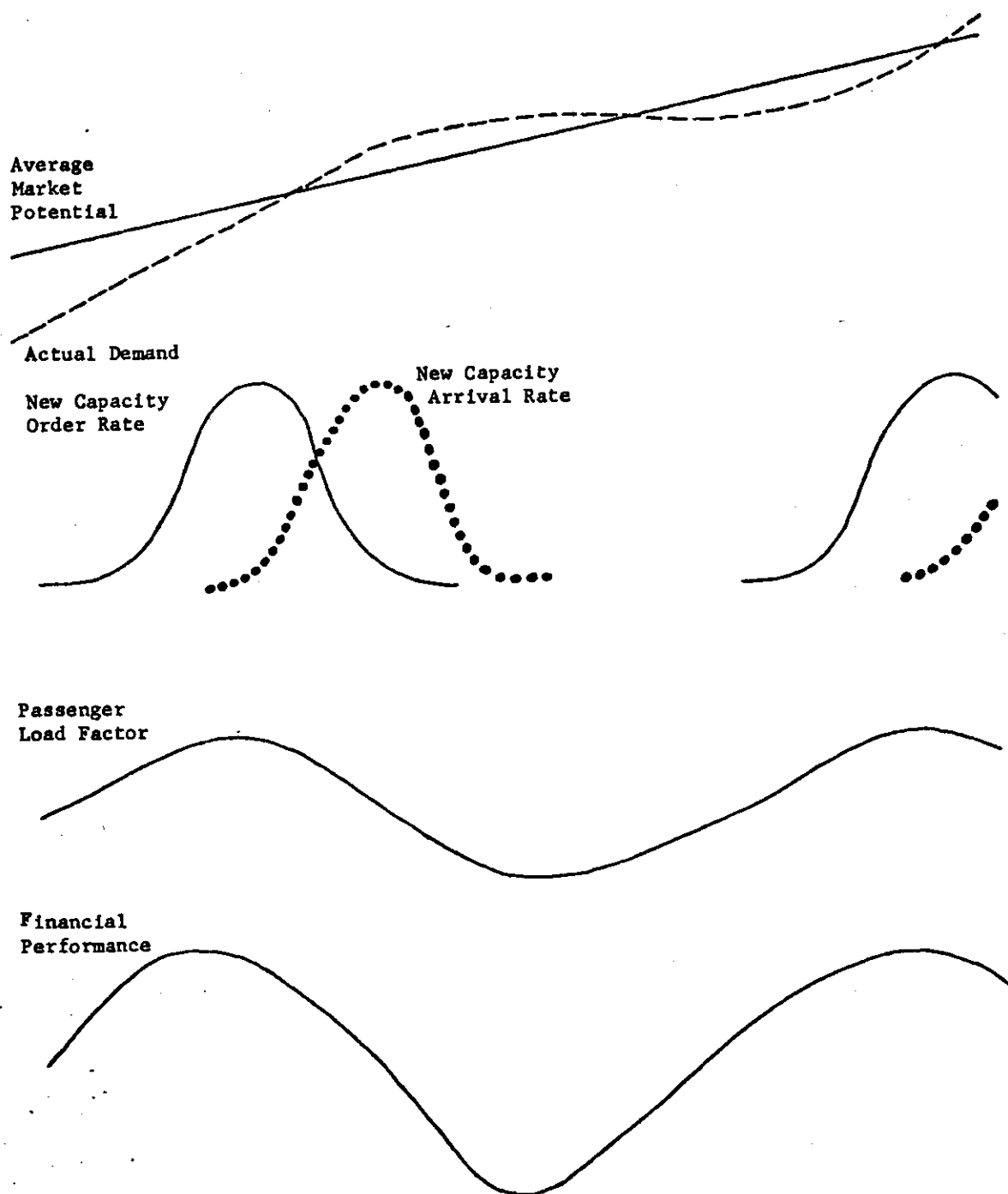


Figure 3. General Behavior Patterns

returns on debt capital characterize an airline approaching the end of a capacity acquisition program. Decreasing profits and a highly levered capital structure reduce the airline's attractiveness from a potential investor's point of view. Declining stock prices and potential dilution of per-share earnings make additional equity capital undesirable. Therefore, the airline must acquire additional debt under unfavorable circumstances.

Large quantities of debt, the resulting costs of servicing the debt, and the increases in fixed costs associated with the purchase of new, more expensive aircraft amplify the airline's poor financial performance. This situation continues until exogenous growth in the airline's market corrects the imbalance between capacity and demand.

At this point the airline should begin to add capacity again at a slower rate to match the market's inherent growth. However, financial conditions may not permit capital expenditures at this point. The debt-equity ratio has increased rapidly due to the addition of long-term debt and depletion of working capital by operating losses. Thus, the airline must achieve a period of profitable operation prior to negotiating for additional external capital. During this period demand may be limited by capacity as opposed to the market limitations experienced earlier. By the time a suitable credit agreement is established, the order is placed, and the initial aircraft are received, the airline may be once again operating well below the average market potential.

Thus, the cyclic pattern of the passenger load factor and

profits begins again with two important exceptions. First, the market for air transportation has continued to increase at a compounded annual rate of approximately fifteen percent per year. Therefore, future capacity acquisition programs will involve more seat-miles, more expensive aircraft, and consequently, greater capital expenditures. Secondly, the airline's present debt is at a higher level than at the beginning of the previous cycle and will have to be renegotiated in subsequent credit agreements. As a result, excess capacity will have an even greater impact on the firm's financial performance during subsequent capacity acquisition programs.

As an example of these general behavior patterns consider the observed performance of Delta Air Lines, Inc. displayed in Figure 4. The initial graph depicts average monthly demand measured in revenue passenger miles. The annual demand was divided by twelve to remove seasonality variations. The second set of curves represents the dollar value of capacity orders and receipts on an annual basis. Annual values and smoothed values of the passenger load factor are presented in the third graph. The fourth curve represents monthly values of net profits from passenger revenue before taxes. Supporting data are shown in Tables 10 and 11 in the Appendices.

These relationships reflect the impact of two major capacity acquisition programs; one beginning in the late 1950's and one beginning in the late 1960's. In both cases the passenger load factor and profits are depressed even though demand continues to increase. Based upon this observed realization of the hypothesized behavior patterns,

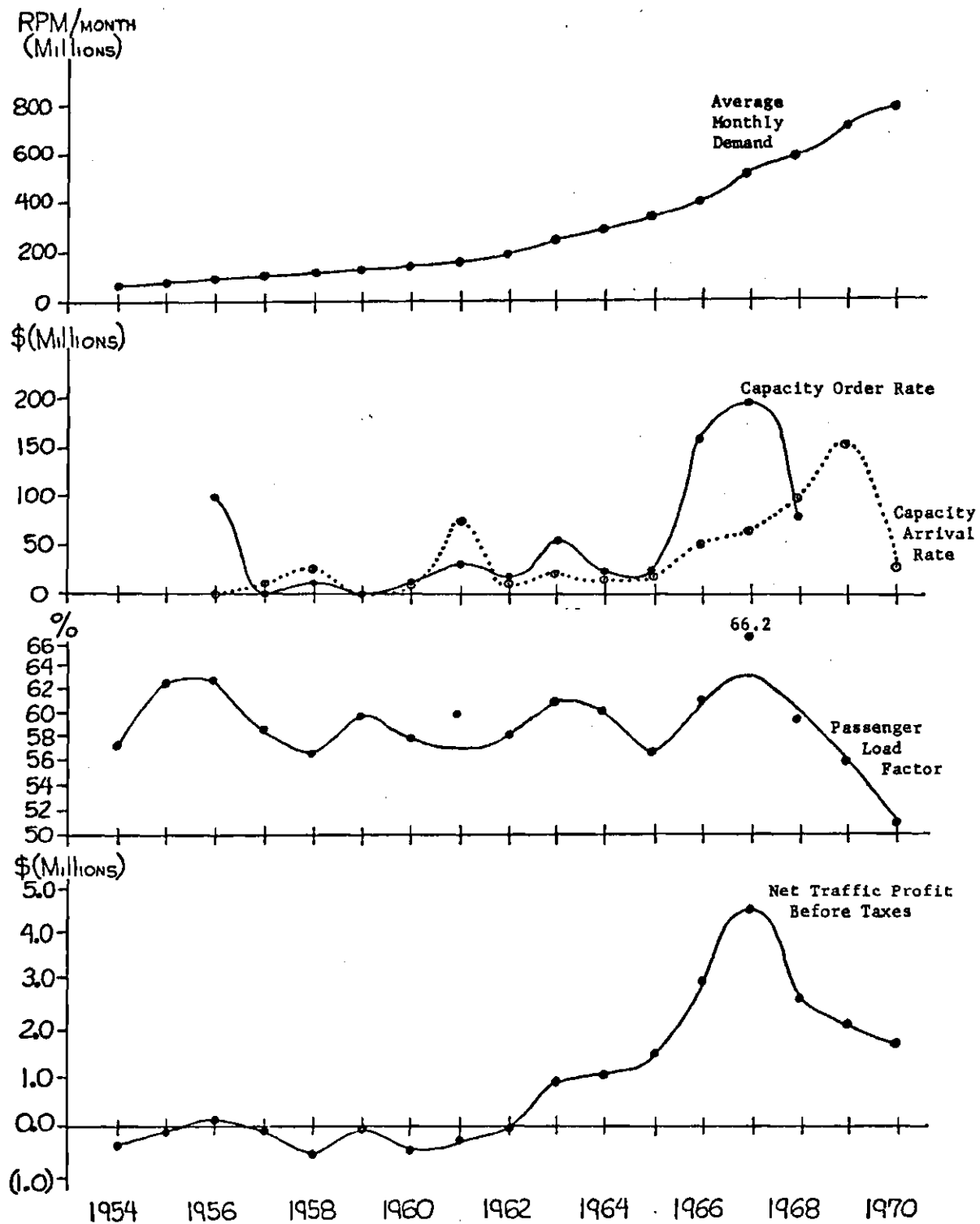


Figure 4. Observed Behavior Patterns  
Delta Air Lines, Inc.

the apparent period of financial variations associated with a capacity acquisition program is approximately six years.

### Model Development

The model developed as a part of this research effort consists of a network of interacting feedback control structures containing alternating accumulations and activities. Typical financial accumulations, or states, of an organization include cash or liquid assets, long-term debt, capital equipment, working capital and stockholders' equity. Over time these accumulations display variations which affect the firm's financial status and operational growth. The magnitude and timing of these variations result from the firm's activities, or flows into and out of the accumulations. Examples of flows influencing the levels of the accumulations are revenue generated by the firm, expenditures associated with this revenue, expenditures for capital equipment, and funds generated by the issuance of stock or assumption of debt. These flows are in turn controlled by the policies of the firm and managerial decisions based upon these policies. The feedback model which has been described qualitatively was transformed into a system of first-order difference equations for the purpose of testing the research hypotheses. The existence of nonlinear relationships between decision inputs and resulting remedial actions, the number of variables, and the system's dynamic nature necessitated the use of digital computer simulation for model synthesis and experimentation.

Although the underlying system of feedback relationships arises from the research hypothesis, model experimentation and synthesis was

necessary to estimate the impact of various system components and parameters. The level of aggregation incorporated into the final model also resulted from evaluating various configurations and their ability to produce behavior representative of the real world system. The primary relationships and key parameters for the financial sector and capacity acquisition sector of the firm are discussed below.

### Financial Sector

The representation of a corporation's financial operations as a network of accumulations and their associated flows corresponds closely with management's present concept of these operations. For instance, the balance sheet provides information on the financial state or accumulations of the firm at the end of an accounting period, and the earnings statement summarizes some of the flows for the same period. In addition, the flow of funds is summarized in the sources and uses of funds statements included in annual reports.

The financial sector of the model contains variables representing cash flows into the firm in the form of operating revenues (OPREV) and new debt (DAR). The resulting accumulations are internal funds (IF) representing working capital and long-term debt (DEBT). Reductions of funds result from operating expenses (OPEXP), internal funds used for capital expenditures (IFCX) and interest expense (INTXP). Operating revenues result from the product of each month's actual demand (AD) and the passenger mile yield (PMYLD), and operating expenses are computed as the product of total capacity (TCAP) and the unit operating cost (UOPC).

Debt control policies are implemented via the desired debt-equity

ratio (DDER) and equity (EQITY) which is comprised of internal funds plus the book value of capacity (NVCAP) less debt. The net profit before taxes realized by the firm consists of operating revenues less operating expenses, depreciation (DEPRT), and interest expenses. The financial sector is coupled with the operational sector via internal funds available for capacity expenditures (IFCXA) and efforts to control the amount of debt acquired by the organization.

#### Capacity Acquisition Sector

This portion of the model relates to the decision processes concerned with forecasting future demand and ordering sufficient capacity to accommodate anticipated growth. Demand forecasts are based upon an exponentially smoothed average of past demand (AVGDM). This average in conjunction with the desired passenger load factor (DPLF) indicates the desired future capacity. The quantity less current capacity and capacity on order yields the desired capacity expansion (DEXPN) without regard for financial constraints. The order is converted to a capital expenditure using the unit cost of capacity (UCC) and compared with available funds. Funds currently available for capacity acquisition (FCACA) consist of internal funds available (IFA) plus the difference between the debt limit (DTLIM) and current debt (DEBT). The capacity order rate (CAPOR) is equated to the minimum of the desired capital expenditure and funds available for capital expenditures. The capacity arrival rate (CAPAR) is a third order delay of the capacity order rate with an average delivery delay (CDD) of twenty months.

#### Demand Sector

The performance dynamics characterizing members of the airline



industry are created by managerial reactions to market growth. Efforts to match capacity acquisitions with increases in demand result in alternating periods of inadequate capacity, during which demand is limited by the availability of seats, and periods of excess capacity when short-term market gains are limited by competitive reactions or market potential.

An airline's average market for air transportation is represented in the model as potential demand (PD). This demand increases from exogenous inputs (representing historical growth experienced by the industry) and market shifts created by managerial actions (PDINC). Increases in an airline's market share are related to the average new capacity arrival rate (ACPAR) via the consumer recognition delay (CRD). Competitive reactions which result in a market share decrease are delayed by the competition reaction time (CRT).

The availability of seats serves as an ultimate limit on the actual demand realized from the market. As the airline's potential market, measured in revenue passenger miles per month, approaches their capacity, all of the potential demand cannot be satisfied due to physical limitations. The portion of potential demand satisfied (AVAIL) decreases as the potential demand-total capacity ratio (PDTCR) increases. The airline's actual demand (AD) is determined from the product of their potential demand (PD) and availability (AVAIL). The model flow diagram of Figure 5 displays the system structure in terms of conventional industrial dynamics flow symbols.

#### System Parameter Values

Having constructed the logical relationships of the model based upon the research hypothesis and interactions with members of airline



management, system parameters were estimated from operating and financial data obtained from the sources listed below<sup>40</sup>. Financial and operational objectives incorporated into the model correspond with stated company policies and goals. In particular, the impact of seat availability on demand is based on Delta's operating experience during July and August of 1966 when their competitors had ceased operations because of labor strikes<sup>41</sup>.

To demonstrate the model's behavioral validity, the historical performance of Delta Air Lines, Inc. was reproduced using the parameter

- <sup>40</sup>Air Carrier Analytical Charts and Supplemental Carrier Statistics, op. cit.  
Air Carrier Financial Statistics, op. cit.  
Air Carrier Traffic Statistics, Civil Aeronautics Board, Washington, D. C.  
Air Transport Facts and Figures, Air Transport Association of America, Washington, D. C.  
Aircraft Operating Cost and Performance Report, op. cit.  
Delta Air Lines, Inc. Annual Report, Delta Air Lines, Inc., Atlanta, Georgia.  
Handbook of Airline Statistics, Civil Aeronautics Board, Washington, D. C.  
Major U. S. Airlines: Financial Requirements and Projections 1968-1971, op. cit.  
Moody's Transportation Manual, op. cit.

- <sup>41</sup>Estimates for intangible parameters representing delays in decision-making and implementation of resulting actions were established as a result of interviews with key operating and financial personnel of Delta Air Lines, Inc. The fact that Delta is characterized as one of the more conservative airlines in the industry provided a frame of reference for these estimates. Formal studies to obtain precise estimates of all behavioral parameters exceeds the scope of this research; however, conclusions are offered regarding the sensitivity of system performance to such parameters. Recommendations are made regarding additional data collection programs to obtain improved estimates of parameters judged to be critical.

estimates and model structure developed. This approach to model design and parameter estimation reflects certain attributes of the system being modeled and the anticipated use of the research results.

1. The basic performance patterns generated by control systems are relatively insensitive to most system parameters. Due to the inherent feedback and self-corrective attributes characterizing control systems, their performance tends to be more sensitive to changes in system structure than changes in individual parameters. Hence, the approach to parameter estimation adopted for this study is to obtain a "reasonable" estimate for the many parameters included and to rely upon the results of sensitivity analysis to identify those few parameters for which additional data collection and more accurate estimates might be justified. These parameters are identified in the conclusions of this study.

2. This approach and the resulting identification of parametric changes which produce different system behavior is consistent with the anticipated use of the research results. Examination of alternative policies and the analysis of decisions using simulated system behavior provides management with the opportunity to locate the leverage points in the system. That is, simulation experiments enable the manager to determine which parametric and structural changes will substantially alter system behavior. Therefore, this study includes development of parameter estimates sufficient to validate the model and focuses on identifying those areas subject to managerial control in which changes produce an improvement in system behavior.

The examination and interpretation of model behavior and

experimental results are presented in the following chapters. Complete listings of the model's equations, parameter values and variable identifications are provided in the Appendices.

## CHAPTER VI

### MODEL BEHAVIOR AND VALIDATION

The purpose of this chapter consists of demonstrating that the model presented provides for achieving the objectives of this research. These objectives, as stated previously, are:

(a) To determine the internal variables and structural relationships accounting for the financial performance of a major domestic airline.

(b) To demonstrate that the characteristic behavior of a systems problem existing in many airlines arises from, and is perpetuated by, the feedback control structure.

(c) To examine the impact of managerial attitudes, judgment and decisions on the system's behavior over time.

(d) To interpret these results and their implications for designing alternative control policies to improve system behavior.

Achievement of the first objective is substantiated by examining the model's behavior relative to observed real world system performance. Comparison of dynamic behavior characteristics (phasing, amplitudes and periods) and variable growth rates demonstrate the model's behavioral validity. Examination of the forces creating the model's behavior during sequential time periods and comparison with real world actions and resulting performance impacts establish the model's behavioral validity. Examination of the forces creating the model's behavior

during sequential time periods and comparison with real world actions and resulting performance impacts establish the model's construct validity. Exogenous inputs were subjected to uncertainty to demonstrate that model outputs still possess the dynamic characteristics of the real world system. Having established the basic model's validity, the remaining objectives are pursued in the next chapter.

### Basic Model Behavior

The managerial control model which has been described was transformed into a system of first order difference equations. Inherent time delays and nonlinear relationships prevent a closed form solution; therefore, simulation of the system's behavior over time was used to achieve the research objectives.

The model is initiated with conditions corresponding to the status of Delta Air Lines, Inc. in July 1954, the beginning of a new fiscal year. An average demand growth rate equivalent to the compounded rate experienced by this airline during the past sixteen years provides the external force to which airline management must react. Model variables are sequentially calculated every one-fourth month and plotted as a function of monthly elapsed time from the initial model conditions. Table 1 shows the symbolic representation of the model variables which are plotted for illustrative purposes. These variables are also identified on each plot of system performance.

In the mid-1950's Delta's management made the decision to not purchase turbo-prop aircraft, which were transitional, and to wait for the first generation of jets. Although the load factor and profits

Table 1. Model Variable Identification for Simulation Plots

Model Variable	Variable Name	Symbol
Value of Capacity Order Rate	VCOR	V
Value of Capacity Arrival Rate	VCAR	Q
Capacity Order Limit One Value	CPOL1V	S
Potential Demand	PD	P
Actual Demand	AD	D
Average Passenger Load Factor	APLF	L
Debt	DEBT	T
Stockholders' Equity	EQTY	E
Average Debt-Equity Ratio	ADER	A
Operating Revenue	OPREV	R
Operating Expense	OPEXP	X
Average Net Profit	ANPROF	N
Average Return On Equity	AROE	E
Average Return On Investment	AROI	I
Average Investment Turnover	ATNOVR	O



were low in the early part of the decade due to the competition's offering of more advanced aircraft, orders and the subsequent receipt of jet aircraft allowed the company to recapture their market by the beginning of the 1960's.

However, continued conversion of the fleet from propellar aircraft to jet aircraft eventually resulted in capacity increases which exceeded demand growth during 1958 through 1961 even though practically no orders were placed after 1956. The passenger load factor fell below fifty-seven percent during this period, and almost fifty million dollars of debt had to be used for financing the last portion of the capacity acquisition program.

When demand caught up with capacity in the early 1960's, the load factor started to increase and additional orders for new aircraft were placed. During this program, however, capacity acquisitions were tempered by financial considerations due to recent operating losses and the extra debt added during the previous program. These orders slowed by the middle of the decade; however, extra capacity still resulted in a reduced load factor and a leveling of profit growth during 1964 and 1965. The impact was not as great due to financial limits imposed on capacity acquisitions, but another thirty-five million dollars in debt was added in 1966 to finance the last units of this program.

Because of the previous program's reduced purchases relative to perceived operating needs, the next capacity acquisition program was initiated after a shorter time interval. The greater needs, coupled with positive economic conditions and the introduction of a new

generation of jets, resulted in the largest capacity acquisition program of the airline's history. Orders of approximately 450 million dollars were placed in the late 1960's. Again the predictable impact has occurred. Debt increased by 140 million dollars (250 percent) and the load factor has dropped to nearly fifty percent.

Figures 6, 7 and 8 portray the model's behavior for this same interval of time. Time 10 corresponds to July 1954 and the time units are months.

#### Time 10 to Time 34

Figure 6 indicates capacity orders (V) are being placed in response to the high passenger load factor (L) and resulting operating profits (N) are displayed in Figure 7. The indicated capacity purchases of 107 million dollars compares to an actual purchase of 100 million dollars.

#### Time 34 to Time 76

As the new aircraft are added to the fleet (Q, Figure 6), the load factor drops to 56.5 percent during the interval (compared with 56.8 percent in the observed data) since capacity increases exceed demand temporarily. Figure 7 illustrates that operating expenses (X) increase more rapidly than passenger revenues (R); therefore, operating profits (N) are reduced. Cash flow problems arise and the remaining new capacity arrivals must be financed with debt capital. Figure 8 indicates the addition of thirty-six million dollars in debt (T) raising the average debt-equity ratio (A) to approximately 0.75.

