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PAGE

COST EFFECTIVENESS ANALYSIS

AN APPLICATION TO MARKET STRATEGY SELECTION

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CHAPTER I

INTRODUCTION

DEFINITION AND SCOPE OF THE PROBLEM

Competition is an essential characteristic of all living beings. The human race is one which has incorporated competition in all phases of its existence. One could see infinitely various forms of this phenomenon in his daily life. It has become such an integral part of our existence that it usually goes unnoticed.

A very important kind of competition is one that exists between manufacturing firms producing identical or substitutable products.

The most dominant kind of market is the one where there is product differentiation.[1] The "Infinite number of firms" condition of pure and monopolistic competition very seldomly holds for a given market, therefore more than often, in actual life monopolistic oligopoly conditions prevail. This last term refers to a few firms manufacturing differentiated products.[2]

A monopolist expects to change the price-demand relationship for his product by increasing its degree of differentiation. This can be achieved by marketing strategics. There are however,

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[1] Lawrence, Abbot, Quality and Competition, (New York: Colombia University Press, 1955), p. 10.

[2] Lawrence, Abbot, Economics and the Modern World, (New York: Harcourt, Brace and Company, 1960), p. 460.

".... an enormous number of strategic possibilities. The dimensions of marketing strategies are so varied that it is inconceivable to include all of them in a formal analysis."[1] Another difficulty in this area is the effect of competition. Each competitor can have a great number of available strategies and even with only one competitor the task would be very complicated.[2]

It is usually assumed that there is a small probability of constructing useful models to describe market behavior because the factors controlling market mechanism are obscure.[3] Forrester says that "This makes the understanding which can come from the model construction more, rather than less, essential".[4]

Our problem is to be able to select among the several marketing strategies available to a firm operating in an imperfect oligopoly. The main problem in such an analysis is adequately stated in H. Speight's statement given below.[4]

Speight says the following about imperfect oligopoly:[5]
"Competition between firms in imperfect oligopoly is rather like a game of chess, or poker, in which each participant must consider

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[1] David W. Miller and Martin K. Starr, Executive Decisions and Operations Research, (Prentice-Hall International Series in Management, Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960), p. 171.

[2] Ibid

[3] Jay W. Forrester, Industrial Dynamics, (Cambridge: The M.I.T. Press, 1961), p.311.

[4] Ibid, p. 312.

[5] Imperfect oliogopoly and monopolistic oliogopoly are different names given to the same phenomenon by Speight and Abbot respectively.

not only his own moves but also the moves which his opponents might be expected to make".[1]

There has been a substantial amount of analysis regarding monopolistic competition. A short discussion of this is presented in the second part of this chapter. Monopolistic oliogopoly however was not subject to extensive analysis because of the inherent uncertainities in the model. The following quotations clarify this statement.

"We can come to no general conclusions about entrepreneural behavior, - not even the tentative kind to which our discussion of perfect oligopoly led us."[2]

"After what was said about oligopolistic indeterminancy it should be obvious that no general theory of outlay determination for the nonprice variables in oligopolistic competition can be formulated. It may be possible to formulate special theories that make specific assumptions regarding the exact way of thinking of every one of the oligopolists in the group. Perhaps it would be interesting to try the construction of such models."[3]

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[1] H. Speight, Economics: The Science of Prices and Incomes, (University Paperbacks, London: Methuen and Co. Ltd., 1960), p. 325.

[2] Ibid, p. 315.

[3] Fritz Machlup, The Economics of Sellers' Competition: Model Analysis of Sellers Conduct, (Baltimore: The Johns Hopkins Press, 1952), pp 459-60.

We will not discuss the validity of these statements yet, we will try to build a model which will guide the managers of a firm operating under the above conditions in selecting market strategies. We do not pretend to predict the best strategy, yet we can make a contribution by demonstrating a method by which better results may be obtained.

The main aim of this thesis is to demonstrate how Cost Effectiveness analysis, the explanation of which will be the subject of the third chapter, can be used as a tool in the selection of a preferred strategy.

Due to the lack of adequate models explaining market behavior under monopolistic oligopoly taking into account non price competition, we were compelled to design such a model. The selection of this latter and the underlying assumptions are open to criticism yet it should be stressed at this stage that our aim is not to construct an economic model but to introduce a decision tool for the systematic selection of marketing strategies of a firm. The economic model designed in the study can be studied further, refined or redesigned. The procedure developed in this thesis is not affected by such changes in the economic model. If such a situation arises then this procedure can be referred to as a program subroutine.

As such, this thesis seemed to be more of a theoretical nature rather than a practical application, therefore, to avoid this, we decided to select a manufacturing firm in Istanbul and to proceed with our study in terms of its products, market, and objectives. The firm has been used as a specific example and by no means should the study be considered relevant only for this firm. The methods could be applied for any other firm provided that the necessary adjustments are made in the assumptions and the economic model.

We have not gone into the search and evaluation of relevant data owing to lack of data in the form desired for the design of the models used in this study.

If the methods proposed in this study are to be actually applied however, such data are indispensable. These should be gathered by analyzing past data concerning the company's and the competitor's sales, prices, qualities, advertising and other selling expenses, company's past cost data, market's total sales and construction trends. This topic is further discussed in the concluding remarks of the study.

The importance of knowledge about market behavior is quite clear in Peter F. Drucker's statement that both resources and results exist outside the firm and that results in a market economy[1] depend on the customer.

The relevance of this quotation can be demonstrated by the following two examples:

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[1] Peter F. Drucker, Managing for Results: Economic Tasks and Risk-Taking Decisions, (New York: Harper and Row, 1964).

Steel has always been referred to as a "Homogenous product" although this statement is not true.[1] A few small firms in the U.S.A. have gone into the production of high-alloy specialty steels where quality rather than price is the major determinant of sales.[2] With this strategy they have managed to increase their sales and their revenues to a much higher level relative to what they could have achieved if they had remained in the ordinary steel market.

The second example comes from the household equipment industry. The Italian manufacturers have succeeded in increasing their sales volume by producing small refrigerators having a short life and relatively very low price.[3] The importance of the decisions concerning product characteristics and market strategies is quite clear.

NON-PRICE COMPETITION

Non-price competition is a phenomenon that can occur only in a market where the products are differentiated by some means or another. This is the necessary condition of monopolistic competition.

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[1] Joel Dean, Managerial Economics, Englewood Cliffs, N.J.: 1951), p. 230.

[2] "Special Case for Speciality Steels!", Fortune, December 1968.

[3] "The First Common Market Industry", The Economist, December 2, 1967.

The theory of monopolistic competition was studied extensively by Joan Robinson's The Economics of Imperfect Competition[1] and Edward H. Chamberlin's The Theory of Monopolistic Competition[2] and although the theory states that there is a product differentiation on the part of the consumer, the demand is taken as a function of price and no further consideration is given as to how the demand-price relationship can change due to a change in the product.

Thus, although a differentiation exists, "theory affords an answer neither as to how far differentiation will naturally be carried, nor as to how far it should be carried".[3]

The major variables that are included in non-price competition analysis are quality and promotion, although other variables exist, they could be incorporated within the first two or disregarded for simplicity.[4]

The effects of quality and promotion on price and output in monopolistic competition has been studied by Machlup quite

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[1] Joan Robinson, Economics of Imperfect Competition, (London: MacMillan, 1932).

[2] Edward Hastings Chamberlin, The Theory of Monompolistic Competition: A Re-orientation of the Theory of Value, (7th ed, Harvard Economic Studies; Cambridge: Harvard University Press, 1958).

[3] Ibid, p. 273.

[4] Fritz Machlup, Op. Cit., pp. 450-51.

extensively.[1] He takes quality as the third axis in a three dimensional analysis where he considers this variable as a discrete property of the product. Points along this axis then have ordinal value only. A representative illustration is given below:

Imperfect polypoly[2] Price and Quality
Competition

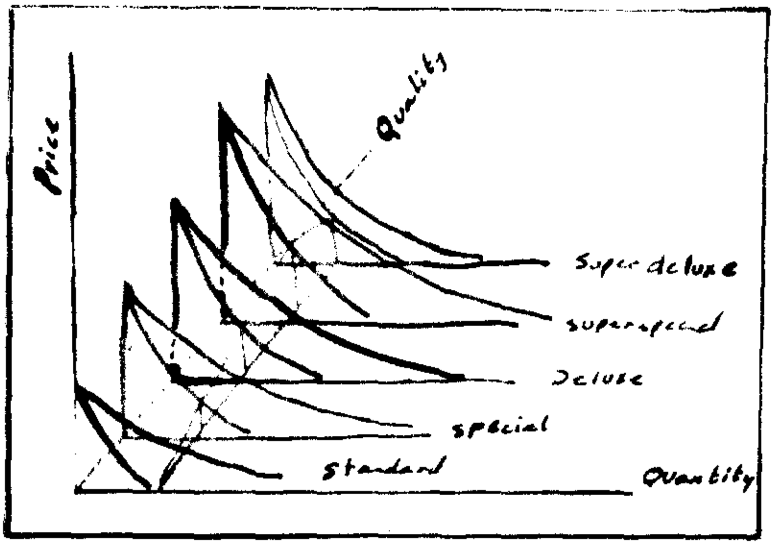

Figure 1. Average and Marginal Revenue Curves for Several Qualities.[3]

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1 Ibid, pp. 161-97.

2 In this paper referred to as monopolistic competition.

3 Ibid, p. 176.

The effect, other things being the same, of a given selling effort on price-demand relationship is shown as follows:

Figure 2. Effects of advertising on demand curve in monopolistic competition.[1]

An extensive study of quality competition can be found in Lawrence Abbot's works Quality and Competition and Economics and The Modern World. In his last text Abbot has also included promotion as a means of non-price competition.

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[1] Ibid, pp. 187.

THE PRODUCT

The product manufactured by the firm for which the market strategies will be evaluated is metallic sanitary equipment. This can be considered as a family of products in which there is a great degree of similarity among its members with respect to their functions, raw material, parts, manufacturing processes and demand. This product line can be considered as a necessity because a functional substitute does not exist. Sanitary equipment are integral parts of constructions and can justifiably be classified as construction materials. Their indispensability, however, is a special characteristic. During the analysis we shall consider an equivalent product rather than treating each item separately. The most appropriate measure of thé product would be in terms of its weight. Thus, if a tab is to be considered as one equivalent unit a shower battery will be evaluated by the ratio of the respective weight. The drawing of one item is presented on the following page.

THE MARKET

The market of metallic sanitary equipment is divided into three distinct segments according to their quality requirements, These behave as different markets except for the fact that there is an upward trend in quality requirements of consumers resulting in a net shift from the lower income levels to the upper ones.[1]

[1] Interview with the president and technical plentipotentiary number of the Board of Directors of the XYZ foundry company March 6th, 1969.

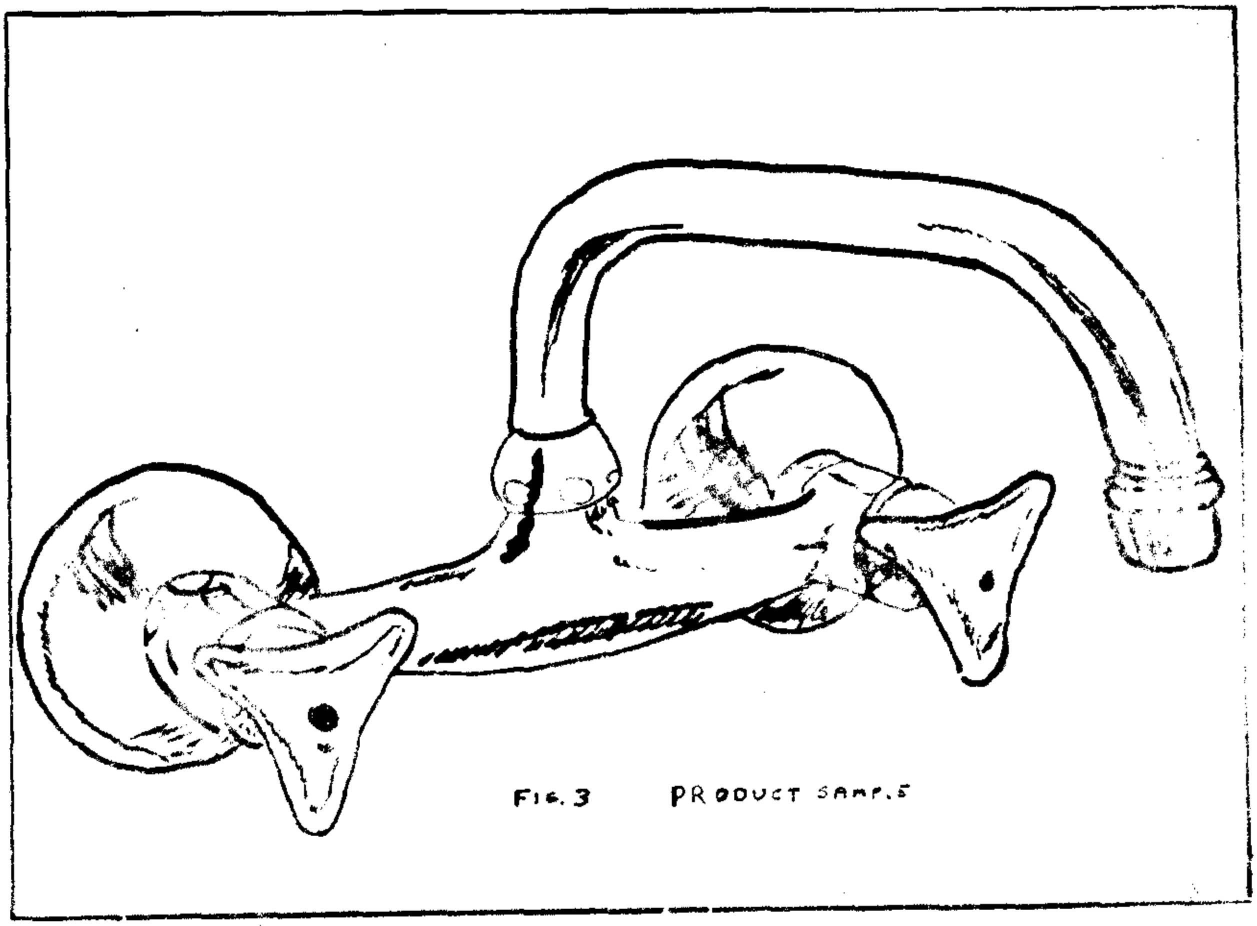

Figure 3. Product Sample

The market segment on the above classification are as follows:

1) Low quality products' market. There are many manufacturers operating at this level. The products are not plated and due to workshop practices they contain many defects. The individual capacities of the manufacturers are small, the capital investments and the prices are low and the assortment of products is limited. The total sales is not known due to the quantity and dispersion of the manufacturers.[1]

[1] Ibid.

2) Medium quality products' market. The products in this market are plated, there is a smaller number of manufacturers than the previous segment, the assortment is richer, producers are small to medium scale, accordingly the capacities, capital investments and prices are higher. The products, due to the finishing operations, have an improved appearance and manufacturing processes are more refined.[1]

3) High quality products' market. This market consists of two large scale manufacturers. The assortments of their factories are much greater than the ones in the previous segments. Prices are considerably higher, manufacturing processes are much more refined and the companies follow the innovations in their field. Quality requirements are stricter and the XYZ foundry cpmpany applies 100% quality control. The capital investments are also much higher.[2]

During the analysis we shall not consider the replacement market. The managers of the firm have stated that they do not know the exact magnitude of the replacement market but they assume it to be small, at present, compared to the actual market.

We shall be considering the two firms market where there is product differentiation. The following assumptions will hold for the rest of the analysis.

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[1] Ibid.

[2] Ibid.

Assumption 1 (Production Potential) > Demand

That the production possibilities for any firm in the market exceeds the demand for the product of that firm. This can be justified because in the long run a firm can adjust its production capabilities and in the short run it is not very likely that the demand will increase by an amount sufficient to exceed the firms capacity.

Assumption 2

That the firms in the market can not directly affect the total demand for the product. This assumption is also justified since if we exclude the replacement market, the demand for metallic sanitary equipment in a period will be dependent on construction during that period.

Assumption 3 $(\text{Sales})_i = (\text{Demand})_i$

This assumption follows immediately from Assumption 1.

The assumption regarding the relation between the production potential and the demand of a firm is essential if the rest of this study is to make sense. If a firm were engaged in activities which would result in an increase of its demand but on the other hand made no capacity adjustment in order to meet this demand then all the efforts would be worthless since the extra amount would shift to the competitors.

The actual case for the XYZ firm is approximately as stated by the assumption, yet the margin is very small and the firm sometimes finds it difficult to meet all the orders.

When the assumption is violated then the market share is determined by the capacity rather than the demand.

The second assumption was made for convenience. Actually it is seriously misleading since having defined the total market as the high quality market and having stated that there exists a net shift from lower quality markets to higher ones, we should consider this expansion and how the firm can affect this shift, that is how it can attract customers from lower markets.

The implication of the assumption is that customers change their habits irrespective of what the firms in different markets do.

The importance of being able to select among several strategies, one that would improve the companies' performance has been discussed above. The model that we have attempted to design and evaluate is a two competitors model. With additional manupulation the model could be extended to deal with a greater number of competitors.

The possibility that Turkey will enter the Common Market is another motivating factor for the better understanding of market behavior with respect to product differentiation and marketing strategies. If accepted in the Common Market, Turkey will be the target of numerous European manufacturers. It has been successfully argued that when high quality product is involved the most effective barrier to new competition is product differentiation.[1]

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[1] Joe S. Bain, Barriers to New Competition: Their Character and Consequences in Manufacturing Industries, (Cambridge: Harvard University Press, 1956).

The following quotation applies to Turkey as much as to Ireland in explaining what the domestic manufacutrers' tasks are.

"On the assumption that the forces making for such European unity are irresistable, the tasks for Ireland's manufacturers are to modernize, to learn to exist without decades-long tariff and quota protection, and to discover whether they are viable enough to cope with intensive competition in a free trade system."[1]

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[1] John E. Weinrich, Optimum Size in Irish Footwear Manufacturing, part of a project involving the study of eleven Irish Industries, (New York: Pergamon Press, 1967), p. 74.

CHAPTER II

METHOD OF APPROACH

GENERAL

The analysis starts with a descriptive evaluation of the relations between market share and the controllable variables that effect market share.[1] These discussions are theoretical and will depend only on logical deduction. We admit that such a procedure will lead to a justified discussion on the validity of the relations yet, as it was previously stated, the purpose of this thesis is to demonstrate the application of an analytic tool to such a decision area and the unavailability of such relations let us to the design of a model. This is to be followed by a graphical representation of the relations, and the boundry conditions are defined. The task of formulating mathematical relationships describing the curves, is accomplished by assigning mathematical expressions which best fit the verbal and graphical analysis.

It is recognized that this procedure is not a very sound method of defining mathematical relationships. Neverthe-

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[1] Market share has been used instead of sales because the performance of the company is revealed by the former value rather than the latter since total sales can increase independently of the compan's policies. If a firm increases its market share when total sales are declining it is successful, although its sales may be decreasing.

less, having knowledge of the characteristics of the curves used and the phenomena that they are to represent, one can fit the equations which will most adequately fulfill the necessary requirements. A better method would have been to analyse past performance; and to use statistical techniques, yet, it would be quite difficult to isolate enough relevant data which would reveal the pure effects of each of the variables on market share. The test of the model, however, has to be done with such actual data and if the predicted results do not match the actual results the model should be revised.[1]

The next step in the analysis is to combine the individual effects in such a way that the actual behavior is adequately predicted. The reasons underlying the particular choice of combination will be discussed in Chapter IV.