#### Time 76 to Time 118

Model output for this interval indicates desired orders (S,

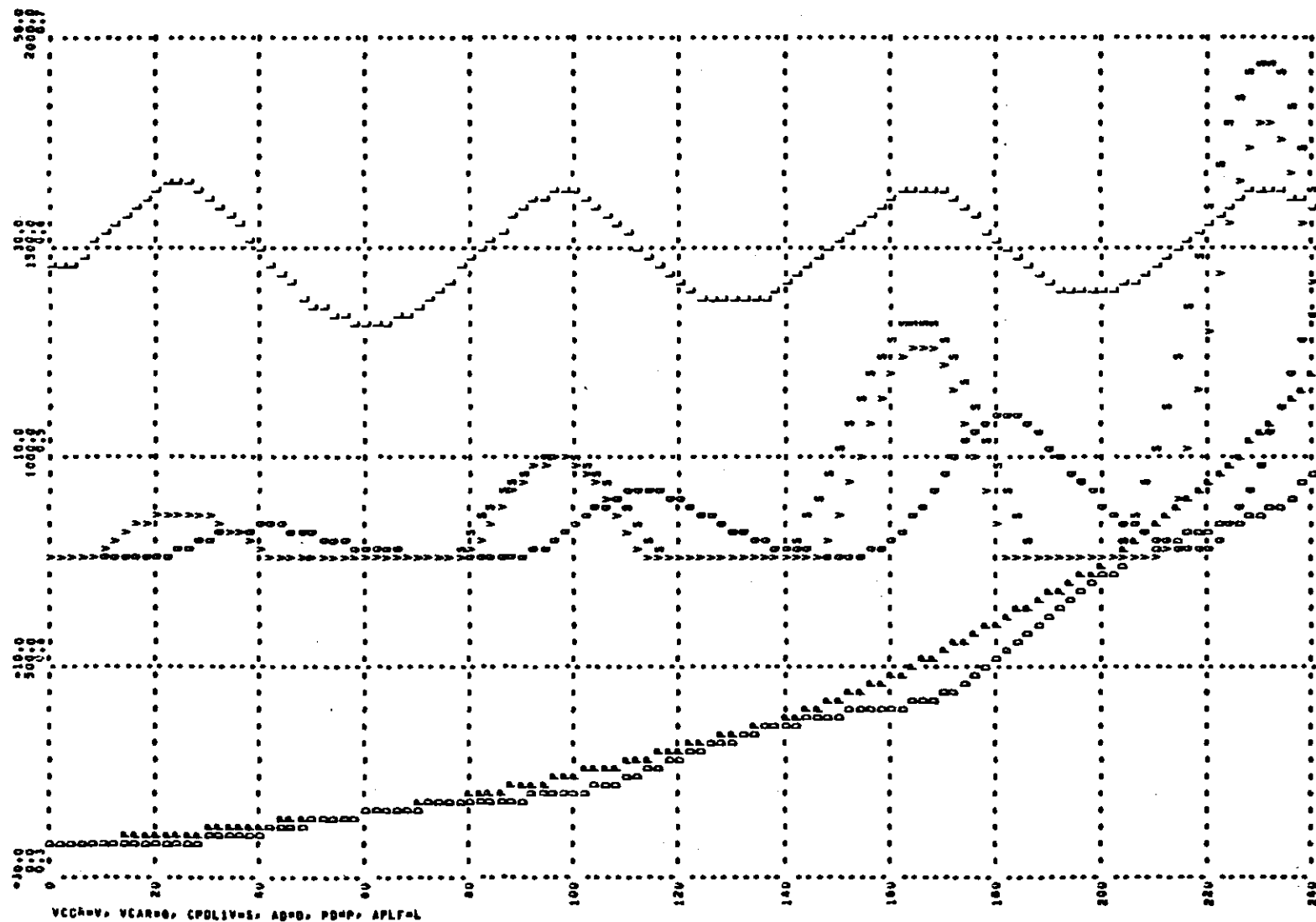


Figure 6. Demand/Capacity Behavior - Basic Model

V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

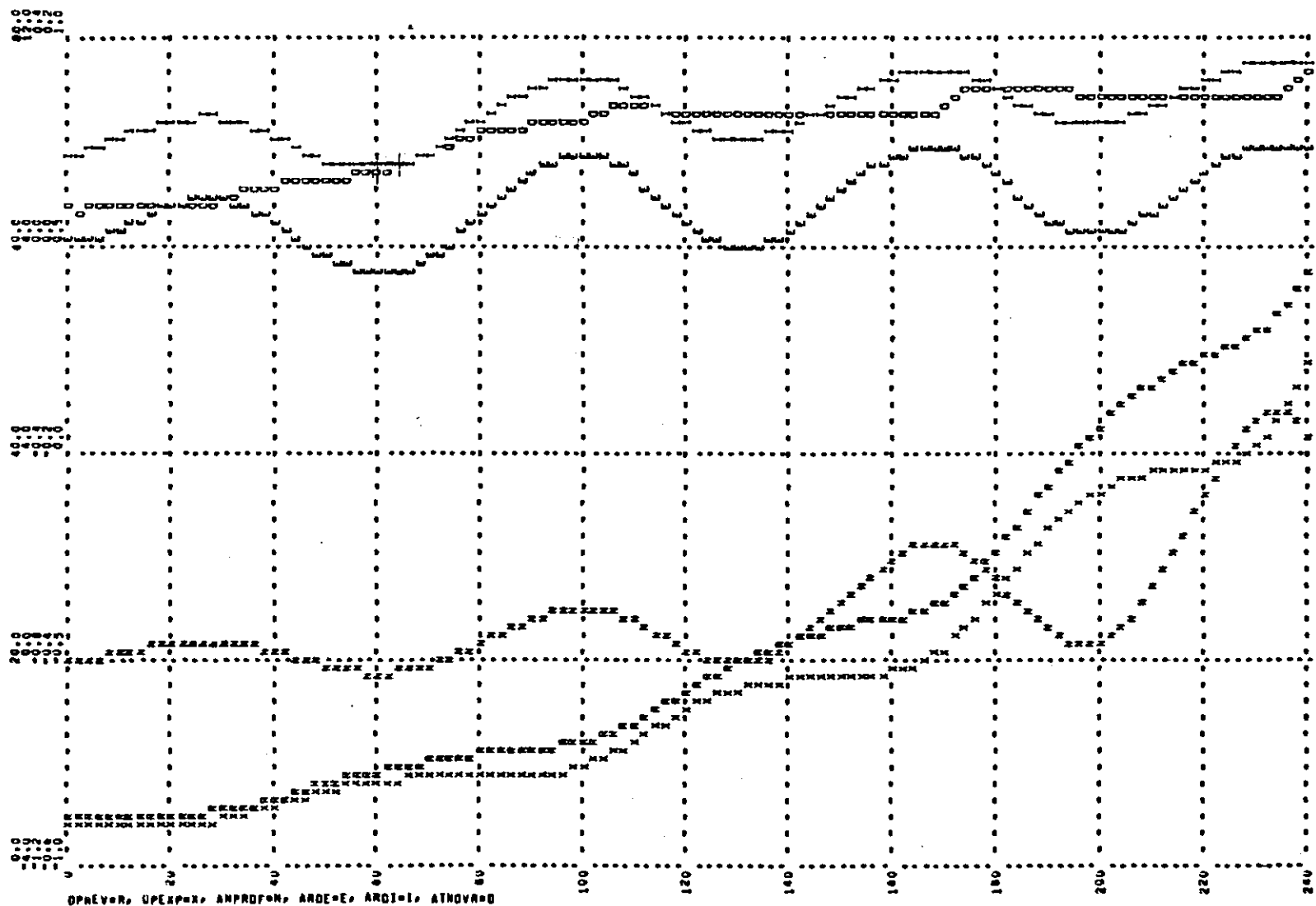


Figure 7. Financial Performance - Basic Model

R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover

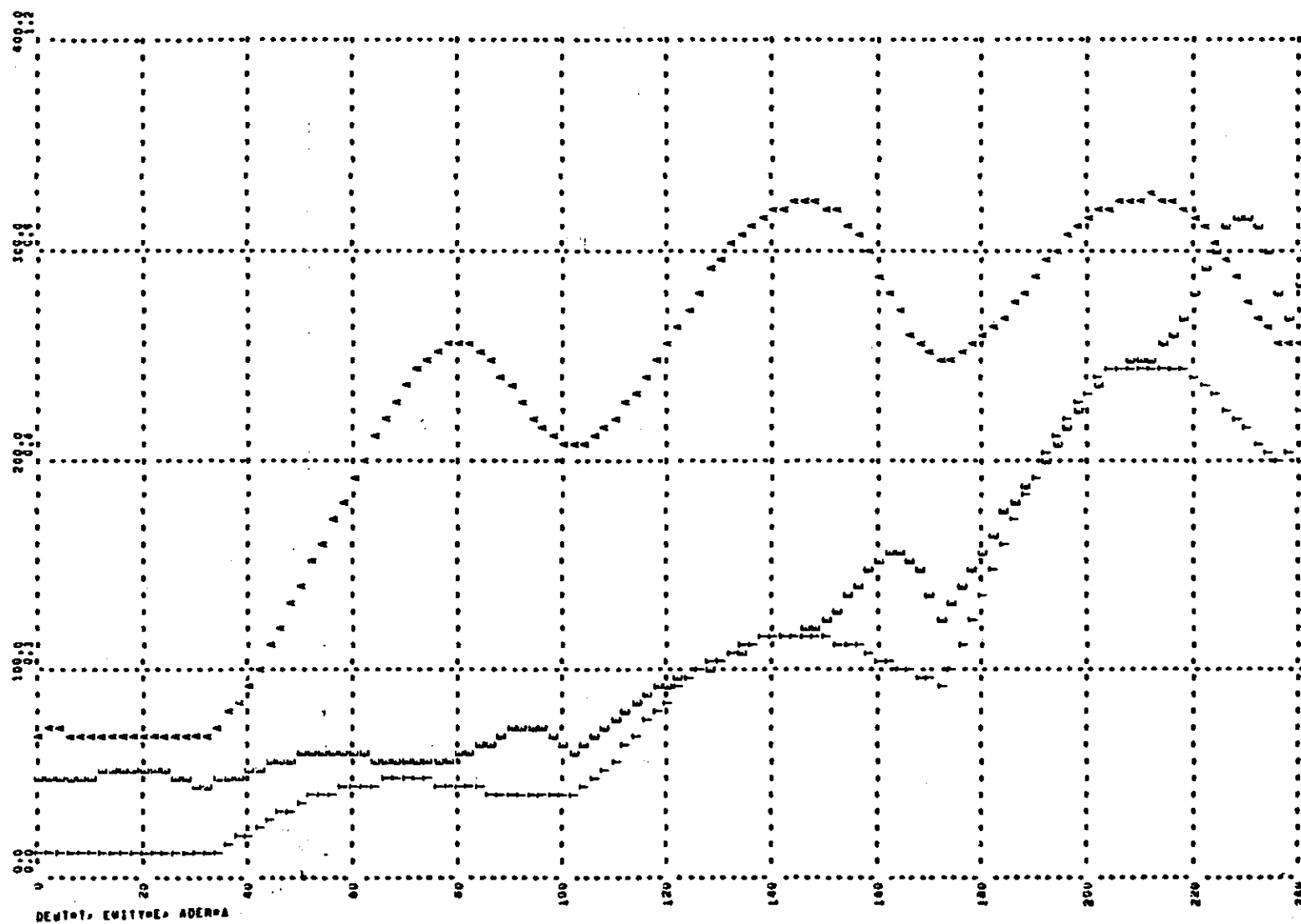


Figure 8. Debt/Equity Behavior - Basic Model  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

Figure 6) of 315 million dollars and actual orders (V), reduced by financial constraints, of 203 million dollars compared with observed orders of 166 million dollars during the first half of the 1960's. The financial constraint on capacity orders results from efforts to maintain a debt-equity ratio between one-half and one. Efforts to correct the actual ratio's deviation from the lower limit are successful until the firm's internal funds are exhausted by the current capacity purchases, and new debt must be added to finance the purchase of remaining aircraft for which orders have been placed.

Time 118 to Time 154

As before, the arrival rate of new capacity exceeds the growth in demand resulting from market share increases and exogenous factors. Demand is limited by market potential, costs increase faster than revenues, internal reserves are inadequate to fund the new capacity and additional debt is acquired. The passenger load factor drops to 57.4 percent (compared to 56.7 percent in the actual system), and debt levels off at slightly over one hundred million dollars (compared to an observed value of ninety million dollars). The resulting capital structure has a debt-equity ratio very near the absolute maximum of one, at a time when the firm's earnings are at the low point of their cycle. As a result even greater financial constraints are placed on future capacity acquisitions.

Time 154 to Time 190

While more restrictive financial constraints are imposed on capacity acquisitions due to the weakened capital structure, and increasing need for additional capacity develops because:

(a) the previous acquisition was less than desired due to financial limitations and

(b) the previous acquisition has increased the market share and stimulated demand.

The result is a desire to place an even greater order for additional aircraft subject to a more severe financial constraint. The load factor increases to 62.9 percent (compared with an actual value of 66.2 percent<sup>42</sup>). The model indicates a desired capacity order of 442 million dollars compared with an observed order of 435 million dollars during 1966 through 1968. The resulting impact of these orders is displayed by the model after time 190. This impact coupled with an economic recession characterizes the financial state of the industry's members in the early 1970's.

Thus, the model generates representative variable performance from logical decision-making processes within an information feedback network. These processes utilize the same information flows as in the actual system as a basis for control actions. The purpose of these actions consists of controlling internal system states and maintaining desired relationships between the firm and its environment. Both system and model decision outputs produce the same impacts on long-term performance. Amplitudes, phasing and frequencies are essentially the same for the actual and model performance patterns.

At the end of the time period for which data were collected (July 1970), actual demand was 780 million RPM's per month and model

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<sup>42</sup>This value is inflated due to labor stoppages affecting Delta's major competitors during fiscal year 1967.

demand is 730 million. Debt was 230 million dollars compared with model output of 238 million. Total capacity orders equaled 706 million dollars for the real world system and 762 million for the model. The interim behavior of these variables and their interrelationships have been examined in detail in the preceding discussion and are summarized in Table 2.

#### Basic Model Behavior With Random Error

The model outputs described above were generated in the absence of random influences. In reality, uncertainty is introduced both as a component of exogenous inputs and in conjunction with the effects of remedial actions taken by decision-makers. The impact of altering the decision-making processes will be examined in the next chapter; however, the following experimental results illustrate the effect of adding a random component to demand inputs.

In the basic model the potential market is computed from a deterministic growth rate which provides for an average monthly growth of approximately four million revenue passenger miles. The first experiment consisted of altering this potential market after it is computed from the deterministic growth rate by adding a random element uniformly distributed between - 4,000,000 and + 4,000,000 revenue passenger miles. Thus, the average growth is maintained; however, the growth occurring in any single period may range from zero to an amount equal to twice the normal growth. Use of the uniform distribution represents the condition in which any monthly growth in this range is equally likely; therefore, forecasts are still made on the basis of average behavior as in the basic model.



Table 2. Representative Variable Values (Model and Actual)  
at the End of Indicated Time Intervals

Time Interval		Demand (mill. RPM)		Passenger Load Factor		Orders (mill. \$)		Debt (mill. \$)	
Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual
10-34	7/54-7/56	97	90	.616	.626	107	100	14	11
34-76	7/56-1/60	171	140	.585	.580	107	107	46	45
76-118	1/60-7/63	274	250	.587	.606	310	225	80	60
118-154	7/63-7/66	395	420	.613	.610	424	433	112	90
154-190	7/66-7/69	730	780	.584	.559	762	706	238	230

The resulting pattern of capacity acquisitions illustrated in Figure 9 indicates the system tends to react sooner in purchasing new capacity to meet demands which are higher than anticipated. Once the order has been placed and received, the resulting dynamics are the same as those produced by the basic model portrayed in Figure 6. Because of the earlier reaction to increases in demand, the resulting orders tend to be smaller since the perceived discrepancy between forecasted demand and current capacity are not as great. In summary, output amplitudes and frequencies are the same for the basic deterministic model and the basic model with a random demand input. A positive phase shift of five months constitutes the primary difference in behavior.

In the second experiment, the underlying growth rate was subjected to a random influence. Uniformly distributed random variables were used in two experiments: one with a range equal to twice the average growth rate which does not provide for a decrease in market potential (the lower limit of the growth in any single period is zero) and one with a range equal to four times the mean which does provide for a possible decrease in the market from one period to the next. The uniform distribution from which monthly growth rates were randomly chosen results in a set of equally likely market changes with no underlying causal mechanisms. Since these changes cannot be predicted, the forecasting structure used in the basic model is still justified. Although the simulated demand in both experiments is slightly more erratic, the system performance patterns display the same average behavior and dynamics as the basic model.

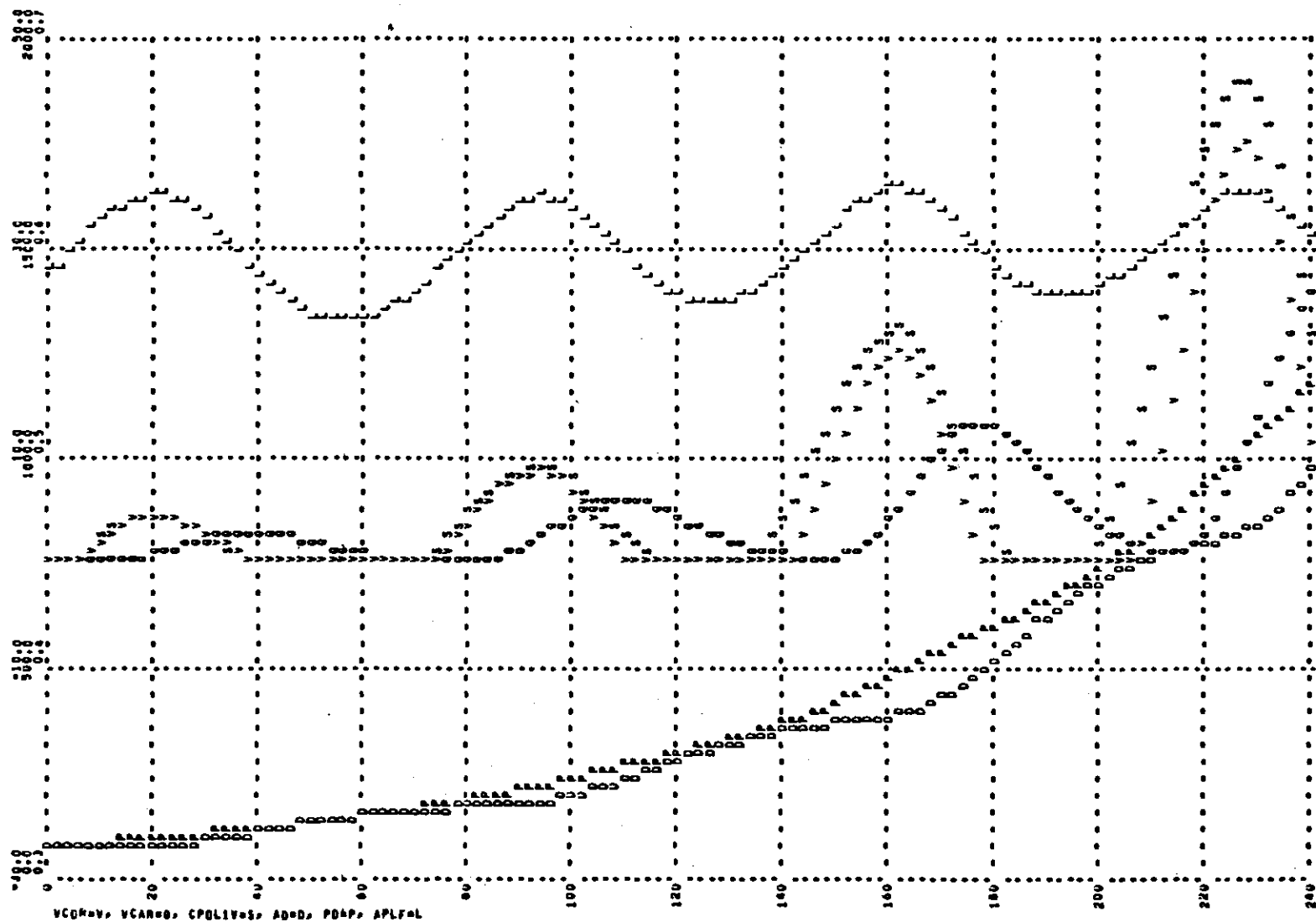


Figure 9. Demand/Capacity Behavior - Random Demand  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

Random noise disturbances such as the ones used in these experiments contain a broad range of component frequencies. When a system amplifies certain frequencies in this range, the system behavior is described as having a natural period. Since the same cyclic behavior patterns are displayed by the model with or without random inputs, consider the deterministic model's average passenger load factor (L) plotted in Figure 6 as a basis for further analysis. The following table gives the sequential high and low values for this variable and the times at which they occur. Also provided are the average values of each pair of successive extreme values and the indicated cycle period.

Table 3. Average Passenger Load Factor Amplitudes and Periods

Time	Variable Value (%)	Average of Last Two Values (%)	Indicated Cycle Period (Months)
24	63.09	--	--
61	56.50	59.80	74
98	62.72	59.61	74
130	57.42	60.07	64
166	62.92	60.17	72
197	57.90	60.41	62
231	62.85	60.38	68
Average Value		60.07	69

Thus, efforts to maintain an average passenger load factor of fifty-nine percent result in an oscillatory load factor with an average value

of sixty percent, an average amplitude of 2.8 percent and an average period of sixty-nine months. The system does display a tendency to move toward the desired value as indicated by the extreme values in Table 3. With one exception (Time 98), each extreme value is closer to the desired value than its preceding counterpart. However, this tendency is slight and may be offset in the real world by the impact of technological advances and changes in economic conditions.

#### Summary of Basic Model Behavior

The variables and feedback control relationships incorporated into the basic model create model performance displaying the same dynamic characteristics as those observed in the real world. Simulated imbalances between exogenous demand and system capacity perpetuated model reactions designed to regain the desired relationship between the system and its environment. Such actions achieved the desired average results but introduced fluctuations about this average creating undesirable performance patterns. Incorporation of random error into exogenous model inputs did not alter the characteristics of model results. This equivalence between model construction and performance and real world relationships and observations establishes the model as a valid basis for experimentation and inductive conclusions.

## CHAPTER VII

### EXPERIMENTAL RESULTS

After model validity was established as shown in the previous chapter, simulated system behavior in the presence of random error was examined to confirm the dynamic patterns generated by the basic model. A cyclic variation with an average period of sixty-nine months was observed. Although internal control mechanisms partially succeed in damping this oscillatory behavior by reducing the amplitude, the response to these efforts is extremely slow. This chapter presents results of model experiments conducted to determine the internal control mechanisms generating the observed responses to environmental inputs.

#### Experimental Design

Outcomes are reported for experiments designed to illustrate the changes in system performance resulting from:

- (a) Changes in exogenous economic patterns.
- (b) Changes in external financial parameters over which management has little control.
- (c) Changes in external market parameters over which management has little control.
- (d) Changes in internal, controllable financial parameters.
- (e) Changes in internal, controllable capacity acquisition parameters.
- (f) Alternative system structures.

Model experiments included in this research were chosen on the basis of their potential value to the managerial decision-maker; that is, they represent environmental and system changes about which the manager is normally concerned. Changes in controllable parameters and system structure represent explicit alternatives which management may choose to implement should the experiments indicate potential improvements in system performance.

As stated earlier, the purpose of this experimentation is to assist system decision-makers in identifying the parametric and structural changes which produce improved system behavior. Similarly, the alternative parameter values chosen for the following experiments represent the maximum changes which seem feasible or can be achieved by changes in management style or decision-making.

With the exception of external financial parameters the scope of this study is limited to first order interactions; that is, simultaneous changes in more than one parameter are not included. This approach is consistent with the purpose of determining those parametric changes which produce improved behavior under the assumption that simultaneous parametric changes will not produce significant improvements if none of the parameters resulted in improvements when varied on an individual basis. Having identified single parametric variations which demonstrate a potential for improvement, higher order studies should be performed in which this parameter is varied with others which are related. Recommendations for such studies based on these experiments are included in the final chapter. However, included in this study are experiments in which unit operating costs, passenger

mile yields and unit capacity costs were increased simultaneously to examine the impact of inflation.

Listed below are the experiments performed and the potential management implications of the results.

#### Changes in Exogenous Economic Patterns

These experiments were conducted to determine the performance changes introduced by the presence of long-term economic cycles and trends as opposed to the short-term random variations examined in the previous chapter. The factors examined in connection with the cyclic inputs were cycle period, cycle amplitude and phasing with natural system behavior. The basic experiments involving cyclic market behavior utilized input amplitudes designed to match natural system amplitudes. Repetitions of these experiments involving amplitude reductions up to fifty percent of the original and amplitude increases of the same amounts were also performed to examine behavior sensitivity to amplitude variations. A fifty percent change was presumed to be the maximum variation with which management would be concerned under normal operating conditions and was further presumed to be a sufficient change for demonstrating the system's sensitivity to these parameters. The results of these experiments, which are summarized in Table 4, should be considered in developing long-range forecasts of demand and planning capacity acquisition programs to accommodate forecasted demand.

Cyclic Input, Same Period, In Phase. This experiment demonstrates the effect of reinforcing the natural system period with an exogenous input having the same period.

Cyclic Input, Same Period, Ninety Degrees Out of Phase. This



result demonstrates the importance of phasing system behavior with economic inputs.

Cyclic Input, Period Twice as Long, In Phase Initially. Findings from this experiment illustrate the impact of alternating in-phase and out-of-phase economic inputs.

Cyclic Input, Period Twice as Long, Ninety Degrees Out of Phase Initially. This outcome depicts the importance of phasing in the previous experiment.

Twenty-five Percent Increase in Market Growth Rate. This experiment demonstrates the ability, or inability, of the system to "keep up" with the maximum market growth rate for which the manager would normally plan.

Twenty-five Percent Decrease in Market Growth Rate. This result illustrates the system's ability to adjust to a substantially lower market growth rate.

#### Changes in Exogenous Financial Parameters

These experiments were performed to determine the future behavior resulting from current decision processes being subjected to external changes affecting unit costs and revenues. Such exogenous changes might result from inflation, cost increases due to technological advances and CAB rulings on fare structures. The parameters included were the unit operating cost (UOPC), the unit cost of capacity (UCC) and the passenger mile yield (PMYLD). The experiments performed were chosen to illustrate the financial implications of current inflationary trends. The magnitudes of parametric variations reflect the changes in these parameters

experienced by Delta Air Lines<sup>43</sup> and the average trends experienced by the airline industry since 1957<sup>44</sup>. Experiments included are listed below, and the results are summarized in Table 5.

Unit Operating Cost and Passenger Mile Yield Increase at Same Rate. This experiment illustrates the impact of inflation even when the operating margin remains constant.

Unit Operating Cost and Passenger Mile Yield Increase at Same Rate. Unit Cost of Capacity Also Increases. The outcome of this experiment depicts the increased impact of inflation when the operating margin remains constant but the cost of capacity increases.

Unit Operating Cost Increases Faster than Passenger Mile Yield. Unit Cost of Capacity Constant. These results illustrate the nature and degree of system performance deterioration when fare increases do not keep pace with inflationary trends.

Unit Operating Cost Increases Faster than Passenger Mile Yield. Unit Cost of Capacity Also Increases. This experiment demonstrates the combined effect of a deteriorating profit margin and increasing capacity costs when fare increases do not keep pace with inflationary trends.

#### Changes in Exogenous Market Parameters

The purpose of these experiments was to determine system reactions to changes in parameters characterizing the market for air transportation. The parameters included are not subject to internal control but can be influenced through marketing programs. These parameters are:

<sup>43</sup>Delta Air Lines, Inc. Annual Report, op. cit.

<sup>44</sup>Major U. S. Airlines: Financial Requirements and Projections 1968-1971, op. cit.

(a) Consumer Recognition Delay - The time required for the market to recognize a change in the technological status or availability of the company's capacity to provide air transportation.

(b) Competition Reaction Time - The time required for the airline's competition to perceive the above changes and react to them.

(c) Availability Effect - The relationship between the airline's capacity and potential demand for their product.

The magnitudes of parameter variations are based on the estimated feasible ranges for each parameter. The outcomes for the experiments listed below are summarized in Table 6.

Increase (Decrease) in Consumer Recognition Delay. This study demonstrates the potential benefits to be achieved from advertising campaigns and other promotional programs designed to acquaint the consumer with recent capacity acquisitions.

Increase (Decrease) in Competition Reaction Time. These findings provide guidance in consideration to be given to competitive reactions as a factor of capacity acquisition decisions.

Increase (Decrease) in Impact of Capacity Availability on Demand. The results of this experiment illustrate the significance of policies governing the desired relationship between capacity and demand.

#### Changes in Endogenous Financial Parameters

These experiments were designed to provide insight into the appropriateness of current policies and decision rules in the financial sector of the organization. Outcomes were examined in terms of impact on the firm's ability to compete in the market and effects on cash flow and profits. The parameters included are:

(a) Desired Debt-Equity Ratio - The preferred relationship between external and internal financing of the organization's assets.

(b) Absolute Debt-Equity Ratio - The point at which no further long-term debt is acquired until the firm's financial condition improves.

(c) Correction Delay - The delay in implementing actions to prevent further deterioration of the capital structure by reducing debt acquisition.

(d) Debt Retirement Delay - The delay in implementing actions to achieve a more desirable capital structure by retiring current debt.

These parameters were varied to the point at which no further system performance changes could be achieved due to other constraints. Results for the experiments listed below are summarized in Table 7.

Increase (Decrease) in Desired Debt-Equity Ratio. This experiment demonstrates the relationship between the primary financial control variable and system performance.

Increase (Decrease) in Absolute Debt-Equity Ratio. These results illustrate the relationship between financial objectives and absolute financial constraints.

Increase (Decrease) Correction Delay. These outcomes depict the results of less (more) aggressive behavior in achieving financial objectives through the limitation of capital expenditures.

Increase (Decrease) Debt Retirement Delay. The outcomes of this set of experiments demonstrate the results of less (more) aggressive actions to modify the capital structure and control the level of debt through retirement of current debt.

Changes in Endogenous Capacity Acquisition Parameters

The purpose of these studies is to examine the effects of altering operating objectives and decision structures for the capacity acquisition decision processes. The effects examined were the long-term relationship between demand and capacity, cash flow and profit performance, and the resulting capital structure. Experiments included changes in objectives and changes in delays for implementing corrective actions. The magnitudes of these changes were based on the maximum feasible changes which can be implemented in the real-world system. Parameters included are:

(a) Expansion Gain - The forecasting interval considered when determining the magnitude of a single capacity order.

(b) Order Interval Desired - A measure of managerial aggressiveness or conservatism in implementing the results of a capacity acquisition decision.

(c) Decision Delay - A delay for collection and processing of information prior to making a capacity acquisition decision.

(d) Desired Passenger Load Factor - A primary operating objective which reflects management's preferred relationship between capacity and demand.

The experiments performed are listed below, and the results are summarized in Tables 8 and 9.

Increase (Decrease) Expansion Gain. These experimental results demonstrate the effects of uncertainty in forecasting future demand growth and the impact of placing capacity orders which are too large or small.

Increase (Decrease) Order Interval Desired. These outcomes

reflect the effects of aggressive versus conservative behavior in capacity acquisition programs.

Increase (Decrease) Decision Delay. This set of experiment depicts the trade-off between delaying a decision to gather more information and making the decision on the basis of less information.

Increase (Decrease) Desired Passenger Load Factor. These findings establish the importance of the desired relationship between demand and capacity as a control variable.

#### Changes in System Structure

These experiments represent a significant contribution of simulation models - the opportunity to test alternative uses of information and revised decision processes without interfering with the firm's actual operation. The experiments selected for this portion of the study were based on the author's understanding of the firm's actual operation, the model and general principles of system design. The experiments are as follows:

Eliminate Financial Constraints. This study demonstrates the outcome of removing the dampening effect of financial considerations from capacity acquisition decisions.

Eliminate Inherent Delays of Capacity Acquisition Decisions. These results demonstrate the outcome of removing the dampening effect of time delays from capacity acquisition decisions.

Restructure Forecasting Process. This set of experiments illustrates the effects of using different information and different time horizons in forecasting future demand.

Results are reported for the above experiments in subsequent

sections of this chapter. These analyses are summarized in the form of conclusions and recommendations in the final chapter.

#### System Reaction to Exogenous Cycles and Trends

By including sine and cosine inputs with varying periods and amplitudes as a component of potential demand, the model was subjected to exogenous influences corresponding to economic cycles of differing severity. System behavior was observed for inputs in phase with the system's natural cycle and ninety degrees out of phase. Input periods were varied from the system's observed period to one twice as long. Input amplitudes were also varied to gain a better appreciation for the sensitivity of system behavior to environmental forces.

The first experiment involved reinforcing the system's natural period by adding a market input with the same period. Market behavior of this nature might be created by external economic influences; whereas, system performance is created by internal forces. Variable behavior produced by these conditions is portrayed in Figures 10, 11 and 12.

Demand and resulting capacity orders are plotted in Figure 10. Since market increases coincide with the company's recovery of its previous market share, orders tend to be larger and subsequent financial constraints are more severe. The resulting aircraft orders are 28 percent greater than those of the basic model, but the amount of capacity which would have been ordered in the absence of financial constraints is 40 percent greater than the corresponding value in the basic model.