The method we use to test the models gives the impression that we are going around a circle, and indeed, we are! In testing the model for several boundary conditions, our intention was to test the program rather than the model and to demonstrate the actual procedure to be followed if past data were available. Testing the model with actual data would free the circular reasoning that is apparent in the study.

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[1] Prediction should be sought within acceptable confidence limits since the actual data will probably not be able to relate exactly the individual relationships.

THE VARIABLES

A firm is considered to have several strategies consisting of four variables. The management has to select the strategy that will best fir the company's objectives. The method of selection will be discussed in Chapter III.

Four variables are considered to affect the market share of a firm.

1) Price
2) Quality
3) Promotion (Advertisement)
4) Distribution (Selling efforsts other than advertisement.

We assume that the relation between market share and each of these variables is continuous. The main advantage of defining continuous relationships is the ease of expressing the curves with mathematical equations.

We accept that actually these relationships are step functions rather than continuous ones. Yet treating them as such would excessively complicate the analysis. The use of continuous functions however, does not affect the results because we select discrete points on the continuum represented by each function. The difficulty of using step functions would not arise in the mathematical formulation of the relations, but in the determination of each interval width, and the change from one step to the other.

Price has been the main variable of interest in classical economic theory. The concept of non-price competition includes quality and promotion as additional variables. These choices are therefore justified. Although Fritz Machlup considers that services competition could be grouped together with quality or promotion competition,[1] we treat this variable separatly because distribution and service are important factors of marketing. "However, a product may be designed, it is of little use to the customer if it is not available to him at the right time and place."[2]

The four variables chosen are by no means exhaustive. Other variables that can be defined could be:

1. Price discounts
2. Quality of advertisement
3. Quality of distributors
4. Incentives offered to distributors
5. Recommendations of distributors
6. Complemantary items in the assortment
7. Supplamentary items in the assortment
8. Repair service
9. Consulation service
10. Credit terms

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1 Fritz Machlup, Op. Cit., p. 450.

2 E. Jerome Macarthy, Basic Marketing: A Managerial Approach, (rev. ed., Homewood, Illinois: Richard D. Irwin, Inc., ;969, 1964(, p. 435.

In fact, the list can be made much longer if one wished to go into very minute details. The above variables could, however, be incorporated into the four variables one way or another. Items 3, 4,8,and 9 could be included in distribution; items 2 and 5 in advertisement; items 1 and 10 in price; and items 6 and 7 in quality.

The dependent variable is chosen as market share instead of sales. One reason for this has been given in footnote 1 on page 16. Another reason is that market share can vary between 0 and 1 and the sum of the market shares of all firms in the market must equal to 1, whereas, the upper limit of sales may change. The curves relating market share to the individual

$$0 < M_i < 1$$

$$\sum_{i=1}^{n} M_i = 1$$

where: M_i = Market share of company i

n = Number of companies in the market.

variables will not be affected by the volume of the total sales. This is an important consideration because it eliminates the necessity of drawing separate graphs for different total sales.[1]

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[1] The shape of the sales vs quality will not differ from the graph of market share vs quality but the scale will need readjustment for each total sales figure.

ANALYSIS AND EVALUATION OF THE RESULTS

The analytic tool that is used is Cost-Effectiveness Analysis whose scope and elements are the subject of the next chapter. This analysis has been chosen because it provides a good criterion of comparing strategies. The analysis does not guarantee, however, the selection of the optimal strategy. It rather eliminates all strategies for which there are better alternatives. The remaining strategies have to be evaluated by the decision-maker. The analysis is continued as far as this point and the final result is a presentation of a set of strategies whose evaluation depends on the judgment of the decision-maker.

PROCEDURE

A computer program was prepared for each of the models and with selected input data the results were obtained. The models that we used are:

1) A deterministic model
2) A simulation model
3) A stochastic model

The discussion of these models will be found in Chapter VI.

In this analysis we are evaluating our available strategies against our opponent's in terms of the effectiveness and cost of our strategies. Although we take the individual effectiveness functions to be continuous, we are interested only in some specific regions of the curves represented by these functions.

We, therefore, selected a few discrete points on these curves and defined out strategies as consisting of a combination of these values. It is understood that one can in fact choose any combination of the four variables.

Since the point of interest is to illustrate how Cost Effectiveness Analysis can be used for the evaluation of such strategies, it is unnecessary and highly unpracticle to try a great number of combinations.[1] In practice we may either assume that the managers have in mind a few levels of each variable which they may be interested in knowing the effectiveness of all the combinations, or that they want to test the effectiveness of some predetermined combinations.

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[1] The computer takes ten seconds to evaluate one of our strategies against one of the opponent's. Thus, if we are to consider three values for each of the four variables, the number of strategies for each competitor representing all possible combinations of the above mentioned values is eighty one and the amount of the combinations to be evaluated in this square matrix is 6561 which lasts twelve and a half hours on the computer.

CHAPTER III

COST-EFFECTIVENESS ANALYSIS

INTRODUCTION

Cost-Effectiveness analysis is a relatively new development.[1] It has found a considerable application area in the designs, evaluation and comparison of defense, weapon and missle systems.

The analysis does not bring forth new concepts in decision making, it is rather the methodology inherit in the analysis that is of importance. The following quotation is characteristic "The need for considering cost in relation to effectiveness must have occured to the earliest planners. Cost-Effectiveness is not a catch word to suggest that planners today are doing something new; at most they are doing somethingebetter. What is novel about Cost-Effectiveness analysis today is the marvelous refinement of the methods for relating cost to effectiveness that has taken place in the last few years and the acceptance of these methods as an aid to decision-making at high policy levels.[2]

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[1] Robert N. Grosse, Preface, Cost-Effectiveness Analysis: New Approaches in Decision Making, Ed. Thomas A. Goldman, Washington Operations Research Council, (Praeger Special Studies in U. S. Economic and Social Development; New York: Frederik A. Praeger Publishers, 1967), p. v.

[2] Edward S. Quade: "Introduction and Overview", Ibid, p. 1.

A broad definition of cost-effectiveness analysis could be the following: "It is any analytic study designed to assist a decision-maker in identifying a prefered choice among possible alternatives."[1] Yet, the author suggests this is too broadly defined. To cite a more specific definition, "Cost-Effectiveness Analysis is an analytical technique for evaluating the broad management and economic implications of alternative choices of action with the objective of assisting in the idetification of the prefered choice."[2] A cost effectiveness analysis provides a quantitative basis for evaluating a systems performance in the light of both its cost and effectiveness.[3] It shows the relation between alternative design decisions and system costs in terms of the system effectiveness. The values of the variable characteristics to be considered in designing the system are identified by the analysis.

A system can be designed by using one of many alternative combination of its characteristics. However, these combinations will differ in the amount of resources they use. The analysis enables the decision-maker to identify the prefered

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1 Ibid.

2 M. C. Hueston and G. Ogawa, "Observations on the theoretical Basis of Cost Effectiveness", Journal of Operations Research Society of America (March-April 1966).

3 David S. Fields, "Cost-Effectiveness Analysis: It's Tasks and Their Interdependence", Journal of Operations Research Society of American (May-June 1966).

characteristics and their cost implications to reach a desired capability level,[1]

In areas such as defense planning, the advice obtained from experts depends largely on subjective judgment, The advice from Cost-Effectiveness Analysis also depends on this yet a more systematic and efficient use of judgement could be made with the analysis.[2] The following statement by W. A. Nishanen about Cost-Effectiveness Analysis helps to determine its place in the analytic spectrum.

"Cost Effectiveness Analysis is part of the general theory of maximizing behavior-about in the middle of an analytic spectrum with the classic theory of the firm at one end and operations analysis at the other.

It shares with the theory of the firm the problem of measuring cost, which is also faced in a cost-benefit analysis of a public investment. It shares with operation analysis the problem of choosing the appropriate measure of effectiveness.[3]

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1 Ibid.

2 Edward S. Quade, Op. cit., p. 3.

3 William A. Niskanen, "Measures of Effectiveness", Cost-Effectiveness Analysis New Approaches in Decision-Making, Op. Cit., p. 17.

TASKS AND ELEMENTS

The major tasks in Cost-Effectivness Analysis can be listed as follows:[1]

1) Definition of the problem
2) Synthesize alternative systems
3) Establish basis for evaluating performance
4) Formulate effectiveness (performance) model
5) Formulate Cost Model
6) Analyze systems costs versus effectiveness

Definition of the Problem

Since the analysis is used primarily to help choose a policy or course of action, the analyst should attempt to discover what objectives the decision-maker is or should be trying to attain and how to measure the extent to which they are attained.

It is also vital that the analyst should know the environmental condition in which the objectives are to be satisfied.

Synthesize alternative systems

This is the most difficult task in Cost-Effectiveness analysis since the usefulness of the analysis depends almost entirely upon the meaninfulness of the criteria chosen for measuring effectiveness.

1 David. S. Fields, Op, Cit.

"The appropriate measure should have two characteristics. First it must be relevant; second it should me measurable.[1]

In general one of the simple and common evaluations concerns the comparative analysis of alternative total systems. The usual criterion involves the selection of the least cost alternative, given that all alternatives evaluated have been designed to achieve the same performance.

Another common evaluation concerns an analysis of the trade-off between design or program characteristics and the selection of the best performance alternative for the money available.

An interesting discussion on the choice of measures of effectiveness is given by Niskanen but has not been included here because it deals with a very specific case of defence system evaluation.[2]

Another interesting subject would be the treatment of multiple criteria. In this case the criterion has been chosen as increase in market share but an additional criterion could be profit consideration. This latter could either be treated as a restriction on the first measure of effectiveness such as requiring a minimum profit for any given strategy or using a weighed effectiveness index that could be found by considering both criteria at the same time. Further effectiveness criteria could be long range

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1 William A. Niskanen, Op. Cit., p. 20.

2 Ibid, pp. 26-32.

objectives of the firm, long range competability and expansion.

The use of utility transforms could be another approach to the definition of the effectiveness function. Given the conditions of the firm one could define a utility transformation of the effectiveness values of each strategy and compare these figures with the cost of each strategy.

Formulating the effectiveness model

This task is one of the most important parts of the analysis. The effectiveness model can be described in terms of its elements and the methods of predicting the value of these latter. All that is required of these elements is that they realistically show the basic relation between themselves and the capability of the system to achieve a desired output.[1]

An effectiveness model is presented as[2]

$$\text{Eff} = \prod_{i=1}^{i=n} e_i$$

where: Eff = Total effectiveness of the system

e_i = effectiveness at the i^{th} element

The total effectiveness function has to be a multiplicative function of the individual elements because if one of the elements ha s zero effectiveness the total effectiveness of the strategy should become zero. This cannot be achieved if an additive function were used. As an example we could show that if the

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1 Heuston and Ogawa, Op. Cit.

2 Ibid.

products quality is zero sales must be zero no matter what the effectivenesses of the remaining variables are. We assume of course, that the customers are rational.

Another example could be given from a weapon selection problem. If a weapon that is considered as an alternative is very efficient but almost impossible to manufacture with the existing technology, i.e., the manufacturing efficiency is close to zero, then the total efficiency of this weapon should be zero.

We must remember that the basic function of the model is to determine the value of the measure of effectiveness an an output when the controllable variables of the system are used as inputs. "Another way of putting this point is to require that the model be particularly sensitive to the differences between the alternatives being considered."[1]

Formulate Cost Model

This task is conceived with relating system costs to system variables through the use of the mathematical equations. "The ideal procedure is to develop a functional relationship between costs and characteristics so that for every value of the characteristic there is a corresponding cost.[2]

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[1] Alfred Blumstein "The Choice of Analytic Techniques", Cost-Effectiveness Analysis; New Approaches in Decision-Making-, op. cit., p. 40.

[2] David S. Fields, Op. Cit.

Heuston and Ogawa say the following: "There are two aspects of the theory of the cost model in cost-effectiveness: Listing and defining the appropriate categories of costs (total system costs), and the technique of cost prediction. Both of these matters are critical because a good cost model is the only way to provide valid and credible estimates with a high degree of confidence for cost-effectiveness analysis."[1]

The article describes the general scope of the model in terms of a cost array. The array includes development, initial investment, and operations costs as major cost elements and these are divided further into subclasses.

The general cost matrix can be represented as:

$$C_T = C_D + C_P + C_O$$

Where:

C_T = Grand Total cost for a proposed plan of action

C_D = Total costs incurred for research, development, test and evaluation

C_P = Total costs incurred for initial investment

C_O = Total costs incurred for operations over a period of time.[2]

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1 Heuston and Ogawa, Op. Cit.

2 Ibid.

Analyze System Costs Versus Effectiveness

This task indicates the trade-off between cost and effectiveness among the alternative candidate systems.

A cost effectiveness schedule shows which alternatives are to be discarded from further analysis.

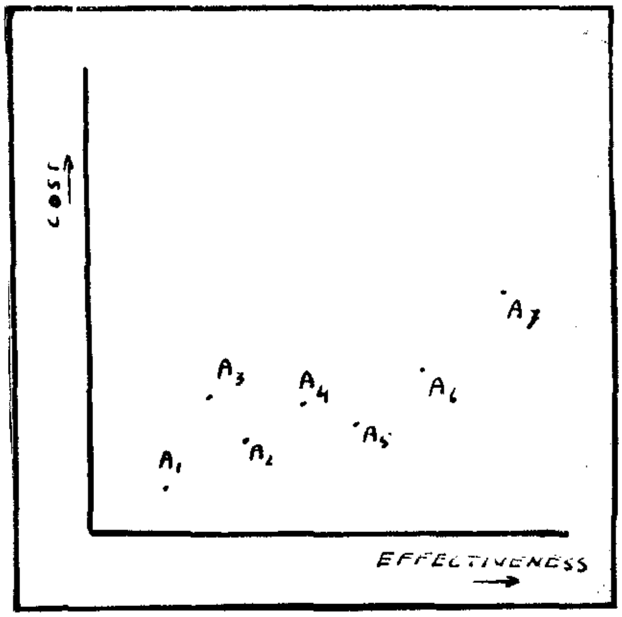

Figure 4. Cost-Effectiveness Schedule[1]

The analysisist will eliminate an alternative that both costs more and is less effective than another alternative.[2] Also if an alternative costs as much but is less effective or costs more but

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1 Peter D. Fox, "A Theory of Cost-Effectivness Analysis", Journal of Operations Research Society of America, (March-April, 1965).

2 Ibid.

is as effective as another alternative. If an alternative costs more but is more effective than another alternative and vice-versa then both must be presented to the decision-maker.[1]

This procedure assumes, however, that each alternative has already been evaluated and the minimum cost required to reach that effectiveness value determined. System characteristics are sought which provide the minimum cost for various performance levels.[2] This is a cost-effectiveness analysis of System Configuration Studies type.[3] Cost-Effectiveness Analysis has limitations as do all other forms of analysis. The analysis is necessarily incomplete because of budget restraints and because some considerations are intagible, measures of effectiveness are approximate and there is not satisfactory way to predict the future.[4] Yet the use of the analysis is not hindered by these limitations. Their existence, however, should be known to the analyst.

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1 Ibid.

2 Harry P. Hatry "The Use of Cost Estimates", Cost-Effectiveness Analysis: New Approaches to Decision-Making, Op. Cit.

3 Ibid.

4 Edward S. Quade, Op. Cit.

CHAPTER IV

EFFECTIVENESS MODEL

GENERAL

The requirements and tasks of the effectiveness model were discussed in the previous chapter. We shall now try to formulate a model which meets these requirements and which also satisfies our needs.

We have stated in Chapter II that our independent variables are quality (Q), Price (P), Advertising (A), and distribution (D); and that we were interested in finding how these could combine to affect the ma rket share. A strategy as we define it, will be the counterpart of a "system" or an "alternative" mentioned in Chapter III. The objective of the firm has been chosen as sales maximization. Although in classical theory profit maximization is accepted as the goal of a firm, it has been recognized that sales maximinzation is sometimes desired as a company objective.[1] The advantage of using market share instead of company sales was also mentioned earlier. Our measure of effectiveness will be then the level of market share that a strategy provides. Each variable is an element of the effectiveness model and the total effectiveness of a strategy will be a multiplicative function of these elements.

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[1] William J. Baumol, Economic Theory and Operations Analysis, (2nd ed., Prentice-Hall International Series in Management; Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1956), pp. 301 303; Joseph W. McGuire, Theories of Business Behavior, (Prentice-

QUALITY

The Concept of Quality

Quality of the product is a very important factor affecting sales in a monopolistic market yet it is a concept that has many dimensions and which is usually considered difficult to be evaluated by the customers on a cardinal scale unique to a linear transform or to a multiplication (scale) transform. Qualities are often evaluated on ordinal scales unique to monotonic transforms.

At the factory level, measurement of quality is on a cardinal scale since it is related to physical factors such as agreement with specified standards and tolerances, e.g., thickness of the plating, surface defects and operational characteristics such as wear under specified conditions, volume of water transmitted per unit time and others.

These values, although relevant to the engineers and workers, do not have much significance to the customers since they are not aware of the physical and operational requirements to start with.

The following statement is true, therefore, only to the extent that it is accepted that the situation is considered from the customers point of view.

Hall International Series in Management and Behavioral Sciences in Business Series; Englewood Cliffe, N.J.: Prentice-Hall, Inc, 1964), pp. 91-92.

"Statements about the relationship between the cost of quality improvement and the corresponding sales expectations are complicated by the fact that quality cannot be physically measured.[1]"

Abbot classifies quality variability as:[2]

1. Horizontal
2. Vertical
3. Innovational

The first kind of quality changes are those for which there is no clear cut agreement. It is characterized by (a) that different people will rank them differently, (b) that cost differences are incidental.

Vertical quality changes are those which can be described as higher or lower. They are distinguished by (a) a similar ranking by all customers, and (b) cost differences.

Innovational changes are considered improvements by all customers and the new quality displaces the other.

Quantification of quality is essential for an analysis of this type. There are mainly two aspects of quality

1. Functional quality
2. Non functional quality[3]

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1 Fritz Machlup, <u>Op. Cit</u>., p. 169.

2 Lawrence Abbot, <u>Quality and Competition</u>, Op. Cit., ch. 10.

3 Martin K. Starr, <u>Production Management: Systems and Synthesis</u>, (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1964), p. 245.

Functional quality is relatively more quantifiable because it is related to physical characteristics. Yet in defining a measure of quality for such an analysis one has to evaluate consumers consideration of quality which does not correspond to the physical values.

Quantification of Quality

Metallic sanitary equipment have two major quality aspects

1. Functional
2. Appearance

The functional quality of the product will be determined by such factors as:

1. Product life
2. Service time until first repair
3. Repairability
4. Ease of manipulation

All of these factors can be technically quantified[1] yet the customer will not evaluate them the same way, therefore, such a quantification would not be adequate. If one of the factors were more important than the others, its value could be determined in terms of the technical measurements and this value conveyed to the consumer. Product life could be for example, established as a basis of quality measure although determination of

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[1] Perhaps with the exception of the last factor which may assume only an ordinal value yet a measure of this could be the force needed to turn the tap if one wished to be quantitative to that extent.

product life would depend on auxiliary variables such as quality of raw matertial, labor per product, competability of the parts, etc.

Appearance is a function of the finishing operations, yet its value cannot be conveyed to the customer in terms of time of immersion in the plating bath or number of polishing operations performed. Perhaps the time taken for the deterioriation of the appearance could be an adequate measure at the consumer level.

We have chosen to use product life as a measure of quality. Deterioriation of the appearance is considered to be a factor affecting product life. Thus product life is determined by the smallest value between functional deterioriation time and appearance deterioriation time. The units of (Q) are then, (years of useful life).