The combination of larger initial orders and the subsequent

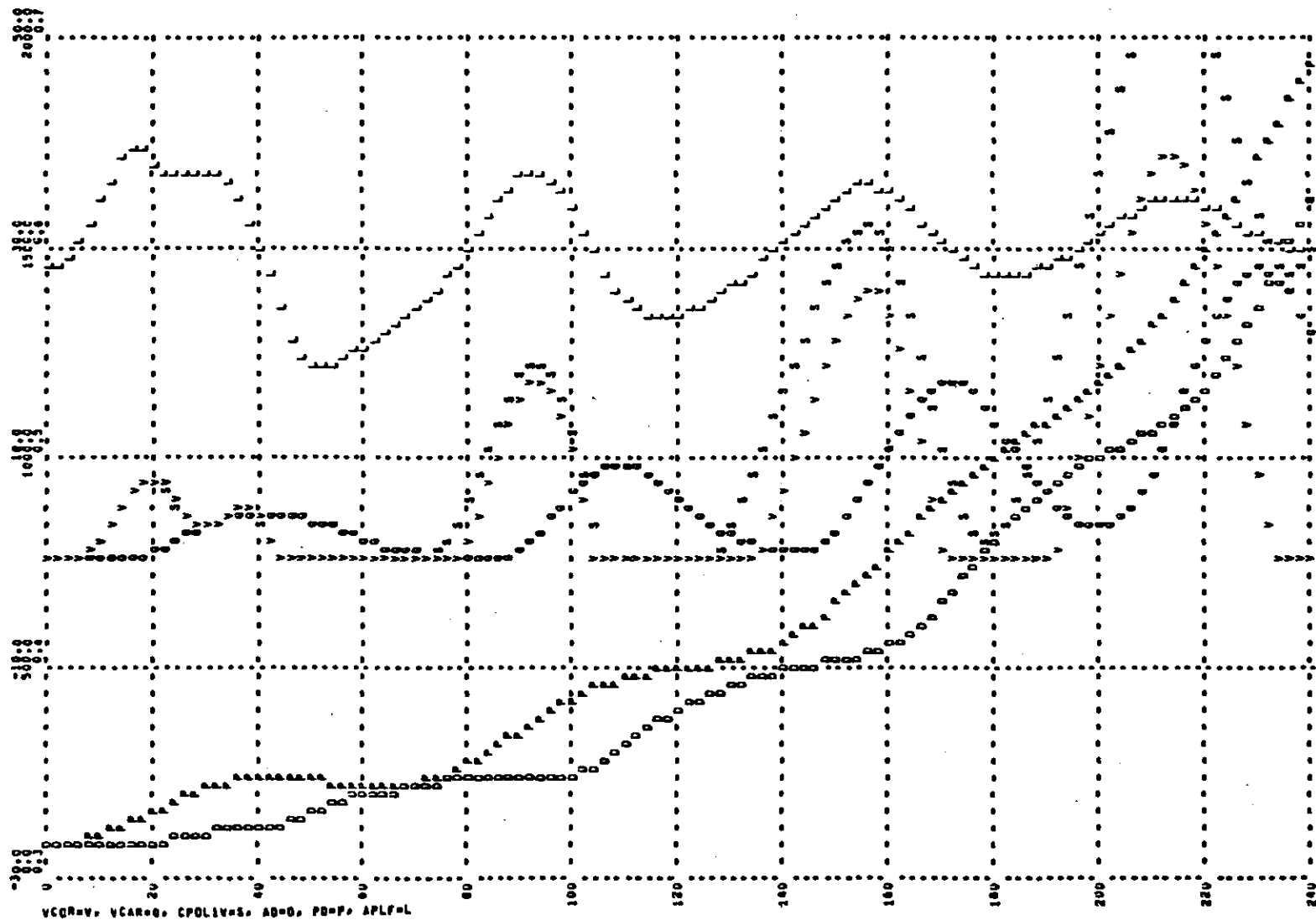


Figure 10. Demand/Capacity Behavior - Cyclic Demand  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF



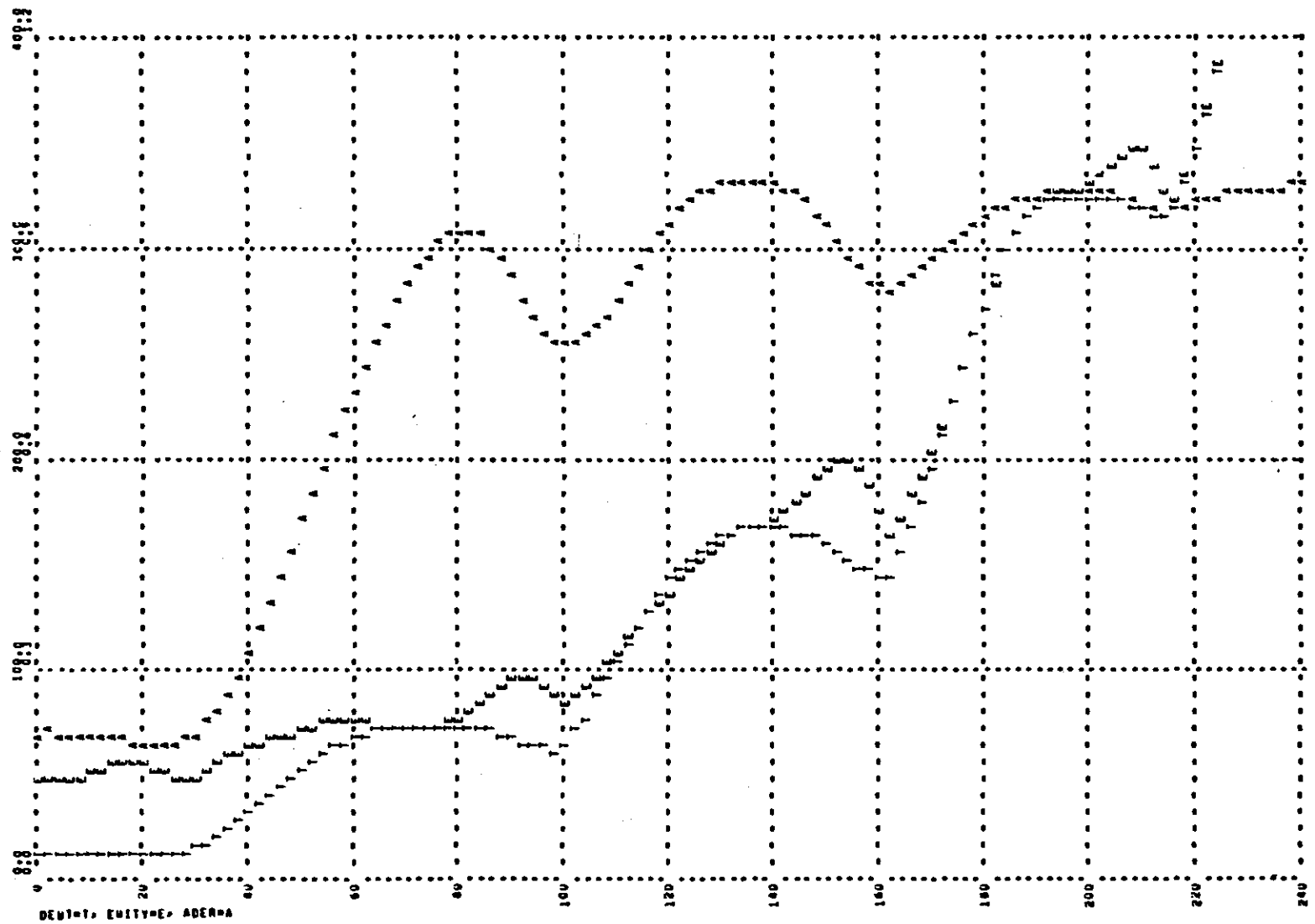


Figure 11. Debt/Equity Behavior - Cyclic Demand  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

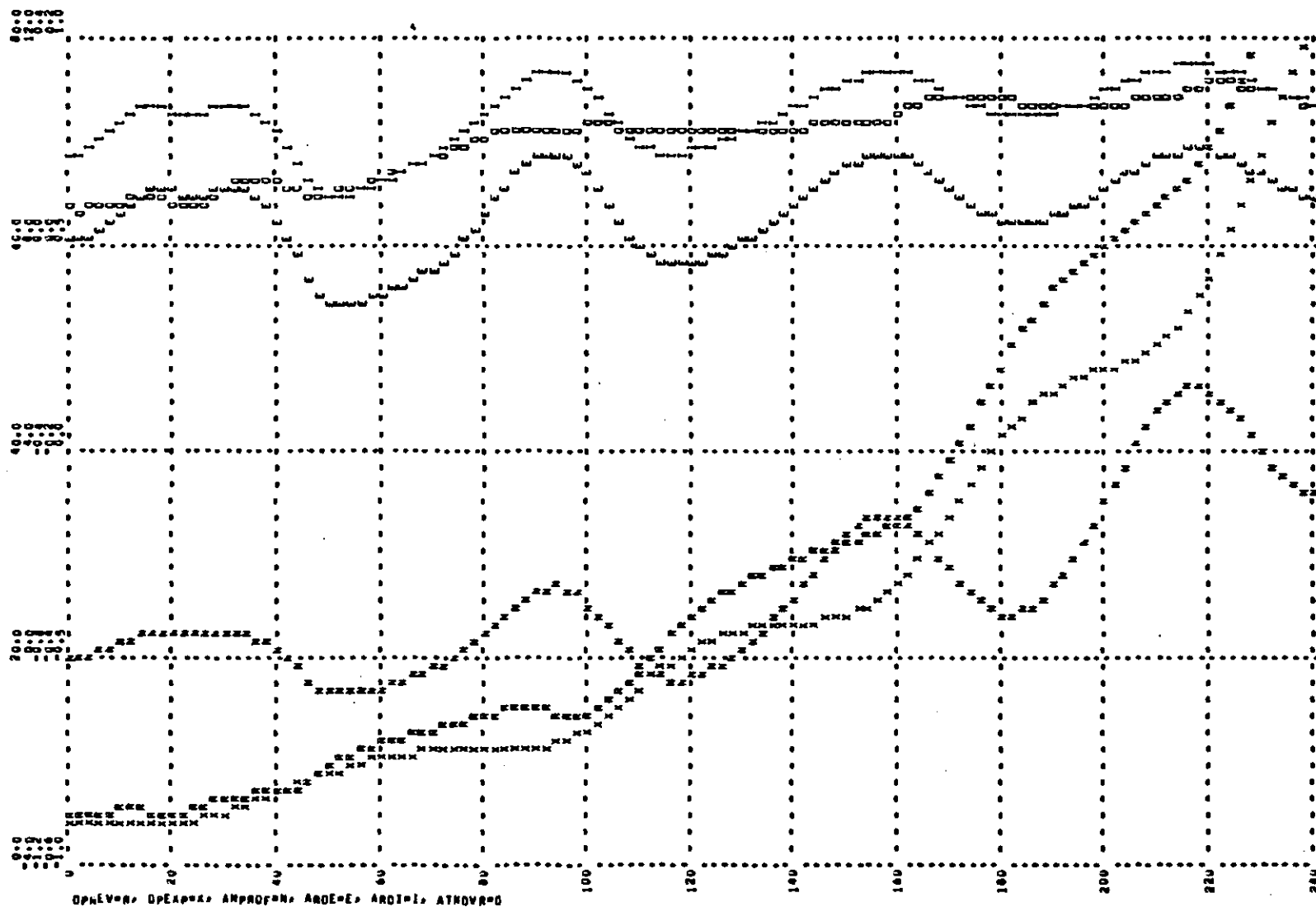


Figure 12. Financial Performance - Cyclic Demand  
R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover

reduction in demand due to the exogenous input cycle necessitates increased debt financing to pay for the extra capacity. As indicated in Figure 11, the average debt-equity ratio levels off very near the absolute maximum of one. However, more favorable long-term financial performance (Figure 12) results from this situation, and control efforts seem more effective. Profits are fifty percent greater for the interval of interest and variations from desired equilibrium positions are reduced.

In the second experiment a phase shift of ninety degrees in the market cycle places an economic recession phase with the firm's big push to regain its lost market position. For this experiment demand and capacity orders are illustrated in Figure 13, and resulting debt is portrayed in Figure 14. Market depression occurs in conjunction with the receipt of a large capacity order and financial chaos results. Over fifty million dollars is lost during the period corresponding to the late 1950's, and the debt-equity ratio rises to almost twice the absolute limit. As a result the subsequent capacity orders are greatly suppressed, and the lost market position is never regained. Both capacity orders and profits are only seventy percent of those produced by the basic model.

In the third experiment a market input with a period twice as long as the system's natural period was used to demonstrate the reaction to an environmental force which coincides with system performance during one cycle and is 180 degrees out of phase the next cycle. Performance patterns for the capacity acquisition sector and financial sector are shown in Figures 15 and 16.

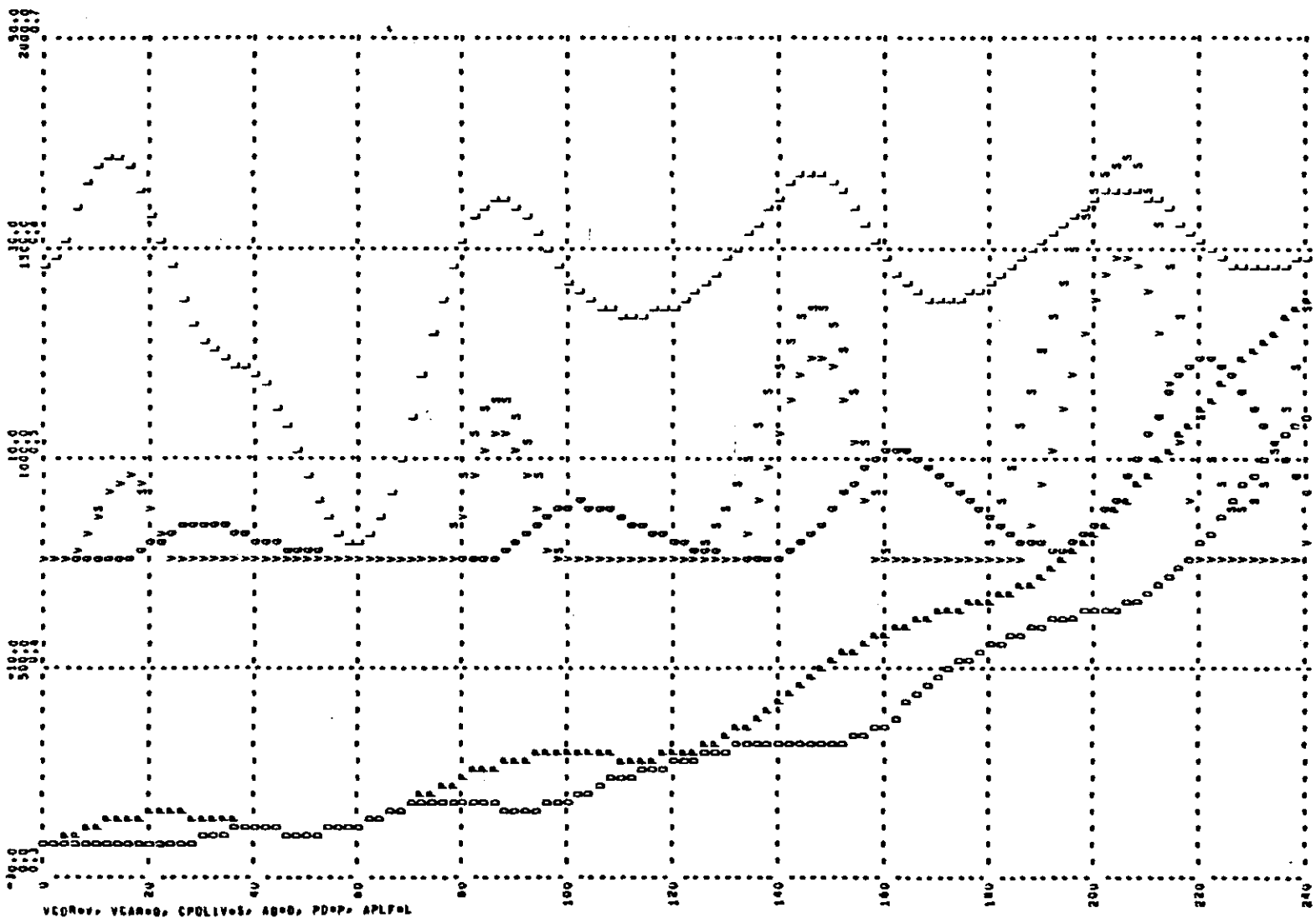


Figure 13. Demand/Capacity Behavior - Cyclic Demand with Ninety Degree Phase Shift  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

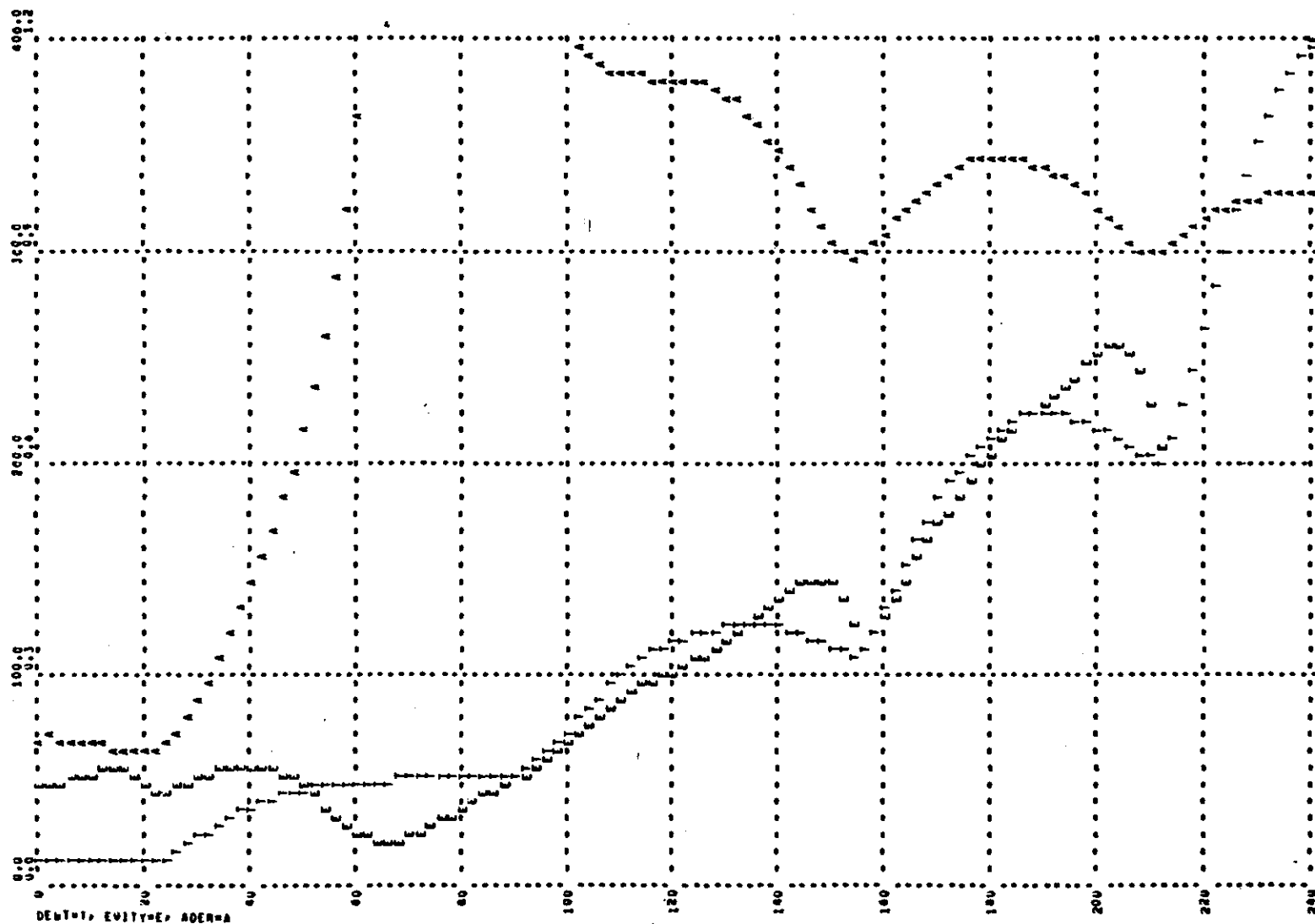


Figure 14. Debt/Equity Behavior - Cyclic Demand with Ninety Degree Phase Shift  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

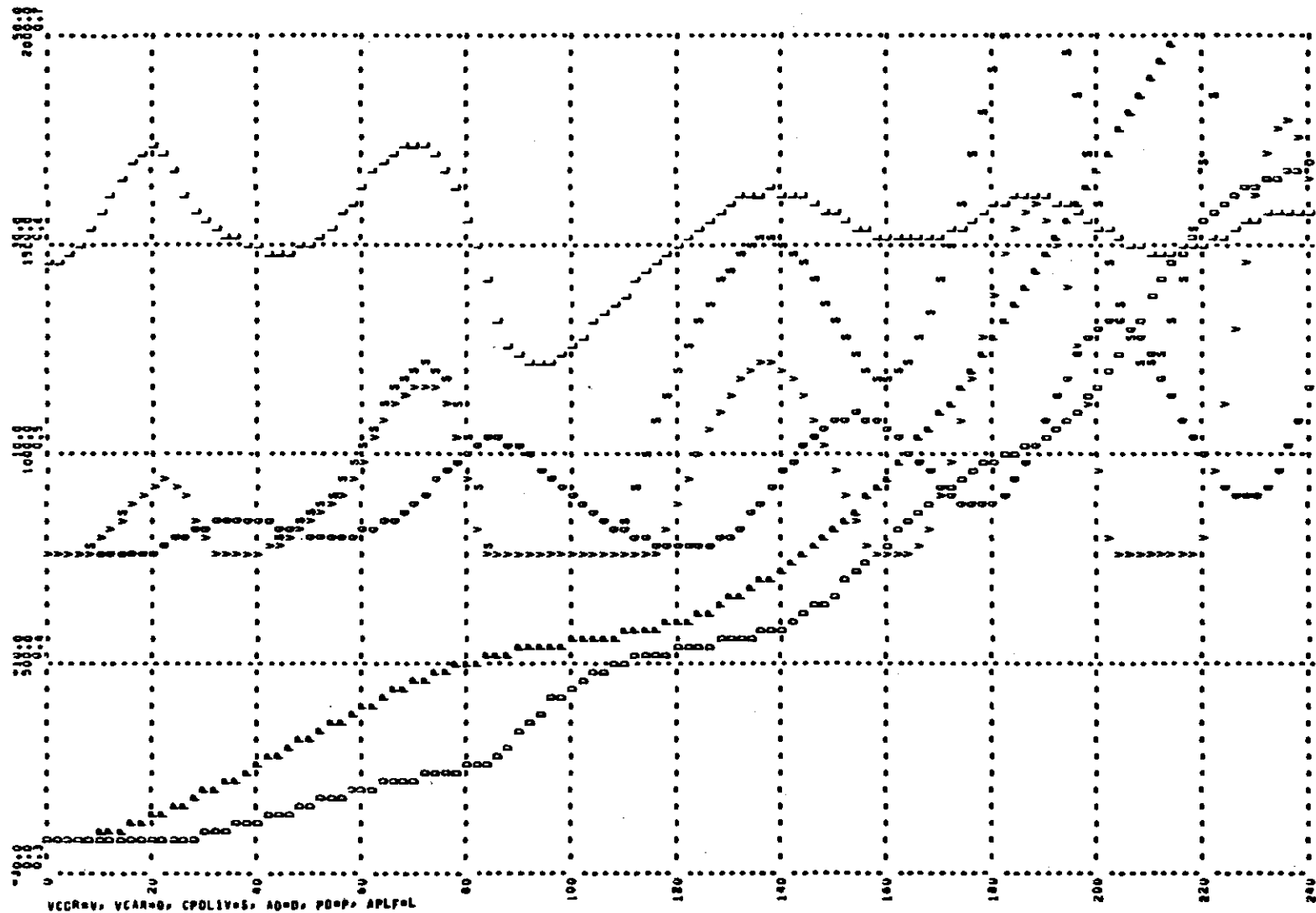


Figure 15. Demand/Capacity Behavior - Long-term Cyclic Demand  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

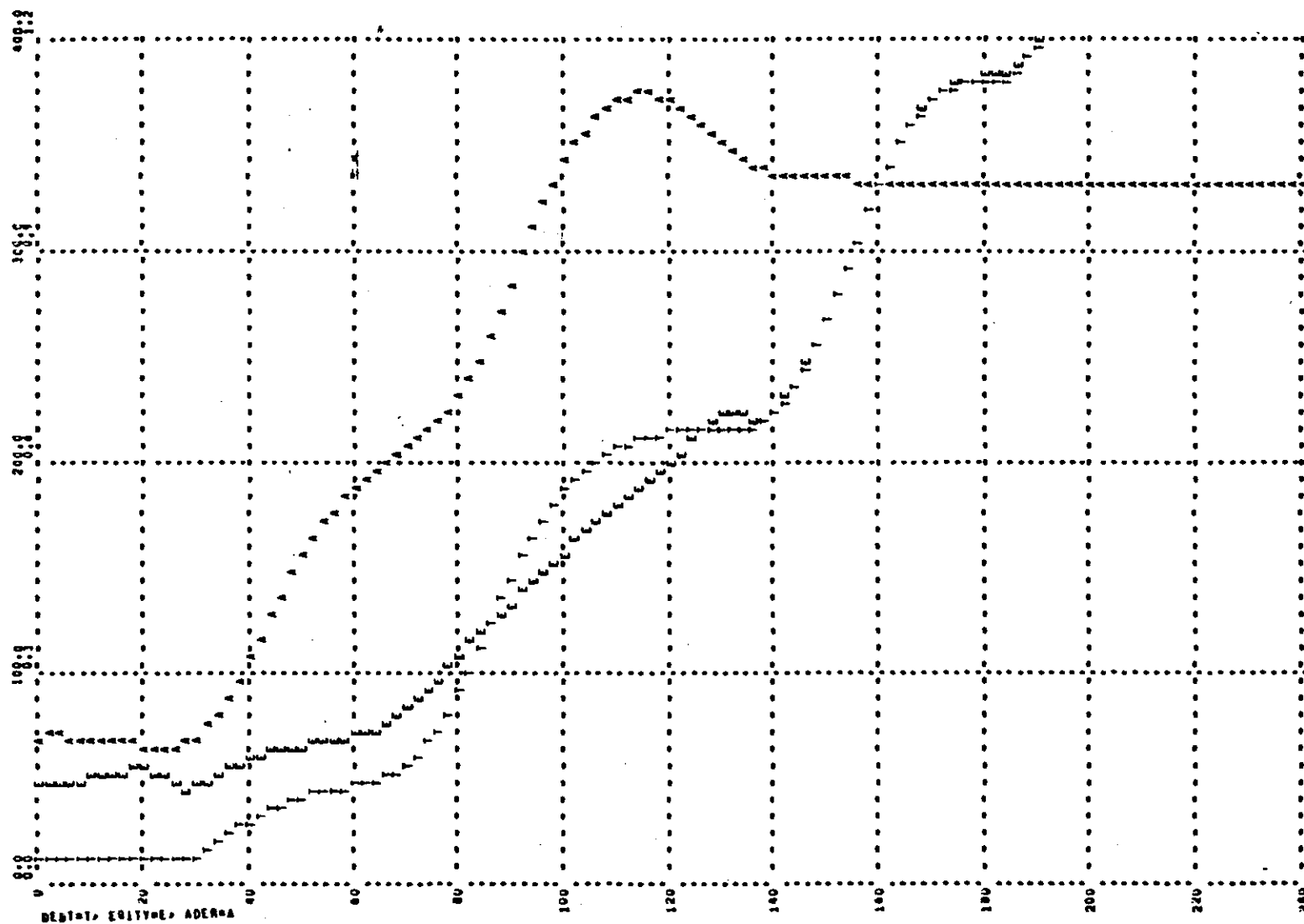


Figure 16. Debt/Equity Behavior - Long-term Cyclic Demand  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

An initial order is placed in an effort to regain previously lost markets. The response to this action coupled with the abnormal growth caused by the cyclic input prompts another order even before the first is completely integrated into the fleet. Thus, the normal profit suppression accompanying a capacity acquisition program is initially offset by favorable market behavior. However, the subsequent recession coincides with the receipt of the second order which requires substantial debt financing. During this period the debt-equity ratio exceeds the absolute limit, and subsequent capacity acquisitions required to maintain the desirable market position achieved earlier do not permit any improvement of the capital structure. The airline is able to achieve and maintain a solid market position but must utilize the maximum amount of debt capital available to do so. Their early capacity acquisitions perpetuate a dominant posture in the market and provide for a favorable return on the debt; however, all funds are required for continued capacity acquisitions and debt cannot be reduced.

When this long-term cycle is shifted ninety degrees, efforts to regain lost markets are damped out by a downturn in the economy (Figure 17). Although an initial capacity acquisition program is achieved, excess capacity combined with adverse economic conditions leave the airline struggling to maintain operations. All funds are depleted, and severe financial constraints prevent ordering capacity to take advantage of subsequent exogenous growth. The airline's demand is limited by capacity, and the lack of demand growth provides no incentive to purchase additional aircraft even when market



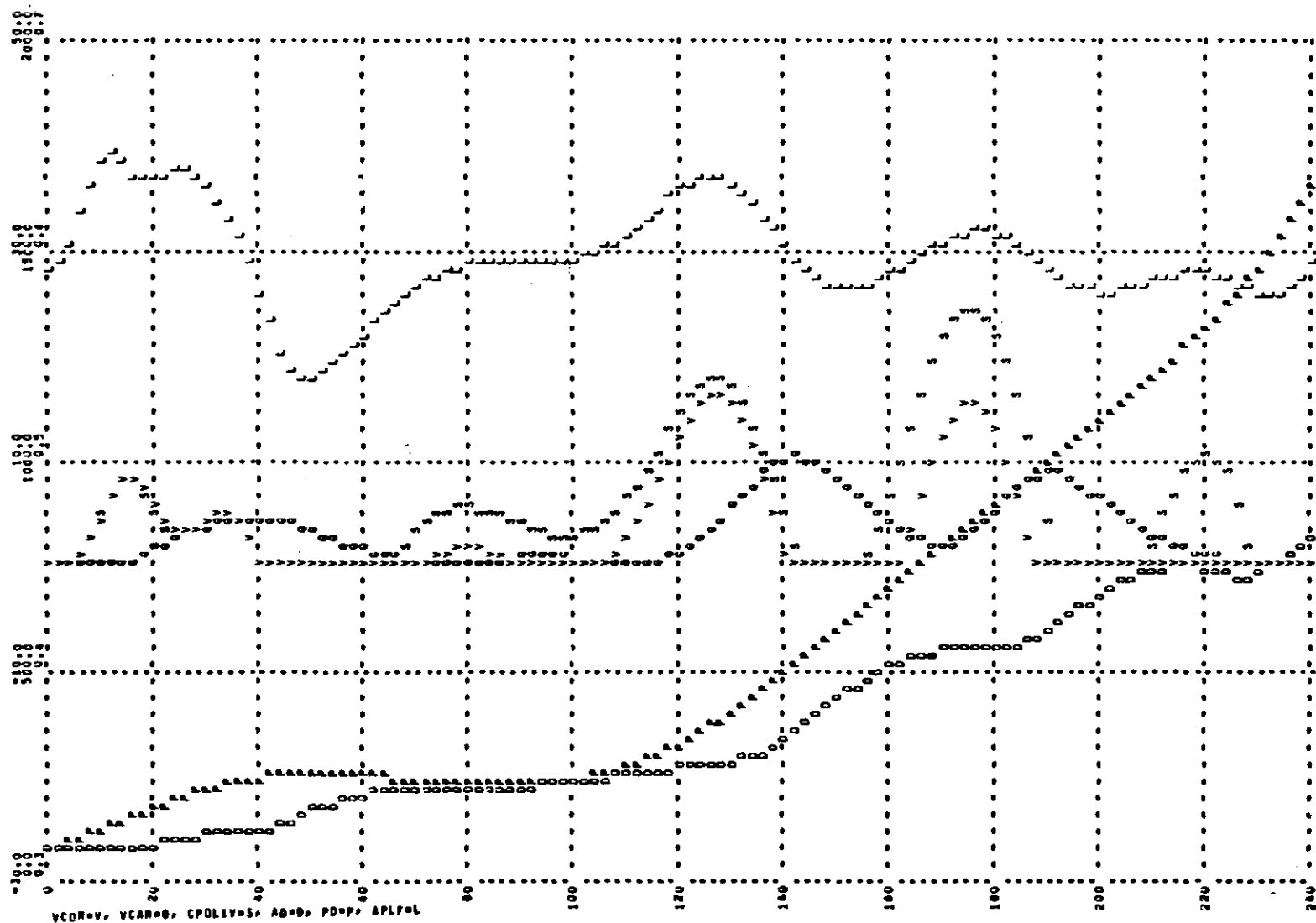


Figure 17. Demand/Capacity Behavior - Long-term Cyclic Demand with Ninety Degree Phase Shift  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

conditions improve. Thus, the marginal operation continues at the current level with no possibility of regaining lost markets.