We could also use a quality index which would be a weighted average of the above considerations. Such a measure would, however, require the determination of the weights that are to be assigned to each factor contributing to the customer's quality concept. The task is more complicated than it may seem, because it implies the investigation of how each factor is weighed by the customer. This could be accomplished by a market study, yet the study should be repeated frequently because changes such as design modification might alter the weights placed on appearance and on the other factors.

In using the more simplified concept of quality as we have done by choosing the most important fa ctor as the only one representing quality, the analyst should be careful to choose the correct concept. If two factors equally qualify for this position, it follows that a weighted average of the two can be used.

Effectiveness of Quality

The effect of quality on sales should be investigated by holding all other variables constant. One thing that can be said about quality variation is that, market share (or sales) will be expected to increase as quality is increased. It is not, however, possible for a firm to increase quality without bounds for the following reasons.

1. There is a technological limit to quality.
2. There is a limit of quality after which there will not be a significant change in demand.
3. As quality is increased, production costs increase exponentially.

Figure 5 demonstrates these facts.

This representation has two defects:

1) Quality is assumed to have the maximum slope at Q = 0 whereas, sales will increase slowly at the beginning. There should also be a treshold quality level below which demand is zero.
2) Use of monetary value will hide the effect of price changes on sales.

Jay W. Forester describes the following relation between market satisfied (as a percentage of the toal market) and quality

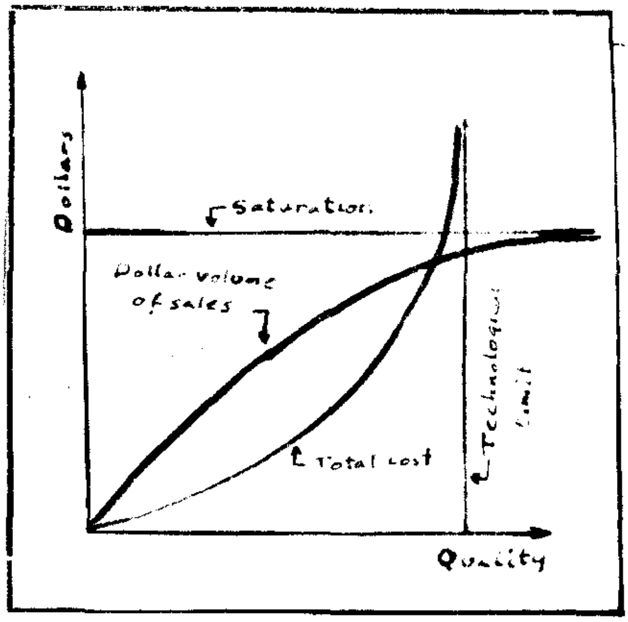

Figure 5. Sales and cost as a function of quality level[1]

level.[2]

As shown in Figure 6, this representation does not meet the requirements of our model because:

1) It does not specify competitive behavior.

2) In case of an indispensable product which has no substitute, the consumers will have to buy whatever is available on the market.

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[1] Ibid., p. 244.

[2] Jay W. Forester, Op. Cit., p. 318.

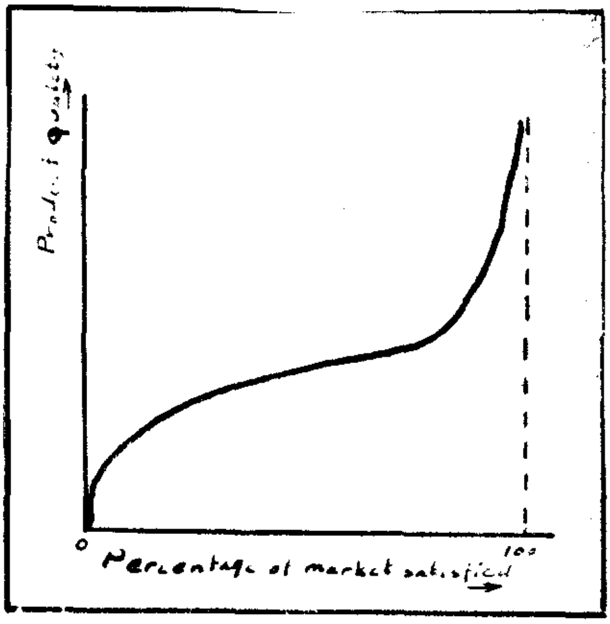


Figure 6. Quality versus percentage of market satisfied.

In the following analysis we assume two competitors. The product has no functional sustitute, therefore, the customers have to buy from one of the manufacuturers. The curve represents the effect of quality on market share irrespective of the other varibles. We are analysing a market where the only consideration about the product is quality. Figure 7 represents the market shares of Company I and Company II as Compa ny I changes its quality and Company II holds its quality fixed. The curve given by Forrester in Figure 6 is used as a basis.

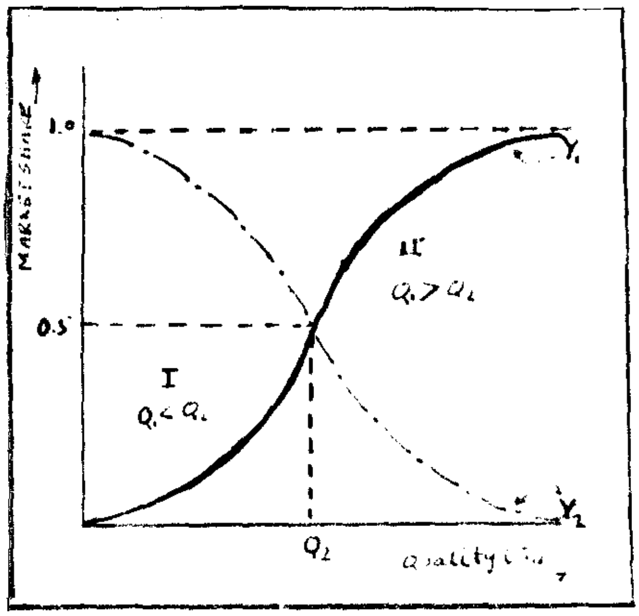


Figure 7. Market share I and II versus Q_1 for a fixed value Q_2

The solid curve in Figure 7 shows the following characteristics.

1) As Company I increases the quality level of its product, its market share is increasing.
2) The market share of Company I increases with an increasing slope, i.e., the marginal increase in the market share gets larger as quality increases.
3) The marginal increase of the market share reaches its maximum at some quality level after which it decreases.

4) As the market share approaches 1.0 the marginal increase in the market share approaches zero.

If the only consideration in the market is quality the two companies must share the market half and half when they operate at the same quality level. The inflection point of the curve will also be at this point. This implies that as the quality of the product approaches that of the competitor's, the marginal increase in market share will increase but immediately after it passes this quality level, the marginal increase will diminish.

The dotted curve represents the effect on the market share of a company due to the change is the quality level of a competitor.

Figure 8 shows the relationship of market share to quality, all other things being equal, for two competative qualities. The curves reveal the fact that market share as quality represents a family of curves the location of which is determined by the competitors quality.

In order to find a mathematical expression that would fit the curve and the few conditions imposed on the curve; two regions were defined as follows:

I $Q_1 \leq Q_2$

II $Q_1 \geq Q_2$

The portion of the curve remaining in the first section can be expressed as:

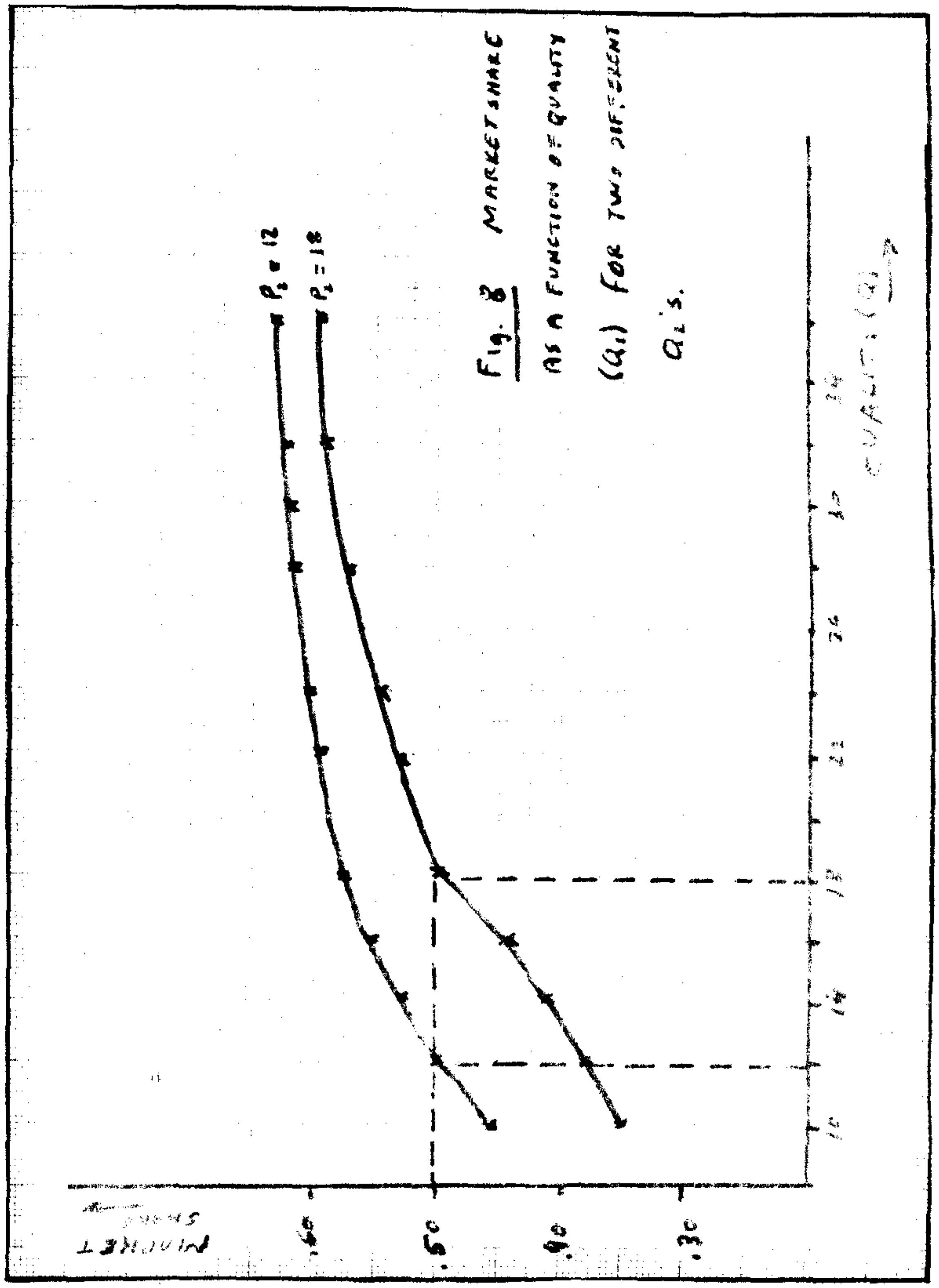


Fig. 8 MARKET SHARE AS A FUNCTION OF QUALITY (Q_1) FOR TWO DIFFERENT Q_2's.

$$Y_Q = a - e^{CQ} \qquad (i)$$

The boundary conditions being:

when $Q = 0$ $Y_Q = 0$

when $Q = Q_2$ $Y_Q = 1/2$

solving (i) for the constants using these boundary values we obtain:

$$0 = a - e^0$$

$$0 = a - 1$$

$$a = -1$$

$$\frac{1}{2} = -1 - e^{CQ_2}$$

$$e^{CQ_2} = \frac{3}{2}$$

$$CQ_2 = \ln \frac{3}{2}$$

$$C = \frac{1}{Q_2} \ln \frac{3}{2}$$

thus:

$$Y_Q = -1 - e^{(Q/Q_2) \text{ In } 3/2}$$

$$Y_Q = -1 - \left(\frac{3}{2}\right)^{Q/Q_2} \qquad (ii)$$

The portion of the curve remaining in the second region can be described by the relation:

$$Y_Q = a - \frac{b}{Q} \qquad (iii)$$

Boundary conditions:

$$Q = Q_2 \qquad Y_Q = 1/2$$

$$Q = \infty \qquad Y_Q = 1$$

Solving for the constants in (iii) using these values

$$1 = a - 0 \qquad a = 1$$

$$\frac{1}{2} = 1 - \frac{b}{Q_2}$$

$$b = \frac{1}{2} Q_2$$

$$Y_Q = 1 - \left(\frac{1}{2}\right) \frac{Q_2}{Q} \qquad \text{(iv)}$$

PRICE:

The analysis of the market share as a function of price is very much like the previous one, It is expected that as the prices of company decreases its market share will increase. When the price equals, zero market share is expected to go to 1. We assume that the consumers will not buy more than what they need at very low prices.

The need for this statement arises only because of assumption 2 on page 13. In terms of the market share this does not add anything to our analysis since even if the customers bought more than their need due to low prices, the market share, by definition, could not be more than one.

Yet if this statement were not made then we would imply that the firm can affect the total market by reducing prices, in which case we would contradict the assumption made on page 13 regarding the control, or rather the lack of control, of a firm over the total market.

As the product price approaches the opponents' price, market share will approach one half with an ever-increasing rate. Once it has reached this price, however, the rate of decrease of market share will diminish as market share approaches zero. The curve showing this relationship is given in Figure 9.

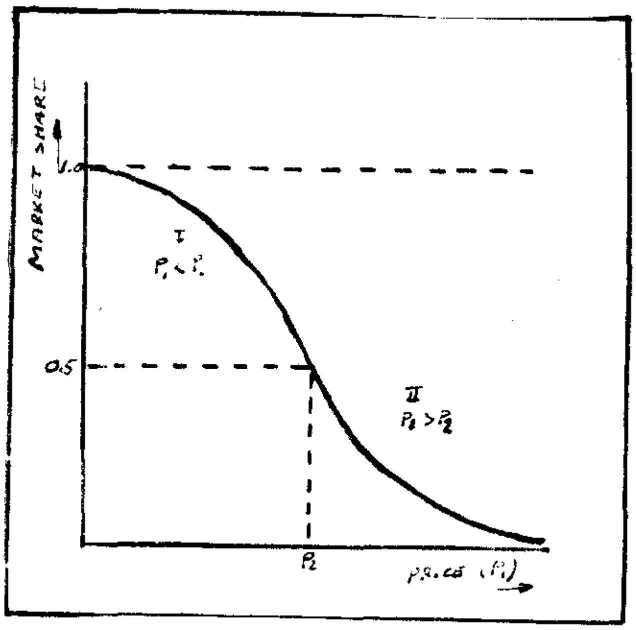


Figure 9. Market share as a function of P_1 for a fixed value of P_2

The term price as it is used here corresponds to the one of an equivalent unit.

In order to find a suitable mathematical relationship, two regions are defined:

I $\quad P_1 \leq P_2$

II $\quad P_1 \geq P_2$

The portion of the curve remaining in region I can be described by the following mathematical relationship:

$$Y_P = a - e^{CP} \qquad (v)$$

Boundary conditions:

$$P = 0 \qquad Y_P = 1$$

$$P = P_2 \qquad Y_p = 1/2$$

Solving for the parameters in (v) using these values:

$$1 = a - 1 \qquad a = 2$$

$$\frac{1}{2} = 2 - e^{CP_2}$$

$$e^{CP_2} = 3/2$$

$$CP_2 = \ln 3/2$$

$$C = \frac{1}{P_2} \ln 3/2$$

$$Y_P = 2 - e^{(P/P_2) \ln 3/2}$$

or

$$Y_P = 2 - (\frac{3}{2})^{P/P_2} \qquad (vi)$$

The remaining part of the curve has the mathematical form of

$$Y_P = a - \frac{b}{P} \qquad \text{(vii)}$$

Boundary conditions:

$$P = \infty \qquad Y_P = 0$$

$$P = P_2 \qquad Y_P = 1/2$$

Evaluating (vii) for the parameters

$$0 = a - 0 \qquad a = 0$$

$$\frac{1}{2} = \frac{b}{P_2} \qquad b = \frac{1}{2} P_2$$

$$Y_P = \left(\frac{1}{2}\right) \frac{P_2}{P} \qquad \text{(vii)}$$

Figure 10 shows the result obtained by giving varying P_1, holding everything else constant for three different P_2 competitor prices.

ADVERTISING

The discussion on the effect of advertising on market share is exactly the same as the one on the effect of quality with one exception.

We assumed that at zero advertising the firm will still sell its products and therefore have a market share. It was further assumed that even if the company increased its advertising to infinity, the competitor will still have a market share. Thus the effect of advertising on market share is to vary it between two limiting values which have been arbitrarily set at 0.2 and 0.8.

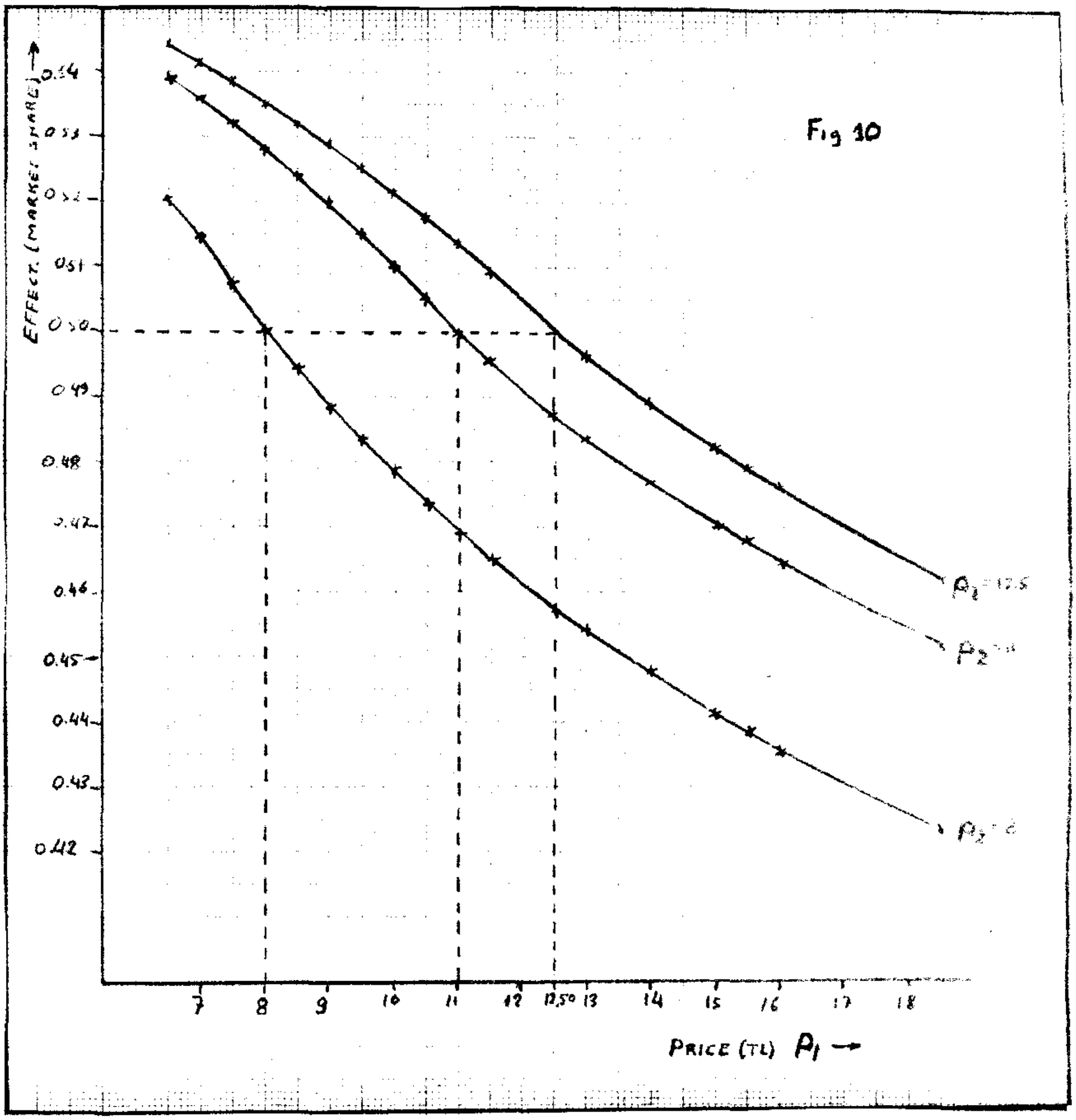


Fig 10
EFFECT (MARKET SHARE)
0.54
0.53
0.52
0.51
0.50
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
7
8
9
10
11
12
12.50
13
14
15
16
17
18
PRICE (TL) P_1

The curve has the same shape as the one discussed in the section dealing with quality.

The two regions defined are:

I $\quad A \leqslant A_2$

II $\quad A \geqslant A_2$

In the region I, the following relation holds

$$Y_A = a + e^{bA} \qquad \text{(ix)}$$

Boundary conditions:

$$A = 0 \qquad Y_A = 0.2$$

$$A = A_2 \qquad Y_a = 0.5$$

solving (ix) for the parameters in terms of the above values.

$$0.2 = a - 1 \qquad a = -0.8$$

$$0.5 = -0.8 + e^{bA_2}$$

$$bA_2 = l_n\, 1.3$$

$$b = \frac{1}{A_2} \quad l_n\,(1.3)$$

thus

$$Y_A = -0.8 + (1.3)^{A/A2} \qquad \text{(x)}$$

In region II

$$Y_A = a - \frac{b}{A} \qquad \text{(xi)}$$

Boundary conditions:

$$A = A_2 \qquad Y_A = 0.5$$

$$A = \infty \qquad Y_A = 0.8$$

Solving (xi) for the parameters in terms of the above values:

$$0.8 = a - 0 \qquad a = 0.8$$

$$0.5 = 0.8 - \frac{b}{A_2}$$

$$b = 0.3\, A_2$$

thus,

$$Y_A = 0.8 - (0.3) \frac{A}{A_2} \qquad \text{(xii)}$$

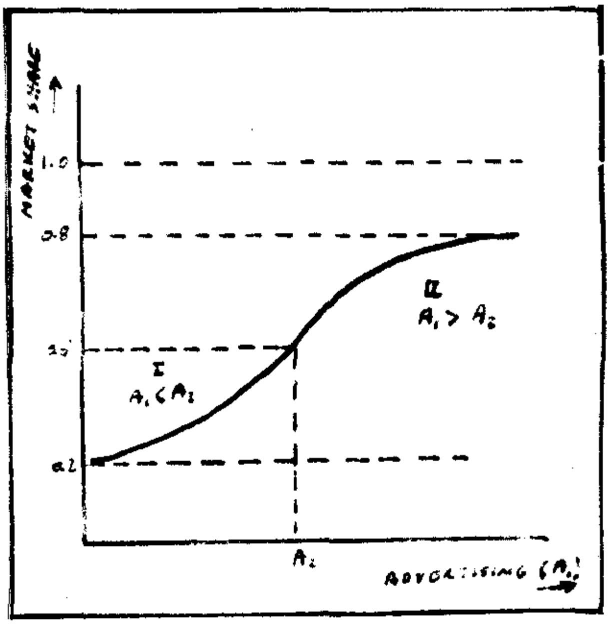


Figure 11. Market share vs Advertising

Figure 11 illustrates the above behavior.

The measure of advertisement is defined as advertising outlay. It is recognized that a better measure would be number of people whose decisions have been influenced by advertising but this concept is very hard to measure, therefore, the former concept was used. It is assumed that the advertisement outlay is used most effectively.

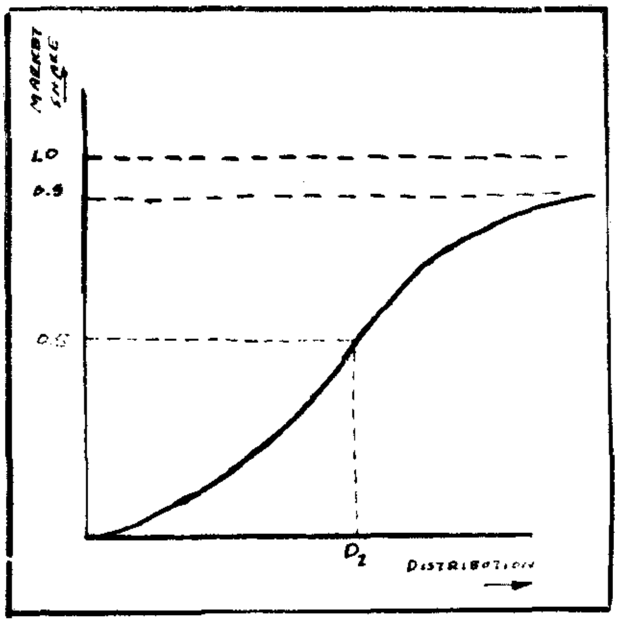


Figure 12. Market share vs Distribution

DISTRIBUTION

Defining a unit for measuring distribution is also very difficult since both the number and density of distribution outlets is important. Distribution expense was accepted as the unit of these variables assuming that this was used most effectively.

The discussion of the effectiveness of distribution is identical to the one in the previous chapter. The only difference is the following. The company is not able to sell any amount of its product if it has no distribution. If the firm has infinite distribution, however, it cannot take away all the market from the competitor.

The two regions defined on this curve are:

$$\text{I} \quad D_1 \leqslant D_2$$

$$\text{II} \quad D_1 \geqslant D_2$$

In region I

$$Y_D = a + e^{bD} \qquad \text{(xiii)}$$

the boundary conditions are:

$$D = 0 \qquad Y_D = 0$$

$$D = D_2 \qquad Y_D = 1/2$$

The resulting equation is

$$Y_D = -1 + \left(\frac{3}{2}\right)^{D/D2} \qquad \text{(xiv)}$$

In region II:

$$Y_D = a - \frac{b}{D} \qquad \text{(xv)}$$

the boundary conditions are:

$$D = D_2 \qquad Y_D = 0.5$$

$$D = \infty \qquad Y_D = 0.9$$

Solving (xv) for the parameters by using the above values.

$$0.9 = a - 0 \qquad a = 0.9$$

$$0.5 = 0.9 - \frac{b}{D_2}$$

$$b = 0.4\ D_2$$

The resulting equation is:

$$Y_D = 0.9 - (0.4)\frac{D_2}{D} \qquad \text{(xvi)}$$

Figure 12 on Page 52 illustrates this behavior.

COMBINED EFFECTIVENESS MODEL

The combined effectiveness model was shown in Chapter III to be:

$$EFFT = \prod_{i=i}^{i=n} e_i$$

Thus,

$$EFFT = (Y_a)^a \, (Y_p)^b \, (Y_A)^c \, (Y_d)^d$$

where:

$$a + b + c + d = 1$$

$$0 \leq a, \quad o \leq b, \quad o \leq c, \quad o \leq d$$

The parameters show the contribution of each element to the total effectiveness. Thus, the variable which has the most effect on the market share will have the highest coefficient.

The values for a, b, c, d have been assigned arbitrarily. Acutally they should be found by a market survey and by statistical analysis.

The values chosen for the parameters are as follows:

$$a = 0.45$$

$$b = 0.20$$

$$c = 0.25$$

$$d = 0.10$$

$$EFFT = (Y_a)^{0.45} \, (Y_p)^{0.20} \, (Y_A)^{0.25} \, (Y_D)^{0.1} \qquad (xvii)$$

EFFECTIVENESS MODEL

SUMMARY

Variable	Region	Equation	Equation Number
Quality	$Q \leq Q_2$	$Y_a = -1 + (\frac{3}{2})^{Q/Q2}$	(ii)
	$Q \geqslant Q_2$	$Y_a = 1 - \frac{1}{2} \frac{Q_2}{Q}$	(iv)
Price	$P \leq P_2$	$Y_p = 2 - (\frac{3}{2})^{P/P2}$	(vi)
	$P \geqslant P_2$	$Y_p = \frac{1}{2} \frac{P_2}{P}$	(viii)
Advertising	$A \leq A_2$	$Y_A = -0.8 + (1.3)^{A/A2}$	(x)
	$A \geqslant A_2$	$Y_A = 0.8 - 0.3 (\frac{A_2}{A})$	(xii)
Distribution	$D \leq D_2$	$Y_D = -1 + (\frac{3}{2})^{D/D2}$	(xiii)
	$D \geqslant D_2$	$Y_D = 0.9 - 0.4 (\frac{D_2}{D})$	(xvi)

$$EFFT = (Y_Q)^{0.45} (Y_P)^{0.20} (Y_A)^{0.25} (Y_D)^{0.1} \qquad \text{(xviii)}$$

CHAPTER V

COST MODEL

The cost model is one of the most important tasks of cost-effectiveness analysis. Unfortunately, because of lack of data, we have used a hypothetical quality-cost relationship and oversimplified the model. The cost not being realistic, the result of the analysis is seriously affected. Nevertheless, assuming that costs are described by the model the analysis gives us a basis of choice among several alternatives.

QUALITY COSTS

It is assumed that in initial increase of quality from a very low level to a relatively higher one, requires a great amount of cost. This high initial increase is due to the need for new machines, better raw material and more highly skilled labor. The curve smooths down as quality is increased further and with small additional cost better quality is achieved. The reason for this behavior can be explained in terms of the changes that are necessitated in the inputs by a quality increase requirement. At relatively high qualities, the firm will have the machinery needed and small improvements in the methods, machinery, tooling and labor could result in higher qualities with small additional cost.

As quality increases further, however, the machinery will have to be changed for high precision equipment and each incremental quality will require meticulous care and, therefore, will increase costs. As the technological limit to quality is approached the cost will rise very steeply. This relationship is sketched in Figure 13.

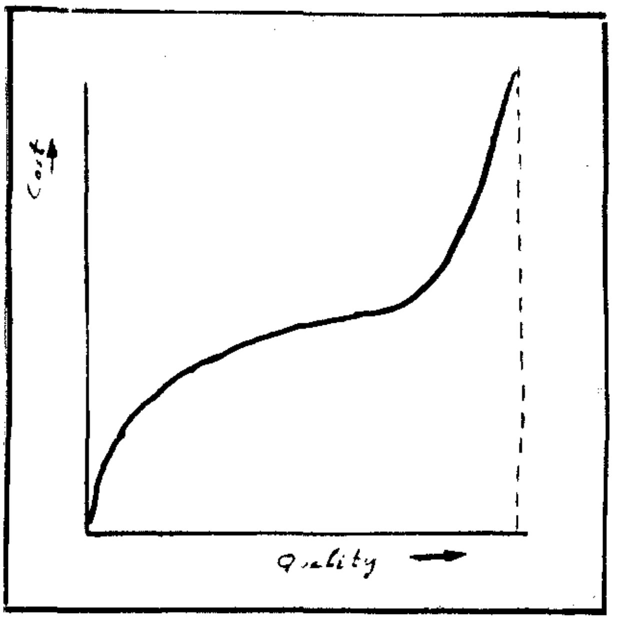


Figure 13. Quality vs Cost

We should make clear at this point that the cost curve connects all the points which are the minimum costs for achieving the respective quality levels. This assumes that a previous study has been done to determine these minimum costs. The procedure of finding these costs is also Cost-Effectiveness analysis where the effectiveness level of quality given, the minimum cost is required. The factors that should be considered to determine such costs are the production factors such as capital, equipment, labor, raw material, tools, etc.

The curve presented above is the inverse of a curve given by the equation:

$$X = e^{A - \frac{B}{Y}} \qquad \text{(xvii)}$$

solving this for Y, we get

$$\ln X = A - \frac{B}{Y}$$

$$Y = \frac{B}{A - \ln X}$$

In equation (xvii) X approaches e^A asymptotically. In Figure 13, however, the asymptode is Q_M referring to maximum quality achievable with existing technology.

Thus,

$$Q_m = e^A$$

OR

$$A = \ln Q_M$$

Thus,

$$CQSM = \frac{B}{\ln Q_M - \ln Q}$$

where

CQSM: Minimum cost per unit required to operate at quality level in strategy 5.

B : an arbitrary constant.

This was chosen arbitrarly to be 5.

$$TCQSM = (EFFT)\ (TS)\ (CQSM)$$

where:

TCQSM: Total cost required to operate at quality level in strategy S

EFFT: Effectiveness (Market share)

TS: Total sales in the market.

We assume that the company sells all its production and produces only as much as it will sell.

Total sales have been taken as constant in this analysis. Actually, TS has to be determined for every period of interest. Since total sales in the market is proportional to construction, one can determine how many equivalent units are used per construction either by survey or statistical analysis. The statistical analysis approach will require a multiple regression corrolation analysis since the different types of constructions are expected to use different amounts of product.

Thus,

$$TCQSM = \frac{5\ (EFFT)\ (TS)}{\ln Q_M - \ln Q} \qquad \text{(xviii)}$$

PRICE COST

Price cost is defined as the opportunity cost of assigning a different price than the minimum price considered in the analysis.

The amount of sales lost will equal to

$$TS\ (EFFM - EFFT)$$

where:

EFFM = Market share at minimum price available

EFFT = Market share at price used in the strategy

CPS = (PM) (TS) (EFFM - EFFT) (xix)

where:

CPS = cost of price

PM = minimum price

ADVERTISING COST

The cost of advertising is the outlay of advertising, thus:

Cost of advertising = A (xx)

DISTRIBUTION COST

The cost of distribution is equal to the distribution expenses, therefore:

Cost of distribution = D (xxi)

TOTAL COST MODEL

Total cost as given by the summation of the cost elements, therefore:

Cost = TCQSM + CPS + A + D (xxii)

CHAPTER VI

COMPUTER PROGRAMS

THE COST AND EFFECTIVENESS MODELS

The computer programs for the cost and effectiveness models are Fortran II function subprograms. The purpose of the program is to translate the mathenatical equations given in Chapters IV and V into computer language. The flow diagrams of these programs are presented below; the print-outs are given in the appendix.

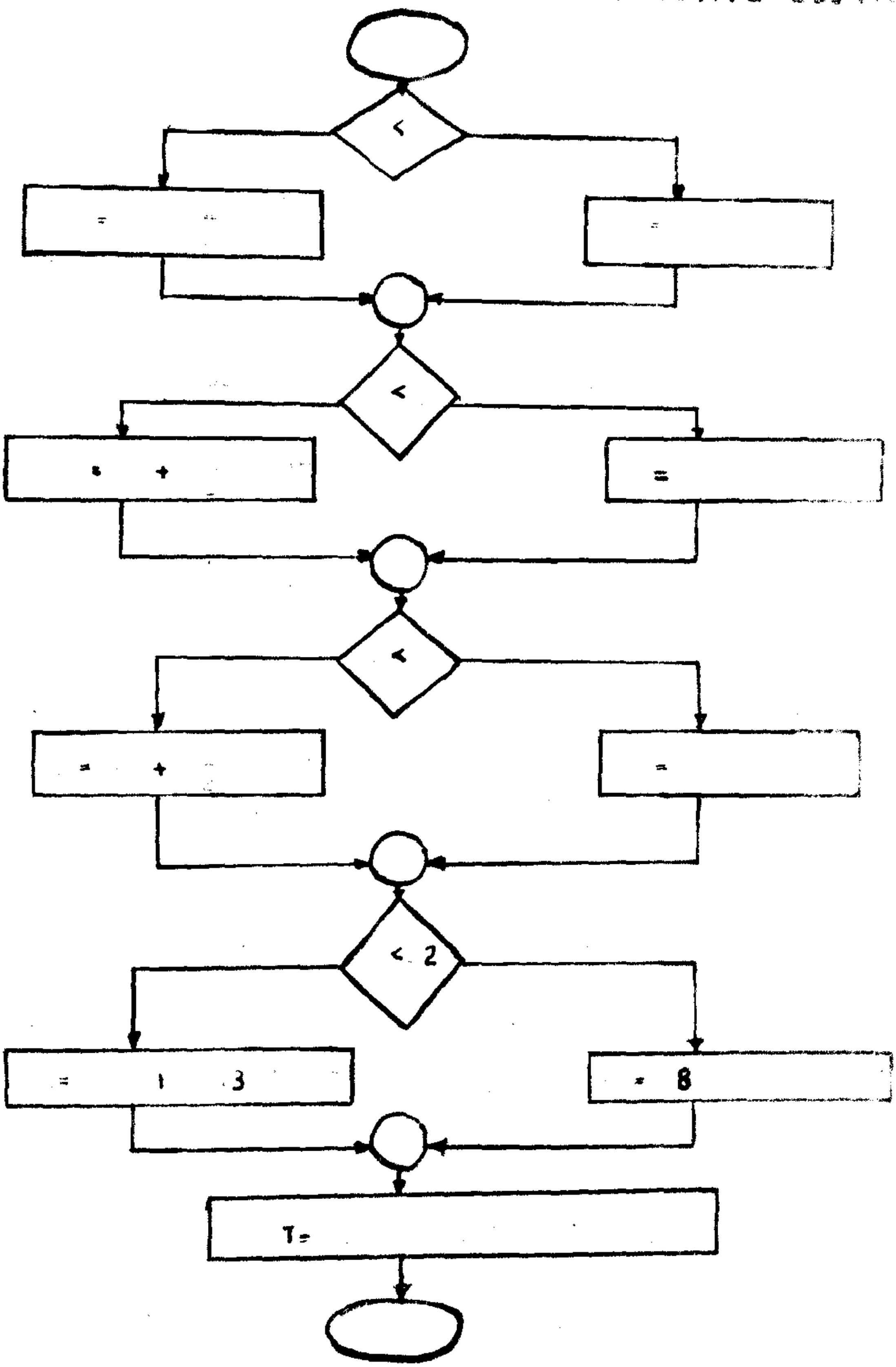
These programs are fed into the computer and stored in the disk. Whenever one of the main programs which are discussed below is put on the computer, it will call on these subprograms for evaluation of the strategies.

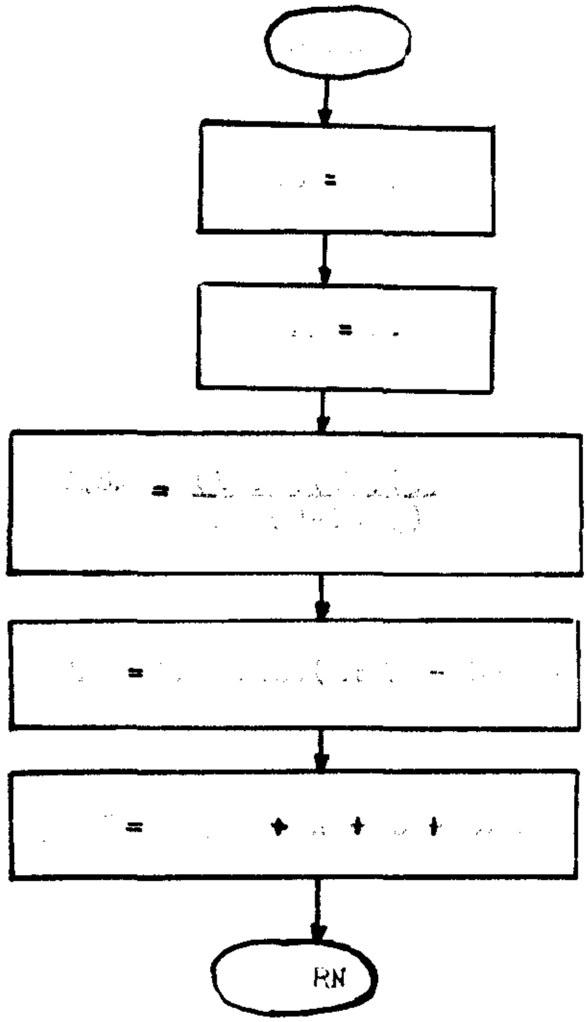
The total market sales in this program has been held constant at 1.000.000 equivalent units. In an analysis of a real-life situation, the total sales must be calculated as described in Chapter V. Calculation of TS will require another subprogram and accordingly on the first operation in the cost subprogram will be calling the TS program which will calculate total sales.