Upon repeating the above experiments with amplitudes increased by twenty-five percent and fifty percent and decreased by the same amounts, essentially the same financial performances were observed with the severity of financial crises related directly to cyclic amplitudes. The system can cope with those cyclic inputs which are in phase with its natural pattern although the periodic financial crises are more acute. Inputs out of phase with normal system behavior produce adverse conditions from which recovery is essentially impossible. Under these circumstances the system seeks an equilibrium position which is not consistent with the market and produces unsatisfactory profits. Thus, one can conclude that (within the ranges considered in these experiments) the managerial decision-maker should be more concerned about when economic conditions are going to change, relative to contemplated capacity acquisition programs, than how much they are going to change.

To complete the analysis of system reactions to exogenous inputs, the underlying growth rate was altered by  $\pm 25$  percent. An increase of 25 percent produces a reaction cycle of approximately fifty months compared with the basic model's period of sixty-nine months. Four capacity acquisition programs occur during the same interval in which three orders are placed in the initial model's performance. However, these four orders result in the same total purchase of capacity as observed for the basic model due to increasingly severe financial constraints. Although these constraints

prevent the airline from adding sufficient capacity to match market growth, they do provide for relatively stable financial performance since adequate sales are realized to replenish depleted internal funds.

Conversely, a lower growth rate produces a longer reaction cycle (approximately 87 months) with a greater amplitude. Financial recovery from capacity acquisitions takes much longer in the "soft" market even though the airline realizes its full market potential. This delay in recovering capacity investments perpetuates a complete loss of control over the debt level and contributes to wide fluctuations in the return on equity. The two behavior patterns resulting from increased and decreased growth rates are contrasted in Figures 18 and 19. Table 4 summarizes the results gained from this set of experiments.

#### System Reaction to Exogenous Parametric Variations

The purpose of this section consists of examining the system's sensitivity to parameters over which management has little or no direct control. Typical financial parameters include the unit cost of capacity (UCC), the operating cost associated with producing an available seat mile (UOPC), and the revenue produced by a revenue passenger mile (PMYLD). Market parameters incorporated into the model include the consumer recognition delay (CRD), which represents the lag between introducing new technology and the consumer's recognition and reaction to the advanced equipment, and the competition's reaction time (CRT) for reaction to the introduction of new equipment. Another market relationship is represented by AVEFT, a continuous function representing the impact of capacity availability on the market.

Table 4. Summary of Experimental Results - Exogenous Inputs

Exogenous Input	Outcome	Supporting Figure(s)
1. Cyclic - Same period. In phase.	Larger orders. Greater financial constraints. Improved performance. Better control.	10, 11, 12
2. Cyclic - Same period. Ninety degree phase shift.	Depressed orders. Financial deterioration. Strong performance in market.	13, 14
3. Cyclic - Period twice as long. In phase initially.	Larger orders. Maximum debt but under control. Strong performance in market.	15, 16
4. Cyclic - Period twice as long. Ninety degree phase shift.	Depressed orders. Financial deterioration. Lost market position.	17
5. Increased growth rate.	Faster growth. Shorter cycle. Same dynamics.	18
6. Reduced growth rate.	Slower growth. Longer cycle. Same dynamics.	19

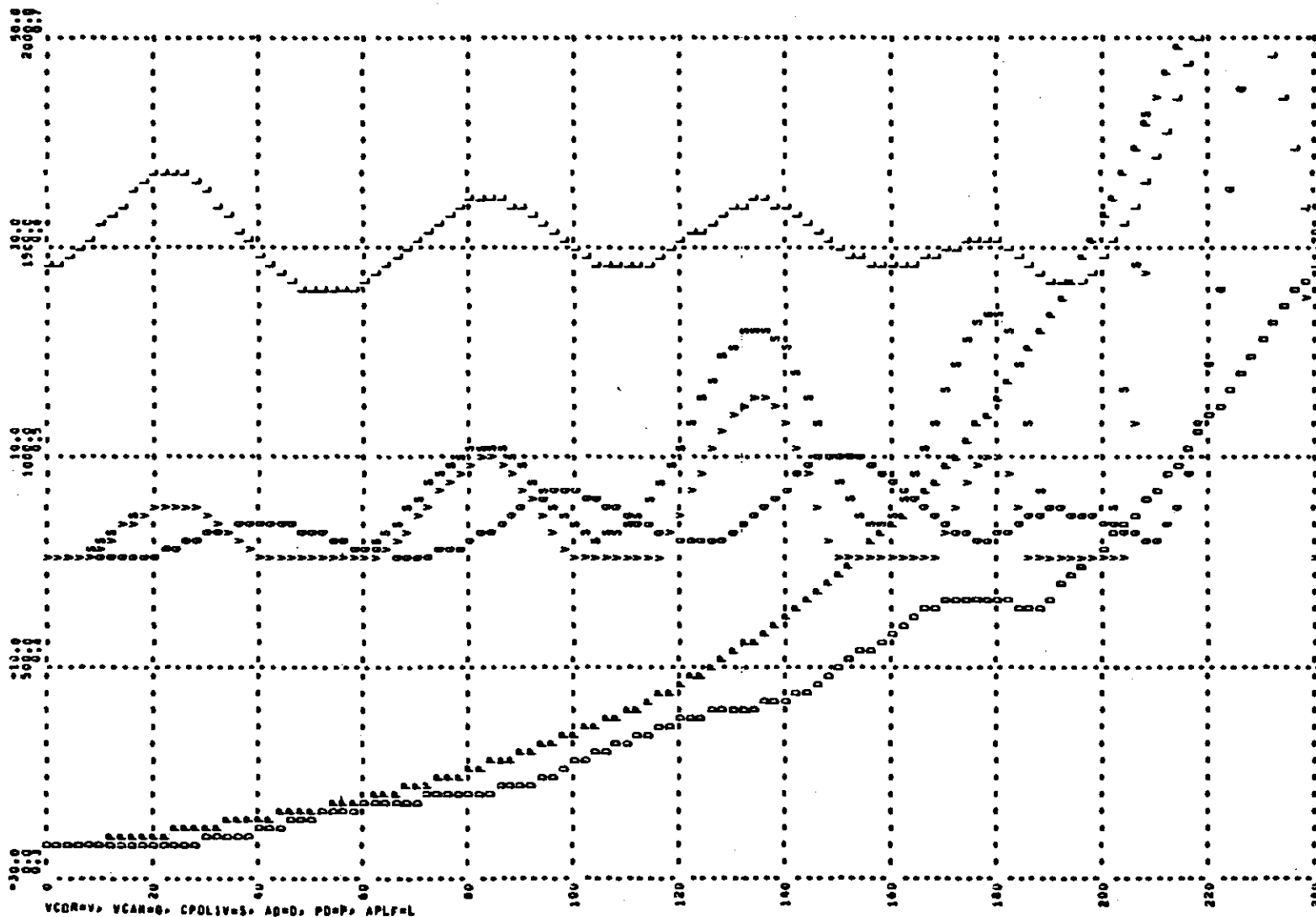


Figure 18. Demand/Capacity Behavior - Increased Market Growth  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

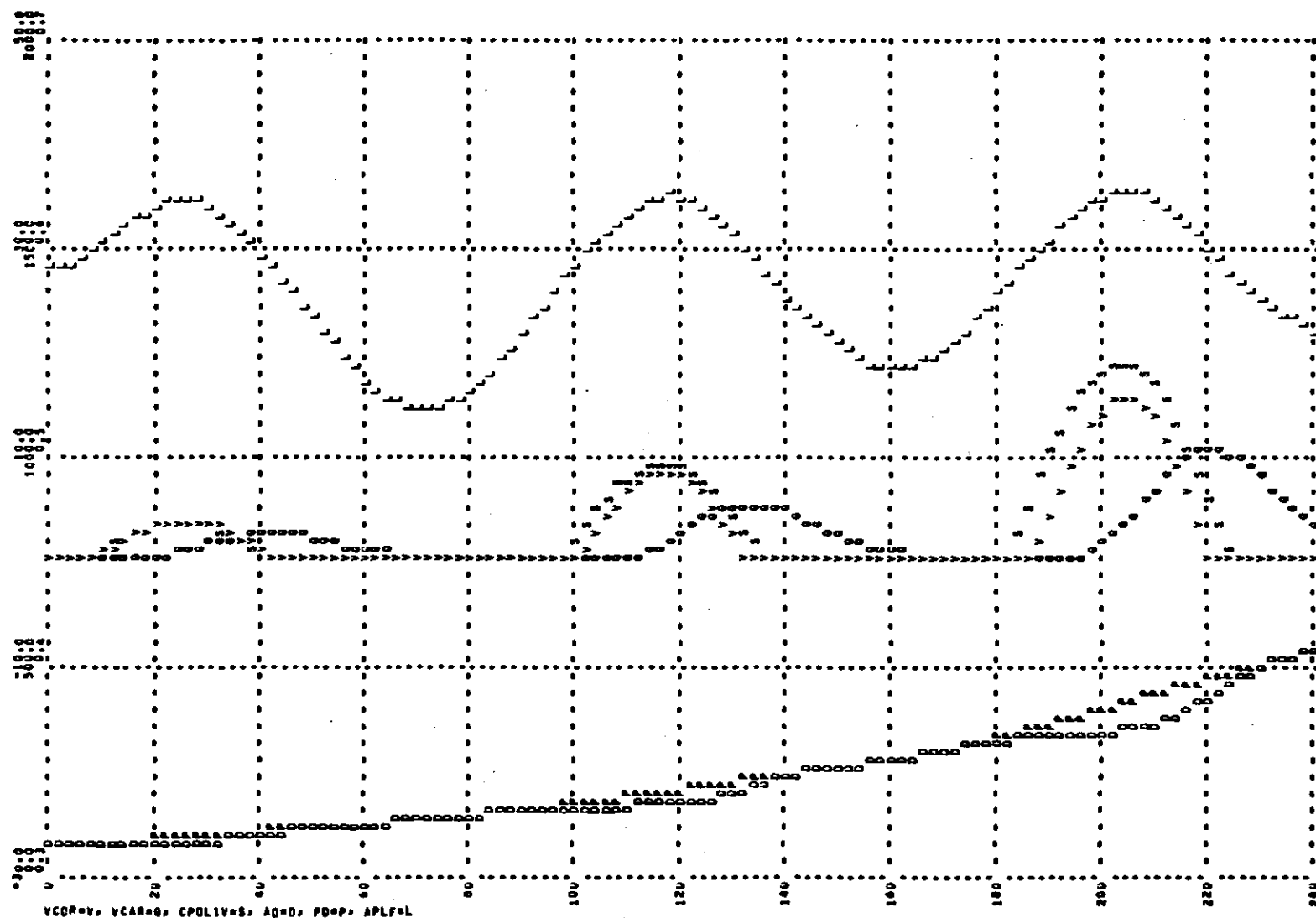


Figure 19. Demand/Capacity Behavior - Decreased Market Growth  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

### Financial Parameters

To study the profit performance of an airline when subjected to the normal increases of prices and costs over time, the passenger mile yield (PMYLD) and unit operating cost (UOPC) were increased each time increment by the same amount. Thus, the profit contribution generated would remain unchanged if costs and associated revenues were perfectly matched over time. Such is not the case however, as costs increase simultaneously with the addition of new aircraft to the fleet; whereas, resulting demand and revenue increases are subject to a substantial lag.

This hypothesis is supported by the model behavior illustrated in Figures 20 and 21. The behavior of demand, capacity acquisitions and the passenger load factor in Figure 20 displays the same dynamic characteristics as the basic model. However, the profit performance in Figure 21 reveals the greater impact of increasing costs which are not offset by simultaneous increases in revenue. This adverse effect is directly proportional to the magnitude of the capacity acquisition; therefore, the large acquisition in the late 1960's results in permanent losses from which the airline cannot recover.

A second experiment included the same changes in unit revenues and costs but the unit cost of capacity (UCC) also increased at a constant rate. Under these conditions the operating losses are even more significant since the ability to finance future acquisitions is further impaired by the increasing cost of new aircraft. Again the same dynamic patterns are displayed. Capacity orders are smaller due to a scarcity of funds. As a result the increases in cost produce

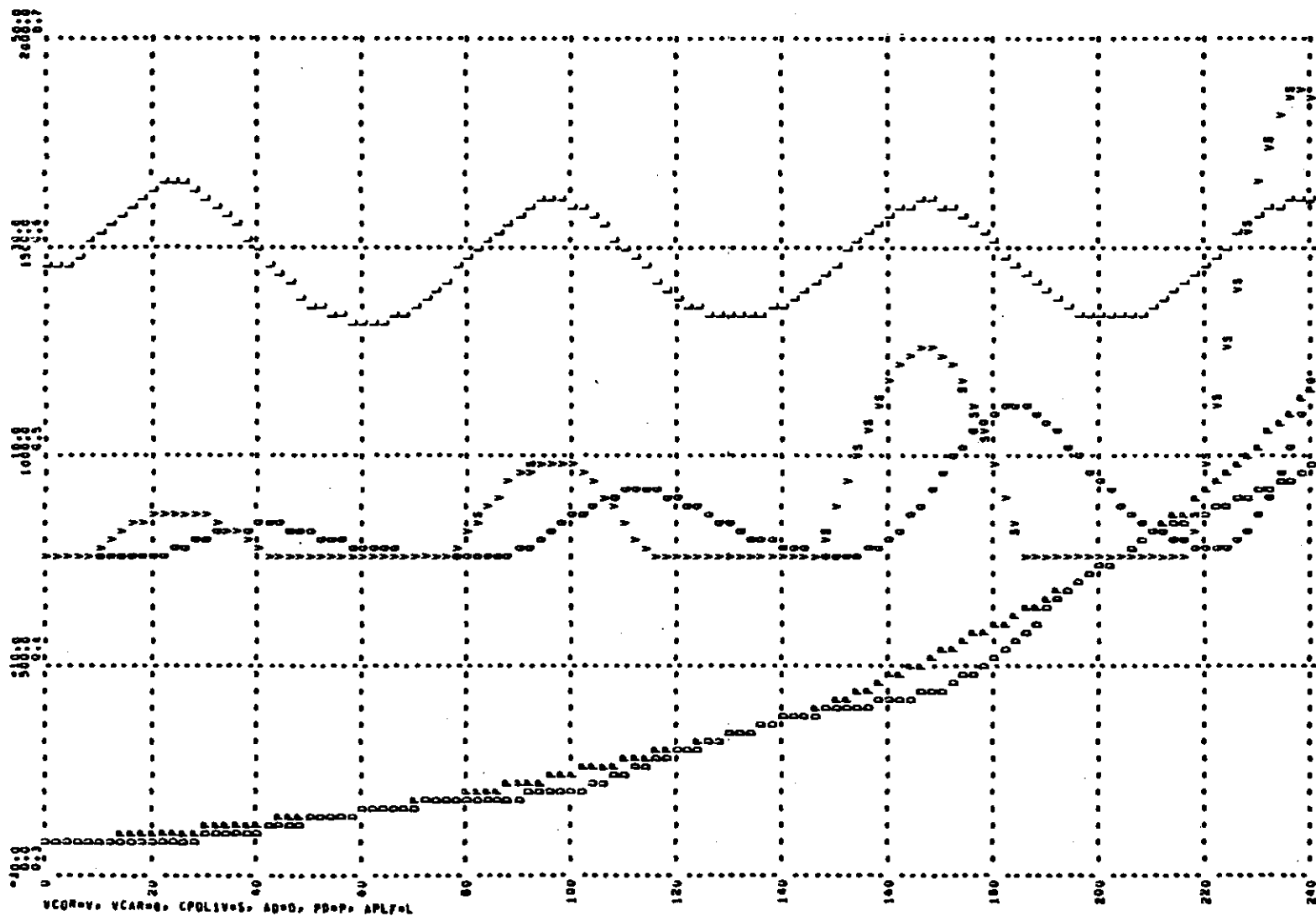


Figure 20. Demand/Capacity Behavior - Increasing Operating Cost and Revenue  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF



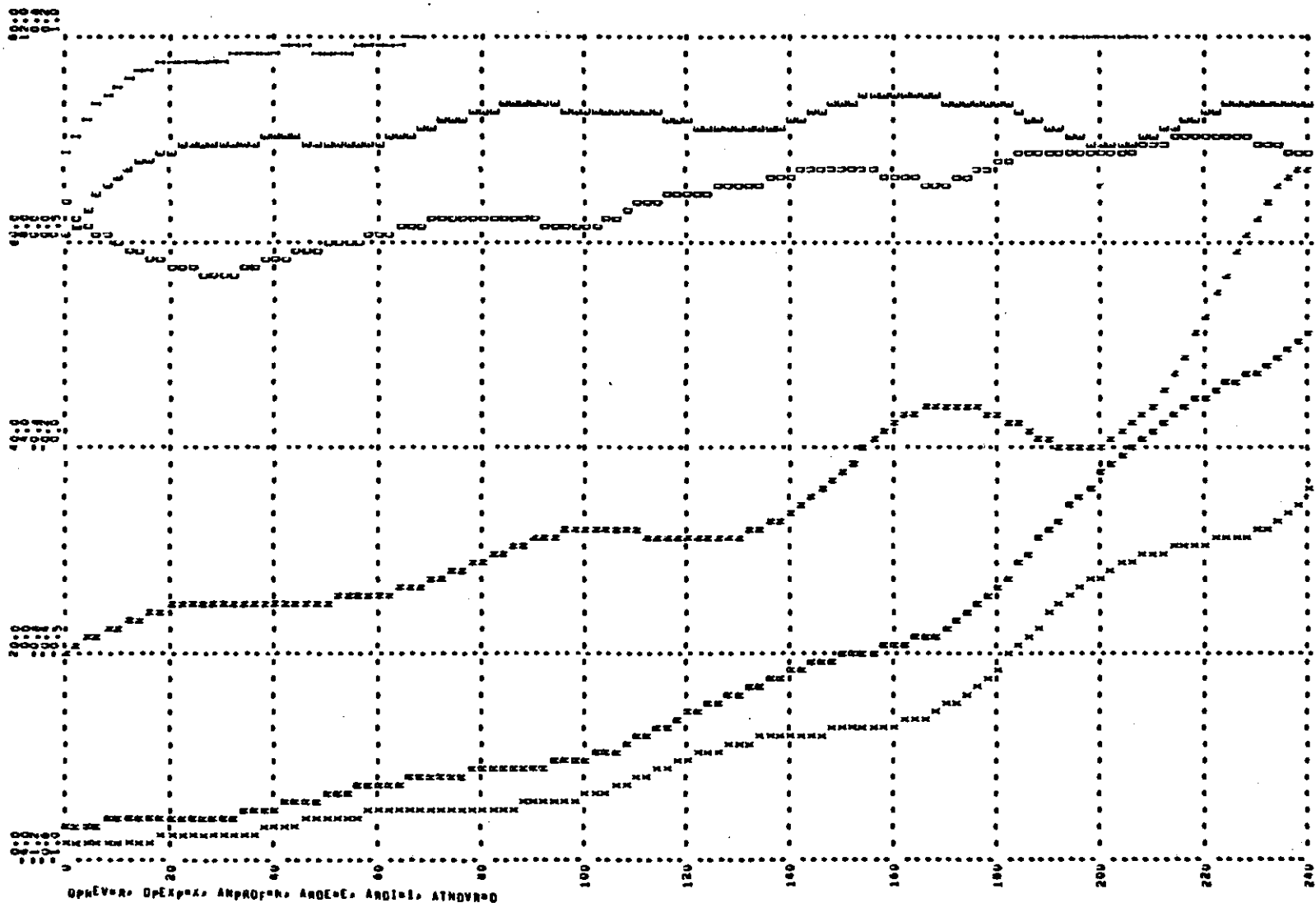


Figure 21. Financial Performance - Increasing Operating Cost and Revenue  
R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover

less effect , but demand increases are not as great due to a lower capacity. Although the patterns are subdued, the eventual outcome is the same since each order produces larger operating losses.

Repetition of the same two experiments with unit operating costs increasing faster than unit revenues produced the same effects in both cases with greater losses being incurred. The results of these experiments, summarized in Table 5, indicate that the systems problem and cyclic performance patterns do not result from inherent financial parameter values. Although increasing costs are contributing to the financial difficulties of airlines, increases in fares will relieve the symptoms only temporarily. The sequential pattern of profits and losses and the scarcity of funds for capital investment would still characterize the members of the industry.

#### Market Parameters

The previous section demonstrates that increasing unit costs and revenues produce a deteriorating profit performance due to the lag between an increase in capacity and the concomitant increase in demand. This lag is represented in the model by the consumer recognition delay (CRD). It is estimated that this parameter can be changed up to fifty percent of its current value (twelve months) by promotional programs focusing on recent capacity acquisitions. Thus, experiments in which this parameter was increased (and decreased) by fifty percent are included to determine the system response.

An increase of fifty percent to eighteen months results in a four to six month increase in the system's period. The same capacity orders eventually occur although the time between orders increases.

Table 5. Summary of Experimental Results

## Exogenous Financial Parameters

Parameter Variation	Outcome	Supporting Figure(s)
1. Unit operating cost and revenue increased at same rate.	Same dynamics. Severe operating losses due to revenue lag.	20, 21
2. Unit operating cost and revenue increased at same rate. Unit cost of capacity increased.	Same dynamics but not as pronounced. Reduced capacity orders. Severe operating losses.	--
3. Same as 1 except unit operating cost increased faster than revenue.	Same as 1 with increased operating losses.	--
4. Same as 2 except unit operating cost increased faster than revenue.	Same as 2 with increased operating losses and reduced capacity orders.	--

Profits are 90 percent of those for the basic model and the debt performance is practically identical.

A fifty percent increase in the market's responsiveness to technological advances represented by a reduction in CRD produces more significant changes. The adverse impact of increasing capacity and costs is offset much sooner by increased demand and revenues. A greater share of the market can be captured and retained; therefore, the airline recovers its investment much sooner and can finance additional growth. Continuing decreases in the period and amplitude of system behavior displayed in Figure 22 suggest an equilibrium position will be reached after an extended period of time. Profits during the period of interest are seventy percent greater than those produced by the basic model; however, debt must be maintained at its absolute maximum to sustain the operation. The apparent benefits of reducing the delay between fleet expansions and corresponding market shifts justify the airlines' emphasis on advertising and promotion. Such an emphasis would be particularly beneficial when technological advances are introduced into a particular market.

The parameter CRT, representing the delay between an airline's actions to capture a larger market share and the competition's subsequent reaction, was also varied in model experimentation. System behavior was almost completely insensitive to these changes due to the long delays associated with a competitor placing and receiving an order of new aircraft.

Changes in the functional relationship between demand and capacity availability produced no change in the system's dynamics. Although

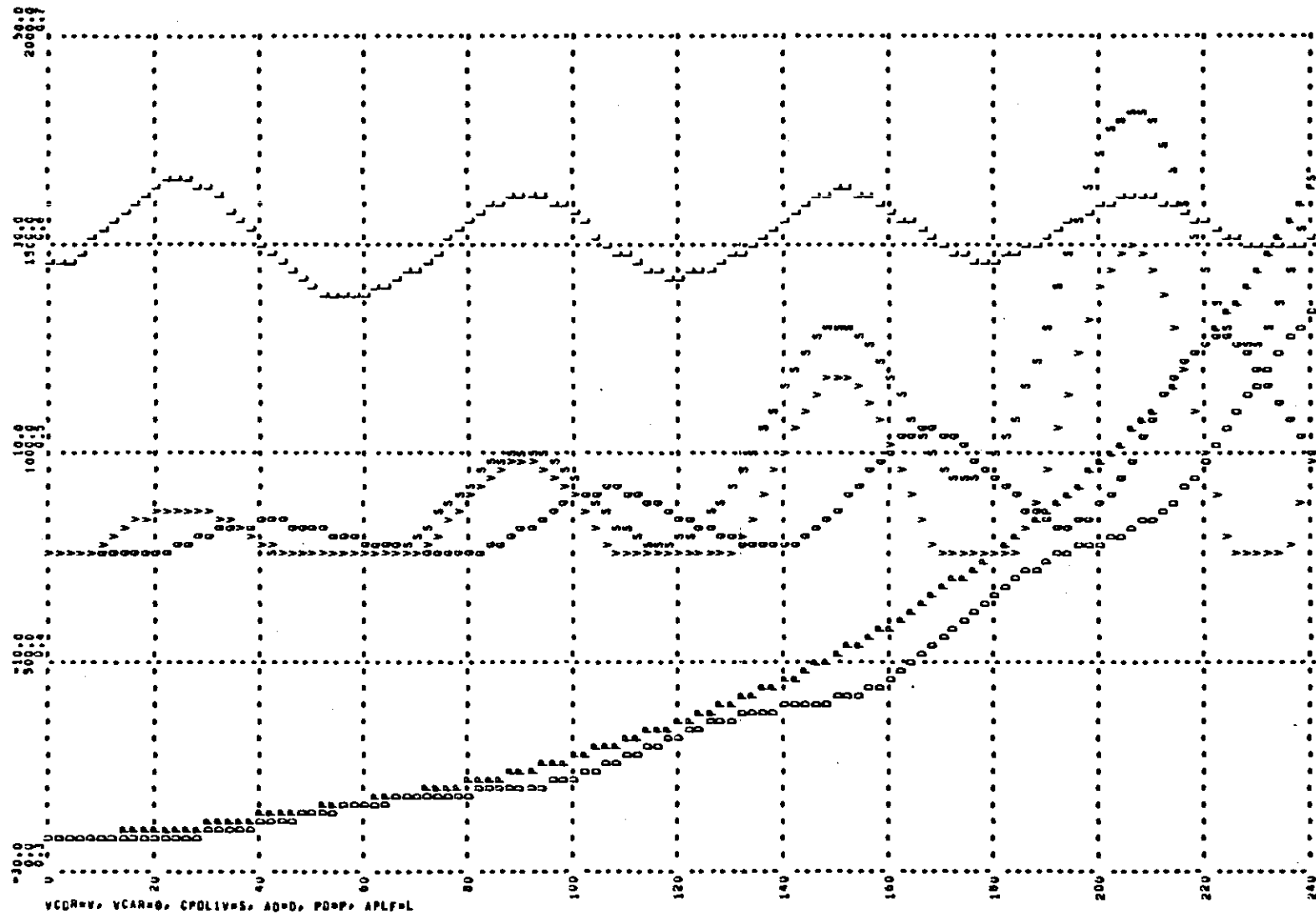


Figure 22. Demand/Capacity Behavior - Reduced Consumer Recognition Delay  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

the rate of recovery from a period of depressed financial performance changes, the cyclic pattern and scarcity of funds are still present.

Summaries of the above experiments are listed in Table 6.

#### System Reaction to Internal Parametric Variations

The experiments described above focused on parameters over which management has little direct control. The one to which system behavior is most sensitive is the inherent delay in the consumer's reaction to an introduction of more advanced flight equipment. Although the airline may alter this delay somewhat through promotional programs, its value cannot be established by an explicit management action. Conversely, the parameters to be considered in this section are those which are internally controlled and characterize management decision processes.

Although behavioral and attitudinal parameters are particularly difficult to measure, they may contribute substantially to decision outputs. Simulation methodology provides a procedure for developing reasonable estimates through a goal-seeking process. Estimates are generated which satisfy the test of reasonableness and produce model behavior which corresponds to observed behavior. The same model can then be used to isolate the variables which significantly alter the system's performance when changed since these are the attitudes or policies to receive further attention.

The model resulting from this research represents the simultaneous operation of two control sectors in the organization: financial and operational. Accordingly, this section deals with internal parameters characterizing decisions in each of these sectors and documents the

Table 6. Summary of Experimental Results - Exogenous Market Parameters

Parameter Variation	Outcome	Supporting Figure(s)
1. Increased Consumer Recognition Delay.	Same orders and profits. Increased system's natural period by six months.	--
2. Decreased Consumer Recognition Delay.	Increased orders and profits. Maximum debt but under control. Period and amplitude reduced as equilibrium approached.	22
3. Increased Competition Reaction Time.	No significant change from basic model behavior.	--
4. Decreased Competition Reaction Time.	No significant change from basic model behavior.	--
5. Increased impact of capacity availability on demand.	Same dynamics. Slightly period. Same orders.	--
6. Decreased impact of capacity availability on demand.	Same dynamics. Longer period. Reduced orders and profits.	--

responsiveness of system behavior to changes in these parameters.

### Financial Parameters

Endogenous financial parameters of the basic model serve two purposes: representation of operating objectives which financial managers strive to achieve and measurement of determination to achieve these objectives. The Average Debt-Equity Ratio (ADER) serves as a primary control variable in the financial sector, and related objectives are represented by the Desired Debt-Equity Ratio (DDER) and the Absolute Debt-Equity Ratio (ADTER). Delays in rectifying deviations of actual conditions from desired levels are expressed by the values of Correction Delay (CORDLY) and Debt Retirement Delay (DRD).