The minimum price used in the strategies has been fixed as 8 TL but this value also has to be changed whenever a price other than 8 TL is used.

The effectiveness model will need revision whenever the

EFFECTIVENESS MODE





[illegible]

A: Advert[illegible] outlay. D: Distribution expe[illegible] coefficients in the model change. This change will be mainly due to variations in the relative importance of the variables on the part of the consumers.

DETERMINISTIC MODEL PROGRAMS

The first deterministic model is the one to which further reference will be made as the model test program. This program needs the data concerning the values of the four variables for both competitors and determines the effectiveness and cost of our strategy when it is used against the opponents strategy which has been fed to the computer along with ours. This program makes no selection among the competitors' strategies and therefore requires that all combinations are fed in individually.

The program was used to test the boundary conditions and to observe the behavior of the quality-market share and price-market share curves. The tabulated results and the corresponding graphs are given below.

This program should be used when the competitors strategy is known, that is for DMUC. Although at first glance the procedure may seem to be one of decision-making under competitive behavior because of the competitor, it is not the case since this last decision making are implies an analysis of the situation from both parties point of view, which is not what we are considering. The strategies of the competitor are given and we are not considering how he makes his choice. The computer will read two cards at a time only, therefore, all the data can be placed

TABLE II

MARKET SHARE vs PRICE FOR THREE DIFFERENT COMPETATIVE PRICES, ALL OTHER VARIABLES BEING EQUAL

(Quality: 20, Advertisement: 1000000, Distribution: 500000)

Price	Market Share (EFFT)		
	P_2: 8 TL	P_2: 11 TL	P_2: 12.5 TL
6.5	0.520	0.539	0.544
7	0.514	0.536	0.545
7.5	0.507	0.532	0.539
8	0.500	0.528	0.535
8.5	0.494	0.524	0.532
9	0.488	0.520	0.529
9.5	0.483	0.515	0.525
10	0.468	0.510	0.521
10.5	0.474	0.505	0.518
11	0.469	0.500	0.513
11.5	0.465	0.445	0.509
12.5	0.457	0.487	0.500
13	0.454	0.484	0.496
14	0.447	0.476	0.489
15	0.441	0.470	0.482
15.5	0.438	0.467	0.480
16	0.435	0.464	0.476
18.5	0.429	0.451	0.462

See Figure 10.

TABLE III

MARKET SHARE vs QUALITY FOR TWO DIFFERENT COMPETATIVE QUALITIES, ALL OTHER VARIABLES BEING EQUAL

Q_1	$Q_2 = 12$	$Q_2 = 20$
10	0.453	0.350
12	0.499	0.374
14	0.525	0.414
16	0.553	0.445
18	0.581	0.499
22	0.491	0.532
24	0.600	0.540
28	0.620	0.570
30	0.622	
32	0.629	0.585
36	0.635	0.600

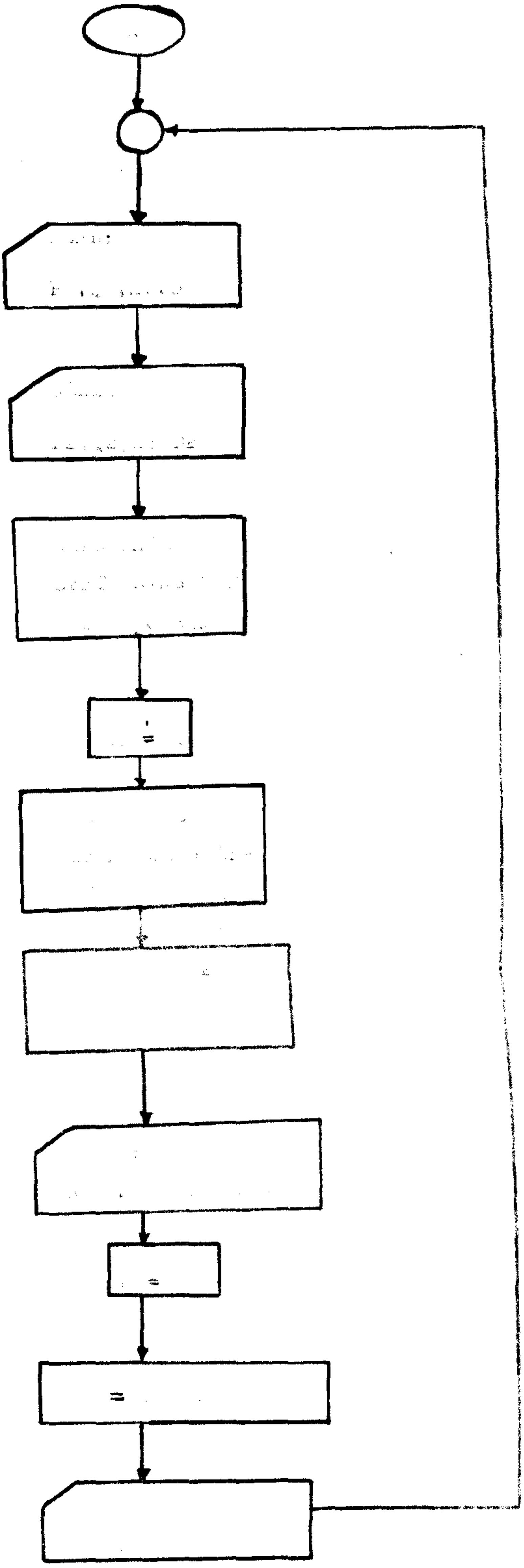
See Figure 8.

together. This will necessitate, however, punching each strategy and duplicating competitors strategy so as to have one copy fed into the computer with each of our alternatives. The flow chart of the program is presented below.

The second deterministic model is used to evaluate a square matrix consisting of all possible combinations of ours and the competitors strategies for a given-number of levels for each variable. This model was first intended to be used for DMUU, but the resulting number of combinations being 4096 $(64)^2$ for the amount of levels chosen., we decided to add to the program a random number selector with a rectangular distribution and evaluate all our strategies against only twelve of the opponents. Among these two representative samples were chosen and analyzed.

The program choses a level for each of the variables to be used by the competitor according to the rectangular distribution. Having selected a combination for the competitor it evaluates all our strategies against this choice and then starts the whole operation once more. This continues until twelve combinations for the competitor have been evaluated after which the program stops. The flowchart is presented in the following pages.

We assume that the competitor has the same choice as we do for the values of the variables that he may select. It would be possible to choose another set of values for the competitor but since there is not any reason to think otherwise, the choices are made identical. This eliminates any predetermined superiority of one firm over the other and therefore is justifi-



able.

If a complete analysis of all competitor behavior versus our selections were made, it would create a square matrix whose size is determined by the number of levels considered for each variable.

The 64 by 64 matrix mentioned above results from the following variable levels.

Price: 4 levels: 8 TL, 10 TL, 12 TL, 14 TL

Quality: 4 levels: 12, 18, 25, 30

Advertising: 2 levels: 1,000,000, 1,500,000

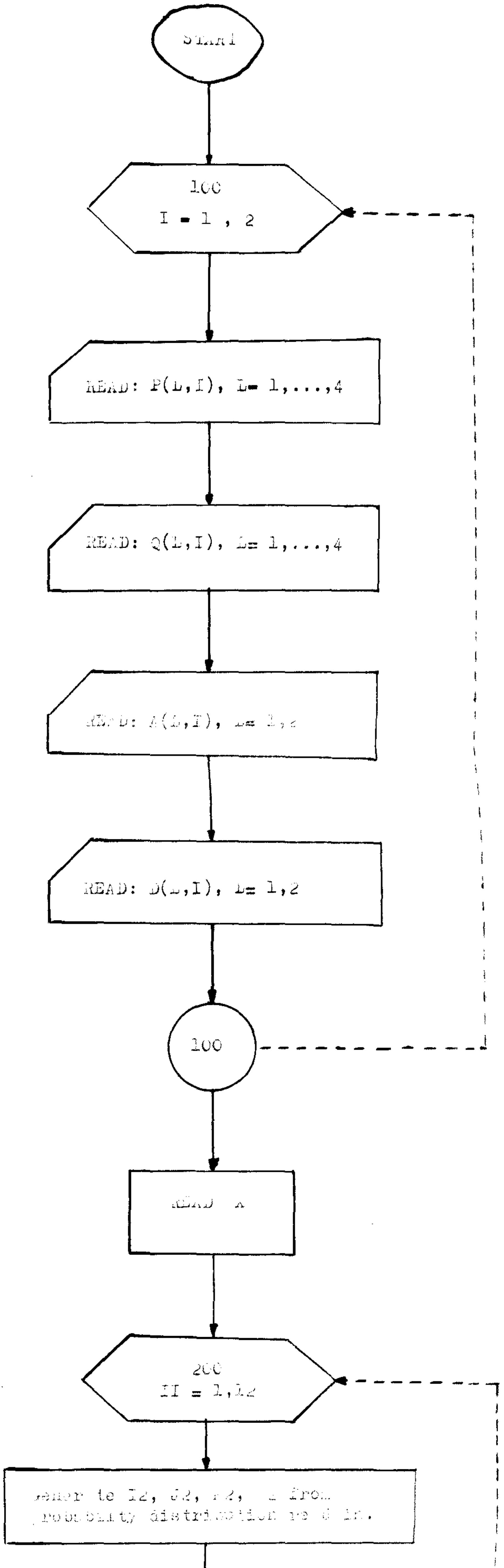
Distribution: 2 levels: 800,000, 1,000,000

Number of strategies = (4) (4) (2) (2) = 64

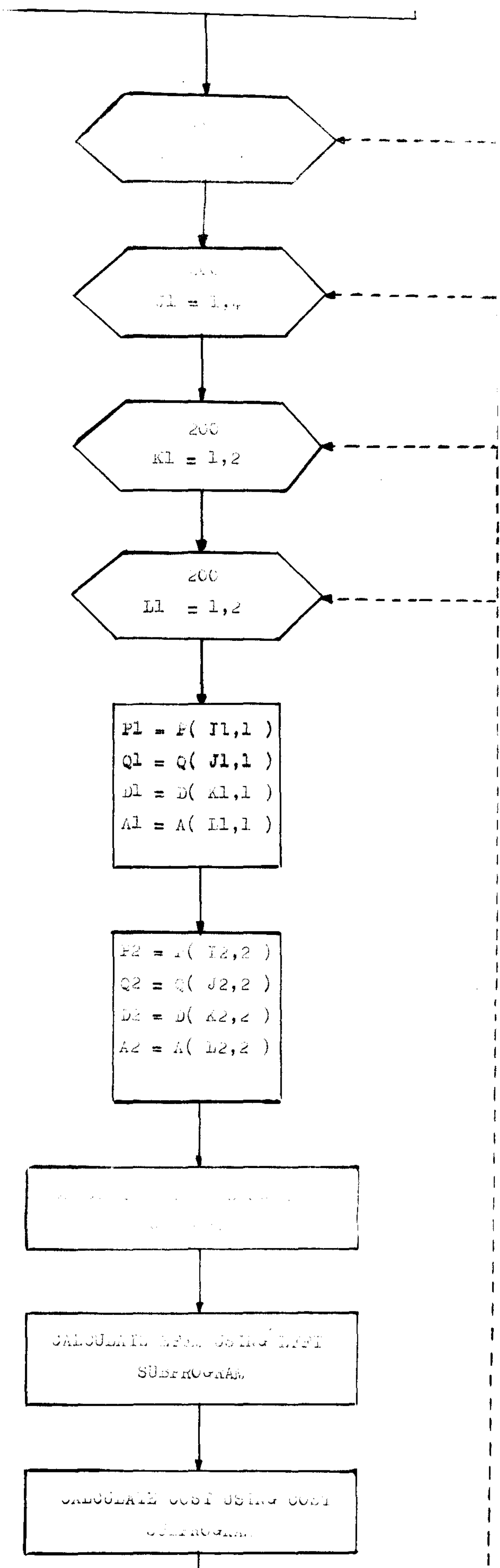
SIMULATION MODEL PROGRAM (ONE PERIOD)

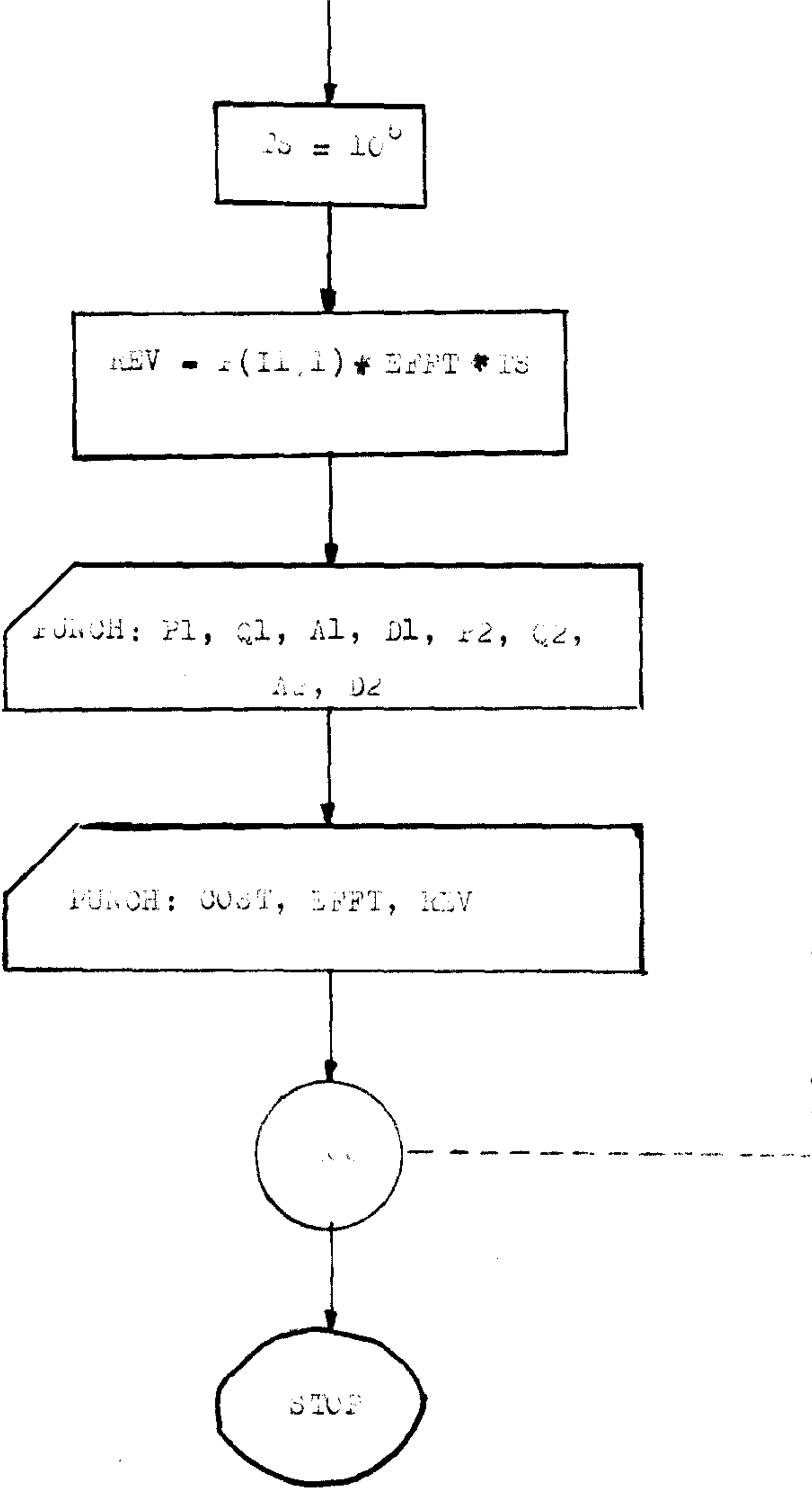
This program is essentially the same as the previous one, the only difference being the probability distribution. We have assumed the following probability distribution for the competitors choice of variable levels. To simplify the evaluations, two levels were assigned to each variable.

Price	: level	8 TL	12 TL
	Prob.	0.7	0.3
Quality	: Level	12	18
	Prob.	.6	0.4
Advertisement	: level	1,000,000	1,500,000
	Prob.	0.4	0.6
Distribution	: level	800,000	1,000,000



100
I = 1 , 2
READ: P(L,I), L= 1,...,4
READ: Q(L,I), L= 1,...,4
READ: D(L,I), L= 1,2
100
200
II = 1,12


200
K1 = 1,2
200
L1 = 1,2
P1 = P(I1,1)
Q1 = Q(J1,1)
D1 = D(K1,1)
A1 = A(L1,1)
P2 = P(I2,2)
Q2 = Q(J2,2)
D2 = D(K2,2)
A2 = A(L2,2)



TS = 10^6
REV = P(I1,1) * EFFT * TS
PUNCH: P1, Q1, A1, D1, P2, Q2, A2, D2
PUNCH: COST, EFFT, REV
STOP

Prob.	0.5	0.5

The results were averaged and the final analysis was done for these averages. The tabulation of the final values is given below,[1] the initial values have been omitted for space considerations. The flow chart follows.

STOCHASTIC MODEL PROGRAM (TWO PERIOD)

A two period simulation provides a clearer view of what may be expected in the coming period as a result of the successive choices of strategies. The competitor has been assumed to select the value of his variables for any period according to his and our previous values. The probability distribution is as follows:

$P_1\ (t) = 10$

$P_2\ (t+1)$ \ $P_2(t)$	10	14
10	0.9	0.7
14	0.1	0.3

$P_1\ (t) = 14$

$P_2\ (t+1)$ \ $P_2(t)$	10	14
10	0.6	0.8
14	0.4	0.2

---

1 See table V

Prob.	0.5	0.5

The results were averaged and the final analysis was done for these averages. The tabulation of the final values is given below,[1] the initial values have been omitted for space considerations. The flow chart follows.

STOCHASTIC MODEL PROGRAM (TWO PERIOD)

A two period simulation provides a clearer view of what may be expected in the coming period as a result of the successive choices of strategies. The competitor has been assumed to select the value of his variables for any period according to his and our previous values. The probability distribution is as follows:

$P_1\ (t) = 10$

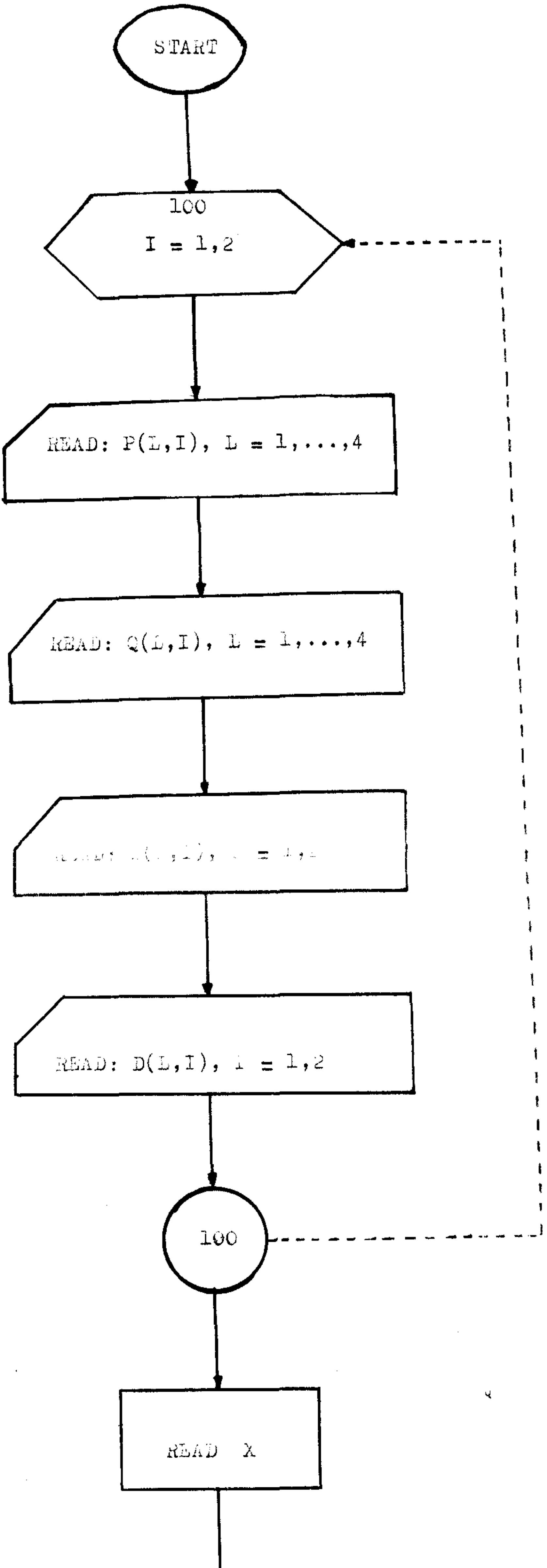
$P_2\ (t+1)$ \ $P_2(t)$	10	14
10	0.9	0.7
14	0.1	0.3

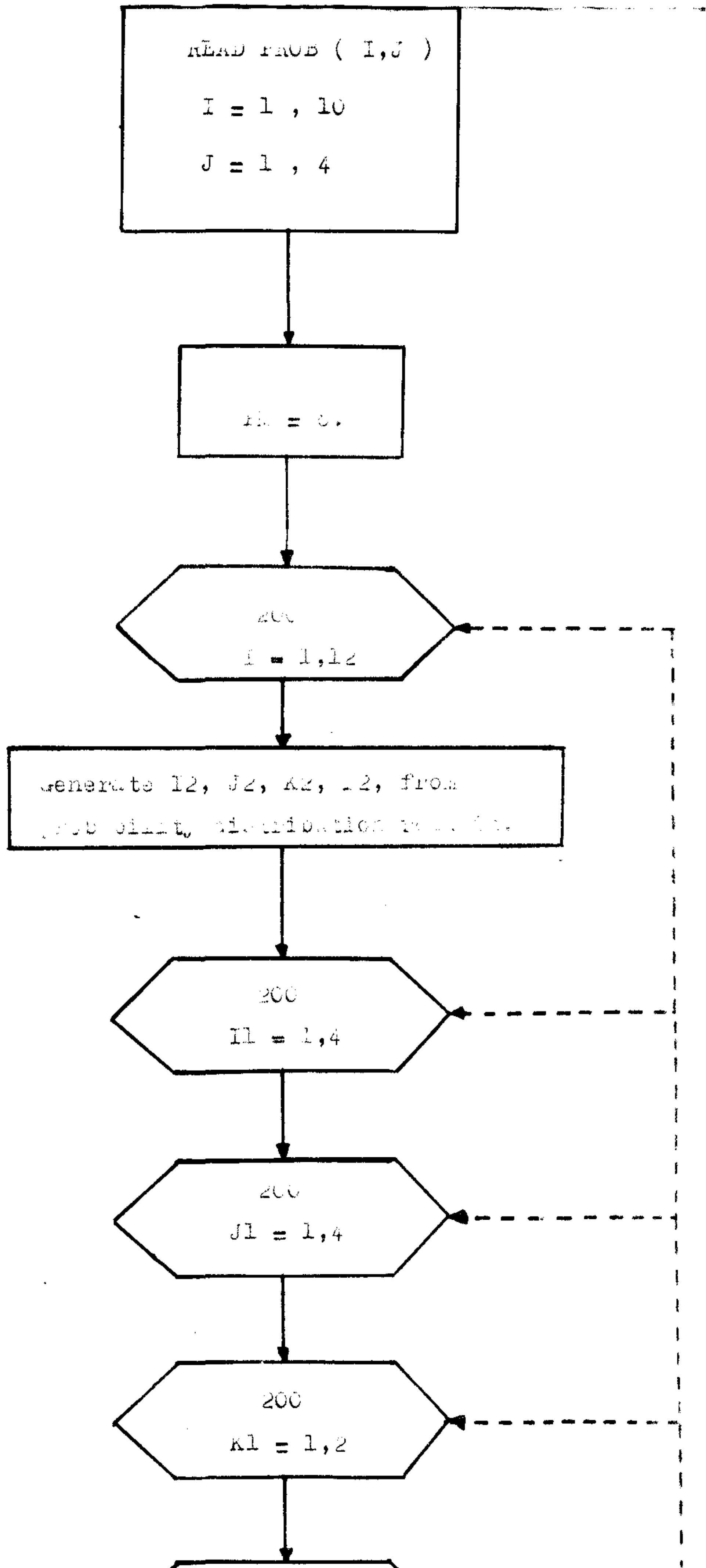
$P_1\ (t) = 14$

$P_2\ (t+1)$ \ $P_2\ (t)$	10	14
10	0.6	0.8
14	0.4	0.2

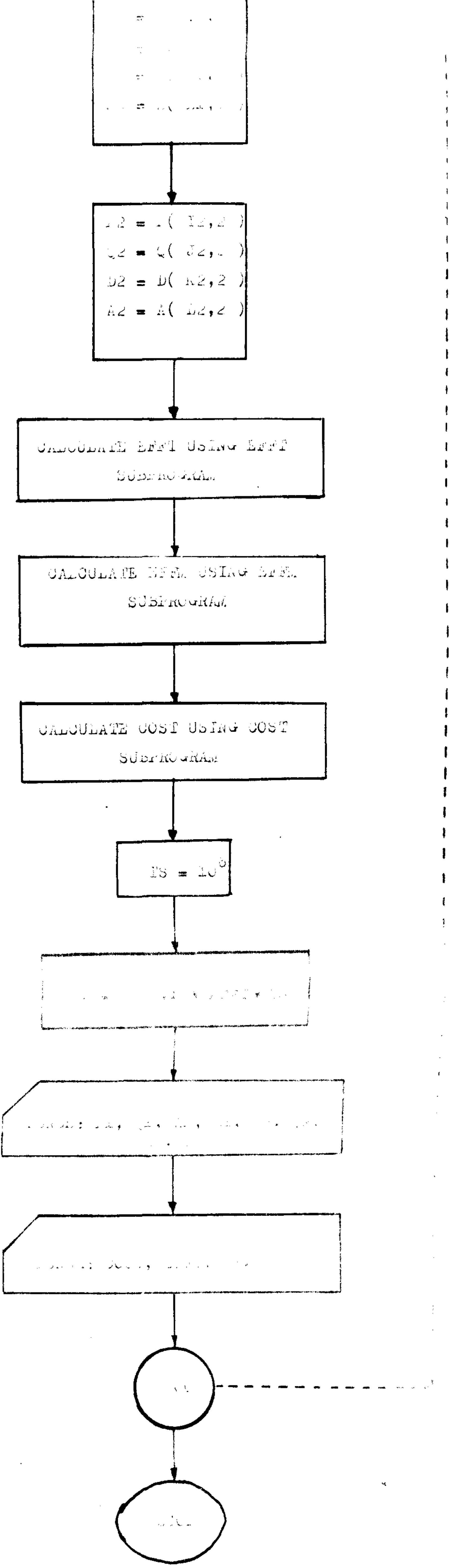
1 See table V

SIMULATION MODEL





READ PROB (I,J)
I = 1 , 10
J = 1 , 4
200
I1 = 1,4
J1 = 1,4
200
K1 = 1,2


D2 = D(K2,2)
CALCULATE EFFT USING EFFT
SUBPROGRAM
CALCULATE EFFM USING EFFM
SUBPROGRAM
CALCULATE COST USING COST
SUBPROGRAM

$Q_1 \ (t) = 18$

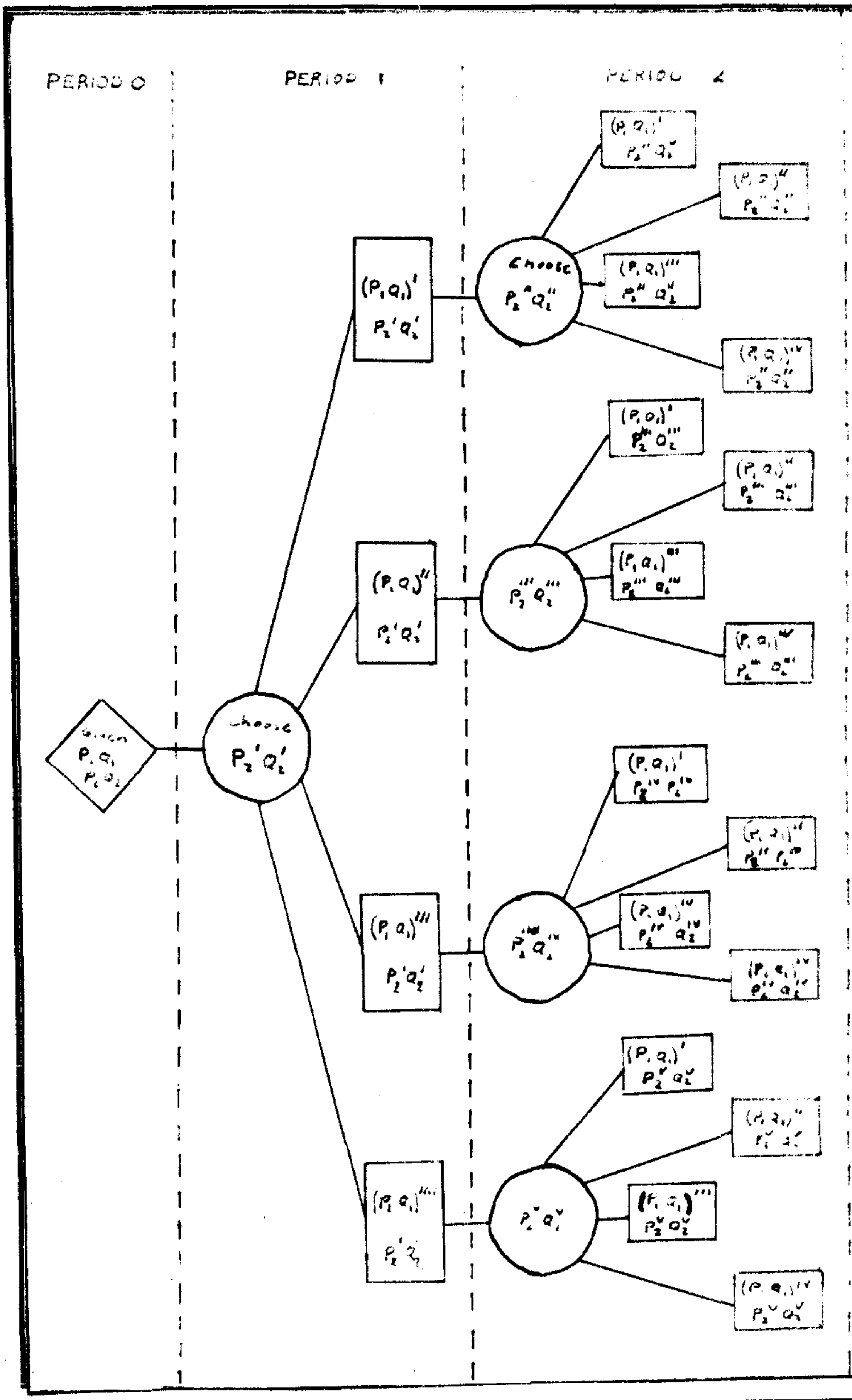
$Q_2 \ (t+1)$		$Q_2 \ (t)$: 18	25
	18	0.5	0.8
	25	0.5	0.2

$Q_1 \ (t) = 25$

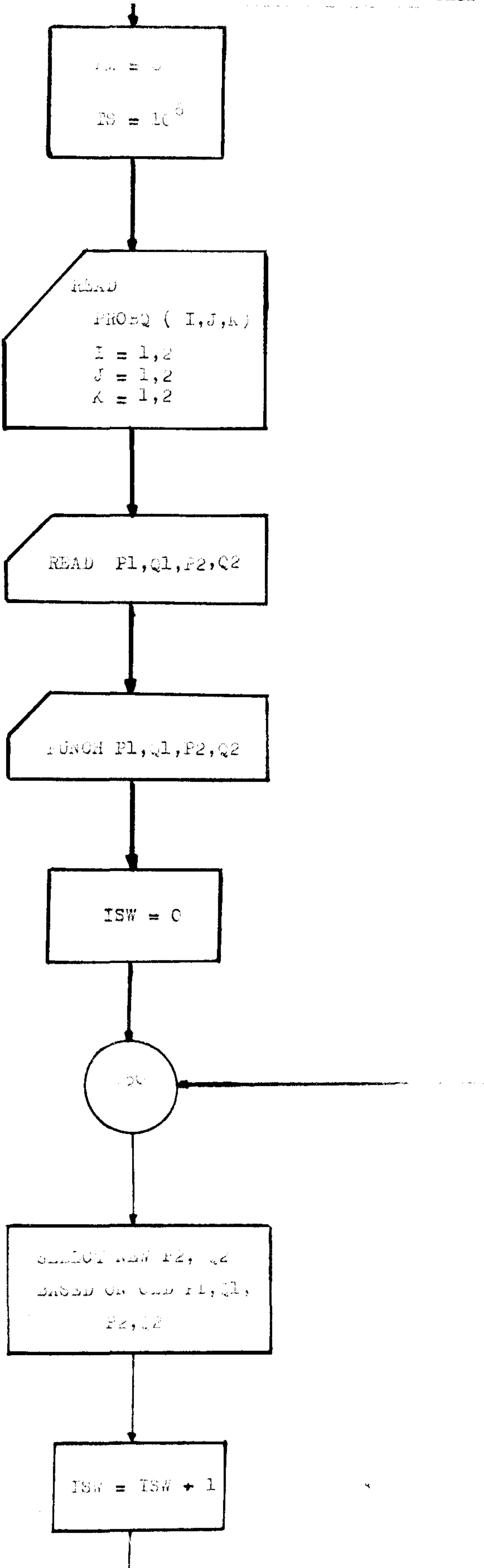
$Q_2 \ (t+1)$		$Q_2 \ (t)$: 18	25
	18	0.4	0.5
	25	0.6	0.5

The advertising outlay and distribution costs were assumed to be constant for simplification of the analysis. The decision tree is given below, the flow chart follows:

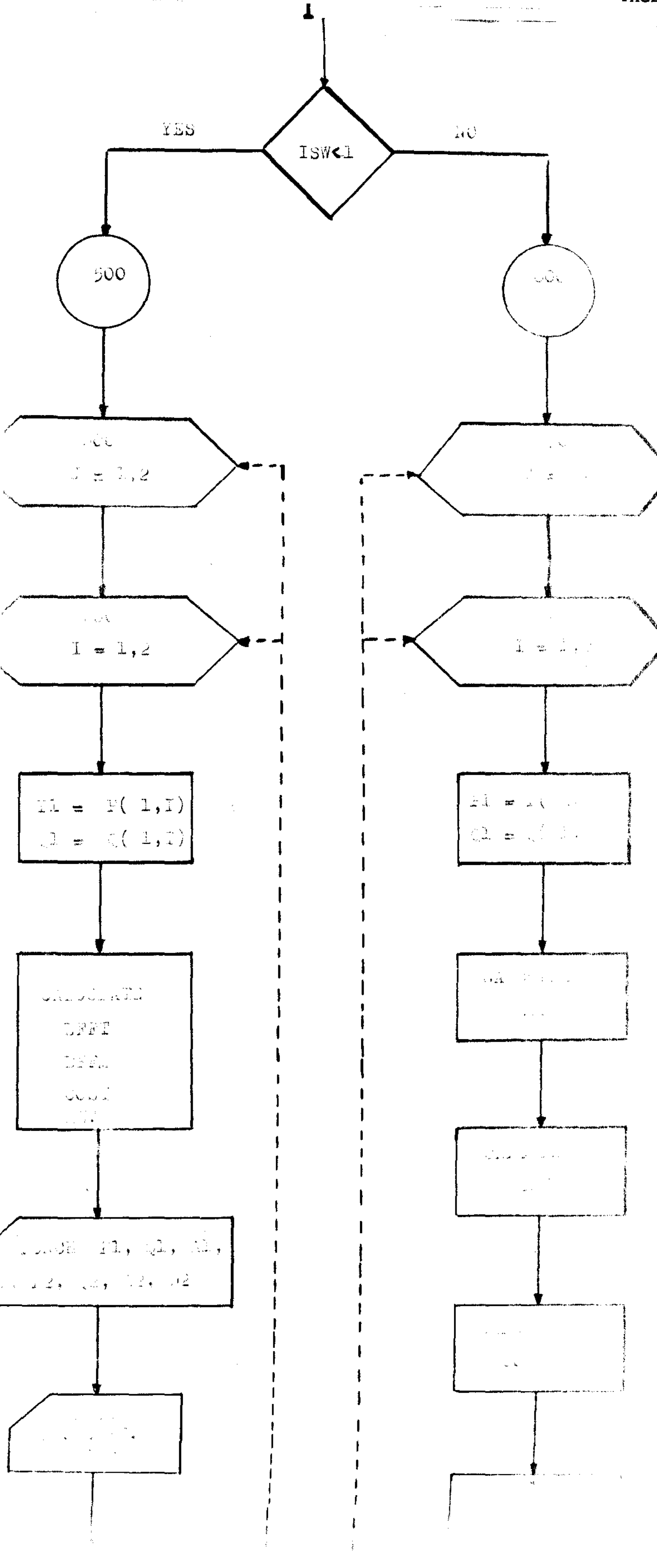
The computer needs P_1, Q_1, P_2, and Q_2 for the initial period and selects P_2 and Q_2 for the first period. The four strategies which represent all possible combinations of our variables are evaluated using the sub-programs and the computer reselects P_2 and Q_2 for the second period based on P_1, Q_1, P_2, and Q_2 in the first periods. The number of selections is determined by the combination of our alternatives used in the previous period and his strategy. The procedures in the second period are identical to the ones in the first period. There are sixteen evaluations to be done after which the program ends. We would like to add that the simulation could be continued for (n) periods by making slight changes in the program.