Experiments were performed in which these parameters were varied from their initial values to identify the importance of financial decision-making in determining system behavior and to estimate the effects of altering these decision processes. In the initial model,  $DDER = 0.5$  and  $ADTER = 1.0$  which implies that the firm strives to maintain a debt-equity ratio of one-to-two and will not permit actions which might result in a ratio greater than one-to-one. For intermediate values, actions are taken to reduce the ratio to the desired value. Typical actions are reduction of current capacity orders and retirement of existing debt. The magnitude and urgency of these actions depend on the inherent delays, CORDLY and DRD, and the magnitude of the overrun. The initial model uses a Correction Delay (CORDLY) of nine months and a Debt Retirement Delay (DRD) of two years. As stated earlier, the initial model was formulated on the basis of performance produced by Delta Airlines, Inc., a relatively conservative organization;



therefore, it is felt that these parameter values reflect a conservative financial viewpoint.

The first experiment incorporated a less conservative attitude by increasing the Desired Debt-Equity Ratio from 0.5 to 1.0. Therefore, no action was taken to reduce debt until it reached the absolute limit. This strategy results in larger capacity orders due to less severe financial constraints; however, the increased capacity is not immediately utilized due to market limitations. Since the airline's demand is limited by the potential market, a longer recovery period is required to accommodate the larger orders. This condition is reflected by the profit behavior in Figure 23 which displays a lengthening period and an increasing amplitude reflecting the lack of financial control. The total profit for the interval of interest is only fifty-three percent of that for the basic model, and operating losses are still being incurred at the end of the interval. Thus, a less conservative financial attitude results in reduced constraints on the capacity acquisition sector and a deterioration in financial performance.

Additional increases in DDER and ADTER simultaneously yield exactly the same results as those just presented; therefore,  $DDER = 1.0$  represents a complete relaxation of financial control. Experiments were also conducted in which the Desired Debt-Equity Ratio remains at 0.5, but the Absolute Debt-Equity Ratio is altered. These trials produce exactly the same behavior as that resulting from the basic model in which  $ADTER = 1.0$ .

Two conclusions can be derived from these observations. First, the primary financial objective in terms of altering system performance

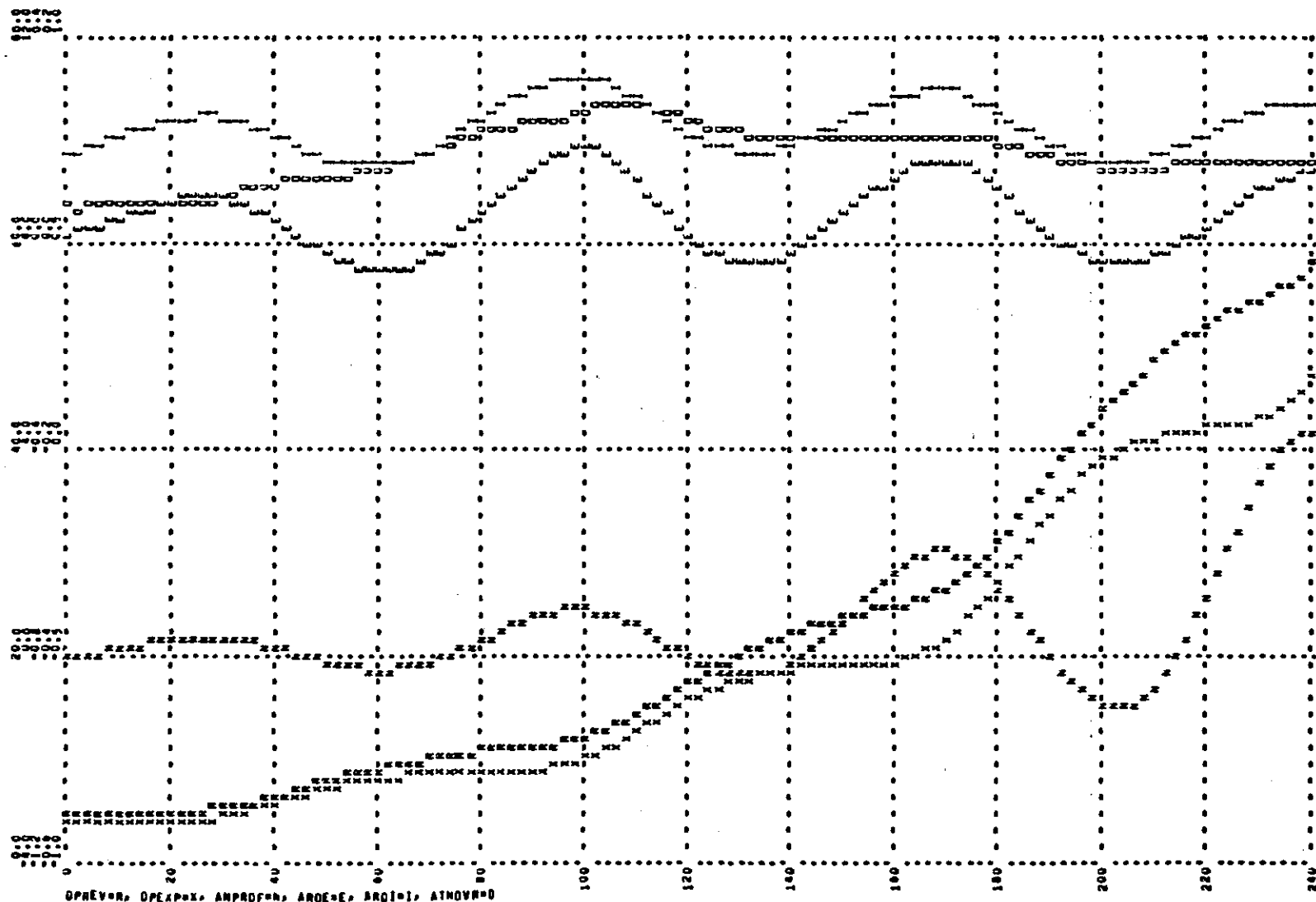


Figure 23. Financial Performance - Increased Desired Debt-Equity Ratio  
R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover

is the desired relationship between debt and equity. When the ratio measuring this relationship exceeds the desired value, financial limitations are imposed on capacity acquisitions to reduce actual orders. These orders are not reduced to zero until the debt-equity ratio exceeds the absolute limit. Thus, financial actions which reduce capacity orders constrain the airline to a strategy which is financially feasible. The continuing restraint resulting in partial orders is much more effective than taking no action until the situation has deteriorated and then eliminating all capacity purchases.

The second conclusion relates to the relative merits of conservative versus aggressive financial management in the airline industry. Less conservative approaches produce poorer financial performance. High profits are achieved temporarily, but are followed by extended periods of depressed earnings. On a long-term basis the system's financial performance is less desirable than that of the basic model.

To measure the effect of increased conservatism, DDER was reduced to values lower than 0.5. These experiment produced behavior in which orders are greatly suppressed. Accordingly debt remains at low levels relative to the basic model results, but the airline is unable to maintain its market position due to insufficient capacity. The system stabilizes at an extremely low level of earnings, and the airline becomes a candidate for acquisition by a competitor.

Increased conservatism can also be introduced into the financial management domain via the Correction Delay, the time period utilized for correcting deviations of actual debt levels from the desired level. A reduction in this parameter results in greater restraint being imposed

on capacity orders if they require the use of additional debt. The outcome of an experiment in which the Correction Delay (CORDLY) was reduced from the nine month value of the basic model to one month is contained in Figure 24. Although the same dynamics are present, the extreme conservatism results in orders which are less than eighty percent of those in the basic model. Consequently the market position, represented by actual demand relative to potential demand, is lost and the airline is unlikely to regain it. The airline produces higher profits (143 percent of those in the basic model) using less debt, but long-term potential is sacrificed to achieve an attractive current performance. This outcome accurately depicts the financial manager's conflicting goals since the development of future potential often requires enduring less than desirable financial conditions until the potential is achieved.

Significant increases in CORDLY reduce the financial restraint imposed on capacity orders and produce the same effects as increases in the Desired Debt-Equity Ratio. Orders increase and the market position is enhanced, but demand is limited by the market potential. Hence, more debt is required and a poor financial performance results from the excess capacity.

To conclude the experiments involving financial parameters, the Debt Retirement Delay was varied. Model behavior is relatively insensitive to this parameter but reductions in the delay did lower the average debt-equity ratio. Since debt retirement is greater during profitable periods, financial constraints are relaxed somewhat and capacity orders are slightly larger. No significant change in financial

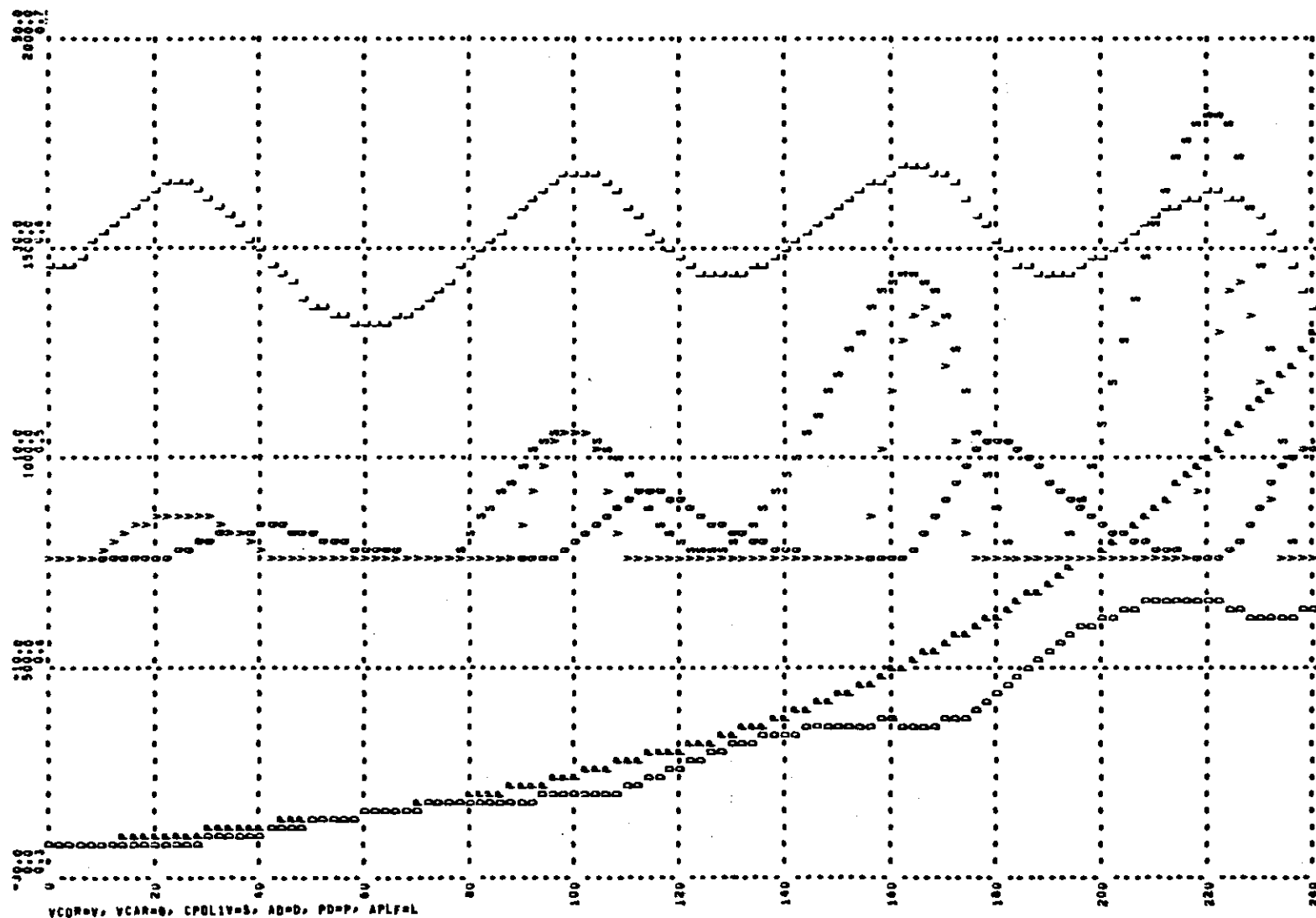


Figure 24. Demand/Capacity - Reduced Correction Delay  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

performance occurred. Increases in the delay produced no change from the basic model.

Summarizing the results obtained from financial parameter variation, the impact of financial management on system performance is heavily dependent on a particular objective (the desired relationship between debt and equity) and the aggressiveness in pursuing this objective (represented by Correction Delay). A relatively conservative attitude on the part of financial managers prevents prolonged periods of excess capacity which destroy the firm's financial base. While extreme conservatism produces short-term financial gains, the organization eventually loses the capability to compete effectively in the market. Each experiment and its outcome are summarized in Table 7.

#### Capacity Acquisition Parameters

Congruent with financial parameters as to their use in the model, parameters in the capacity acquisition sector of the model represent operating objectives and the desired rate of achieving these objectives. The parameter identified as Expansion Gain (EG), measured in months, incorporates the inherent discreteness of the airline industry's ordering process into the model. Although the decision processes resulting in orders are continuous phenomena, the placement of orders are discrete due to manufacturer constraints, the significance of external financing, and the importance of order positions. Each order must be large enough to accommodate the forecasted growth during the time required for delivery and for placing a subsequent order. In the basic model  $EG = 19$  months. System behavior is examined for alternative values of 16 months and 22 months.

Table 7. Summary of Experimental Results

## Endogenous Financial Parameters

Parameter Variation	Outcome	Supporting Figure(s)
1. Increased Desired Debt-Equity Ratio from 0.5 to 1.0.	Greater orders. More debt. Good market position. Poor financial performance.	23
2. Further increases in Desired and Absolute Debt-Equity Ratios.	Same behavior as that produced in 1 above.	--
3. Increased ADTER without changing DDER.	No change from basic model.	--
4. Equated ADTER to DDER.	No change from basic model.	--
5. Reduced Desired Debt-Equity Ratio.	Suppressed orders. Less debt. Loss of market position. Poor financial performance.	--
6. Reduced Correction Delay.	Suppressed orders. Less debt. Loss of market position. Strong financial performance but no future potential.	--
7. Increased Correction Delay.	Same behavior as that produced in 1 above.	--
8. Reduced Debt Retirement Delay.	Slightly larger orders. Average debt-equity ratio lower. No change in other financial performance.	--
9. Increased Debt Retirement Delay.	No change from basic model.	--

Another parameter under management control is represented by Order Interval Desired (ORDID) expressed in months. This parameter reflects managerial aggressiveness or conservatism in implementing the results of a decision process. When conditions initially indicate a need for more capacity, a delay is introduced to permit additional observation. If the conditions persist, a decision is made to order additional aircraft. The length of this delay is a measure of management responsiveness to perceived system states and their relationship to desired states. Experimental values for this parameter range from 18 months to 36 months with the basic model value being 24 months.

Another inherent delay in decision-making (DD) is included in the experimentation; however, alternative values produced no system behavior significantly different from that of the basic model. These results are summarized in Table 9 with other experimental results, but no further discussion will be presented for this parameter.

The Desired Passenger Load Factor (DPLF) depicts the capacity acquisition sector's primary operating objective. This parameter represents the desired relationship between a major system state, total capacity, and a key environmental input, demand. The basic model value of 0.59 corresponds with the value currently used by Delta Air Lines. Variations of this parameter produce significant changes in system behavior which are examined subsequently.

The experiments involving variation of operating objectives and behavioral parameters in the capacity acquisition sector illustrate the conflicting forces and trade-offs associated with decision-making in this environment. Aggressive actions represented by increased values



of EG and/or reduced values of ORDID produce larger orders and consequently more severe financial impacts when the new aircraft arrive. However, larger orders ensure a greater availability of aircraft to service increasing demand; therefore, a more desirable market posture is maintained providing a greater long-term earning potential.

Conversely smaller orders resulting from more conservative attitudes reduce the financial stress and produce a more stable financial behavior. Unfortunately failure to compete effectively in terms of aircraft technology and availability destroys the firm's market position in the highly competitive airline industry. Model behavior reflects this condition for conservative parameter values as lower demand levels are achieved, and the airline cannot generate sufficient sales to justify expansions necessary for market share recovery.

Reduction of Expansion Gain (EG) to 16 months dampens the financial and operational oscillations associated with receipt of an order. Although the upper limit of actual load factor variations remains the same as in the basic model, load factor depressions are not as great when the smaller orders are added to the fleet. This outcome generates a higher average load factor and a greater return on the capital investment; however, the airline eventually sustains substantial losses in the market due to a reduced fleet capacity. Market position, measured by actual demand relative to potential demand, at the end of the experiment is only 83 percent compared with 96 percent for the basic model.

An increase of EG to 22 months produces more severe performance outcomes. The amplitude of system oscillations increases greatly, and the debt level can only be controlled by emergency measures. Recurring

periods of abnormal profits and large losses make financial management impossible; however, the airline succeeds in capturing the maximum market share. Actual demand is 99.5 percent of potential demand at the end of the experiment, compared with 96 percent for the basic model. Experiments were also conducted using larger changes ( $\pm$  four months and  $\pm$  six months); however, the deterioration in performance described above progressed to such an extreme that the results were not judged worthy of consideration.

A reduction of ORDID without a concomitant tightening of financial controls begets capacity orders of increased magnitude with the same frequency. Total capacity orders resulting from a 25 percent reduction of ORDID (from 24 to 18 months) are 121 percent of those in the basic model. These larger orders produce more oscillatory financial performance with losses being incurred after the receipt of each order. The same phasing is evident but behavior amplitudes are magnified. As a result profit for the interval is only 54 percent of that generated by the basic model, and debt continuously exceeds the absolute limit after 1960 except for a brief period in fiscal year 1963. The severity of such behavior is illustrated in the performance patterns of Figures 25, 26 and 27.

A 25 percent increase in this parameter to thirty months yields the opposite effects. Total orders are only 85 percent of basic model output and uniformly improved financial performance results. Total profits for the interval exceed those of the basic model by eighty percent. Debt is confined within the absolute limit with the average debt-equity ratio being 0.7. Although less capacity is acquired during the

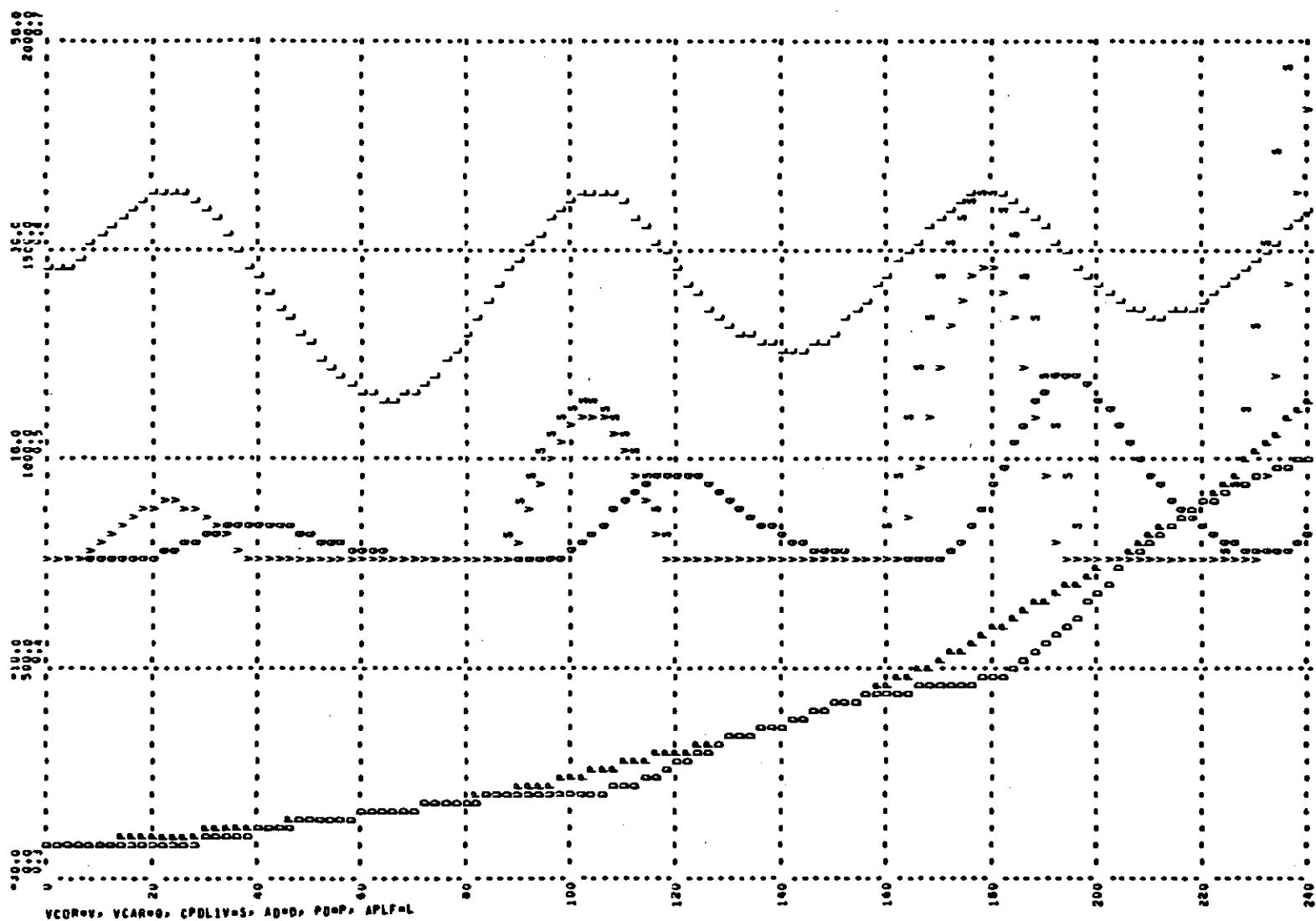


Figure 25. Demand/Capacity Behavior - Aggressive Ordering Policy  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

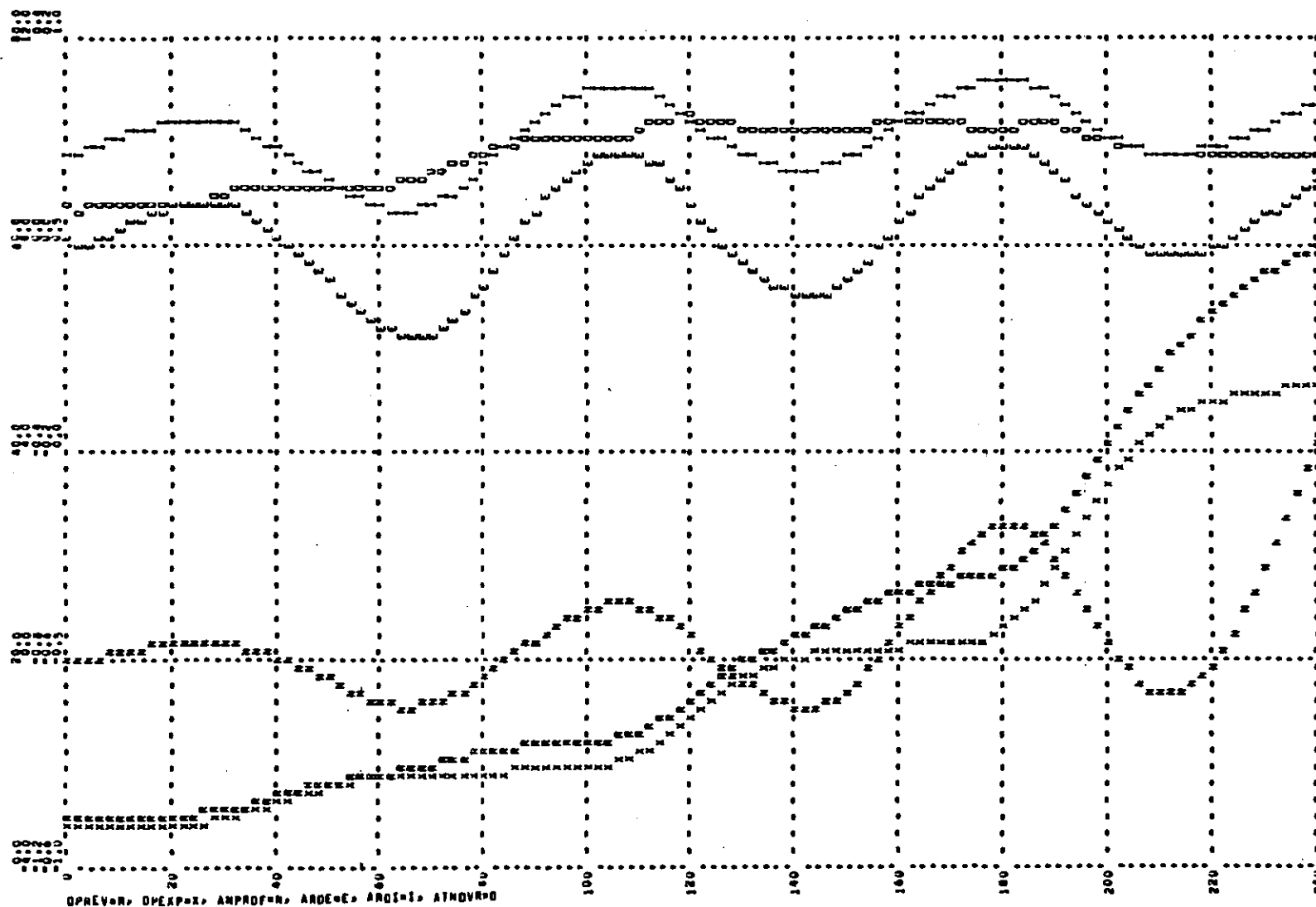


Figure 26. Financial Performance - Aggressive Ordering Policy  
R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover

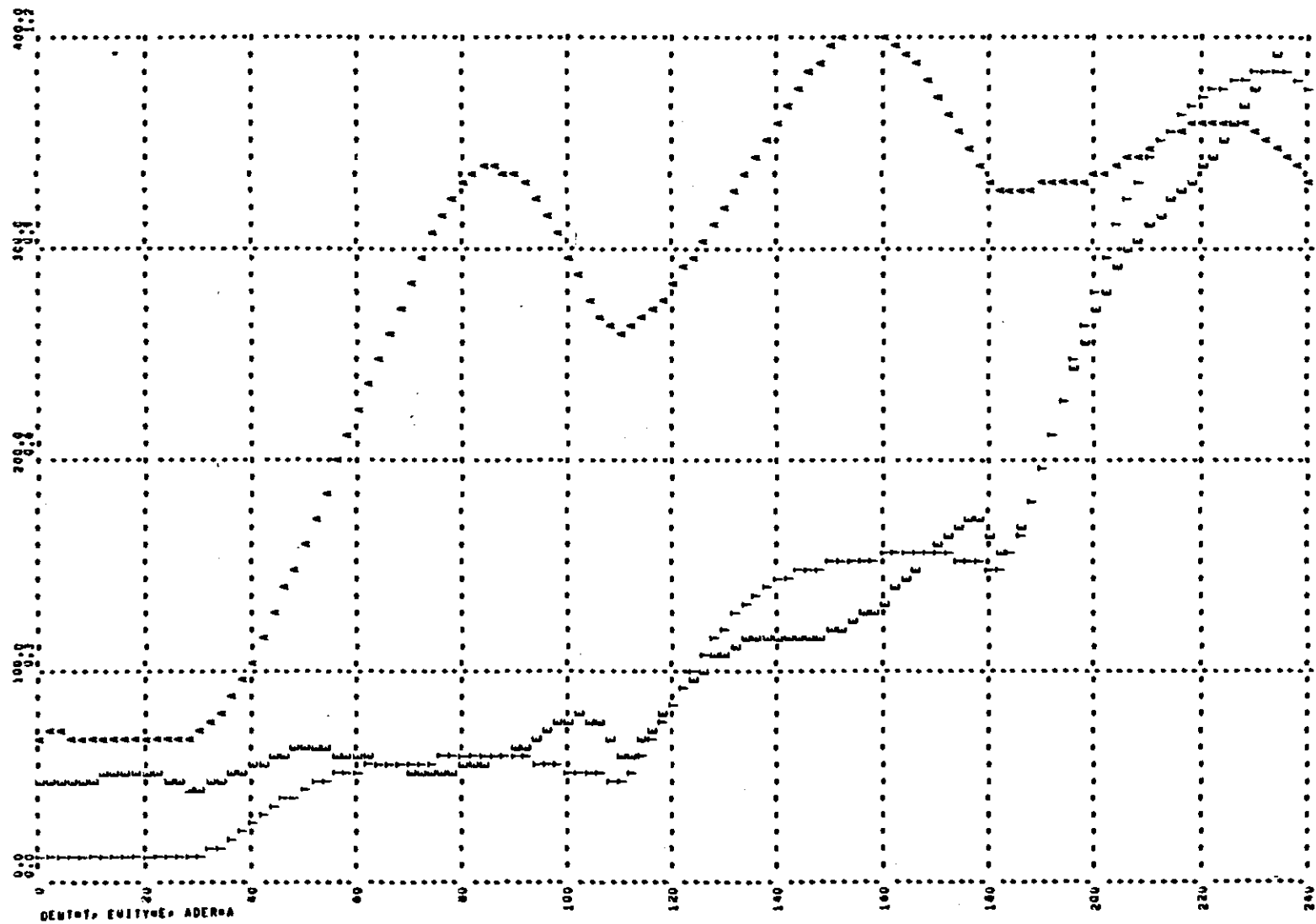


Figure 27. Debt/Equity Behavior - Aggressive Ordering Policy  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

interval of interest, the final market position (91 percent) compares favorably with that of the basic model (96 percent). These behavior patterns are presented in Figures 28, 29 and 30 to afford a direct comparison with the less desirable performance illustrated by Figures 25, 26 and 27.