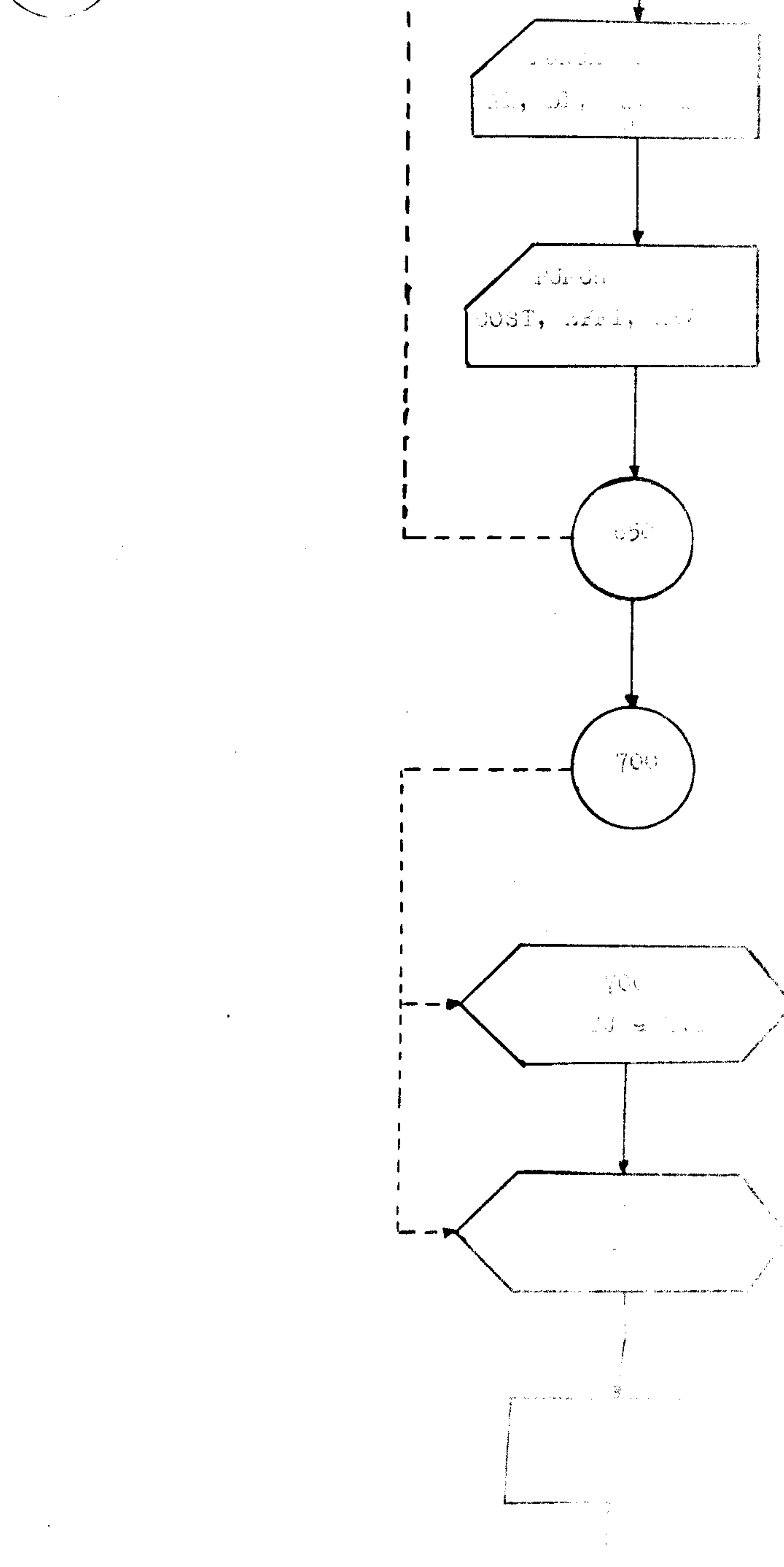


PERIOD 0
PERIOD 1
PERIOD 2
Given
Choose



READ
I = 1,2
J = 1,2
K = 1,2
READ P1,Q1,P2,Q2
P1,Q1,P2,Q2
ISW = 0
ISW = ISW + 1


YES
ISW<1
NO
500
I = 1,2
CALCULATE


700

CHAPTER VII

RESULTS

DETERMINISTIC MODEL

We selected two competitive strategies and evaluated our possible 64 combinations. The competitors alternatives were not selected at random but rather chosen so as to be representative of the spectrum formed by all probable combinations of variables that he could use.

The computer output has not been included in this paper to avoid a cumbersome accumulation of data. The cost effectiveness schedules for each analysis are given in the next pages.

The values that were considered for the variables of both parties are the following:

T	P :	8.	10.	12.	14.
	Q :	12.	18.	25.	30.
	A :	1,000,000		1,500,000	
	D :	800,000		1,000,000	

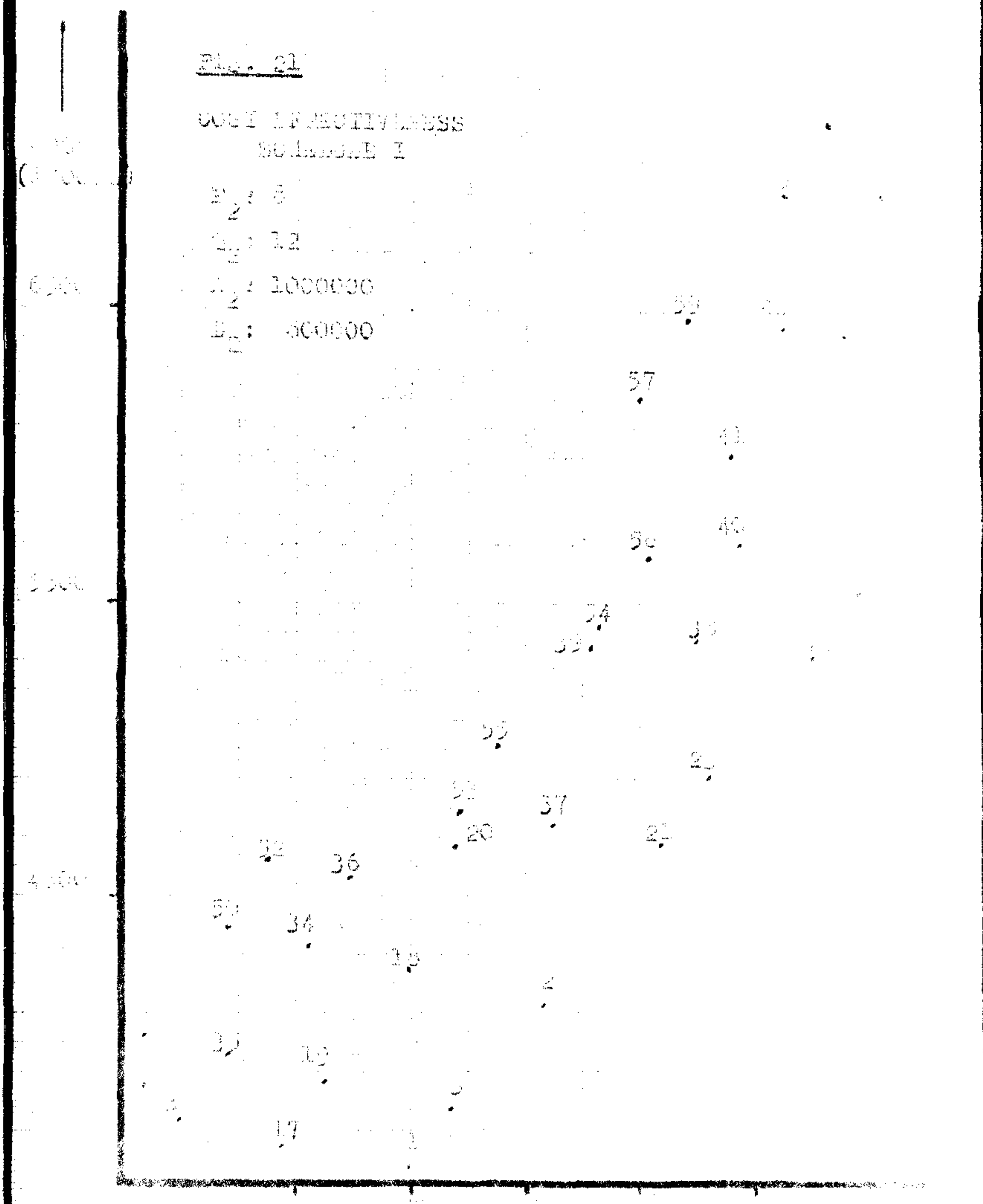
First competitive strategy selected was the following:

P_2 : 8 Q_2 : 12 A_2 : 1,000,000 D_2 : 800,000

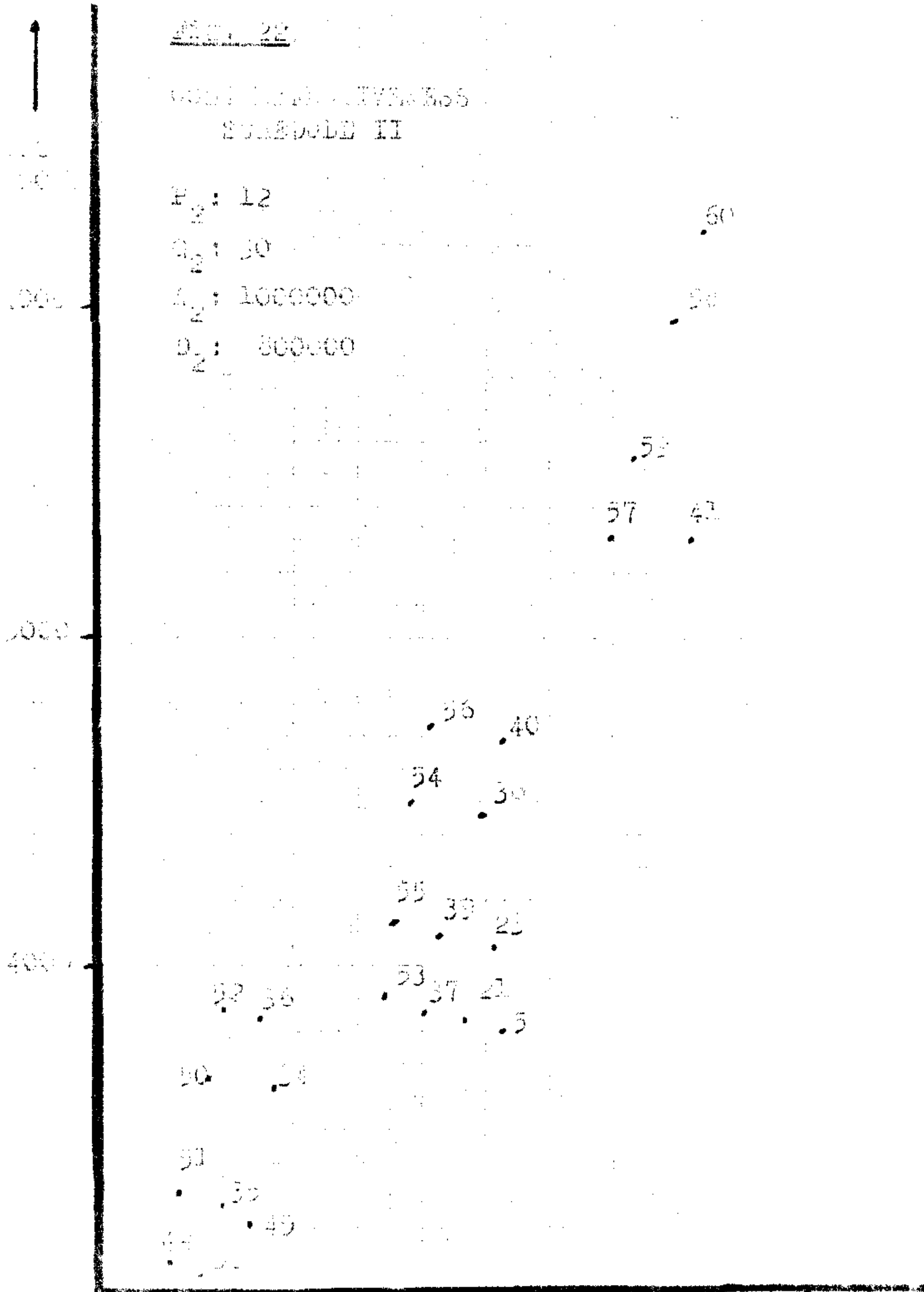
The cost effectiveness schedule for this strategy is given in Figure 21. All strategies resulting in losses are eliminated from consideration. Our dominant strategies are 1, 2, 3, 21, 22, 23, 24, and 42.

The alternatives represent the following selections:

Strategy	P	Q	A 10^6	D 10^6	EFF.	Cost (1000TL)
1	8	12	1	0.8	0.50	3550
2	8	12	1.5	0.8	0.523	4130
3	8	12	1	10	0.507	3780
21	10	18	1	0.8	0.544	4660
22	10	18	1.5	0.8	0.570	5295
23	10	18	1	1	0.552	4910
24	10	18	1.5	1	0.578	5540
42	12	25	1.5	0.8	0.583	6900



57
36
34
37
20
17


SCHEDULE II
12
1000000
60
52
57
42
56
40
54
55
39
53
37
5

The second competitive strategy is:

P_2 : 12 Q_2 : 30 A_2 : 1,000,000 D_2 : 800,000

The cost effectiveness schedule is given in Figure 22.

The dominant alternatives indicated by this schedule are:

Strategy	P	Q	A	D	EFF.	Cost
5	8	18	1	0.8	0.408	5780
33	12	12	1	0.8	0.313	3061
41	12	25	1	0.8	0.463	5970
49	12	25	1.5	0.8	0.303	3100
60	14	12	1.5	1.0	0.469	6240

If we were interested in finding the best strategy that would allow us to capture most of the market, such a solution would be given by the analysis as it can be seen above.

In the first case, the best strategy is 42, and in the second, 60. The difference between the effectiveness of the best and the second best strategies in the first case is only 0.005 yet the difference in cost is 1,400,000 TL. The choice depends on how much the manager values this increase in the market share. If the value is greater than the difference of cost than he should choose it. The merit of this analysis is that it will not allow the decision-maker to be attracted by alternatives with high effectiveness. The measure of cost is a check on this evaluation.

TABLE IV

SIMULATION MODEL

The following strategies have been used in the simulation model:

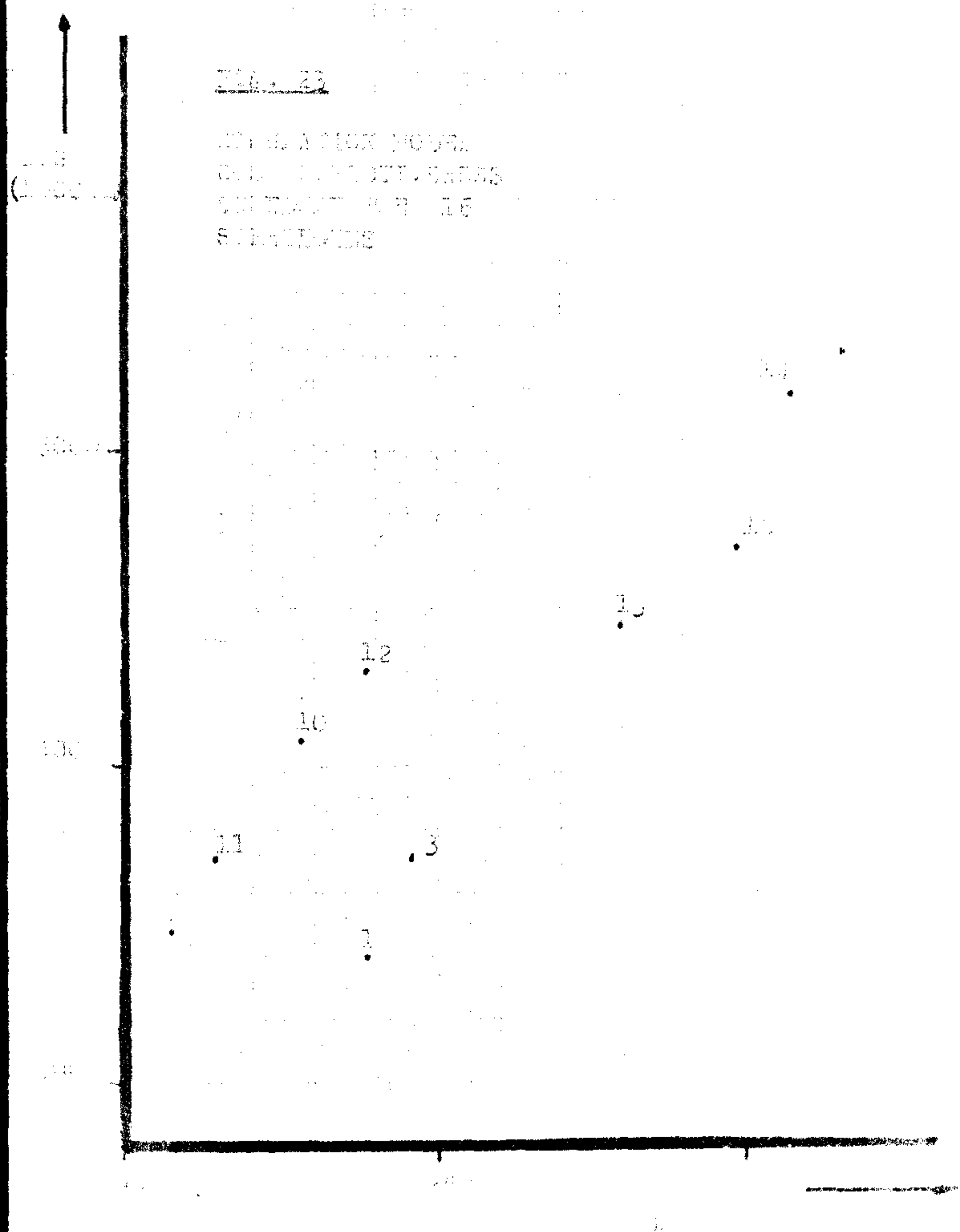
Strategy Number	Price	Quality	Advertising ($\times 10^6$)	Distribution ($\times 10^6$)
1	8	12	1	0.8
2	8	12	1.5	0.8
3	8	12	1.0	1.0
4	8	12	1.5	1.0
5	8	18	1.0	0.8
6	8	18	1.5	0.8
7	8	18	1.0	1.0
8	8	18	1.5	1.0
9	12	12	1.0	0.8
10	12	12	1.5	0.8
11	12	12	1.0	1.0
12	12	12	1.5	1.0
13	12	18	1.0	0.8
14	12	18	1.5	0.8
15	12	18	1.0	1.0
16	12	18	1.5	1.0

TABLE V

The Results of the Simulation

(Average over the twelve randomly chosen alternative competitor strategies rounded off to three significant digits.)

Strategy 1	Cost (1000TL)	Effectiveness	Revenue (1000 TL)
1	3350	0.439	3500
2	3920	0.464	3700
3	3550	0.446	3580
4	4160	0.472	3780
5	4330	0.518	4140
6	4980	0.547	4350
7	4590	0.529	4230
8	5240	0.558	4470
9	3480	0.407	4880
10	4080	0.428	5150
11	3720	0.414	5000
12	4300	0.438	5250
13	4450	0.480	5260
14	5100	0.508	6100
15	4700	0.490	5400
16	5320	0.516	6200



12
10
11
3

Strategies 2, 4, 5, 6, 7 and 8 will not be further considered because they result in a loss for the firm. Figure 23 shows that strategies 1, 3, 13, 14, 15 and 16 dominate all the other strategies. The analysis shows that operating at the quality level 18 is desirable only if the price is 12 TL. At a price of 8 TL the firm suffers a loss although the market shares obtained for combinations containing price 8 TL result always in higher effectiveness than strategies using 12 TL for the value of the price alternative. The profit constraint then, eliminates the possibility of getting a higher market share. The values obtained here are expected values rather than actual values. The choice among the dominant strategies will depend on the budget of the firm. If managment decides that a limited amount of cost can be incurred than the alternative giving the highest effectiveness for that amount of cost will be chosen.

Strategy 14 may be selected due to such a reason. If, however, the only consideration is market share, the alternative providing the highest value for this measure (in this case 16) should be used.

TWO PERIOD STOCHASTIC MODEL

In using this model, we try to investigate what would be our market share in some future period due to the successive choices that have been made before. For simplicity, we consider two periods only.

The results at the end of the second period are as follows

Strategy	Cost (1000 TL)	Effect
1	4620	0.500
2	4720	0.467
3	6120	0.559
4	6250	0.522
5	4250	0.444
6	4330	0.420
7	5910	0.530
8	5930	0.500
9	4620	0.500
10	4720	0.470
11	6220	0.559
12	6250	0.522
13	4250	0.444
14	4330	0.420
15	5910	0.529
16	5930	0.500

The reason that all strategies are in pairs is due to the random selection process in the program. With the more appropriate probability distribution a more significant result could be expected.

Assuming that we had obtained such a result the schedule would again give us a set of alternatives which we would evaluate depending on our judgment.

CONCLUSION AND REMARKS

The use of cost effectiveness analysis as we have suggested here, we think has an acceptable degree of applicability. In practice the managers evaluate alternatives in a very much similar manner although they may not be aware of it. The contribution of Cost Effectiveness Analysis to decision-making is not the introduction of new methods, but the refinement of the existing ones. Since firms are confronted with such problems very frequently, a systematic approach that cost effectiveness analysis can bring on our opinion, is quite desirable.

The two period simulation model that was used above has a potential application if extended (n) periods to determine phenomena such as destructive price competition and price leadership by choosing values for probabilities of the competitor behavior.

The major réstraint on the use of this method is the unavailability of the functional relations used for the effectiveness model. In practice the effects of the independent variables on the dependent variable cannot be isolated. The task is complicated enough for the firm's variables let alone the ones of the competitor.

Actually the functioned relations have to be determined empirically. This would involve a detailed study of the past performance of the firm and the competitors with respect to their strategies, consumer preference, detectable trends and other relevant factors. Advanced statistical techniques should be used to isolate the effects of those factors and the common characteristics of the outcomes.

Yet for a duopolistic situation such as the one considered in this study, the relations introduced are, generally speaking, logical. Their validity could be tested by isolating data at discrete time intervals and investigate how closely the relations approximate the actual figures, taking into account the effect of noise and other factors.

The value of this method is more pronounced if one can assume the relations are available. Cost Effectiveness Analysis as applied in this study, allows the evaluation of a great number of strategies.

The major application of this method would be under the conditions specified in the above paragraph. Management could use the deterministic or simulation model, depending on the knowledge concerning competitive behavior, to evaluate the firms alternatives for a given set of opponent strategies.

Although, theoretically, the combinations that are available amount to very large figures, actually, a firm being at certain levels with respect to the four variables cannot switch to any other level immediately. Thus, knowledge of the competitors present position facilitates the determination of his future action.

A further result that could be achieved with this method is evaluating all our possible strategies against all opponent strategies, and after having determined the dominating ones through the use of Cost Effectiveness Schedules, investigate the common characteristics of these strategies. One could thus get a general view of the preferred variable values for a given opponent behavior, and having the firm's budget limitation, approximate the strategies that are to be evaluated in the future if a similar competative action arises.

A further application of this method with the assumption that the relations are known, is to use game theory for the evaluation of the matrix in which case the result will be a (n) by (m) two-persons zero-sum game which will have to be solved by the appropriate methods.

Most of the time the market will not be a duopoly. In such cases the analysis will be more complicated than what has been discussed in this study. Such situations could be handled by considering all competitors as a single competitor, or taking into account only one of them which might be the one with the highest market share or the one closest to the firm.

Any of these methods would be, however, an over simplification of the actual situation. A better method could be segmenting the market either by geographic or quality considerations such that the resulting segment is a duopoly. In this case, the second assumption on page 13 should be released and the possibility that a firm can affect the market in which it operates should be taken into consideration.

A useful extension of the methods proposed in this thesis would be to develop a stochastic model for (n) periods. Thus, management would have a useful tool for the evaulation of available strategies in terms of long-range planning, future expectations, expansion plans, etc.

In Chapter V, the determination of total sales for a given market was outlined. The mathematical equation would be as follows:

$$TS = a_1A_1 + a_2A_2 + a_3A_3 + \ldots\ldots\ldots\ldots + a_nA_n$$

or

$$TS = \sum_{i=1}^{n} a_iA_i$$

where:

A_i = The number of construction units of a particular kind of building, i.e., hotel, residential, administrative, industrial, etc., in sq. mt. or number of rooms (for hotels) or wha tever other unit is found appropriate.

a_i = Amount of equivalent product used per unit of A_i.

A multiple regression and correlation analysis will require past data concerning the toal sales in the market and the number of buildings constructed.

The market survey technique consists of examining the plans of a representative sample of buildings constructed in the past and investigate the number of equivalent products used. The results will represent the values of the a_i co-efficients in the above quation.

Since we define the total market as the high quality market, only the buildings using this quality should be considered. This could be achieved by investigating the investment per sq. mt. of construction. We can safely assume that high quality products will be used only in buildings for which there is at least some minimum investment.

The analysis that was done is by no means complete in relation to what could have been done, yet time limitation and inaccessibility to relevant data forced us to a more theoretic rather than a practical study. We feel however, the satisfaction of having accomplished our task and hope that our efforts have not gone in vain.

APPENDIX

EFFECTIVENESS MODEL

```
ZZJOB
ZZDUP
*DELETEFF
ZZZZ
ZZJOB
ZZFOR
*LDISK
      FUNCTION EFF(P1,Q1,D1,A1,P2,Q2,D2,A2)
      IF(P1-P2)10,20,20
   10 YP=2.-EXP(P1/P2*LOG(1.5))
      GO TO 100
   20 YP=.5*P2/P1
  100 CONTINUE
      IF(Q1-Q2)110,120,120
  110 YQ=-1.+EXP(Q1/Q2*LOG(1.5))
      GO TO 200
  120 YQ=1.-.5*Q2/Q1
  200 CONTINUE
      IF(D1-D2)210,220,220
  210 CONTINUE
      YD = -1. + 1.5**(D1/D2)
      GO TO 300
  220 CONTINUE
      YD = .9 - .4*D2/D1
  300 CONTINUE
      IF(A1-A2)310,320,320
  310 YA=-.8+EXP(A1/A2*LOG(1.3))
      GO TO 400
  320 YA=.8-.3*A2/A1
  400 CONTINUE
      EFF = YA**.25*YP**.2*YQ**.45*YD**.1
      RETURN
      END
ZZZZ
```

COST MODEL

```
ZZJOB
ZZDUP
*DELETCOST
ZZZZ
ZZJOB
ZZFOR
*LDISK
      FUNCTION COST( P,Q,D,A, EFFT, EFFM  )
      TS = 10.**6
      PM = 8.
      TCQSM = EFFT*TS/( LOG(50.) - LOG(Q)   )  *5.
      CPS = PM*TS*(EFFM - EFFT )
      COST = TCQSM + A + D+ CPS
      RETURN
      END
ZZZZ
```

MODEL TEST PROGRAM

```
ZZJOB
ZZFORX 4
   99 CONTINUE
      READ 1, P1, Q1, A1; D1
      READ 1, P2, Q2, A2, D2
    1 FORMAT(    4F10.2    )
      EFFT = EFF( P1, Q1, D1, A1, P2, Q2, D2, A2   )
      PM = 8.
      EFFM = EFF(PM, Q1, D1, A1, P2, Q2, D2, A2      )
      CST = COST( P1, Q1, D1, A1, EFFT, EFFM     )
      PUNCH 2 , CST, EFFT
    2 FORMAT(   7HCOST =     , F20.2     /
     1  16HEFFECTIVENESS =    ,   F20.4                   )
      TS = 10.**6
      REV = P1*EFFT*TS
      PUNCH 98, REV
   98 FORMAT(     8HREVENUE     F20.2       )
      GO TO 99
      END
```

DETERMINISTIC MODEL PROGRAM

```
ZZJOB
ZZFORX 4
      DIMENSION P(4,2),Q(4,2),A(4,2),D(4,2)
      DO 100 I=1,2
      READ 1,(P(L,I),L=1,4)
      READ 1,(Q(L,I),L=1,4)
      READ 1, (A(L,I),L=1,2)
      READ 1,(D(L,I),L=1,2)
  100 CONTINUE
      READ 1, X
      PM=8.
    1 FORMAT(4F10.1)
      DO 200 II = 1, 12
      I2 = RAND(X)*4. + 1.
      J2 = RAND(X)*4. + 1.
      K2 = RAND(X)*2. + 1.
      L2 = RAND(X)*2. + 1.
      DO 200 I1=1,4
      DO 200 J1=1,4
      DO 200 K1=1,2
      DO 200 L1=1,2
      P1 = P(I1, 1  )
      Q1 = Q(J1, 1)
      D1 = D( K1, 1  )
      A1 = A(L1, 1  )
      P2 = P(I2, 2  )
      Q2 = Q(J2, 2)
      D2 = D(K2, 2  )
      A2 = A( L2, 2   )
      EFFT = EFF( P1, Q1, D1, A1, P2, Q2, D2, A2      )
      EFFM = EFF( PM, Q1, D1, A1, P2, Q2, D2, A2      )
      CST=COST(P(I1,1),Q(J1,1),D(K1,1),A(L1,1),EFFT,EFFM)
      TS = 10.**6
```

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DETERMINISTIC MODEL PROGRAM

(CONTINUED)

```
      REV = P(I1, 1)*EFFT*TS
      PUNCH2,P(I1,1),Q(J1,1),A(L1,1),D(K1,1),P(I2,2),Q(J2,2),A(L2,2
     1   D(K2, 2)
    2 FORMAT(2F5.0,2F15.0,2F5.0,2F15.0)
      PUNCH 3, CST,EFFT, REV
    3 FORMAT(4HCOST,16X,F20.0/
     1  13HEFFECTIVENESS, 7X,F20.5/
     2   7HREVENUE, 13X,F20.0/ )
C
  200 CONTINUE
      END
8.        10.       12.       14.
12.       18.       25.       30.
1000000.  1500000.
800000.   1000000.
8.        10.       12.       14.
12.       18.       25.       30.
1000000.  1500000.
800000.   1000000.
.?4125
ZZZZ
```

SIMULATION MODEL PROGRAM (1)

```
ZZJOB
ZZFORX 4
      DIMENSION P(4,2),Q(4,2),A(4,2),D(4,2)
      DIMENSION PROB (10,4 )
      DO 100 I=1,2
      READ 1,(P(L,I),L=1,4)
      READ 1,(Q(L,I),L=1,4)
      READ 1, (A(L,I),L=1,2)
      READ 1,(D(L,I),L=1,2)
  100 CONTINUE
      READ 1, X
      READ11,((PROB(I,J),I=1,10),J=1,4 )
   11 FORMAT ( 4(10I1,10X) )
      PM=8.
    1 FORMAT(4F10.1)
      DO 200 II = 1, 12
      IPB=10.*RAND(X)+1.
       I2=PROB(IPB,1)
      IPB = 10.*RAND(X) + 1.
      J2 = PROB(IPB, 2)
      IPB = 10.*RAND(X) + 1.
      K2 = PROB( IPB, 3)
      IPB = 10.*RAND(X) + 1.
      L2 = PROB( IPB, 4)
      DO 200 I1=1,2
      DO 200 J1=1,2
      DO 200 K1=1,2
      DO 200 L1=1,2
      P1 = P(I1, 1   )
      Q1 = Q(J1, 1)
      D1 = D( K1, 1   )
      A1 = A(L1, 1   )
      P2 = P(I2, 2   )
      Q2 = Q(J2, 2)
      D2 = D(K2, 2   )
      A2 = A( L2, 2    )
      EFFT = EFF( P1, Q1, D1, A1, P2, Q2, D2, A2       )
      EFFM = EFF( PM, Q1, D1, A1, P2, Q2, D2, A2       )
      CST=COST(P(I1,1),Q(J1,1),D(K1,1),A(L1,1),EFFT,EFFM)
      TS = 10.**6
```

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SIMULATION MODEL PROGRAM (1)

(CONTINUED)

```
      REV = P(I1, 1)*EFFT*TS
      PUNCH2,P(I1,1),Q(J1,1),A(L1,1),D(K1,1),P(I2,2),Q(J2,2),A(L2,2)
     1   D(K2, 2)
    2 FORMAT(2F5.0,2F15.0,2F5.0,2F15.0)
      PUNCH 3, CST,EFFT, REV
    3 FORMAT(4HCOST,16X,F20.0/
     1  13HEFFECTIVENESS, 7X,F20.5/
     2   7HREVENUE, 13X,F20.0/ )
C
  200 CONTINUE
      END
8.        12.
12.       18.
1000000.  1500000.
800000.   1000000.
8.        12.
12.       18.
1000000.  1500000.
800000.   1000000.
.34125
1111111222          1111112222          1111222222          1111122
ZZZZ
```

SIMULATION MODEL PROGRAM (TWO PERIODS)

```
ZZJOB
ZZFORX 4
      DIMENSION P(2,2),Q(2,2),D(2),A(2),PROBP(2,2,2),PROBQ(2,2,2
      READ 1,X
    1 FORMAT(F10.1)
      READ 2,(P(1,I),I=1,2)
      READ 2,(Q(1,I),I=1,2)
      READ 2, D1
      READ 2, A1
      READ 2,(P(2,I),I=1,2)
      READ 2,(Q(2,I),I=1,2)
      READ 2, D2
      READ 2, A2
      PM = 8.
      TS=10.**6
    2 FORMAT(  2F10.1   )
C
      READ 3, (((PROBP(I,J,K),K=1,2),J=1,2),I=1,2)
    3 FORMAT(8F10.1)
      READ 3,(((PROBQ(I,J,K),K=1,2),J=1,2),I=1,2)
C
      READ 4, P1, Q1, P2, Q2
      PUNCH 4, P1, Q1, P2, Q2
    4 FORMAT(   4F10.2    )
      ISW = 0
      GO TO 750
  500 CONTINUE
      DO 600 J=1,2
      DO 600 I=1,2
      P1 = P(1,I)
      Q1 = Q(1,J  )
      EFFT=EFF(P1,Q1,D1,A1,P2,Q2,D2,A2)
      EFFM=EFF(PM,Q1,D1,A1,P2,Q2,D2,A2)
      CST=COST(P1,Q1,D1,A1,EFFT,EFFM)
      REV=P1*EFFT*TS
      PUNCH 5,P1,Q1,D1,A1,P2,Q2,D2,A2
      PUNCH 6,CST,EFFT,REV
    5 FORMAT(2F5.0,2F15.0,2F5.0,2F15.0)
    6 FORMAT(4HCOST,16X,F20.0/
```

(CONTINUED)

SIMULATION MODEL PROGRAM (TWO PERIODS)

(CONTINUED)

```
    1  13HEFFECTIVENESS,7X,F20.5/
    2  7HREVENUE,13X,F20.0 / )
  600 CONTINUE
C
      DO 700 JJ = 1,2
      DO 700 II = 1,2
      P1 = P(1, II)
      Q1 = Q(1, JJ)
  750 CONTINUE
      XRAND = RAND(X)
      IF( P1 - P(1,1))  11, 10, 11
   10 I=1
      GO TO 20
   11 I = 2
   20 CONTINUE
C
      IF(P2-P(2,1) )22,21,22
   21 K=1
      GO TO 25
   22 K=2
   25 CONTINUE
      IF(XRAND-PROBP(I,1,K))100,100,101
  100 J=1
      GO TO 102
  101 J=2
  102 CONTINUE
      P2 = P(2,J)
C
      X=RAND(X)
      IF(Q1-Q(1,1))211,210,211
  210 I=1
      GO TO 220
  211 I=2
  220 CONTINUE
      IF(   Q2 - Q(2,1)    )    222, 221, 222
  221 K=1
```

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SIMULATION MODEL PROGRAM (TWO PERIODS)

(CONTINUED)

```
      GO TO 225
  222 K=2
  225 CONTINUE
      IF(XRAND-PROBQ(I,1,K))300,300,301
  300 J=1
      GO TO 302
  301 J=2
  302 CONTINUE
      Q2 = Q(2,J)
      ISW = ISW + 1
      IF( ISW - 1  )  600, 600, 800
  800 CONTINUE
      DO 650 J=1,2
      DO 650 I=1,2
      P1 = P(1,I)
      Q1 = Q(1,J  )
      EFFT=EFF(P1,Q1,D1,A1,P2,Q2,D2,A2)
      EFFM=EFF(PM,Q1,D1,A1,P2,Q2,D2,A2)
      CST=COST(P1,Q1,D1,A1,EFFT,EFFM)
      REV=P1*EFFT*TS
      PUNCH 5,P1,Q1,D1,A1,P2,Q2,D2,A2
      PUNCH 6,CST,EFFT,REV
  650 CONTINUE
  700 CONTINUE
      END
.51342
10.        14.
18.        25.
1000000.
1000000.
10.        14.
18.        25.
1000000.
1000000.
.9         .7         .1         .3         .6         .8         .4
.5         .8         .5         .2         .4         .5         .6
10.        18.        10.        18.
ZZZZ
```

BIBLIOGRAPHY

A. Books

1. Abbott, Lawrence. Quality and Competition, New York: Columbia University Press, 1955.

2. Abbott, Lawrence, Economics and Modern World, New York: Harcourt, Brace and Company, 1960.

3. Bain, Joe S. Barriers to New Competition: Their Character and consequences in manufacturing Industries, Cambridge: Harvard University Press, 1956.

4. Baumol, William J. Economic Theory and Operations Analysis, 2nd. Ed., Prentice-Hall International Series in Management: Englewood Cliffs, N. J.: Prentice-Hall, 1956.

5. Chamberlin, Edward Hastings. The Theory of Monopolistic Competitions: A Re-orientation of the Theory of Value. 7th ed. Harvard Economic Studies: Cambridge Harvard University Press, 1958.

6. Dean, Joel. Managerial Economics, Englewood Cliffs, N. J.: Prentice-Hall, 1951.

7. Drucker, Peter F. Managing for Results; Economic Tasks and Risk-Taking Decisions, New York: Harper and Row, 1964.

8. Forrester, Jay W. Industrial Dynamics, Cambridge: the M.I.T. Press, 1961.

9. Goldman, Thomas A. Cost Effectiveness Analysis: New Approaches in Decision Making, Praeger Special Studies in U. S. Economic and Social Development, New York: Frederik A. Praeger, 1967.

10. Johnston, J. Econometric Methods, New York: McGraw-Hill Book Company, Inc., 1963.

11. Machlup, Fritz. The Economics of Sellers Competition: Model Analysis of Sellers Conduct, Baltimore: The Johns Hopkins Press, 1952.

12. McGuire, Joseph W. Theories of Business Behavior, Prentice-Hall International Series in Management and Behavioral Sciences in Business Series, Englewood Cliffs, N. J.:

Prentice-Hall, Inc., 1964.

13. Miller, David W. and Starr, Martin K. Executive Decisions and Operations Research, Prentice-Hall International Series in Management, Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1964.

14. Speight, H. Economics: The Science of Prices and Incomes, London: Methuen and Company, Ltd., 1960.

15. Starr, Martin K. Production Management: Systems and Synthesis Englewood Cliffs, N. J.: Prentice-Hall, 1964.

B. Articles

1. Fields, David S. "Cost Effectiveness Analysis: It's Tasks and Their Interdependence." Journal of Operations Research Society of American, (May-June 1966).

2. Fox, Peter D. "A Theory of Cost Effectiveness Analysis", Journal of Operations Research Society of America, (March-April, 1965).

3. Heuston, M. C. and Ogawa G. "Observations on the Theoretical Basis of Cost Effectiveness", Journal of Operations Research Society of America, (March-April, 1966).

4. "Special Case for Speciality Steels", Fortune, December 1968.

5. "The First Common Market Industry", The Economist, December, 2 1968.