To determine if further gains can be realized from a greater increase in this parameter, an experiment was conducted with ORDID increased fifty percent to 36 months. This degree of conservatism produces uniform financial performance but does not allow the firm to remain competitive in the marketplace. No aggressive actions are taken to regain previously lost markets and market position at the end of the time interval is only 78 percent compared with the basic model's position of 96 percent.

Interestingly, financial control under the conditions of the last experiment also proves to be a problem even though earnings are rather uniform and predictable. The low equity base associated with reduced capacity orders necessitates tight controls to maintain a reasonable debt-equity ratio. Even with these controls and extremely conservative ordering actions, the absolute debt limit is exceeded during the time interval. Thus, conservatism in the two organizational sectors does not possess a one-to-one correspondence; that is, increased conservatism in the capacity acquisition sector produces effects different from those produced by tighter financial controls. Similarly a more aggressive ordering policy generates behavioral characteristics different from those created by relaxing financial constraints.

Experiments involving variation of the Desired Passenger Load

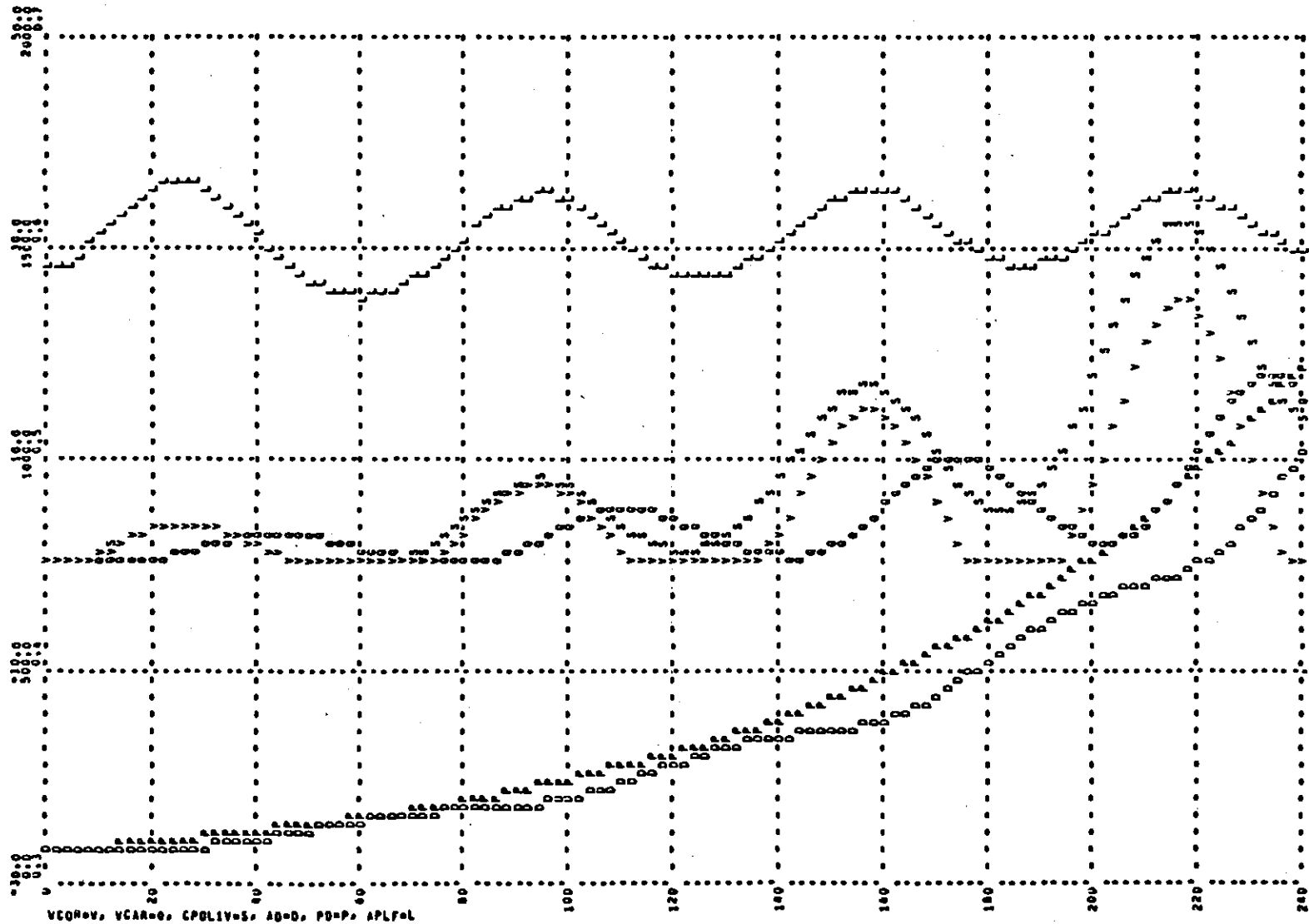


Figure 28. Demand/Capacity Behavior - Conservative Ordering Policy  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

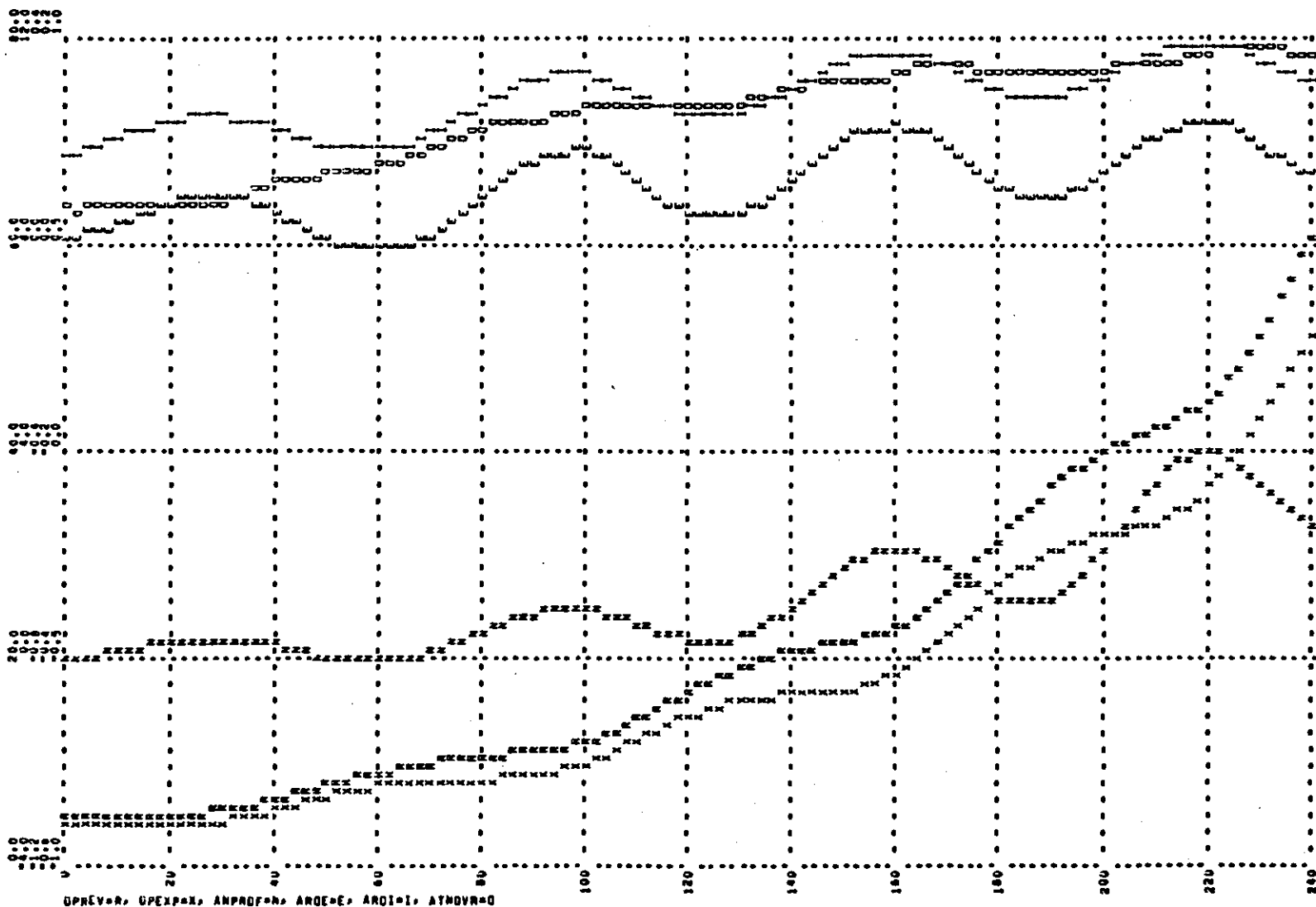


Figure 29. Financial Performance - Conservative Ordering Policy  
R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover



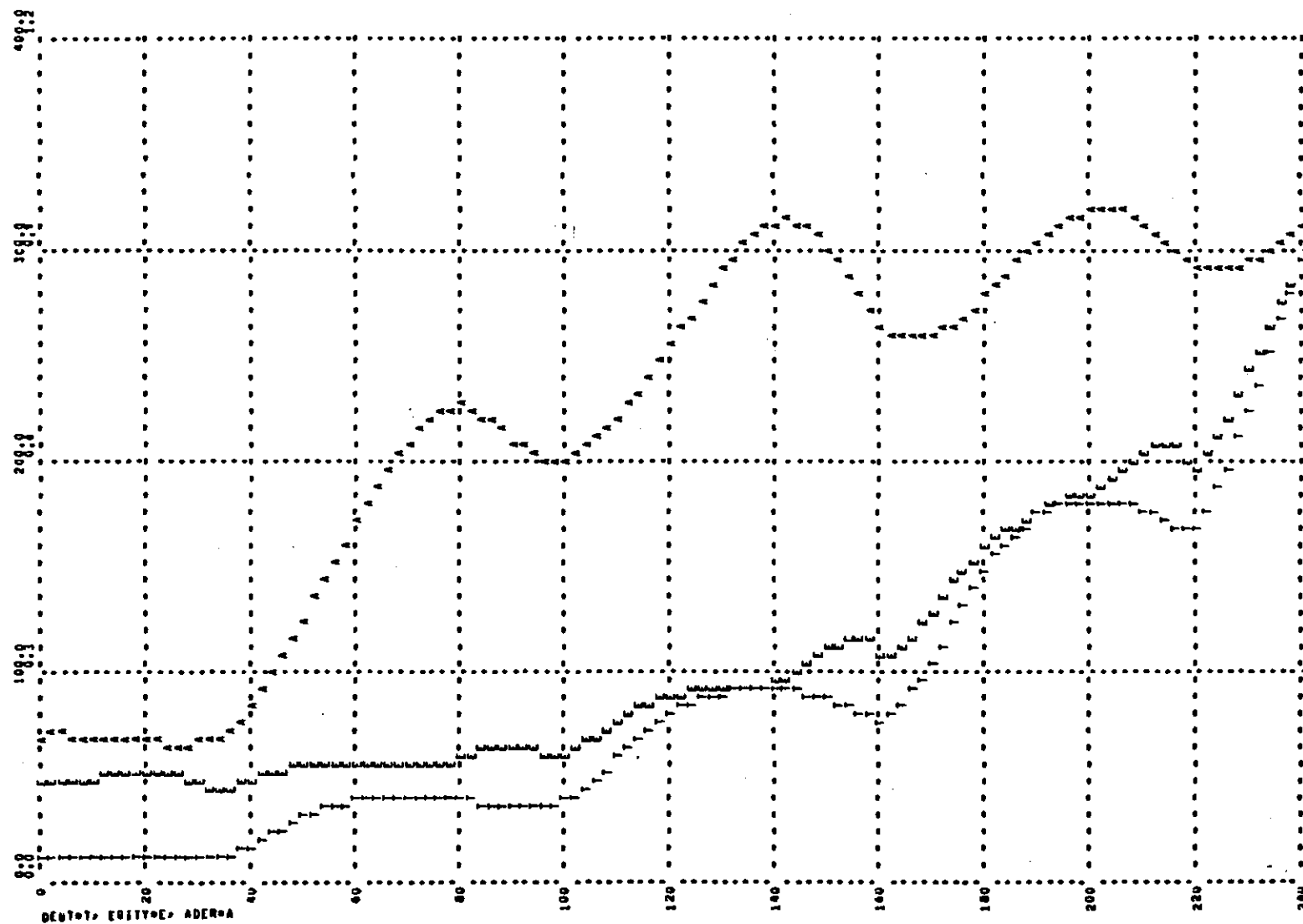


Figure 30. Debt/Equity Behavior - Conservative Ordering Policy  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

Factor (DPLF) have the purpose of ascertaining the importance of operating objectives in the capacity acquisition sector. Since this parameter expresses the relationship management desires to maintain between organizational capacity and demand, a higher value reduces the need to purchase capacity while a lower value necessitates greater capital investments. The outcomes summarized in Table 8 vividly depict the conflicting goals and necessary trade-offs imposed on these decision-makers. All values are cumulative for the interval of interest except for Demand Relative to Potential which is computed at the end of the interval. Any apparent deviations from established trends can be attributed to minor phase shifts which characterized output for the extreme values.

The larger orders associated with efforts to maintain a low passenger load factor create more adverse financial effects upon their receipt. For the cases in which  $DPLF = 0.54$  and  $0.56$ , the severity of these effects may be sufficient to jeopardize the firm's existence. Debt financing exceeds all control limits, and continuous efforts to maintain a low load factor prevent the high profit interval which normally succeeds a period of sustained losses. Although the firm realizes practically one hundred percent of its market potential, demand levels are insufficient to accommodate the increased orders. Hence, financial deterioration is prolonged.

For  $DPLF = 0.58$  the first order produces a severe impact, but the system eventually achieves the same behavior pattern as observed in the basic model which utilized a value of  $0.59$  for DPLF. However, larger orders are necessary to maintain the lower load factor. Since

Table 8. Summary of Experimental Results

## Variations of DPLF

Value of DPLF (dimensionless)	Orders (mill.\$)	Desired Orders (mill.\$)	Profits (mill.\$)	Demand Relative to Potential(%)	Debt (mill. \$)
0.54	1748	4672	(311)	100	630
0.56	1161	4648	(77)	97	428
0.58	872	1497	60	98	345
0.59	762	1006	121	96	238
0.60	680	1000	202	77	136
0.62	636	759	158	75	209
0.64	415	438	155	50	122

no further improvements can be achieved in the market, the extra aircraft must be financed with debt capital rather than retained earnings.

Values greater than 0.59 demonstrate the necessary sacrifice of market position to achieve higher current profits. Orders are deferred as the actual load factor increases and greater profits are realized. When an order is placed, its magnitude is reduced to maintain the high load factor. Consequently the financial impact is lessened, and a more stable earnings pattern results. However, as demonstrated by results in Table 8 for larger values of DPLF, reduced capacity acquisitions may impair the firm's ability to compete in the market. If capacity is insufficient to service demand, market shares shift and the airline experiences a lower growth rate. The absence of significant growth in demand perpetuates reduced capacity acquisitions. Thus no action is prompted to aggressively pursue an increased market. Concurrently, reduced market shares affect earnings and more stringent financial constraints are imposed. Thus, airline decision-makers must constantly weigh short-term profit potential against the long-term capability to compete effectively. This trade-off is an inherent factor in establishing the Desired Passenger Load Factor. The outcomes for all experiments involving variation of endogenous capacity acquisition parameters are summarized in Table 9.

#### System Reaction to Alternative Structures

Whereas previous experimentation involved examination of performance changes produced by variation of one or more parameters, this section presents outcomes derived from structural modifications. These

Table 9. Summary of Experimental Results  
Capacity Acquisition Parameters

Parameter Variation	Outcome	Supporting Figure(s)
1. Sixteen percent reduction of EG.	Smaller orders more frequently. Less financial impact but constraints more severe due to low equity base. Lost market position.	--
2. Sixteen percent increase of EG	Captured maximum market but sustained severe financial oscillations due to large, infrequent orders.	--
3. Twenty-five percent reduction of ORDID.	Increased orders. Financial behavior oscillates severely with debt out of control. Good market position maintained.	25, 26, 27
4. Twenty-five percent increase of ORDID.	Reduced orders. More uniform financial behavior with higher profits. Good market position maintained.	28, 29, 30
5. Fifty percent increase of ORDID.	Greatly reduced orders. More uniform financial performance with tighter controls. Market position lost.	--
6. Thirty-three percent reduction of DD.	No significant change in system performance.	--
7. Thirty-three percent increase of DD.	No significant change in system performance.	--
8. Changes in DPLF.	See Table 8.	--

modifications include elimination of financial constraints, eliminating the inherent delays of capacity acquisition decisions, matching capacity acquisitions with changes in demand and ordering capacity on the basis of current conditions without regard for past actions.

The first structural change investigated involves removal of all financial considerations from the capacity acquisition decision. The outcome, displayed in Figures 31, 32 and 33, reflects larger orders in the absence of financial constraints and a greater availability of capacity to service the market (market position remained close to one hundred percent during the entire interval). However, market limitations prevent similar increases in demand; therefore, the extra costs must be assimilated without offsetting increases in revenues. Financial and operational performance patterns display an increasing amplitude and lengthening period with total profit for the interval being only fifty-three percent of that for the basic model. Comparison of these results with those produced in financial parameter experiments in which the Desired Debt-Equity Ratio (DDER) is greater than or equal to one (see Figure 23) confirms the earlier conclusion that increasing this parameter to one is equivalent to removing all financial constraints.

A number of experiments focused on restructuring the capacity acquisition decision by altering the inherent delays and the information used as inputs to the decision. Results demonstrate without exception the importance of delays in implementing the outputs of this decision process. To place orders for additional aircraft upon the first indication of growth in demand proves to be financially irresponsible even when demand increases are included as a deterministic input. Large

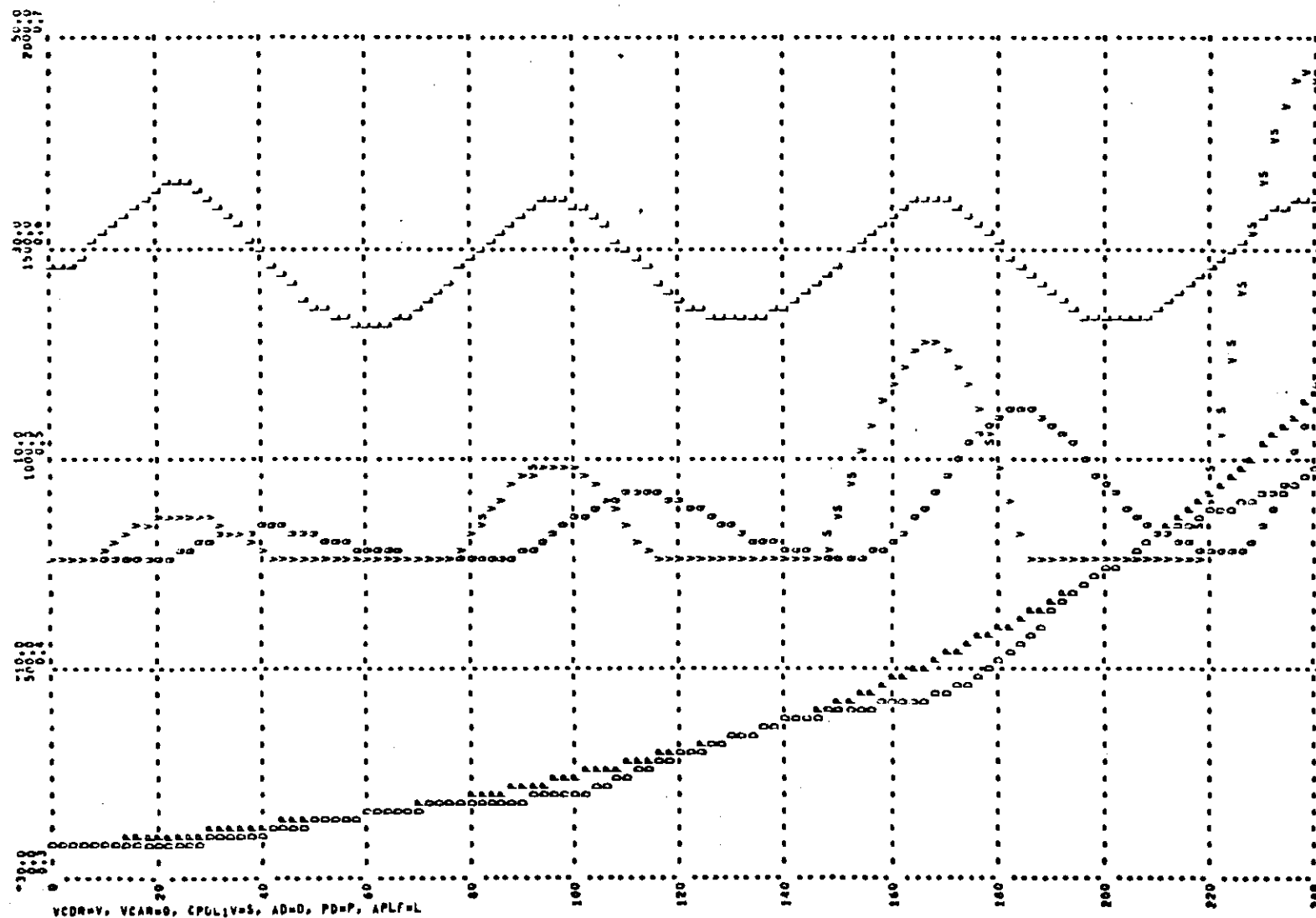


Figure 31. Demand/Capacity Behavior - No Financial Constraint

V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

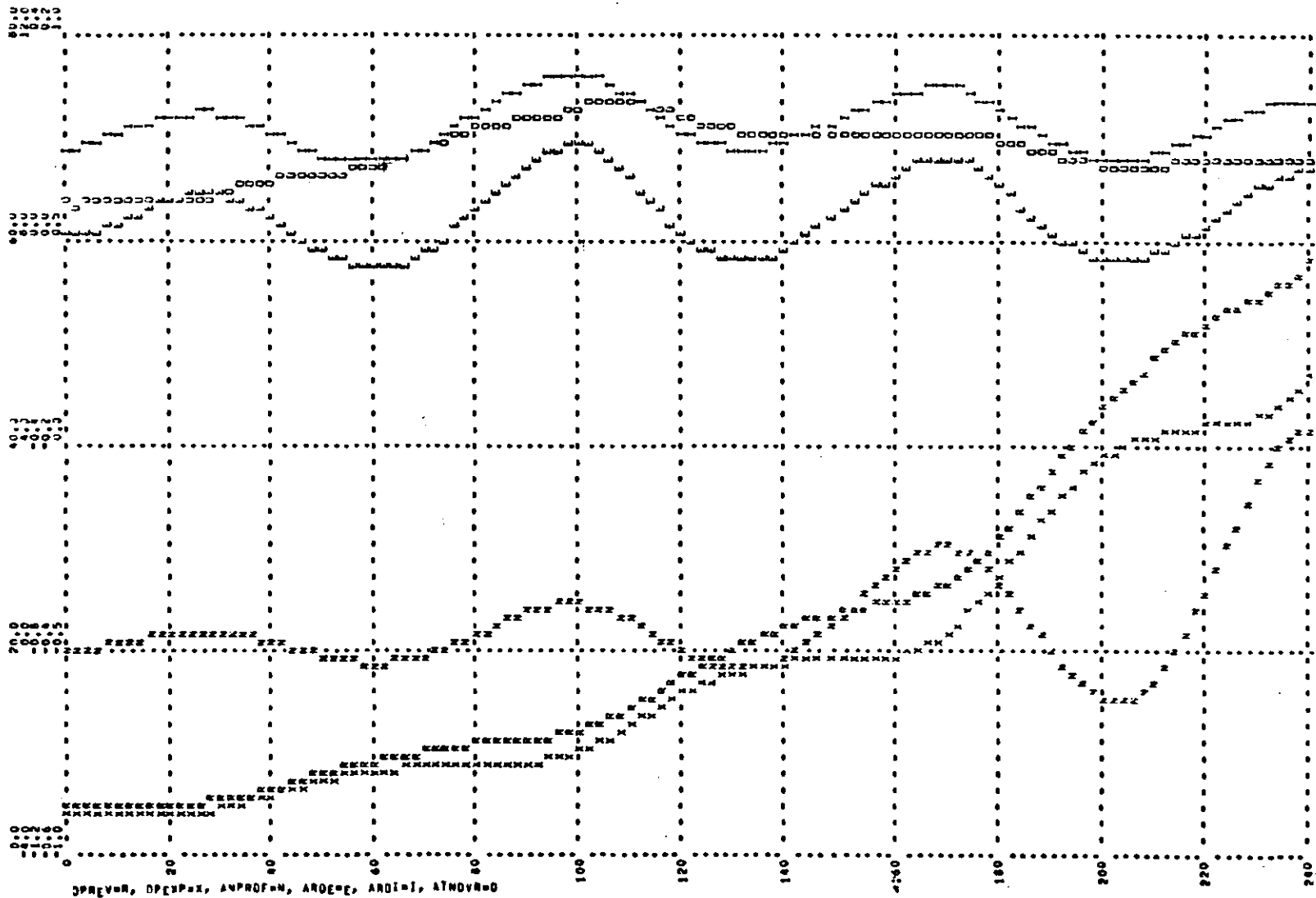


Figure 32. Financial Performance - No Financial Constraints  
R=Oper. Rev. (\$), X=Oper. Exp. (\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover



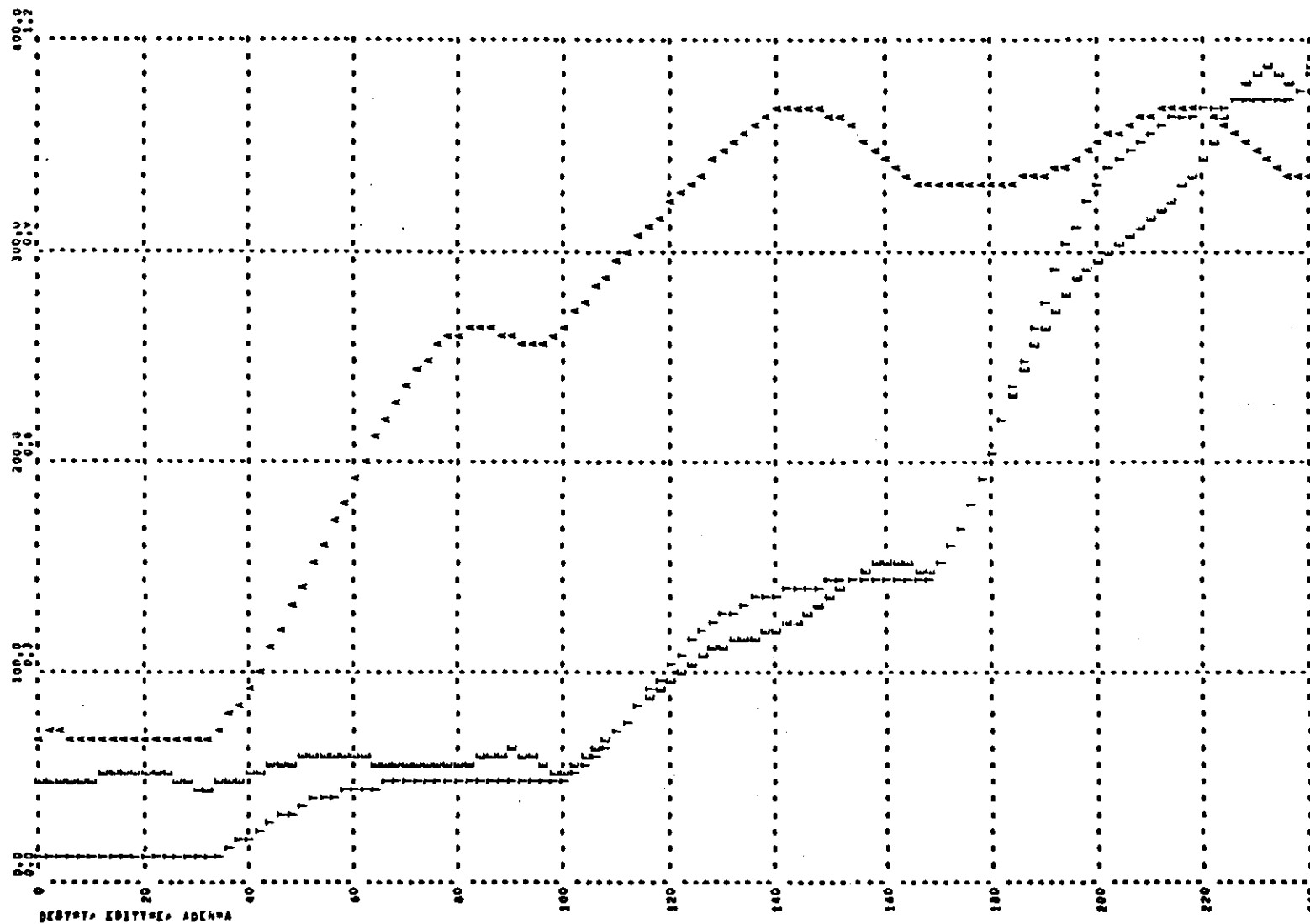


Figure 33. Debt/Equity Behavior - No Financial Constraint  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

orders placed in anticipation of continued growth without regard for market limitations result in severely depressed earnings and extreme debt financing when forecasted growth fails to occur. Although the aggressive placement of orders assures a maximum market share (one hundred percent of potential), profits are only 54 percent of those in the basic model and debt consistently exceeds the absolute limit. Except for an eight month phase shift, the dynamics are indistinguishable from the results produced by a more aggressive ordering policy achieved by parametric variation. These results are presented in Figures 25, 26 and 27. Thus, inherent delays in this decision process provide for continued observation of market behavior and a chance to adjust orders accordingly.

Since the trade-off between a good market position and stable financial performance illustrated by earlier experiments requires close coordination of capacity acquisitions with market increases, system modifications were examined to determine if a better perception of true market conditions could be achieved. One set of experiments with this goal is characterized by orders based on changes in demand rather than the absolute value of demand. Such ordering strategies would be designed to match capacity with demand at some point in time and subsequently match all increases in demand with appropriate increases in capacity. The results of these experiments indicate, however, that the delays introduced for averaging information about the market and measuring past changes are too substantial to provide adequate responsiveness to compete in the airline industry. Although this basis for specifying order magnitude and frequency is theoretically feasible, it

produced a less than favorable market position (78 percent) due to the slow response to demand increases.

Another set of experiments designed to test alternative information flows for capacity acquisition decisions involved basing these decisions on the current relationship between capacity and demand without regard for capacity already on order. With appropriate adjustments in decision parameters, this formulation produced a more favorable outcome with respect to financial performance and operational stability illustrated in Figures 34, 35 and 36. The passenger load factor (L, Figure 34) is consistently higher with a shorter period and reduced amplitude due to smaller, more frequent orders (V, Figure 34). No losses are incurred (N, Figure 35) and the profit generated during the interval is 166 percent of that produced by the basic model.

However, two shortcomings are associated with this alternative:

1. The approach is relatively conservative and produces some deterioration in market position (81 percent compared with 96 percent for the basic model).
2. System performance is much more sensitive to parametric changes.

The second shortcoming is illustrated in Figures 37, 38 and 39. which depict performance resulting from a 25 percent reduction of ORDID representing a more aggressive capacity acquisition program. The extreme orders and financial behavior indicate the system is out of control. A corresponding increase in ORDID representing increased conservatism produces a market position of 52 percent, even less desirable than the original alternative. In either case the final status of the firm would be unacceptable.

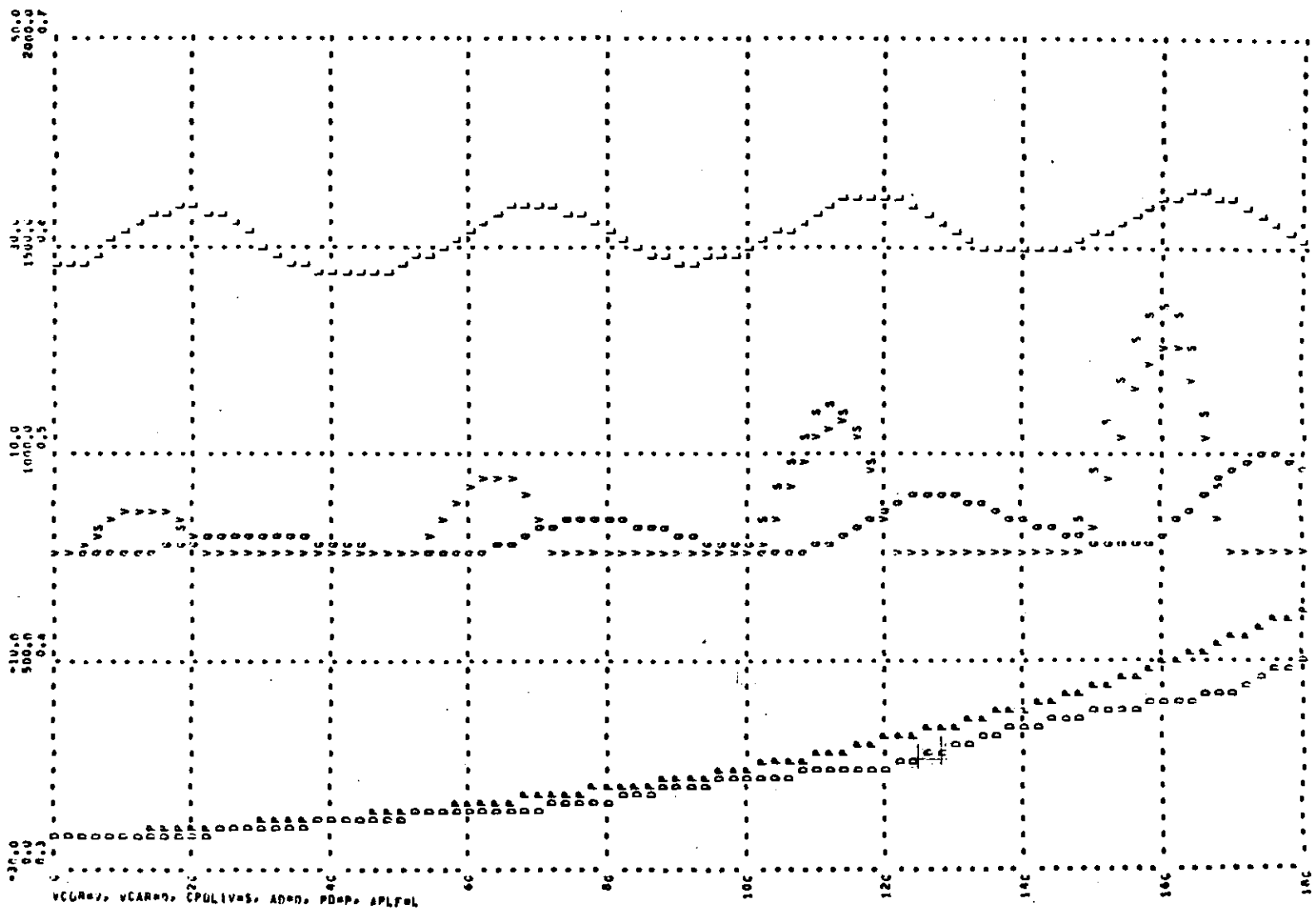


Figure 34. Demand/Capacity Behavior - Revised Information  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

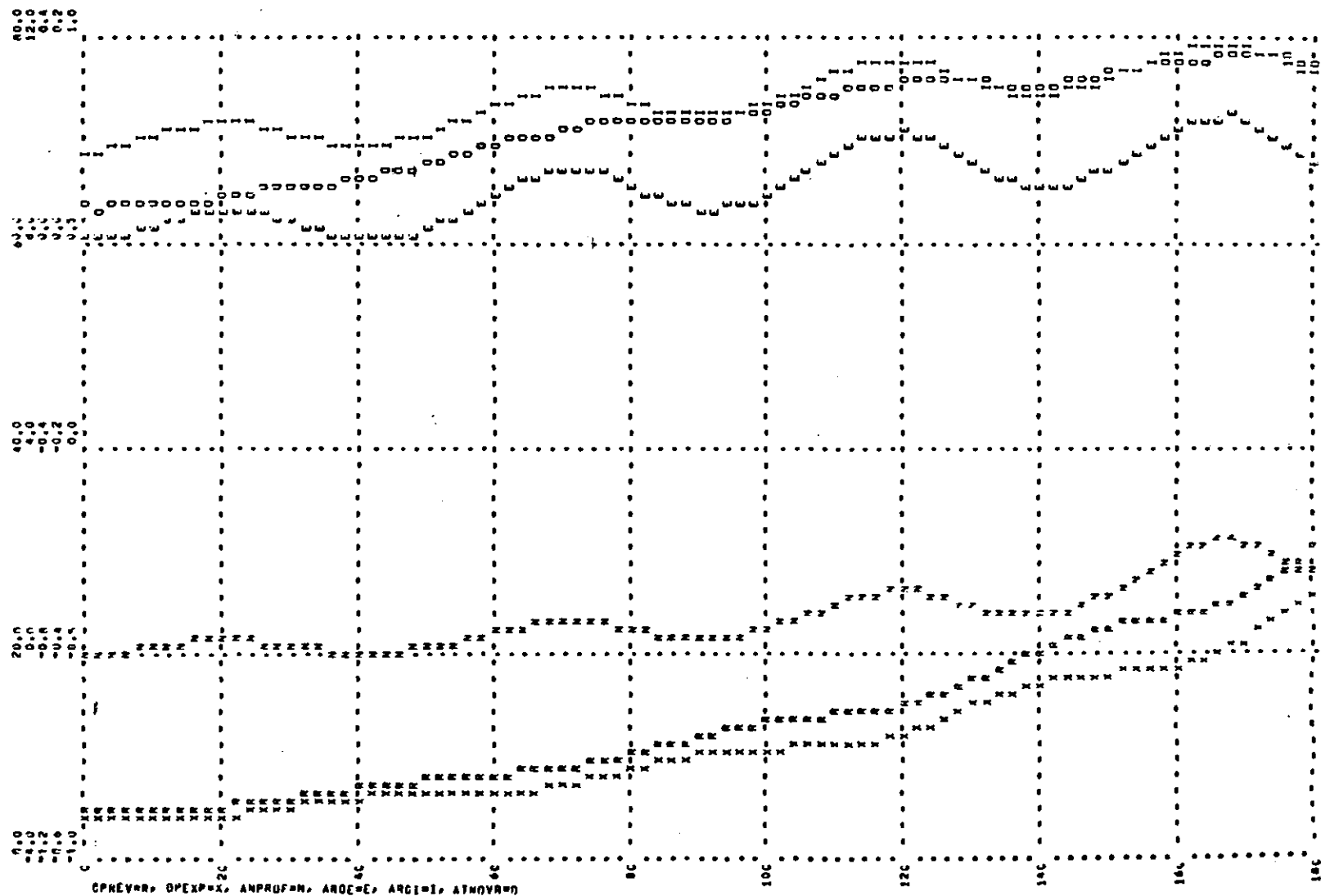


Figure 35. Financial Performance - Revised Information

R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover

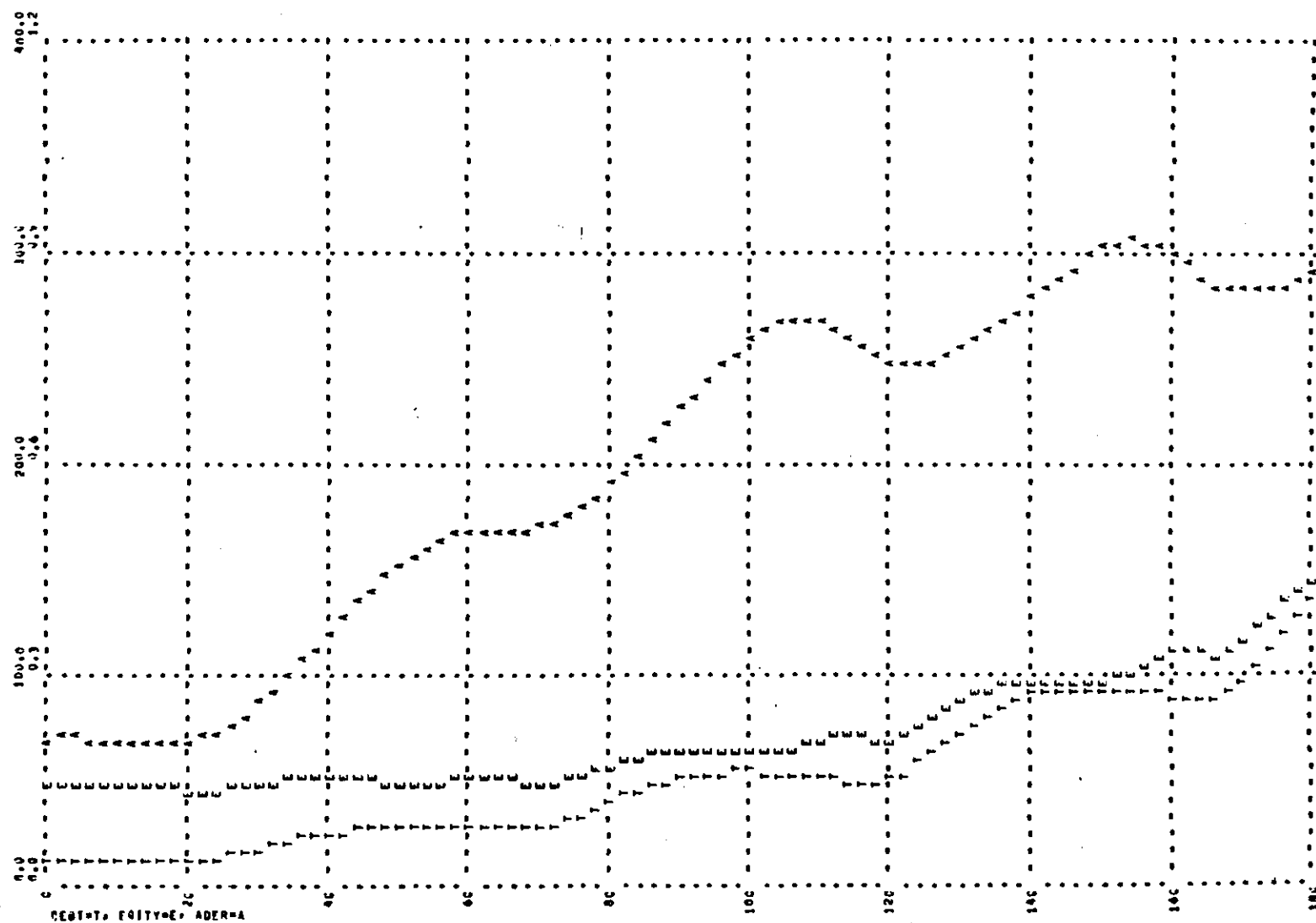


Figure 36. Debt/Equity Behavior - Revised Information  
T = Debt (\$), E = Equity (\$), A = Average Debt-equity Ratio

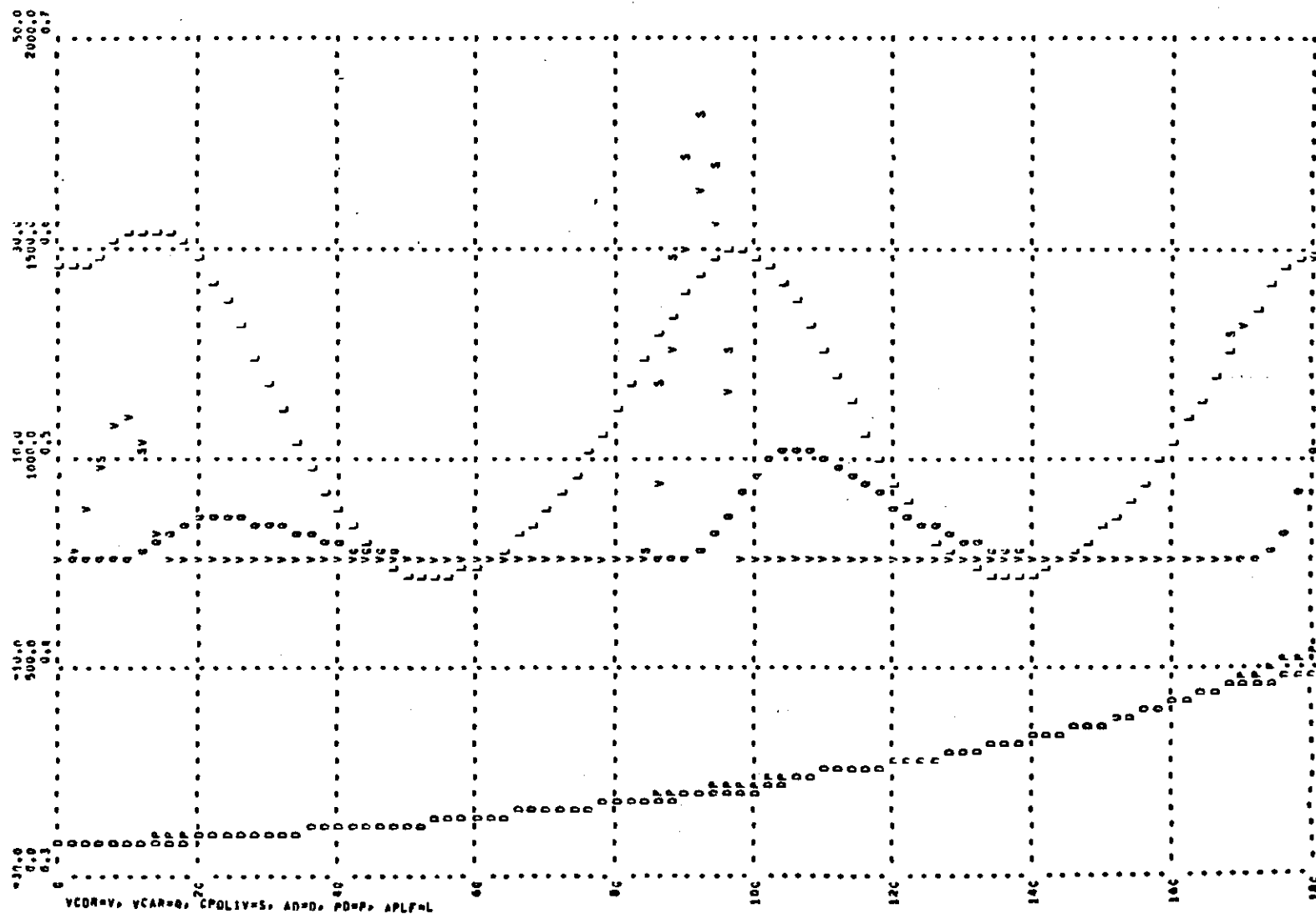


Figure 37. Demand/Capacity Behavior - Revised Information, Parametric Change  
V=Cap. Orders(\$), Q=Cap. Arrivals(\$), S=Desired Cap. Orders(\$), P=Potential Dem.(RPM), D=Actual Dem.(RPM), L=Avg. PLF

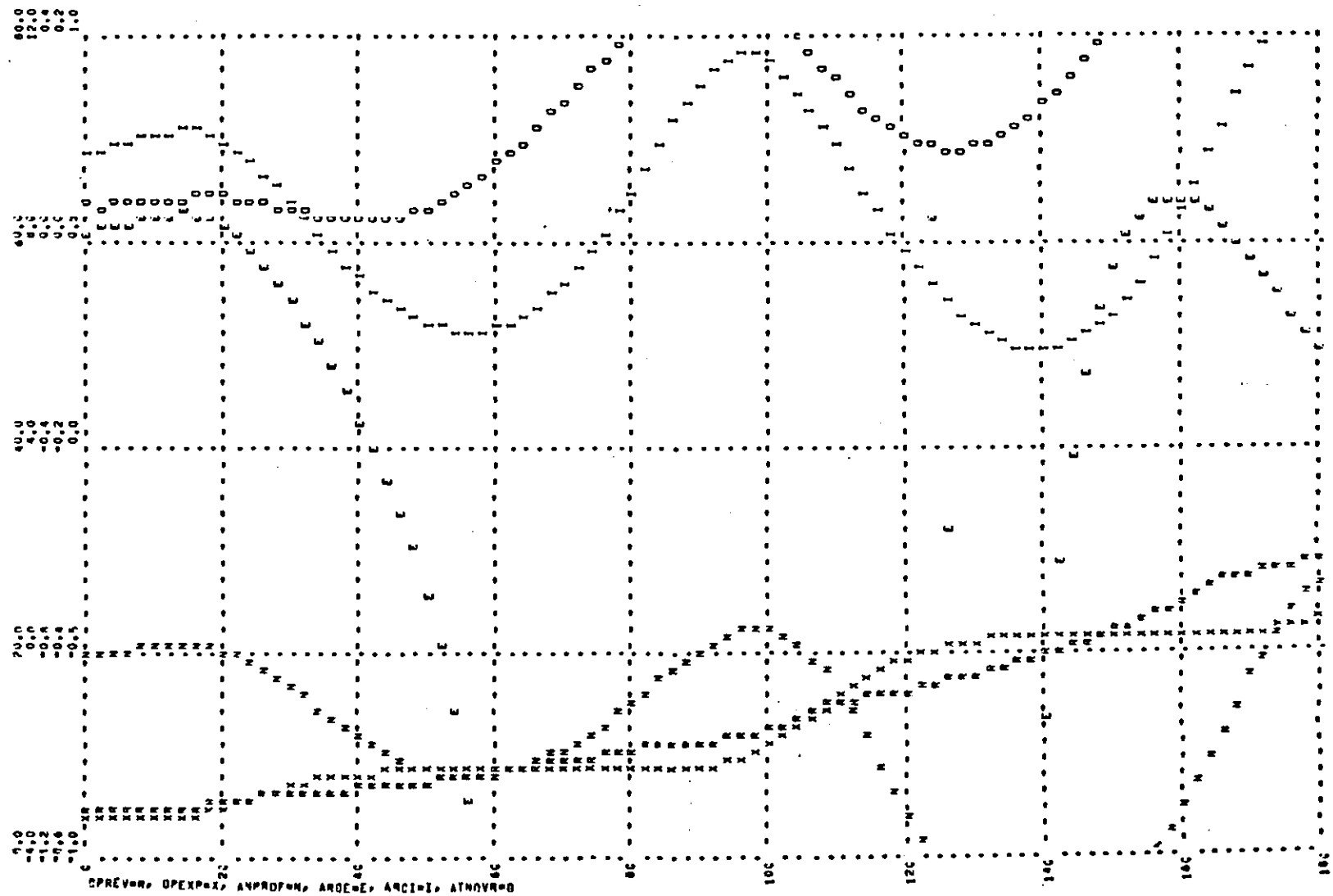


Figure 38. Financial Performance - Revised Information, Parametric Change  
R=Oper. Rev.(\$), X=Oper. Exp.(\$), N=Oper. Profit(\$), E=Return on Equity, I=Return on Investment, O=Investment Turnover



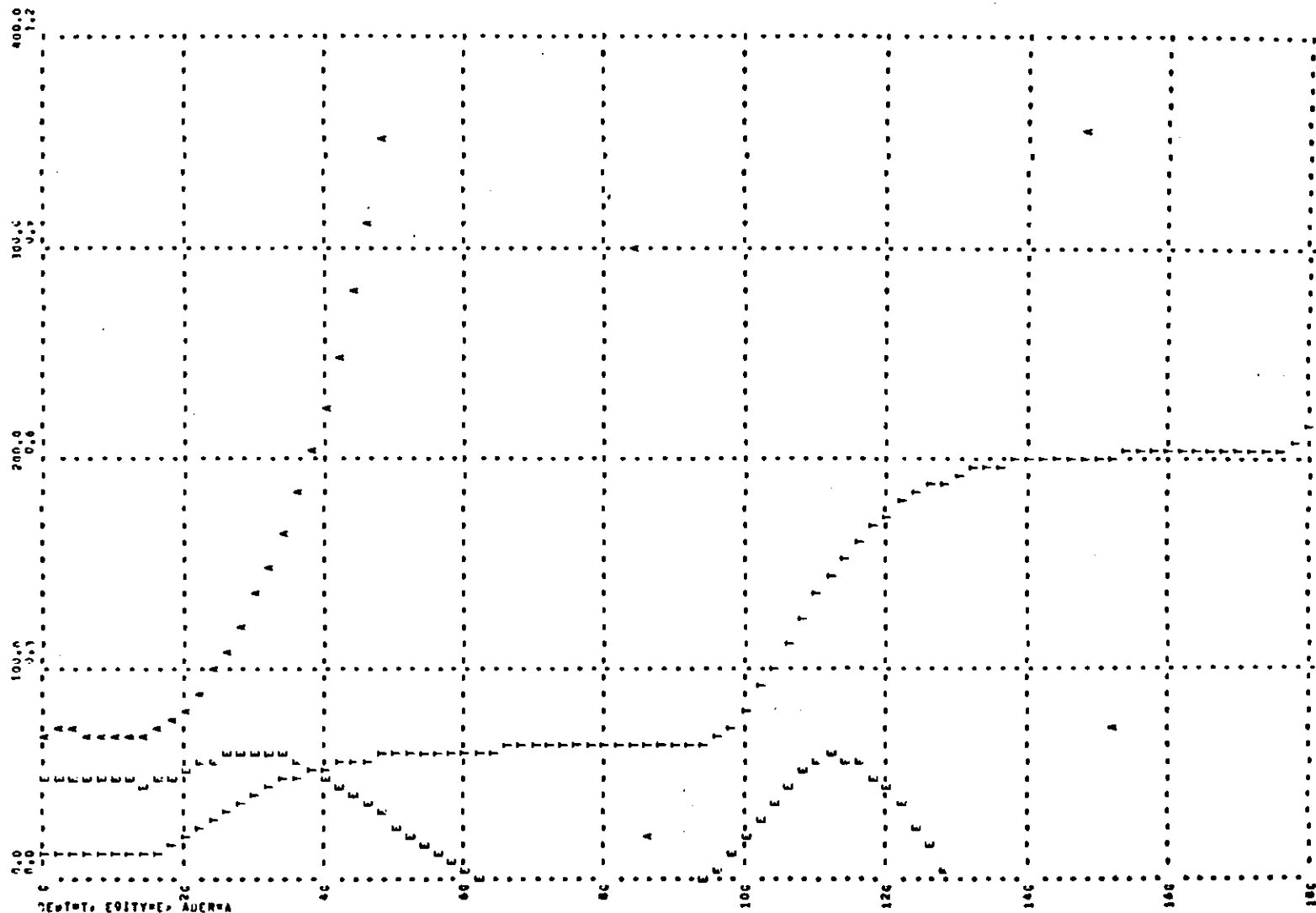


Figure 39. Debt/Equity Behavior - Revised Information, Parametric Change  
 T = Debt (\$), E = Equity (\$), A = Average Debt-Equity Ratio

## CHAPTER VIII

### CONCLUSIONS AND RECOMMENDATIONS

This dissertation reports the results of model development and experimentation designed to accomplish the research objectives identified in Chapter I. These objectives are:

(a) To determine the internal variables and structural relationships accounting for the financial performance of a major domestic airline.

(b) To demonstrate that the characteristic behavior of a system's problem existing in many airlines arises from, and is perpetuated by, the feedback control structure.

(c) To examine the impact of managerial attitudes, judgment and decisions on the system's behavior over time.

(d) To interpret these results and their implications for designing alternative control policies to improve system behavior.

The first two objectives are addressed in the following section on general conclusions. The impact of managerial attitudes, judgment and decisions on the system's behavior over time is summarized as specific conclusions resulting from model experimentation while the implications for designing alternative control policies are presented as recommendations.

#### General Conclusions

The results of this study provide for the conclusion that the

internal variables and structural relationships constituting the model account for the financial performance of a major domestic airline. The model generates representative variable performance from logical decision-making processes within an information feedback network. These processes are based on the same information flows utilized by airline decision-makers in monitoring and controlling relationships between their organizations and their environment.

Behavioral validity was further demonstrated by using parameters for a particular major domestic trunkline (Delta Air Lines, Inc.) and examining model outputs relative to the real world system's performance for the same time interval. Comparison of dynamic behavior characteristics (phasing, amplitudes and periods) and variable growth rates (summarized in Table 2) substantiates the conclusion that the model is a valid representation of the real world system.

Exogenous inputs were then modified by random components to demonstrate that model outputs still possess the dynamic characteristics of the real world system. Observed amplification of only certain frequencies within the broad range of input frequencies permits a conclusion regarding the system's natural period; namely, efforts to maintain an average passenger load factor of fifty-nine percent result in an oscillatory load factor with an average value of sixty percent, an average amplitude of 2.8 percent and an average period of sixty-nine months. There exists a slight dampening effect and a tendency to move toward the desired value; however, this tendency is slight and may be offset in the real world by the impact of technological advances and changes in economic conditions.

The level of aggregation and the feedback relationships between demand for air transportation, capacity acquisition decisions, increases in capacity and financial performance incorporated into the model provide for the conclusion that the model is applicable to any major domestic trunkline in the airline industry. The fact that the model was validated after development using data and parameter estimates for a particular member of the industry strengthens this conclusion.

#### Specific Conclusions

In addition to the broad conclusion offered above, several specific conclusions can be drawn on the basis of model analysis and experimentation. Although these conclusions result from model experiments using parameter estimates based on Delta Air Lines' operations, the nature of the conclusions reflect general system aspects to be considered by all industry members.

#### Exogenous Inputs

Upon subjecting the model to cyclic inputs corresponding to economic cycles of differing severity, observed results indicated high sensitivity to the phasing relationships between the inputs and the system's natural behavior pattern. Since each capacity acquisition program is followed by a period of depressed earnings, the occurrence of an economic recession during this period amplifies the financial difficulties normally incurred. Although the severity of financial crises varies directly with the amplitude of the cyclic economic inputs, the system can cope with those cyclic inputs which are in phase with its natural pattern. However, inputs out of phase with normal system

behavior produce adverse conditions from which recovery is essentially impossible. Thus, one can conclude that (within the ranges considered in these experiments) the managerial decision-maker should be more concerned about when economic conditions are going to change, relative to contemplated capacity acquisition programs, than how much they are going to change.

Experiments in which the underlying growth rate was varied independent of managerial actions demonstrate the effects of inflexible forecasting and decision-making procedures. The system failed to respond sufficiently to match a twenty-five percent increase in market growth and debt went out of control when the system was subjected to a twenty-five percent decrease in growth. Thus, any set of events substantially changing the market's basic growth, such as introduction of a substitute for air transportation, will require a restructuring of forecasting and decision-making processes.

Introduction of increasing costs and passenger mile yields designed to duplicate historical inflationary trends demonstrated that financial performance deteriorates over time even when the operating margin and the unit cost of new capacity remain constant. This condition is attributed to the fact that costs increase simultaneously with the addition of new aircraft to the fleet; whereas, resulting demand and revenue increases are subject to a substantial lag. Introduction of increasing capacity costs produced further deterioration in financial performance.

The above conclusion is substantiated by the results of experiments in which the delay between increasing or improving fleet capacity

and the consumer's recognition and response to this action is varied. Reduction of this delay permits the airline to more quickly recover the capacity investment and purchase new capacity to maintain the increased market share. By decreasing the delay the airline can generate greater profits; however, debt must be maintained at its maximum tolerable level to sustain the operation. Since this market parameter is not subject to direct managerial control, promotional programs designed to inform the consumer of recent capacity acquisitions or technological improvements appear to be justified.

#### Financial Control Sector

Two types of financial control actions were examined in this research: control through the moderation or cessation of capacity acquisitions and control through the retirement of current debt. A general conclusion is that financial control actions in an airline serve as a moderator or dampener for capacity acquisition decision outputs but introduce no unique performance patterns.

Continuing moderation of capacity acquisitions stabilizes financial performance more effectively than the alternative approach consisting of imposing no constraints on orders until financial constraints require a cessation of all orders.

The primary financial objective in terms of altering system performance is the desired relationship between debt and equity. Since an organization's equity base may consist largely of its investment in aircraft, this financial objective, which affects future acquisitions, is based upon the results of past acquisition decisions.

Another conclusion relates to the relative merits of conservative

versus aggressive financial management in the airline industry. Less conservative approaches produce poorer financial performance. Higher profits may be achieved temporarily, but are followed by extended periods of depressed earnings when unconstrained capacity acquisitions produce excess capacity. Conversely, extreme conservatism results in low debt levels, but the airline is unable to maintain its market position due to insufficient capacity. The system stabilizes at a low earnings level, and the airline becomes a candidate for acquisition by a competitor. Based on model experimentation one can conclude that a debt-equity ratio of approximately one-half yields preferred long-term financial performance.

Control actions involving the retirement of current debt prove to be ineffectual unless concomitant actions are taken to reduce capacity acquisitions.

#### Capacity Acquisition Sector

Based on this research it is concluded that the characteristic oscillatory behavior can be attributed to capacity acquisition decision processes. While financial control actions may moderate the effects of these decisions, the financial sector does not create the basic dynamic patterns.

The overwhelming consideration of managerial control in the airline industry stems from the inherent trade-off of a stable financial performance versus a solid market position enhanced by aggressive capacity acquisition policies. Aggressive capacity ordering actions produce larger orders and consequently more severe financial impact when the new aircraft arrive. However, larger orders ensure a greater

long-term earning potential. Conversely, smaller orders resulting from more conservative attitudes reduce the financial stress but may limit the firm's ability to compete effectively in the highly competitive airline industry.

In model experiments involving differing degrees of conservatism in the capacity acquisition sector, more conservative policies resulted in increased profits for the first five years but produced a long-term deterioration of market share which destroyed the firm's earning potential. However, more aggressive acquisition policies and the resulting larger orders created extreme debt conditions requiring severe financial constraints. Due to market limitations, increases in demand and revenues cannot be achieved and excess capacity occurs. This situation produced large losses and made financial management impossible. Thus, as in financial decision-making, a conservative management style in capacity acquisition offers a greater potential for profitable operations but can eventually limit the organization's ability to grow.

The capacity acquisition sector's primary operating objective, the desired relationship between organizational capacity and demand, is represented in the model by the parameter Desired Passenger Load Factor (DPLF). The results of parametric variation emphasize the linkages between capacity acquisition decisions and financial performance. The larger orders associated with efforts to maintain a low passenger load factor created more adverse financial effects upon their receipt. For the cases in which  $DPLF = 0.45$  and  $0.56$ , the severity of these effects may be sufficient to jeopardize the firm's existence. Debt financing exceeded all control limits, and continuous efforts to



maintain a low average load factor prevented the high profit interval which normally succeeds a period of sustained losses. Although the firm realized practically one hundred percent of its market potential, demand levels were insufficient to accommodate the increased orders. Hence, financial deterioration was prolonged.

Values greater than 0.60 demonstrated the necessary sacrifice of market position to achieve higher current profits. Orders were deferred as the actual load factor increased and greater profits were realized. When an order was placed, its magnitude was reduced to maintain the high load factor. Consequently the financial impact was lessened, and a more stable earnings pattern resulted; however, reduced capacity acquisitions may impair the firm's ability to compete in the market. If capacity is insufficient to service demand, market shares shift and the airline experiences a lower growth rate. The absence of significant growth in demand perpetuated reduced capacity acquisitions. Thus no action is prompted to aggressively pursue an increased market. Concurrently, reduced market shares affect earnings and more stringent financial constraints are imposed.

#### Recommendations

Numerous recommendations for further research and analysis can be suggested as logical extensions of the fundamental research presented in this dissertation. The results of this investigation tend to be broad in scope since the decision processes under study represent aggregate activities of numerous decision-making entities. Thus, one set of recommendations pertains to more microscopic studies which might focus on one or more parameters, structural relationships and/or decision

processes included in this research. A second set of recommendations has to do with activities required for implementation of research results. Included in this set are recommendations for second-order experiments involving sensitive parameters and further experimentation with alternative system structures.

#### Extensions of the Research

The immediate accomplishment of this research consists of a macroscopic model which integrates the decision processes and structural relationships of a major domestic airline. This model can be utilized as a framework within which more detailed studies are conducted to improve decision-making. Using this approach the model would provide a mechanism for evaluating the impact of revised decision processes on all parts of the organization and would prevent the sub-optimization often resulting from such efforts conducted without a general framework.

Based on the conclusions regarding the capacity acquisition process drawn from this study, it is recommended that further research at a more detailed level be focused on these decisions and their information inputs. For example, a more detailed study of the capacity acquisition sector might include consideration of the allocation of aircraft to different routes, the interaction of various aircraft capabilities and route requirements and alternative plans for higher utilization; whereas, the present study is concerned with total system capacity as a single state. Also, based on the success achieved in this study with alternative structures for these decisions, additional analysis of this sector should focus on alternative forecasting methodologies and their relative capabilities to generate future demand estimates since seemingly

insignificant forecast errors produce a substantial impact on financial performance. One reference which might provide background for such research is Calderone's survey of air travel forecasting techniques<sup>45</sup>. This research should also consider forecasting horizons and the degree to which forecasts are discounted for uncertainty prior to use in capacity acquisition decisions.

Due to the close linkage of current airline decision processes and past demand growth rates, it is recommended that a substantial effort be invested in thinking about the future of the industry. Although some members of the industry have diversified into related industries, the overriding tendency is to continue doing more of the same. In the author's opinion, a major rethinking and broadening of the industry's definition is necessary to provide a basis for actions designed to reverse the trend toward a fully subsidized oligopoly or a Government-owned air transportation system.

#### Implementation of Research Findings

Recommendations can also be made relative to implementing particular research findings. Once such recommendation has to do with the importance of the firm's potential market and its current position relative to this potential. In addition to measuring actual demand, a program for collecting data on unfulfilled demand and stand-by demand is recommended to provide for measuring the unrealized market potential which might be captured by increased capacity.

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<sup>45</sup> Ralph A. Calderone, A Digest and Assessment of Air Travel Forecasting Techniques, Berkeley: The Institute of Transportation and Traffic Engineering, University of California, 1967.

Given such a procedure for establishing the airline's position within the market, a relatively conservative financial posture and capacity acquisition program is recommended. If such an approach is adopted, organizational growth should be closely monitored and compared with growth achieved by competitors and the industry to prevent stabilization at a level of operation which impairs the organization's long-term earnings potential.

An aggressive promotional program is also recommended, particularly when a significant improvement in aircraft technology or availability has been recently achieved.

This study demonstrates that a passenger load factor of approximately sixty percent is preferred with the current constraints and operating objectives; however, further research in this area is recommended. In particular, second order studies involving simultaneous variation of this objective and the desired debt-equity ratio should be pursued. Studies in which the desired debt-equity ratio and capacity acquisition parameters (EG and ORDID) are varied simultaneously are also recommended.

Finally it is recommended that airline decision-makers formulate and implement dynamic control policies. That is, decision parameters should be based on current information about inflationary trends and economic cycles to insure that current actions are appropriate even when environmental conditions are changing.

## APPENDIX A

## DATA

Table 10. Operating Statistics - Delta Air Lines, Inc.<sup>46</sup>

Date	RPM/mon. (mill.)	ASM/mon. (mill.)	Cap. Orders (mill. \$)	Cap. Arrivals (mill. \$)	PLF
1954	60	110	-	-	57.3
1955	80	130	-	-	62.3
1956	90	140	100	2	62.6
1957	110	180	0	12	58.9
1958	120	210	7	32	56.8
1959	130	220	0	0	59.3
1960	150	250	8	5	58.0
1961	170	280	33	75	60.0
1962	200	340	21	16	58.1
1963	250	410	56	22	60.6
1964	280	470	24	17	60.1
1965	320	570	24	18	56.7
1966	420	680	160	51	61.0
1967	530	810	194	62	66.2
1968	590	1000	79	99	59.4
1969	690	1230	-	150	55.9
1970	780	1570	-	28	50.6

<sup>46</sup>The above data were derived from information in:

Air Carrier Traffic Statistics, op. cit.

Delta Air Lines, Inc. Annual Report, op. cit.

Handbook of Airline Statistics, op. cit.

Moody's Transportation Manual, op. cit.

Table 11. Monthly Financial Statistics - Delta Air Lines, Inc.<sup>47</sup>

Date	Pass.Rev. (mill.\$)	Oper.Exp. BD & Int. (mill.\$)	Oper.Prof. BD & Int. (mill.\$)	Net Prof. Bef.Taxes (mill.\$)	Debt (mill.\$)
1954	3.8	3.6	0.2	(0.4)	24.7
1955	4.5	3.9	0.6	(0.1)	23.6
1956	5.0	4.4	0.6	0.1	11.4
1957	6.0	5.5	0.5	(0.1)	17.4
1958	6.7	6.4	0.3	(0.5)	30.0
1959	7.8	7.1	0.7	(0.1)	35.0
1960	9.1	8.4	0.7	(0.4)	55.0
1961	11.2	9.9	1.3	(0.2)	57.5
1962	13.0	11.4	1.6	(0.1)	62.5
1963	15.9	13.1	2.8	0.9	60.0
1964	17.1	14.0	3.0	1.1	50.0
1965	19.5	15.9	3.6	1.6	55.6
1966	24.3	18.9	5.4	3.0	90.2
1967	30.2	22.9	7.3	4.4	89.7
1968	33.0	27.0	6.4	2.6	140.2
1969	39.2	31.4	7.8	2.1	222.5
1970	47.1	38.3	8.8	1.7	229.9

<sup>47</sup>The above data were derived from information in:

Air Carrier Financial Statistics, op. cit.

Delta Air Lines, Inc. Annual Report, op. cit.

Handbook of Airline Statistics, op. cit.

Moody's Transportation Manual, op. cit.

## APPENDIX B

## LIST OF VARIABLES AND PARAMETERS

Capacity Acquisition Sector

ACARD	-	Average Capacity Arrival Rate Delay (months)
ACORD	-	Average Capacity Order Rate Delay (months)
ACPAR	-	Average Capacity Arrival Rate (millions of available seat miles per month)
ACPOR	-	Average Capacity Order Rate (millions of available seat miles per month)
AD	-	Actual Demand (millions of revenue passenger miles per month)
APD	-	Average Potential Demand (millions of revenue passenger miles per month)
APDD	-	Average Potential Demand Delay (months)
APLF	-	Average Passenger Load Factor (dimensionless)
APLFD	-	Average Passenger Load Factor Delay (months)
ATCAD	-	Average Total Capacity Delay (months)
ATCAP	-	Average Total Capacity (millions of available seat miles per month)
AVAIL	-	Availability (dimensionless)
AVDMD	-	Average Demand Delay (months)
AVEFT	-	Availability Effect (dimensionless)
AVGDM	-	Average Demand (millions of revenue passenger miles per month)
CAPAR	-	Capacity Arrival Rate (millions of available seat miles per month)
CAPOD	-	Capacity Order Desired (millions of available seat miles per month)

CAPOO	-	Capacity on Order (millions of available seat miles per month)
CDD	-	Capacity Delivery Delay (months)
CPOBR	-	Capacity Obsolescence Rate (millions of available seat miles per month)
CRD	-	Consumer Recognition Delay (months)
CRT	-	Competition Reaction Time (months)
DEXPN	-	Desired Expansion (millions of available seat miles per month)
DPLF	-	Desired Passenger Load Factor (dimensionless)
EG	-	Expansion Gain (months)
EXOG1	-	Exogenous Growth in Potential Demand (millions of revenue passenger miles per month)
IEXPN	-	Indicated Expansion (millions of available seat miles per month)
ORDID	-	Order Interval Desired (months)
PD	-	Potential Demand (millions of revenue passenger miles per month)
PDG	-	Potential Demand Growth (dimensionless)
PDINC	-	Potential Demand Increase Due to New Capacity (millions of revenue passenger miles per month)
PDTCR	-	Potential Demand Total Capacity Ratio (dimensionless)
PLF	-	Passenger Load Factor (dimensionless)
RI	-	Rate of Increase in Potential Demand (millions of revenue passenger miles per month)
RL	-	Rate of Loss of Potential Demand (millions of revenue passenger miles per month)
RLAUX	-	Rate of Loss in Potential Demand Auxiliary (millions of revenue passenger miles per month)
RLD	-	Rate of Loss Delay (months)
TCAP	-	Total Capacity (millions of available seat miles per month)
TDS	-	Total Demand Satisfied (millions of revenue passenger miles per month)



TEST - Test Condition  
 UL - Useful Life (months)

Financial Control Sector

ACDEP - Accumulated Depreciation (millions of dollars)  
 ADTER - Absolute Debt Equity Ratio (dimensionless)  
 ADTLIM - Absolute Debt Limit (millions of dollars)  
 CAPOR - Capacity Order Rate (available seat miles per month)  
 CAPORA - Capacity Order Rate Auxiliary (available seat miles per month)  
 CAPORD - Capacity Order Desired (available seat miles per month)  
 CORDLY - Correction Delay (months)  
 CPOLL - Capacity Order Limit One (available seat miles per month)  
 COOLIV - Capacity Order Limit One Value (millions of dollars)  
 CPOL2 - Capacity Order Limit Two (available seat miles per month)  
 CXREQ - Capital Expenditures Required (millions of dollars)  
 DAR - Debt Acquisition Rate (millions of dollars)  
 DARI - Debt Acquisition Rate Indicated (millions of dollars)  
 DBTPOS - Debt Position (millions of dollars)  
 DD - Decision Delay (months)  
 DDER - Desired Debt-Equity Ratio (dimensionless)  
 DDTLIM - Desired Debt Limit (millions of dollars)  
 DEBT - Debt (millions of dollars)  
 DEPCR - Depreciation Credit (millions of dollars)  
 DEPRT - Depreciation Rate (millions of dollars)  
 DL - Depreciation Life (months)  
 DRD - Debt Retirement Delay (months)

DRR	- Debt Retirement Rate (millions of dollars)
DRRA1	- Debt Retirement Rate Auxiliary One (millions of dollars)
DRRA2	- Debt Retirement Rate Auxiliary Two (millions of dollars)
DRRD	- Debt Retirement Rate Desired (millions of dollars)
DRRI	- Debt Retirement Rate Indicated (millions of dollars)
EQITY	- Stockholders' Equity (millions of dollars)
FCCA	- Financial Constraint on Capacity Acquisitions (available seat miles per month)
FNCORR	- Financial Correction (millions of dollars)
FNINPT	- Financial Input (millions of dollars)
IF	- Internal Funds (millions of dollars)
IFA	- Internal Funds Available (millions of dollars)
IFCC	- Internal Funds Control Constant (dimensionless)
IFCX	- Internal Funds for Capital Expenditures (millions of dollars)
IFCXA	- Internal Funds for Capital Expenditures Auxiliary (millions of dollars)
IFCXI	- Internal Funds for Capital Expenditures Indicated (millions of dollars)
IFI	- Internal Funds Initial (millions of dollars)
IFU	- Internal Funds Used (millions of dollars)
INTR	- Interest Rate (dimensionless)
INTXP	- Interest Expense (millions of dollars)
MINAUX	- Minimum Internal Funds Auxiliary (millions of dollars)
MINIF	- Minimum Internal Funds (millions of dollars)
NVCAP	- Net Value of Capacity (millions of dollars)
OPEXP	- Operating Expense (million dollars per month)
OPREV	- Operating Revenue (million dollars per month)

PDPTD	-	Proportion Depreciated (dimensionless)
PMYLD	-	Passenger Mile Yield (dollars per revenue passenger mile)
TCPOL1	-	Total Capacity Order Limit One Value (millions of dollars)
TVCAR	-	Total Value of Capacity Arrival Rate (millions of dollars)
TVCOR	-	Total Value of Capacity Order Rate (millions of dollars)
UCC	-	Unit Cost of Capacity (dollars per available seat miles per month)
UOPC	-	Unit Operating Cost (dollars per available seat mile)
VCAR	-	Value of Capacity Arrival Rate (millions of dollars)
VCOR	-	Value of Capacity Order Rate (millions of dollars)

Performance Evaluation Sector

ADER	-	Average Debt Equity Ratio (dimensionless)
ADERD	-	Average Debt Equity Ratio Delay (months)
ANPRFD	-	Average Net Profit Delay (months)
ANPROF	-	Average Net Profit (millions of dollars)
AROE	-	Average Return on Equity (dimensionless)
AROED	-	Average Return on Equity Delay (months)
AROI	-	Average Return on Investment (dimensionless)
AROID	-	Average Return on Investment Delay (months)
ATNOVR	-	Average Investment Turnover (dimensionless)
ATOVRD	-	Average Investment Turnover Delay (months)
DER	-	Debt Equity Ratio (dimensionless)
GRASTS	-	Gross Assets (millions of dollars)
NPROF	-	Net Profit (millions of dollars)
OPROF	-	Operating Profit (millions of dollars)
ROE	-	Return on Equity (dimensionless)

ROI - Return on Investment (dimensionless)  
TNOVR - Investment Turnover (dimensionless)  
TPROF - Total Profit (millions of dollars)

## APPENDIX C

## LIST OF MODEL EQUATIONS

## AIRLINE MANAGEMENT CONTROL SYSTEM MODEL

## CAPACITY ACQUISITION SECTOR

```

1L PD.K=PD.J+(DT)*(RI.JK-RL.JK)
6N PD=75
8H RI.KL=PDINC.K+EXOG1.K+TEST.K
12A EXOG1.K=(PDG)(PD.K)
C PDG=0.0135
6A TEST.K=0
39H RL.KL=DELAY3(RLAUX,JK,CRT)
C CRT=12
20A RLAUX.K=ACPOR.K/RLD
C RLD=4
3L ACPOR.K=ACPOR.J+(DT)*(1/ACORD)(CAPOR,JK-ACPOR,J)
6N ACPOR=0
C ACURD=24
20A PDINC.K=ACPAR.K/CRD
C CRD=12
3L ACPAR.K=ACPAR.J+(DT)*(1/ACARD)(CAPAR,JK-ACPAR,J)
6N ACPAR=0
C ACARD=2
39H CAPAR.KL=DELAY3(CAPOR,JK,CDD)
C CDD=20
1L TCAP.K=TCAP.J+(DT)(CAPAR,JK-CPOBR,JK)
20N TCAP=PD/UPLF
C DPLF=0.59
20R CPOBR.KL=TCAP.K/UL
C UL=180
1L ATCAP.K=ATCAP.J+(DT)*(1/ATCAD)(TCAP,J-ATCAP,J)
6N ATCAP=TCAP
C ATCAD=6
12R AD.KL=(PD.K)(AVAIL,K)
58A AVAIL.K=1ABHL(AVEFT,PDTCR.K,0,1.6,0.1)
C AVEFT*=1/1/1/1/1/1/1/1/.90/.80/.70/.60/.50/.50/.50/.50/.50/.50
3L APD.K=APU.J+(DT)(1/APOD)(PD,J-APD,J)
6N APD=PD
C APOD=2
20A PDTCR.K=APD.K/ATCAP.K
1L TDS.K=TDS.J+(DT)(AD,JK-0)
6N TDS=0
20A PLF.K=AD,JK/TCAP.K
3L APLF.K=APLF.J+(DT)(1/APLFD)(PLF,J-APLF,J)
6N APLF=DPLF
C APLFD=12
3L AVGDM.K=AVGDM.J+(DT)(1/AVDMD)(AD,JK-AVGDM,J)
6N AVGDM=PD
C AVDMD=4
1L CAPOC.K=CAPOD.J+(DT)(CAPOR,JK-CAPAR,JK)
6N CAPOC=0
21A CAPOC.K=(1/ORDID)(DEXPN,K-CAPOC,K)
C ORDID=24
12A DEXPN.K=(EG)(IEXPN,K)
C EG=19
27A IEXPN.K=(AVGDM,K/DPLF)-ATCAP,K

```

## FINANCIAL CONTROL SECTOR

```

12R  OPREV.KL=(AD.JK)(PMYLD)
C    PMYLD=0.06
12R  OPEXP.KL=(TCAP.K)(UOPC)
C    UOPC=0.03
52L  IF.K=IF.J+(DT)(OPREV.JK-OPEXP.JK-IFCX.JK-INTXP.J)
6N   IF=IF1
C    IF1=9.6
12A  INTRP.K=(INTR)(DEBT.K)
C    INTR=0.005
56A  MINIF.K=MAX(MINAX.K,IF1)
27A  MINAX.K=(DEBT.K/IFCC)-NVCAP.K
C    IFCC=0.5
7A   IFA.K=IF.K-MINIF.K
56A  IFU.K=MAX(IFA.K,0)
54A  IFCXI.K=MIN(IFA.K,CXREQ.K)
13R  CXREQ.K=(UCC)(CAPAR.JK)(DT)
C    UCC=0.65
56A  IFCXA.K=MAX(IFCXI.K,0)
20R  IFCX.KL=IFCXA.K/DT
7A   DARI.K=CCREQ.K-IFU.K
56R  DAR.KL=MAX(DARI.K,0)
1L   DEBT.K=DEBT.J+(DT)(DAR.JK-DRR.JK)
6N   DEBT=10
54R  DRR.KL=MIN(DRRI.K,DEBT.K)
20A  DRRI.K=DRRD.K/DRD
56A  DRRA1.K=MAX(-DARI.K,0)
56A  DRRA2.K=MAX(DRTPUS.K,0)
7A   DRTPUS.K=DEBT.K-DDTLIM.K
54A  DRRD.K=MIN(DRRA1.K,DRRA2.K)
C    DRD=24
12R  VCOR.KL=(UCC)(CAPOR.JK)
1L   TVCOR.K=1VCOR.J+(DT)(VCOR.JK-0)
6N   TVCOR=0
12R  VCAR.KL=(UCC)(CAPAR.JK)
1L   TVCAR.K=1VCAR.J+(DT)(VCAR.JK-0)
6N   TVCAR=0
56R  CAPOR.KL=MAX(CAPORA.K,0)
27A  CAPORA.K=(-FNINPT.K/UCC)+CPOL1.K
56A  CPOL1.K=MAX(CAPORD.JK,0)
12R  CPOL1V.KL=(UCC)(CPOL1.K)
1L   TCPOL1.K=1CPOL1.J+(DT)(CPOL1V.JK-0)
6N   TCPOL1=0
39R  CAPORD.KL=DELAY3(CAPCD.JK,DD)
C    DD=6
56A  FNINPT.K=MAX(FNCORR.K,0)
21A  FNCORR.K=(1/CORLDY)(DEBT.K-DDTLIM.K)
C    CORLDY=9
12A  DDTLIM.K=(DDER)(EQUITY.K)
C    DDER=0.5
8A   EQUITY.K=IF.K+NVCAP.K-DEBT.K
14A  NVCAP.K=ACDEP.K+(UCC)(TCAP.K)
1L   ACDEP.K=ACDEP.J+(DT)(DEPRT.JK-DEPCR.K)
13N  ACDEP=(0.42)(UCC)(TCAP)
46R  DEPRT.KL=(TCAP.K)(UCC)(PDPTD)/((DL)(1)(1))
C    PDPTD=0.90
C    DL=120
13R  DEPCR.KL=(CPORH.K)(UCC)(PDPTD)
56A  CPOL2.K=MAX(FCCA.K,0)
24A  FCCA.K=(1/UCC)(ADTLIM.K-DEBT.K+IFA.K)
12A  ADTLIM.K=(ADTER)(EQUITY.K)
C    ADTER=1.0

```

## PERFORMANCE EVALUATION SECTOR

```

20A  DER,K=DEBT,K/EQITY,K
3L   ADER,K=ADER,J+(DT)*(1/ADERD)*(DER,J-ADER,J)
6N   ADER=0.21
C    ADERD=12
44A  ROE,K=(12)*(NPROF,K)/EQITY,K
3L   AROE,K=AROE,J+(DT)*(1/AROEU)*(ROE,J-AROE,J)
6N   AROE=0.01
C    ARUED=12
44A  ROI,K=(12)*(OPROF,K)/GRASTS,K
8A   GRASTS,K=EQITY,K+ACDEP,K+DEBT,K
3L   AROI,K=AROI,J+(DT)*(1/AROID)*(ROI,J-AROI,J)
6N   AROI=0.09
C    AROID=12
44A  TNOVR,K=(12)*(OPREV,JK)/GRASTS,K
3L   ATNOVR,K=ATNOVR,J+(DT)*(1/ATOVRD)*(TNOVR,J-ATNOVR,J)
6N   ATNOVR=0.59
C    ATOVRD=12
1L   TPROF,K=TPROF,J+(DT)*(NPROF,JK-0)
6N   TPROF=0
8R   NPROF,KL=OPROF,K-DEPRT,JK-INTXP,K
7A   OPROF,K=OPREV,JK-OPEXP,JK
3L   ANPROF,K=ANPROF,J+(DT)*(1/ANPRFD)*(NPROF,JK-ANPROF,J)
C    ANPRFD=12
6N   ANPRCF=0

PLOI  VCOR=V,VCAR=0,CPOLIV=S(-30,50)/AD=D,PD=P(0,2000)/APLF=L(.30,.70)
PLUT  OPREV=R,OPEXP=X(0,80)/ANPROF=N(-4,12)/AROE=E(-1.2,0.4)/AROI=I(-0.6
X1     ,0.2)/ATNOVR=D(-1.0,1.0)
PLUT  DEBT=T,EQITY=E(0,400)/ADER=A(0,1.2)
SPEC  DT=.25/LENGTH=240/PRIPER=40/PLTPER=2

```

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## VITA

Richard Lee Leatherwood was born in Maryville, Tennessee on April 22, 1939. He is the son of Frances Feezell Leatherwood and Alvin Alexander Leatherwood. He graduated from Maryville High School in Maryville, Tennessee, in June 1957.

In September 1957, he began undergraduate studies at the University of Tennessee in Knoxville, Tennessee. While attending Tennessee he was elected to Who's Who Among Students in American Universities and Colleges, 1960-1961 and Omicron Delta Kappa (honorary scholarship-leadership society). He served as president of the Kappa Sigma Social Fraternity and participated in the United States Army Reserve Officer Training Corps from which he received the Distinguished Military Student Award. On July 22, 1961, Mr. Leatherwood was married to the former Mary Ann Anthony of Maryville, Tennessee, daughter of Mr. and Mrs. John W. Anthony. He graduated from Tennessee with a Bachelor of Science degree in Industrial Management in December, 1962, and was commissioned as a second lieutenant in the United States Army.

After completing his undergraduate studies, Mr. Leatherwood was accepted into the graduate program of the Statistics Center at Rutgers - The State University, New Brunswick, New Jersey. During his graduate studies he taught in the Statistics Center and in the School of Business. During the summer of 1963, he served as a mathematical statistician for the U. S. Naval Supply Research and Development Facility in Bayonne, New Jersey. While at the Statistics Center Mr. Leatherwood co-authored

"Bibliography - Acceptance Sampling", Statistics Center Technical Report Number 12, January 6, 1964, with Mr. Harold F. Dodge, and was elected to associate membership in The Society of Sigma Xi (research honorary) for "The Approximation of  $2^n$  Factorial Designs by  $2^{n-1}$  Factorial Designs With Center Points" (unpublished). In June 1964 Mr. Leatherwood was awarded the degree Master of Science in Applied and Mathematical Statistics.

After graduation Mr. Leatherwood entered the service as a second lieutenant in the United States Army Transportation Corps. The first year of duty was spent as a mathematical statistician in the Nuclear Research Division of Picatinny Arsenal, Dover, New Jersey. During the second year of active duty, Lieutenant Leatherwood served as commanding officer of the 116th Transportation Company in the Republic of Vietnam.

Upon his completion of active duty Mr. Leatherwood entered the doctoral program in the School of Industrial and Systems Engineering at the Georgia Institute of Technology, Atlanta, Georgia. With the financial assistance provided by a National Aeronautics and Space Administration Fellowship and a National Science Foundation Fellowship, he pursued his doctoral studies and research on a full-time basis. During his doctoral program Mr. Leatherwood was elected to membership in Alpha Pi Mu (honorary industrial engineering society).

On September 1, 1969, Mr. Leatherwood was appointed Assistant Professor of Management Science in the College of Industrial Management at the Georgia Institute of Technology.

During the spring of 1970, Mr. Leatherwood participated in the establishment of AVISO Inc., a management services organization for

which he currently serves as a member of the board of directors.

In December 1970, a daughter, Katherine Lea, was born into the Leatherwood family.

In July 1972, Mr. Leatherwood resigned from the Georgia Institute of Technology to serve as president of Transaction Systems Inc., a firm engaged in management consulting and contract research.